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UNITED STATES NAVAL

POSTGRADUATE SCHOOL

Catalogue for 1964-1965

MONTEREY ★ CALIFORNIA

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UNITED STATES NAVAL POSTGRADUATE SCHOOL, MONTEREY, CALIFORNIA

MISSION

The Secretary of the Navy has defined the mission of the Naval Postgraduate School as follows:

"To conduct and direct the Advanced Education of commissioned officers, to broaden the professional knowledge of general line officers, and to provide such other indoctrination, technical and professional instruction as may be prescribed to meet the needs of the Naval Service; and in support of the foregoing, to foster and encourage a program of research in order to sustain academic excellence."

Superintendent
CHARLES KNIESE BERGIN
Rear Admiral, U. S. Navy
B.S., USNA, 1927; USNPGS, 1936
National War College, 1962

U. S. NAVAL POSTGRADUATE SCHOOL

Deputy Superintendent

HENRY FILLEDES LLOYD

Captain, U. S. Navy
B.S., USNA, 1939; M.S., MIT, 1946

Academic Dean

ALLEN EDGAR VIVELL

B.E., Johns Hopkins Univ., 1927;
D.Eng., 1937

Director of Programs

JOHN W. MURPH

Captain, U.S. Navy
B.A., Wofford College, 1939;
Naval War College, 1958

Dean of Programs

WILBERT FREDERICK KOEHLER

B.S., Allegheny College, 1933; M.A.,
Cornell Univ., 1934; Ph.D., Johns Hopkins Univ., 1948

Assistant Director for Curricular Programs

GEORGE T. SMITH

Commander, U.S. Navy
Naval War College, 1961

Dean of Curricula

LAWRENCE EDWARD KINSLER

B.S., California Institute of Technology, 1931;
Ph.D., 1934

Dean of Admissions

BROOKS JAVINS LOCKHART

B.A., Marshall Univ., 1937; M.S., West
Virginia Univ., 1940; Ph.D., Univ. of Illinois, 1943

Dean of Research Administration

CARL ERNEST MENNEKEN

B.S., Univ. of Florida, 1932;
M.S., Univ. of Michigan, 1936

Head of Computer Facility

DOUGLAS GEORGE WILLIAMS

M.A. (honors), Univ. of Edinburgh, 1954

Superintendent's Staff Assistants

Plans Officer ....Cdr Jack Hilton, usn

Comptroller ....Cdr E. W. Hurn, usn

Industrial Relations Officer ....Mr. John J. Coyle

Aviation Officer (C.O., NAF) ..Capt W. H. Craven, Jr., usn

Senior Medical Officer (NAF) ......Capt J. E. Goebel, MC, usn

Marine Corps Representative Lt Col H. H. Stirling, Jr., usmc

Aide to the Superintendent ....Lt Ivan V. A. Nance, usn

Programs Administrative Staff

Registrar ....Mrs. Bessie Wilk

Class Scheduler ....Miss Elizabeth A. Kirby

Cataloguer ....Mrs. Bertha Ayers

Foreign Officer Coordinator ......Cdr George W. Fairbanks, usn

Flight Officer ....Lcdr Archie G. Lane, usn

Administrative Officer for
Curricular Programs ....Lcdr Nancy L. Denton, usn

Program Allotment and
Material Control Officer ....Lcdr John F. Campbell, usn

Administrative and Logistic Services

Director of Logistics ....Capt John W. Shong, usn

Head, Administration Dept. ......Cdr Phillip W. Nicholas, usn

Head, Supply Dept. ....Cdr William F. Paulson, SC, usn

Head, Public Works Dept. ......Cdr Wayne S. Mitter, CEC, usn

Head, Dental Dept. ....Capt Robert C. Millard, DC, usn

Catholic Chaplain .... Lcdr J. J. O'Connor, ChC, usn

Protestant Chaplain ....Lcdr H. D. Johns, ChC, usn

Public Information & Visit Liaison Cdr Lawrence R. Bemis, usn

POSTGRADUATE SCHOOL CALENDAR

Academic Year 1964-1965

JANUARY

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1964

"Elements of Management" summer course begins ....Monday, 29 June
Summer Term ends for Baccalaureate Curriculum ....Thursday, 2 July
Fourth of July (Holiday) ....Friday, 3 July
"Elements of Management" Course Ends ....Friday, 24 July
Registration for all curricular areas ....Monday, 27 July
Fifth Term Ends ....Thursday, 30 July
First Term begins for all curricula ....Monday, 3 August
Graduation, Baccalaureate Curriculum ....Tuesday, 4 August
Labor Day (Holiday) ....Monday, 7 September
First Term Ends ....Thursday, 8 October
Second Term Begins ....Monday, 12 October
Veterans' Day (Holiday) ....Wednesday, 11 November
Thanksgiving Day (Holiday) ....Thursday, 25 November
Graduation, General Line Class 1964B ....Friday, 18 December
Second Term Ends; Christmas Holiday begins ....Friday, 18 December
Registration for all curricula except Management ....Monday, 28 December

JANUARY

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FEBRUARY

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MARCH

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APRIL

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JUNE

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JULY

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AUGUST

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OCTOBER

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NOVEMBER

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DECEMBER

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1965

Third Term begins for all curricula ....Monday, 4 January
Washington's Birthday (Holiday) ....Monday, 22 February
Third Term ends ....Thursday, 11 March
Fourth Term begins ....Monday, 15 March
Graduation, Class Bacc 10, and
Engineering Science (March 1964) input ....Tuesday, 16 March
Fourth Term Ends ....Thursday, 20 May
Fifth Term Begins ....Monday, 24 May
Graduation, all technical curricula, Engineering Science (August
1964 input), and General Line Class 1965A ....Friday, 28 May
Memorial Day (Holiday) ....Monday, 31 May
Space and Astronautics Orientation begins ....Wednesday, 23 June
Space and Astronautics Orientation ends ....Friday, 25 June
"Elements of Management" summer course begins ....Monday, 28 June
Summer Term for Baccalaureate Curriculum ends ....Friday, 2 July
Fourth of July (Holiday) ....Monday, 5 July
"Elements of Management" summer course ends ....Friday, 23 July
Registration for all curricular areas ....Monday, 26 July
Fifth Term Ends ....Thursday, 29 July
First Term Begins ....Monday, 2 August
Graduation Baccalaureate and Management curricula ....Tuesday, 3 August

DISTINGUISHED ALUMNI

Among those who have completed a postgraduate curriculum who attained flag (USN) or general (USMC) rank on the active list are the following: (The asterisk (*) indicates those on active list as of 1 January 1964.)

Admiral Walter F. Boone
Admiral Arleigh A. Burke
General Clifton B. Cates
Admiral Arthur C. Davis
Admiral Robert L. Dennison
Admiral Donald B. Duncan
Admiral Frank G. Fahrion
Admiral Cato D. Glover, Jr.
Admiral Roscoe F. Good
Admiral Charles D. Griffin*
Admiral Byron H. Hanlon
Admiral Royal E. Ingersoll
Admiral Albert G. Noble
Admiral Alfred M. Pride
Admiral James O. Richardson
Admiral Claude V. Ricketts*
Admiral Samuel M. Robinson
Admiral James S. Russell*
Admiral Ulysses S. G. Sharp, Jr.*
Admiral John H. Sides
General Holland M. Smith
Admiral Felix B. Stump
General Merrill B. Twining
Admiral John M. Will
Vice Admiral Walter S. Anderson
Vice Admiral Harold D. Baker
Vice Admiral Wallace M. Beakley*
Vice Admiral George F. Beardsley
Vice Admiral Donald B. Beary
Vice Admiral Frank E. Beatty
Vice Admiral Robert E. Blick, Jr.
Vice Admiral Harold G. Bowen
Vice Admiral Roland M. Brainard
Vice Admiral Carleton F. Bryant
Vice Admiral Edmund W. Burrough
Vice Admiral William M. Callaghan
Vice Admiral John H. Carson
Vice Admiral Ralph W. Christie
Vice Admiral Edward W. Clexton
Vice Admiral Oswald S. Colclough
Vice Admiral Thomas S. Combs
Vice Admiral George R. Cooper
Vice Admiral William G. Cooper
Vice Admiral Maurice E. Curts
Vice Admiral John C. Daniel
Vice Admiral Glenn B. Davis
Vice Admiral Harold T. Deutermann*
Vice Admiral Glynn R. Donaho*
Vice Admiral James H. Doyle
Vice Admiral Irving T. Duke
Vice Admiral Calvin T. Durgin
Vice Admiral Ralph Earle, Jr.
Vice Admiral Clarence E. Ekstrom
Vice Admiral Emmet P. Forrestel
Vice Admiral Roy A. Gano*
Vice Admiral William E. Gentner, Jr.*
Vice Admiral Elton W. Grenfell*
Lieutenant General Field Harris
Vice Admiral Robert W. Hayler
Vice Admiral Truman J. Hedding
Lieutenant General Leo D. Hermle
Vice Admiral Ira E. Hobbs
Vice Admiral Ephraim P. Holmes*
Vice Admiral George F. Hussey, Jr.
Vice Admiral Olaf M. Hustvedt
Vice Admiral Thomas B. Inglis
Vice Admiral Albert E. Jarrell
Vice Admiral Harry B. Jarrett
Lieutenant General Clayton C. Jerome
Vice Admiral Robert T. S. Keith*
Vice Admiral Ingolf N. Kiland
Vice Admiral Fred P. Kirtland
Vice Admiral Willard A. Kitts
Vice Admiral Harold O. Larson
Vice Admiral Ruthven E. Libby
Vice Admiral Frank L. Lowe
Vice Admiral James E. Maher
Vice Admiral William J. Marshall
Vice Admiral Charles B. Martell*
Vice Admiral John L. McCrea
Vice Admiral Ralph E. McShane
Vice Admiral Charles L. Melson*
Vice Admiral Arthur C. Miles
Vice Admiral Milton E. Miles
Vice Admiral Earle W. Mills
Vice Admiral Marion E. Murphy
Vice Admiral Frank O'Beirne
Vice Admiral Francis P. Old
Vice Admiral Howard E. Orem
Vice Admiral Harvey E. Overesch
Vice Admiral Edward N. Parker*
Vice Admiral Frederick W. Pennoyer, Jr.
Vice Admiral Charles A. Pownall
Vice Admiral Thomas C. Ragan
Vice Admiral Lawson P. Ramage*
Vice Admiral William L. Rees
Vice Admiral Robert H. Rice
Vice Admiral Hyman G. Rickover*
Vice Admiral Horacio Rivero, Jr.*
Vice Admiral Rufus E. Rose*
Vice Admiral Richard W. Ruble
Vice Admiral Theodore D. Ruddock, Jr.
Vice Admiral Lorenzo S. Sabin, Jr.
Vice Admiral Harry Sanders
Vice Admiral Walter G. Schindler
Vice Admiral William A. Schoech*
Vice Admiral Harry E. Sears
Vice Admiral Thomas G. W. Settle
Vice Admiral William B. Smedberg, III*
Vice Admiral Allan E. Smith
Vice Admiral Chester C. Smith
Vice Admiral Roland N. Smoot
Lieutenant General Edward W. Snedeker*
Vice Admiral Selden B. Spangler
Vice Admiral Thomas M. Stokes
Vice Admiral Paul D. Stroop*
Lieutenant General James A. Stuart
Vice Admiral Wendell G. Switzer
Vice Admiral John Sylvester*
Vice Admiral John McN. Taylor*
Vice Admiral Aurelius B. Vosseller
Vice Admiral Homer N. Wallin
Vice Admiral Alfred G. Ward*
Vice Admiral James H. Ward
Vice Admiral Charles Wellborn, Jr.
Vice Admiral George L. Weyler
Vice Admiral Charles W. Wilkins
Vice Admiral Ralph E. Wilson
Vice Admiral Chester C. Wood
Vice Admiral George C. Wright
Rear Admiral John W. Ailes, III*
Rear Admiral Frank Akers
Rear Admiral Jackson D. Arnold*
Rear Admiral Frederick L. Ashworth*
Rear Admiral Edgar H. Batcheller*
Rear Admiral Richard W. Bates
Rear Admiral Frederick J. Becton*
Rear Admiral Fred G. Bennett*
Rear Admiral Rawson Bennett, II
Rear Admiral Charles K. Bergin*
Rear Admiral Abel T. Bidwell
Major General Arthur F. Binney
Rear Admiral Calvin M. Bolster
Rear Admiral Charles T. Booth, II*
Rear Admiral Harold G. Bowen, Jr.*
Rear Admiral Frank A. Braisted
Rear Admiral Harold M. Briggs
Rear Admiral William A. Brockett*
Rear Admiral Charles B. Brooks, Jr.
Rear Admiral James A. Brown*
Rear Admiral Henry C. Bruton
Rear Admiral Louis A. Bryan*
Rear Admiral Charles A. Buchanan*
Rear Admiral Thomas Burrowes
Rear Admiral Robert L. Campbell*
Rear Admiral Milton O. Carlson
Rear Admiral Worrall R. Carter
Rear Admiral Robert W. Cavenagh*
Rear Admiral Lester S. Chambers*
Rear Admiral John L. Chew*
Rear Admiral Ernest E. Christensen*
Rear Admiral David H. Clark
Rear Admiral Henry G. Clark, CEC
Rear Admiral Sherman R. Clark
Rear Admiral Leonidas D. Coates, Jr.*
Rear Admiral Howard L. Collins
Rear Admiral John B. Colwell*
Rear Admiral Thomas F. Connolly*
Rear Admiral Joshua W. Cooper
Rear Admiral Roy T. Cowdrey
Rear Admiral Ormond L. Cox
Rear Admiral Richard S. Craighill*
Rear Admiral Frederick G. Crisp
Rear Admiral Robert E. Cronin

Rear Admiral Charles A. Curtze*
Rear Admiral Lawrence R. Daspit*
Rear Admiral James R. Davis, CEC*
Rear Admiral James W. Davis*
Rear Admiral James C. Dempsey*
Rear Admiral Joseph E. Dodson*
Rear Admiral William A. Dolan, Jr.
Rear Admiral Marshall E. Dornin*
Rear Admiral Jack S. Dorsey*
Rear Admiral Jennings B. Dow
Rear Admiral Wallace R. Dowd
Rear Admiral Louis Dreller
Rear Admiral Norman J. Drustrup, CEC*
Rear Admiral Clifford H. Duerfeldt*
Rear Admiral Charles A. Dunn
Rear Admiral Donald T. Eller*
Rear Admiral Robert B. Ellis
Rear Admiral Edward J. Fahy*
Rear Admiral James M. Farrin, Jr.*
Rear Admiral Emerson E. Fawkes*
Rear Admiral John J. Fee*
Rear Admiral William E. Ferrall*
Rear Admiral Charles W. Fisher
Rear Admiral Henry C. Flanagan
Rear Admiral Eugene B. Fluckey*
Rear Admiral Mason B. Freeman*
Rear Admiral Laurence H. Frost*
Rear Admiral Robert B. Fulton, II*
Rear Admiral Julius A. Furer
Rear Admiral Daniel V. Gallery
Rear Admiral Robert O. Glover
Rear Admiral Willard K. Goodney
Rear Admiral Arthur R. Gralla*
Rear Admiral Lucien McK. Grant
Rear Admiral Edward E. Grimm*
Rear Admiral Peter W. Haas, Jr.
Rear Admiral Ira F. Haddock*
Rear Admiral Frederick E. Haeberle
Rear Admiral Welsey M. Hague
Rear Admiral Grover B. H. Hall
Rear Admiral Lloyd Harrison
Rear Admiral Hugh E. Haven
Rear Admiral Frederick V. H. Hilles*
Rear Admiral Wellington T. Hines*
Rear Admiral Morris A. Hirsch
Rear Admiral George A. Holderness, Jr.
Rear Admiral Ralston S. Holmes
Rear Admiral Ernest C. Holtzworth*
Rear Admiral Leroy V. Honsinger
Rear Admiral Edwin B. Hooper*
Rear Admiral Harold A. Houser
Rear Admiral Herbert S. Howard
Rear Admiral Miles H. Hubbard
Rear Admiral Harry Hull*
Rear Admiral James McC. Irish
Rear Admiral William D. Irvin*
Rear Admiral Joseph A. Jaap*
Major General Samuel S. Jack
Rear Admiral Andrew M. Jackson, Jr.*
Major General Arnold W. Jacobsen
Rear Admiral Ralph K. James
Rear Admiral Frank L. Johnson*
Rear Admiral Horace B. Jones, CEC
Rear Admiral Timothy J. Keleher
Rear Admiral Sherman S. Kennedy
Rear Admiral Husband E. Kimmel
Rear Admiral Grover C. Klein
Rear Admiral Denys W. Knoll*
Rear Admiral Sydney M. Kraus
Rear Admiral Thomas R. Kurtz, Jr.
Rear Admiral David Lambert*
Major General Frank H. Lamson-Scribner
Rear Admiral Martin J. Lawrence
Rear Admiral William H. Leahy
Rear Admiral Joseph W. Leverton, Jr.*
Rear Admiral John K. Leydon*
Rear Admiral Theodore C. Lonnquest
Rear Admiral Almon E. Loomis*
Rear Admiral Wayne R. Loud
Rear Admiral Vernon L. Lowrance*
Rear Admiral Charles H. Lyman, III*
Major General William G. Manley
Rear Admiral Charles F. Martin
Rear Admiral Kleber S. Masterson*
Rear Admiral John B. McGovern
Rear Admiral Eugene B. McKinney
Rear Admiral Kenmore M. McManes
Rear Admiral John H. McQuilken*
Rear Admiral William K. Mendenhall, Jr.
Major General Lewie G. Merritt
Rear Admiral William Miller
Rear Admiral Benjamin E. Moore*
Rear Admiral Robert L. Moore, Jr.*
Rear Admiral Armand M. Morgan
Rear Admiral Thomas H. Morton*
Rear Admiral Albert G. Mumma
Rear Admiral Joseph N. Murphy
Rear Admiral Lloyd M. Mustin*
Rear Admiral William T. Nelson*
Rear Admiral Charles A. Nicholson, II
Rear Admiral Robert H. Northwood*
Rear Admiral Ira H. Nunn
Rear Admiral Emmet O'Beirne*
Rear Admiral Edward J. O'Donnell*
Rear Admiral Clarence E. Olsen
Rear Admiral Ernest M. Pace
Rear Admiral Charles J. Palmer*
Rear Admiral Lewis S. Parks
Rear Admiral Goldsborough S. Patrick*
Rear Admiral John B. Pearson, Jr.
Rear Admiral Henry S. Persons*
Rear Admiral William F. Petrovic*
Rear Admiral Carl J. Pfingstag
Rear Admiral Richard H. Phillips
Rear Admiral Paul E. Pihl
Rear Admiral Frank L. Pinney, Jr.*
Rear Admiral Walter H. Price*
Rear Admiral Schuyler N. Pyne
Rear Admiral John Quinn
Rear Admiral Joseph R. Redman
Rear Admiral Harry L. Reiter, Jr.*
Rear Admiral Henry A. Renken*
Rear Admiral Joseph E. Rice*
Rear Admiral Lawrence B. Richardson
Rear Admiral Basil N. Rittenhouse, Jr.
Rear Admiral Walter F. Rodee
Rear Admiral William K. Romoser
Rear Admiral Gordon Rowe
Rear Admiral Donald Royce
Rear Admiral Edward A. Ruckner*
Rear Admiral George L. Russell
Rear Admiral Dennis L. Ryan
Rear Admiral Ben W. Sarver*
Rear Admiral Malcolm F. Schoeffel
Rear Admiral Floyd B. Schultz*
Rear Admiral John N. Shaffer*
Rear Admiral William B. Sieglaff*
Rear Admiral Harry Smith*
Rear Admiral John V. Smith*
Rear Admiral Levering Smith*
Rear Admiral John A. Snackenberg
Rear Admiral Philip W. Snyder
Rear Admiral Thorvald A. Solberg
Rear Admiral Edward A. Solomons
Rear Admiral Robert H. Speck*
Rear Admiral Frederick C. Stelter, Jr.
Rear Admiral Edward C. Stephan
Rear Admiral Earl E. Stone
Rear Admiral Charles W. Styer
Rear Admiral Robert L. Swart
Rear Admiral William E. Sweeney*
Rear Admiral Evander W. Sylvester
Rear Admiral Frank R. Talbot
Rear Admiral Raymond D. Tarbuck
Rear Admiral Arthur H. Taylor*
Rear Admiral Theodore A. Torgerson*
Rear Admiral George C. Towner
Rear Admiral Robert L. Townsend*
Rear Admiral David M. Tyree*
Rear Admiral Alexander H. Van Keuren
Rear Admiral Frank Virden
Rear Admiral George H. Wales*
Rear Admiral Frederick B. Warder
Rear Admiral William W. Warlick
Rear Admiral Odale D. Waters, Jr.*
Rear Admiral Charles E. Weakley*
Rear Admiral Hazlett P. Weatherwax*
Rear Admiral Charles D. Wheelock
Rear Admiral Francis T. Williamson*
Rear Admiral Frederick S. Withington
Rear Admiral Edward A. Wright
Rear Admiral Howard A. Yeager*
Rear Admiral Elmer E. Yeomans*
Commodore Harry A. Badt
Commodore Harold Dodd
Brigadier General Edward C. Dyer
Commodore Stanley D. Jupp
Commodore John H. Magruder, Jr.
Brigadier General Keith B. McCutcheon*
Brigadier General Ivan W. Miller
Commodore Robert E. Robinson, Jr.
Commodore Henry A. Schade
Commodore Oscar Smith
Commodore Ralph S. Wentworth

HISTORY

The U. S. Naval Postgraduate School had a modest beginning at the Naval Academy at Annapolis in 1909, at which time the first class of ten officers enrolled in a Marine Engineering curriculum. The need for technically educated officers became evident at the turn of the century. The idea of a naval graduate school had its inception in a course of instruction in Marine Engineering which the Bureau of Engineering instituted in 1904. The results of this course were so encouraging that in 1909 the Secretary of the Navy established a School of Marine Engineering at the Naval Academy in Annapolis. In 1912 the School was designated the Postgraduate Department of the U. S. Naval Academy.

The operation of the school was temporarily suspended during World War I, but in 1919 classes were resumed in converted Marine Barracks on the Naval Academy grounds. At this time curricula in Mechanical Engineering and Electrical Engineering were added. With the passing years other curricula—Ordnance Engineering, Radio Engineering, Aerological Engineering and Aeronautical Engineering were added as the Navy's need for officers with technical knowledge in these fields became evident.

In 1927 the General Line Curriculum was established within the Postgraduate School to provide courses of instruction to acquaint junior line officers returning from sea duty with modern developments taking place in the Navy. The courses dealt with naval and military subjects for the most part. The General Line Curriculum remained as an integral part of the Postgraduate Department until the declaration of the emergency prior to the outbreak of World War II, at which time it was discontinued because of the need for officers in the growing fleet.

The enrollment in the Postgraduate School increased rapidly in the war years both in the several engineering curricula and in the communications curriculum which was added to meet the need for trained communication officers in the naval establishment. The School outgrew its quarters necessitating the building of an annex to house the additional classrooms and laboratories required, but even with this addition, the space requirements of the expanded school were not met.

The post-war program called for still further expansion and the re-establishment of the General Line Curriculum with a greatly increased enrollment. In 1946 the General Line School was established at Newport, Rhode Island, as an outlying element of the Postgraduate School and continued until disestablished in 1952; in 1948 an additional General Line School was established at Monterey, California. The objective of the General Line School program—that of providing an integrated course in naval science to broaden the professional knowledge of unrestricted line officers of the Regular Navy—continued in effect as it had since the inception of this program. From 1946 until 1955 a curriculum varying in length from six months to one year provided such a course for Reserve and ex-Temporary officers who had transferred to Regular status. From 1955 to 1962, the curriculum was of nine and one-half months duration.

The physical growth of the School and its increase in scope and importance were recognized in Congressional action which resulted in legislation during the years 1945 to 1951 emphasizing the academic stature of the School, and providing for continued growth in a new location with modern buildings and equipment. This legislation authorized the Superintendent to confer Bachelor's, Master's, and Doctor's degrees in engineering and related subjects; created the position of Academic Dean to insure continuity in academic policy; established the School as a separate naval activity to be known as the United States Naval Postgraduate School; authorized the establishment of the School at Monterey, California; provided funds to initiate the construction of buildings to house modern laboratories and classrooms at that location.

On 22 December 1951, by order of the Secretary of the Navy, the United States Naval Postgraduate School was officially disestablished at Annapolis, Maryland, and established at Monterey, California. This completed the transfer of the School from the East to the West Coast, which had begun in 1948 when Aerology Department and Curricular office were moved to the new location. Concurrently with this relocation, the U. S. Naval School (General Line) at Monterey was disestablished as a separate military command and its functions and facilities were assumed by the U. S. Naval Postgraduate School. At the same time, there was established the U. S. Naval Administrative Command, U. S. Naval Postgraduate School, Monterey, to provide logistic support, including supply, public works, medical and dental functions, for the Naval Postgraduate School and its components.

In June 1956, by direction of the Chief of Naval Personnel, the Navy Management School was established as an additional component of the Postgraduate School. Its mission was to provide an educational program for officers in the application of sound scientific management practice to the complex organizational structure and operations of the Navy with a view to increasing efficiency and economy of operation. The first class included only Supply and Civil Engineering Corps officers and emphasis was placed on general management theory, financial management, and inventory management. In August 1957 this school was expanded to include input from both Line and Staff Corps officers. Since that time the curriculum has been under constant revision to include new areas of import to, and changes of concept in, the field of management. In August 1960 the school curriculum was lengthened from a five to a ten month course leading to a master's degree for those who can meet the requirements for such a degree. Commencing in August 1964 the Management Curriculum will be lengthened from a four to a five term course, thus requiring 12 months for completion.

Discussions commenced in mid-1957 resulted in the establishment in August 1958 of a Bachelor of Science curriculum in the General Line School and a change in the name of that school, effective 1 July 1958, to the General Line and Naval Science School. The new curriculum, with planned semi-annual inputs of 50 officers, was to become a part of the Navy's Five-Term Program, with the long range prospect of having the entire program carried out at Monterey.

The curriculum was to include subjects taught in the General Line curriculum plus new courses adequate in number, level, and scope to support a degree of bachelor of science, no major designated. The success of the program through the early classes led to the addition of an Arts program in August

1961 to provide for those officers whose previous education emphasized the humanities rather than science and mathematics.

The continuing growth and projected expansion of the School led the Superintendent to establish, in the fall of 1961, a special group of staff and faculty members to study internal organization. The outgrowth of this study coupled with further deliberations of the Superintendent and other staff and faculty members was the decision to undergo major reorganization. In June 1962, the Administrative Command was disestablished as a separate command, its functions continuing to be performed by personnel reporting to a new Director of Logistic Services. In August 1962, the three component schools were disestablished and a completely new organization became effective. There is now but one School—the U. S. Naval Postgraduate School—with unified policy, procedure, and purpose. The position of Chief of Staff was replaced by Deputy Superintendent and responsibility for the operation of the academic programs was placed under the dual control of a naval officer Director of Programs and a civilian Dean of Programs.

ORGANIZATION AND FUNCTIONS

The Superintendent of the Postgraduate School is a rear admiral of the line of the Navy. His principal assistants are a Deputy Superintendent who is a captain of the line, and an Academic Dean who is the senior member of the civilian faculty.

The academic programs and direct supporting functions are administered and operated through a unique organization composed of Curricular Offices and Academic Departments. The former are staffed by naval officers whose primary functions are threefold: (1) academic and military supervision and direction of officer students; (2) coordinating, in conjunction with Academic Associates, the elements of each curriculum within their program areas; and (3) conducting liaison with curricula sponsor representatives. Officer students are grouped into the following curricular programs areas:

- Aeronautical Engineering
- Electronics and Communications Engineering
- Ordnance Engineering
- Naval Engineering
- Environmental Sciences
- Naval Management and Operations Analysis
- Engineering Science
- General Line and Baccalaureate

Officer students in each curricular group pursue similar or closely related curricula. With most of these areas a common core program of study is followed for at least half the period of residency.

Objectives and details of curricula are contained elsewhere in this catalogue.

The teaching functions of classroom and laboratory instruction and thesis supervision are accomplished by a faculty which is organized into eleven academic departments:

- Aeronautics
- Mathematics and Mechanics
- Mechanical Engineering
- Government and Humanities
- Electrical Engineering
- Management
- Naval Warfare
- Meteorology and Oceanography
- Physics
- Operations Research
- Metallurgy and Chemistry

Approximately two-thirds of the teaching staff are civilians of varying professorial rank and the remainder naval officers. The latter are spread amongst most of the departments with the majority being in the Department of Naval Warfare which offers courses only in the naval professional area.

Detailed listings of faculty members and course offerings are contained in later sections of the catalogue.

The Academic Program organization just described is tied together at the top by a naval officer Director of Programs and a civilian Dean of Programs who collaborate to share jointly the responsibilities for planning, conduct and administration of the several educational programs. An Assistant Director for Curricular Programs similarily shares curricular responsibilities with a Dean of Curricula in a position just above the Curricular Officers.

The close tie between elements of this dual organization is further typified by the Academic Associates. These are individual civilian faculty members appointed by the Academic Dean to work closely with the Curricular Officers in the development and continuing monitoring of curricula—the Navy's needs being the responsibility of the Curricular Officer and academic soundness being the responsibility of the Academic Associate.

The educational programs conducted at Monterey fall into several general categories:

a. Engineering and scientific education leading to designated baccalaureate and/or advanced degrees.

b. Management education to the Master's level.

c. Undergraduate education leading to a first baccalaureate degree, either B.S. or B.A.

d. Navy professional type education designed to build upon and/or broaden the base of professional experience.

Supplementing category a. above is a recently inaugurated program entitled Engineering Science. The major portion of the officers selected for this program undergo two terms of refresher and prerequisite study. Those who are so motivated and available for the requisite time may be selected by the Superintendent for a two or three year engineering or science curriculum. Those not selected continue in a non-degree program with the primary objective of basic scientific education which will better prepare them for advanced functional training and/or general updating in technical areas.

Logistic service support is rendered by conventional departments such as Supply and Disbursing, Public Works, Dental, Public Information and Visit Liaison, etc., grouped organizationally under a Director of Logistics. Certain other offices such as those of the Comptroller and Plans are directly responsible to the Deputy Superintendent in a slightly modified but typical naval staff organization.

FACILITIES

The School is located about one mile east of downtown Monterey on the site of the former Del Monte Hotel. Modern classroom and laboratory buildings have been constructed and are situated on a beautifully landscaped campus. A group of buildings comprising new Aeronautical Propulsion Laboratories has recently been completed.

The Superintendent and central administrative offices are located in the main building of the former hotel, now called Herrmann Hall. The East wing of the main building complex has been converted into classroom and administrative spaces and a portion of the ground floor of the West wing has been similarly converted.

Spanagel, Bullard, Halligan, and Root Halls are modern buildings which are devoted to classroom, laboratory and faculty office space. About one-third of the last named houses the Library and Reference Center. A fifth new building of matching architecural style is King Hall—the main auditorium.

Additional smaller buildings spread throughout the campus house specialized laboratory facilities as well as various support activities.

STUDENT AND DEPENDENT INFORMATION

Monterey Peninsula and the cities of Monterey, Carmel, Pacific Grove, and Seaside, all within 5 miles of the School, provide community support for the officers of the Postgraduate School.

La Mesa Village, located 3 miles from the School, consisting of former Wherry Housing and new Capehart Housing, contains 608 units of public quarters for naval personnel. An elementary school is located within the housing area.

The Naval Air Facility is located about one mile from the School. Aircraft are available for maintaining flight proficiency. Cross-country flights up to 1200 miles are now permitted. One half-day each week is scheduled for flying as part of the student work-week.

On the main School grounds are 149 BOQ rooms, an Open Mess, a Navy Exchange, 4 tennis courts, a large swimming pool and 6 lane bowling alley. An eighteen-tee nine-hole golf course has been built and opened on 1 April 1963. It is located in the old polo ground area across the street from the main campus.

Medical facilities include a Dispensary at the Naval Air Facility, Monterey, supported by the U. S. Army Hospital, Fort Ord (7 miles away) and the U. S. Navy Hospital at Oakland (120 miles away). A Dental Clinic is located in Hermann Hall.

DEGREES, ACCREDITATION, AND ACADEMIC STANDARDS

The Superintendent is authorized to confer Bachelor's, Master's, or Doctor's degrees in engineering or related fields upon qualified graduates of the School. This authority is subject to such regulations as the Secretary of the Navy may prescribe, contingent upon due accreditation from time to time by the appropriate professional authority of the applicable curricula. Recipients of such degrees must be found qualified by the Academic Council in accordance with prescribed academic standards.

The Naval Postgraduate School was accredited in 1962 as a full member of the Western College Association (WCA). Initial accreditation as an associate member was given in 1955 and was renewed in 1959. Specific engineering curricula have been accredited by the Engineer's Council for Professional Development (ECPD), originally in 1949, renewed in 1955 and again in 1959.

The term length at the School is 10 weeks. The School's term credit hours are equivalent to two-thirds semester hours, as compared with schools using semesters of 15-16 weeks.

Students' performance is evaluated on the basis of a quality point number assigned to the letter grade achieved in a course, as follows:

Performance	Grade	Quality Point Number
Excellent	A	3.0
Good	B	2.0
Fair	C	1.0
Barely Passing	D	0.0
Failure	X	—1.0

When the term hour value of a course is multiplied by the quality point number of the student's grade, a quality point value for the student's work in that course is obtained. The sum of the quality points for all courses divided by the sum of the term hour value of all courses gives a weighted numerical evaluation of the student's performance termed the Quality Point Rating (QPR). A student achieving a QPR of 2.0 has maintained a B average in all courses undertaken with a proper weight assigned for course hours.

Courses listed in this catalogue carry a letter designator following the course number to indicate the kind of credit received for the successful completion of that course as follows:

A. Graduate credit.
B. Graduate or undergraduate credit.
C. Upper division credit.
D. Lower division credit.
E. No credit.

The two numbers in parenthesis (separated by hyphens) following the course title indicate the hours of instruction per week in classroom and laboratory respectively. Laboratory hours are assigned half the value shown in calculating term hours for the credit value of the course. Thus a (3-2) course (having three hours recitation and two hours laboratory) will be assigned a credit value of 4 term hours.

GENERAL REQUIREMENTS FOR DEGREES

The following paragraphs set forth the requirements for the various degrees:

(1) *Requirements for the Baccalaureate Degrees:*

(a) The Bachelor's degree may be awarded for successful completion of a curriculum which serves the needs of the Navy and has the approval of the Academic Council as meriting a degree. Such curricula shall conform to current practice in accredited institutions and shall contain a well-defined major with appropriate cognate minors. The Bachelor's degree requires a minimum of 216 term hours including at least 36 term hours in Mathematics and the Physical Sciences and at least 36 term hours in Humanities and the Social Sciences.

(b) Admission with suitable advanced standing and a minimum of two academic years of residence at the Naval Postgraduate School are normally required. With the approval of the Academic Council, this residence requirement may be reduced to not less than one academic year in the case of particular students who have had sufficient prior preparation at other institutions.

(c) To be eligible for the degree, the student must attain a minimum average quality point rating of 1.0 in all courses of his curriculum. In very exceptional cases, small deficiencies from this figure may be waived at the discretion of the Academic Council.

(d) With due regard for the above requirement, the Academic Council will decide whether or not to recommend the candidate to the Superintendent of the Naval Postgraduate School for the award of the Bachelor's degree.

(2) *Requirements for the Master of Science Degree:*

(a) The Master's degree in engineering and related fields is awarded for the successful completion of a curriculum which complements the basic scientific education of a student and which has been approved by the Academic Council as meriting a degree, provided the student exhibits superior scholarship, attains scientific proficiency, and meets additional requirements as stated in the following paragraphs.

b) Since curricula serving the needs of the Navy ordinarily contain undergraduate as well as graduate courses, a minimum of two academic years of residence at the Naval Postgraduate School is normally required. With the approval of the Academic Council, the time of residence may be reduced in the case of particular students who have successfully pursued graduate study at other educational institutions. In no case will the degree be granted for less than one academic year of residence at the Naval Postgraduate School.

(c) A curriculum leading to a Master's Degree shall comprise not less than 48 term hours (32 semester hours) of work that is clearly of graduate level. The curriculum, which is proposed as the result of joint effort on the part of the pertinent Curricular Officer and Academic Associate, is submitted to the cognizant department chairman for review and approval relative to departmental degree requirements. After approval the department chairman forwards it to the Dean of Curricula for review and approval relative to the School's general degree requirements. After approval the Dean of Curricula forwards it to the Academic Council for final action.

(d) To become a candidate for the Master's degree the student shall have completed at least half of the final year of his curriculum with an average quality point rating in all his courses of not less than 1.75.

(e) To be eligible for the Master's degree the student must attain a minimum average quality point rating of 2.0 in all the (A) and (B) level courses of his curriculum and either 1.5 in the (C) level courses or 1.75 in all courses of the curriculum. In special cases, under very extenuating circumstances, small deficiencies from the figures noted in paragraphs (d) and (e) may be waived at the discretion of the Academic Council.

(f) A reasonable proportion of the graduate work leading to the Master's degree shall be composed of research and a thesis reporting the results obtained. The thesis topic is selected by the student in conjunction with a faculty advisor, and is subject to the approval of the cognizant department chairman. The research must indicate ability to perform independent work. In addition, the completed thesis must indicate an ability to report on the work in a scholarly fashion. The thesis in final form is submitted via the faculty advisor to the cognizant department chairman for review and evaluation. Upon final approval of the thesis the student shall be certified as eligible for examination.

g) If the thesis is accepted, the candidate for the degree shall take a final oral examination, the duration of which will be approximately one hour. An additional comprehensive written examination may be required at the discretion of the cognizant department chairman. Not more than one-half of the oral examination shall be devoted to questions directly related to the candidate's thesis topic; the remainder of the candidate's major and related areas of study.

(h) With due regard for the above requirements, the Academic Council will decide whether or not to recommend the candidate to the Superintendent of the Naval Postgraduate School for the award of the Master's degree.

(3) *Requirements for the Doctor's Degree:*

(a) The Doctor's degree in engineering and related fields is awarded as a result of very meritorious and scholarly achievement in a particular field of study which has been approved by the Academic Council as within the purview of the Naval Postgraduate School. A candidate must exhibit faithful and scholarly application to all prescribed courses of study, achieve a high level of scientific advancement and establish his ability for independent investigation, research, and analysis. He shall further meet the requirements described in the following paragraphs.

(b) Any program leading to the Doctor's degree shall require the equivalent of at least three academic years of study beyond the undergraduate level, and shall meet the needs of the Navy for advanced study in the particular area of investigation. At least one academic year of the doctorate work shall be spent at the Naval Postgraduate School.

(c) A student seeking to become a candidate for the doctorate shall hold a Bachelor's degree from a college or university, based on a curriculum that included the prerequisites for full graduate status in the department of his major study, or he shall have pursued successfully an equivalent course of study. The student shall submit his previous record to the Academic Council, via the chairman of the department of the major subject, for determination of the adequacy of his preparation.

(d) This chairman will specify one or more minor subjects and, with the chairmen of the corresponding departments, will nominate a Doctorate Committee consisting of five or more members, at least three of whom are under different departments. The chairman of the department of the major subject will submit to the Academic Council for its approval the choice of minor fields and the names of the faculty members nominated for the Doctorate Committee.

(e) After a sufficient period of study in his major and minor fields, the student shall submit to qualifying examinations, including tests of his reading knowledge of foreign languages. The selection of these languages depends on the field of study. The minimum is a reading knowledge of German and a second language to be suggested by his Doctorate Committee and approved by the Academic Council. The language examinations will be conducted by a committee especially appointed by the Academic Council. The other qualifying examinations will cover material previously studied in his major and minor fields; they will be written and oral and will be conducted by the Doctorate Committee. The members of the Academic Council or their delegates may be present at the oral examinations. The Doctorate Committee will report the results of the qualifying examinations to the Academic Council for consideration and, upon approval, the student becomes a candidate for the Doctorate. The qualifying examinations are not given, ordinarily, before the completion of the first year of residence at the Naval Postgraduate School; they must be passed successfully at least two years before the degree is granted.

(f) Upon successful qualification as a candidate the student will be given a further program of study by the Doctorate Committee. This program must be approved by the Academic Council.

(g) The distinct requirement of the doctorate is the successful completion of an original, significant, and scholarly investigation in the candidate's major area of study. The results of the investigation, in the form of a publishable dissertation, must be submitted to the Academic Council at least two months before the time at which it is hoped the degree will be granted. The Academic Council will select two or more referees, who will make individual written reports on the dissertation. Lastly, the Academic Council will vote upon the acceptance of the dissertation.

(h) After the approval of the dissertation, and not later than two weeks prior to the award of the degree, the candidate will be subject to written and oral examination in his major and minor subjects. Written examinations will be conducted by the department having cognizance of the particular subject. The occasion and scope of each examination will be arranged by the Doctorate Committee, after consultation with the department concerned and the members of the Academic Council. The Doctorate Committee will notify the Academic Council of the time of the oral examination and will invite their attendance, or that of their delegates. The Committee will also invite the attendance of such other interested persons as it may deem desirable. In this oral examination, approximately one-half of the allotted time will be devoted to the major subject and one-half to the minor subjects. The Doctorate Committee will submit the results of all examinations to the Academic Council for their approval.

(i) With due regard for all of the above requirements, the Academic Council will decide whether to recommend the candidate to the Superintendent of the Naval Postgraduate School for the award of the doctorate.

(j) It is not to be expected that the course requirements for the doctorate can be met while pursuing one of the three-year curricula shown in this catalogue unless the student has previously had suitable graduate work and signifies his desire to become a candidate within three months of the beginning of his curriculum.

THE LIBRARIES

DESCRIPTION

The Library system serves the research and instructional needs of the community comprising students, faculty, and staff of all departments of the School. It embraces an active collection of 112,000 books, 222,000 technical documents, over 2200 periodical works currently received, and 140,000 abstract cards and microcards. These materials parallel the School's curricular fields of engineering, physical sciences, industrial engineering, management, naval sciences, government and the humanities.

The Reference Library, located at the southeast end of Root Hall, provides the open literature sources such as books, periodicals and journals, indexes and abstracting services, pamphlet materials and newspapers. It also furnishes facilities for microfilming and microfilm reading, for photographic and contact reproduction of printed matter, and for borrowing, from other libraries, publications not held in its collections.

The Technical Reports and Classified Materials Section is the principal repository for technical research documents received by the School. It houses 222,000 documents, 66,000 of which are classified, and exercises control over the microcard collection. A machine information storage and retrieval system that utilizes the School's computer facilities is now available for literature searches of documents received since November, 1960.

The Christopher Buckley, Jr., Library is a branch of the Reference Library and is located on the first floor adjacent to the lobby. It is a collection of some 8,000 volumes pertaining principally to naval history and the sea. The establishment of this collection was made possible by the interest and generosity of Mr. Christopher Buckley, Pebble Beach, California, who has been donating books to the School for this Library since 1949.

STAFF

George R. Luckett, Professor and Librarian (1950); B.S., Johns Hopkins University, 1949; M.S., Catholic University, 1951.

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Alice M. Stude, Cataloger (1957); B.S., University of Minnesota, 1930; M.S., University of California, Berkeley, 1961.

Beth Peterson, Cataloger (1958); A.A., Red Oak College, 1938.

LIBRARY

LABORATORY FACILITIES

Extensive laboratory experimentation is carried on in connection with the instructional and research programs of the various departments. The experimental facilities have been greatly improved and expanded in recent years, and further improvement is planned for the future.

The PHYSICS LABORATORIES are equipped to carry on instructional and research work in nuclear physics, low temperature and solid state physics, plasma physics, spectroscopy, and acoustics.

The laboratory facilities include a nuclear physics laboratory centering around a two million volt Van de Graaff accelerator and an Aerojet Nucleonics nuclear reactor operating at power levels up to 1000 watts. In low temperature and solid state physics the equipment includes nitrogen liquifiers, a Collins helium liquifier, He^3 refrigeration equipment to reach temperatures below 1°K, a 12 inch uniform-field electromagnet, microwave gear for spin resonance and maser studies, and high frequency pulse acoustic equipment for phonon studies. The plasma physics equipment includes a number of small vacuum systems, a large plasma system, and diagnostic equipment for studies of plasma dynamics. A steady state plasma source with magnetic fields up to 10,000 gauss will soon be available for plasma research. The spectroscopy equipment includes a large grating spectrograph, a large prism spectograph, and an infrared spectrophotometer. The acoustics laboratory equipment includes a large anechoic chamber, a small reverberation chamber, and a multiple-unit acoustics laboratory for student experimentation in airborne acoustics. Sonar equipment, test tanks, and instrumentation for investigation in underwater sound comprise the sonar laboratory.

The AERONAUTICAL LABORATORIES contain facilities for experimentation and research in aerodynamics, structural and stress analysis, aerothermodynamics, rocket and jet propulsion, and turbomachinery.

The Subsonic Aerodynamics Laboratory consists of a low turbulence subsonic wind tunnel with a 32x45 inch test section and a speed range up to 185 knots. Force and moment beam balances measure aerodynamic reactions. A small classroom wind tunnel, 7x10 inches in cross-section, and a small two-dimensional smoke tunnel are also in use. Equipment for operating powered propeller aircraft models is available. Experiments in boundary layers, pressure distribution, component aerodynamics, performance and dynamics can be performed.

The Structural Test Laboratory contains testing machines with varying capacities up to 600,000 pounds for demonstration and analysis of relatively small structures. Large aircraft components such as a P2V wing, a F8U-3 wing, and an A3D tail are accommodated on the loading floor of the laboratory where static and vibration tests are carried out. Several electromagnetic shakers are used for vibration testing of turbomachine components and other aeronautical structure components.

The facilities of the Compressibility Laboratory include a transonic wind tunnel having a 4"x16" test section and operating in the Mach number range from 0.4 to 1.4; a supersonic wind tunnel having a 4"x4" test section and a vertical free-jet of 1"x1" cross-section, both operating in the Mach number range from 1.4 to 4; and a 4"x16" shock tube. Instruments associated with these facilities include a 9" and a 6" Mach-Zehnder interferometers and a 9" and two 5" Schlieren systems for flow observations.

The Rocket and Jet Engine Laboratory facilities, recently completed, provide for full scale operation of current and future Naval aircraft jet engines, and for small rocket engines of 2,000 pounds thrust or less. Two separate and complete test cells are provided in one building for the operation of a J57 engine with afterburner and for a T56 turboprop engine. A separate engine maintenance shop is located adjacent to these test cells. A separately located external pad and control house are also in use for the operation of a J34 jet engine and a Boeing XT-50 turboprop engine. Rocket engine tests can be run from a common control room in three test cells housed in the rocket engine building, which also contains a propellant chemistry laboratory. The three test cells provide for operation of solid rocket engines, liquid rocket engines, and hybrid or experimental engines.

The advanced facilities of the Cascade and Turbomachinery Laboratories, recently completed, are distributed in three buildings one of which provides low speed tests with rectilinear, cylindrical and rotating cascades of large dimensions. The source of air is a 700 HP fan, used either to draw or to blow air through the test items. The fan delivers about 100,000 cfm of air at a pressure difference of about 40 inches of water. The fan can be run at speeds of 50% and 75% of the design speed This source can be used also to perform model tests with flow channels, inlet and discharge casings, scrolls and diffusors. The special rectilinear cascade test rig is equipped with semi-automatic instrumentation; data are obtained with an electronic logging system for data reduction on digital computers. A second building houses a centrifugal compressor test rig, instrumented for conventional performance measurements and for special investigations of three-dimensional flows about both the stationary and the rotating vanes. The third building is devoted to high speed tests, in three tests cells, monitored from a central control room. A 1250 HP variable-speed axial-flow compressor, which is instrumented also for interstage measurements, produces high pressure air either for turbine testing, or to drive test compressors, pumps, and other test items. The compressor is capable of delivering 10,000 cfm of air at sea-level conditions. The design pressure ratio is three, and speed control is possible between 40% and 100% of design speed by means of a hydraulic drive. A surge-suppressing device makes it possible to operate test items with greatly varying flow rates. Data acquistion is carried out with an electronic logging system as well as with conventional instrumentation. Adjacent to this building is a hotspin test unit, where disks and propellers can be rotated at speeds up to 50,000 rpm. Heating and cooling elements make it possible to impose radial temperature gradients. Instrumentation is provided to conduct stress work, with strain gauges, up to 27,000 rpm and at maximum temperatures of 1800°F.

The CHEMICAL LABORATORIES of the Department of Metallurgy and Chemistry are well equipped for instructional purposes at both the undergraduate and graduate level in chemistry and chemical engineering. The laboratories include a radio-chemistry ("hot") laboratory with Geiger and scintillation counters and special apparatus for handling and testing radioactive materials; a well-equipped fuel and lubricant laboratory; a plastics laboratory and shop where plastics are synthesized, molded in compression or injection presses, and their mechanical, physical and chemical properties determined; an explosives laboratory with impact tester, ballistics mortar, chronograph and other apparatus for evaluating explosives. Space is also available for faculty and student research projects.

The METALLURGY LABORATORIES are completely equipped with the standard mechanical testing machines and heat-treating furnaces. The latest type of microscopes and metallographs are available for metallographic examination. Facilities for the study of crystal structures include X-ray diffraction units, powder cameras and heating cameras, Weissenberg X-ray goniometers and a recording photo densitometer. Metal fabricating and melting equipment includes a swaging machine, rolling mill, induction and vacuum melting furnaces, a die-casting machine and a welding laboratory. Studies of the effect of high and low temperatures on metals are made in a laboratory equipped with creep testing apparatus and facilities for obtaining low temperatures.

The ELECTRICAL ENGINEERING LABORATORIES, separately housed in a modern two-story building designed for the purpose, have facilities for instruction and research in feedback control systems, electronics, electrical machinery, circuits and measurements. The building and the equipment are arranged for the most effective utilization by students and faculty. Ample equipment is available so that each student may take an active part in the laboratory work.

In addition to the conventional instructional type equipment, the laboratories provide many items of a specialized nature suitable for research projects. Items of special interest in this category include precision primary and secondary standard instruments, a five unit harmonic generating set, a generalized machine laboratory set, a high voltage test set and Schering bridge, a large electronic analog computer with thirty amplifiers and associated function generators and readout equipment, eight Donner analog computers, X-Y recorders, servo analyzers including oscilloscopes with attached Polaroid-Land cameras, an Esiac computer for algebraic functions of a complex variable, Tektronix transistor curve tracer, magnetic amplifiers, wave analyzers, special bridges and electromechanical oscillographs.

The Machine Laboratory has many motors and motor-generator sets with control and measurement benches. Dynamometer sets permit control system study and analysis. The harmonic generator is available for magnetic material studies at higher power frequencies. The generalized machine set permits a quantitative study of basic electromagnetic phenomena. Machine design calculations may be verified by measurements of the characteristics of laboratory equipment.

The Servomechanisms Laboratory is completely equipped with analyzers, Brush recorders, oscilloscopes and cameras, and the basic units required to synthesize and test a wide variety of systems. The computers serve an important part in the synthesis and analysis of control systems.

The Computer Laboratory, used in conjunction with the work of the other laboratories, has ten electronic analog computers and accessories. The equipment is used to solve and analyze many electrical circuit and control system problems. In addition the electronics control and measurement laboratory has many devices, used in modern control systems, and magnetic amplifiers with their accessory equipment.

A well equipped standards and calibration laboratory is used for precision measurements and to calibrate the laboratory instruments used for instruction and research. Photographic records of test results are obtained from electromagnetic oscillographs, oscilloscope cameras, and Polaroid-Land cameras. The film is processed in a completely outfitted dark room. Brush recorders are used extensively to obtain test results in graphic form. A number of research rooms are assigned to students and faculty for the study of special projects and research.

The ELECTRONICS LABORATORIES are equipped for carrying on programs of extensive study and research in all branches of the electronics field, and constructing special electronic equipment as may be needed. Facilities are available for investigating the operational characteristics of radio and electronic circuits and equipments at frequencies ranging from d-c to the microwave region. For precision measurements and accurate calibration of instruments, there are standard frequency sources and standardizing equipment.

To illustrate modern communications practices, the laboratories are furnished with representative systems covering a wide range of operating frequencies, power outputs and methods of modulation. These include systems for transmitting manual and automatic telegraphy, voice and video signals.

Improved facilities are now provided for the study of telemetering systems, computing systems, modern radar systems, antenna radiation characteristics, microwave phenomena, and transistors as well as for advanced work in circuit measurements. Additional space is also available for conducting individual research and project work.

The MECHANICAL ENGINEERING LABORATORIES provide facilities for instruction and research in elastic-body mechanics and dynamics, in hydromechanics and in heat-power and related fields. Noteworthy equipment in the heat-power laboratories includes a gas or oil-fired boiler, 200 psi, and 8000 lb/hr, full automatic controls; a 175 HP gas turbine installation, dynamometer loaded; a two dimensional supersonic air nozzle with Schlieren equipment for analysis of shock-wise flows; a two-stage axial flow test compressor; a packaged steam power plant; an experimental single cylinder diesel engine; and a CFR diesel fuel test engine. Facilities of the mechanics laboratories include a universal fatigue tester, for testing in tension, compression, bending or torsion, a Chapman polariscope for stress determination by photoelastic method; vibration inducer units and associated equipment for inducing vibrations in mechanical systems with controlled amplitudes and frequencies from 20 to 20,000 cycles per second; dynamic balancing machines; and a linear accelerometer and calibrator unit. Facilities are available for electronic analog simulation of engineering problems.

The FACILITIES IN METEOROLOGY AND OCEANOGRAPHY include all instruments in present-day use for measuring the current physical and dynamic state of the atmosphere, as well as teletype and facsimile communications equipment for the rapid reception and dissemination of weather data in coded and analyzed form for the entire northern hemisphere.

The instruments for gathering weather data include rawinsonde equipment, which provides a continuous recording of temperature, pressure, humidity and wind direction and velocities at designated levels above the surface; radiosonde equipment whereby pressure, temperature and humidity information is transmitted to ground via radio signals from heights that may extend above 100,000 feet; a wiresonde that measures air temperature and humidity conditions in the lower strata of the atmosphere, an inversion meter designed for remote recordings of free air temperature at designated heights in the boundary layer.

The school has recently acquired a 63-foot boat converted for use in Oceanographic Instruction and Research. It is utilized for actual field oceanographic studies by Environmental Science Students. Included in its installed equipment are deep and shallow echo sounders, a bathythermograph winch, and a deep sea hydrographic winch using 20,000 feet of wire.

Oceanographic equipment installed in the area near the school includes a wave gauge and a tide gauge for recording nearshore wave action and local tide fluctuations.

Laboratory equipment for MATHEMATICS AND MECHANICS now available includes an electronic and analogue computer and a digital differential analyzer both of which are used to find the solutions of differential equations; a specially modified accounting machine used in finite differences computations, a variety of planimeter type instruments including a large precision moment integrator, a Stieltjes integrator and a harmonic analyzer. A large number of modern electric desk calculators are available in the laboratory for numerical methods and statistics. Many special models and demonstrators, including the only two automatic relay controlled Wald Sequential Sampling Machines ever made, and other devices and visual aids in mathematics, probability and mechanics are used in support of courses in these subjects. An 85 foot Foucault Pendulum with an 184 lb. bob is kept in constant operation and display.

The COMPUTER FACILITY provides a variety of services to the school. Its primary function is to support the academic programs, serving as a laboratory adjunct to courses on computer programming, logical design and the use of computers in solving scientific and engineering problems as well as those of interest specifically to the Navy. The Facility has a small permanent staff of programmer/mathematicians who provide a consulting service to students and faculty in programming and problem formulation. In addition, their efforts are concentrated towards developing and maintaining a good library of programs and subroutines, improving programming systems and, generally, creating a suitable environment for class and research use of computers. Current Facility activity includes work in the areas of scientific and engineering computing systems programming, information retrieval, simulation, command and control, and student administration.

The School owns the following digital computers: a Control Data Corporation (CDC) 1604, 2 CDC 160's and an IBM 1401. Both CDC 160 Computers are connected to the CDC 1604 in a satellite mode, thus providing a moderately complex computer system with which to study and develop experience in machine-machine interactions such as encountered in operational units in the Navy.

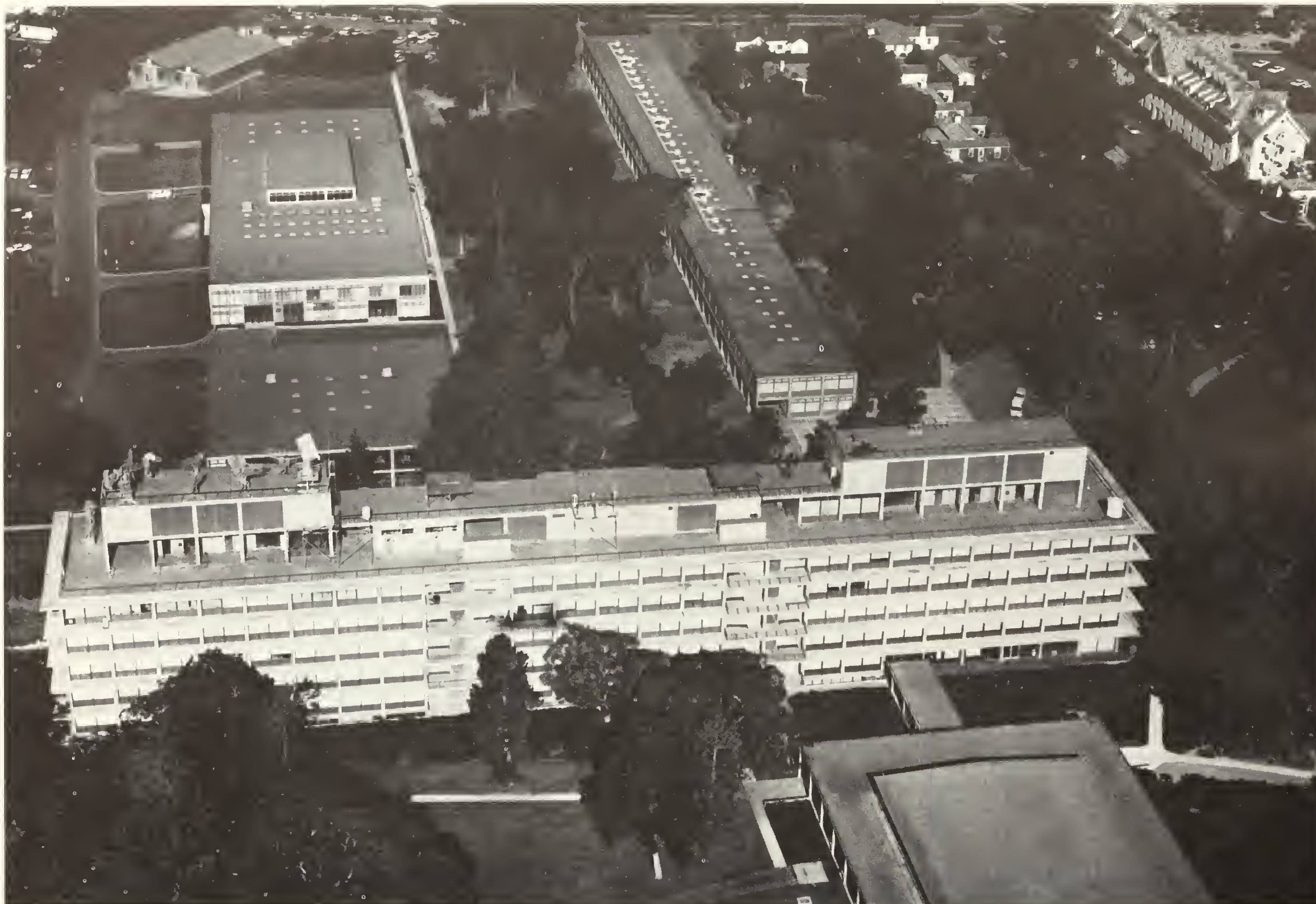
The REACTOR LABORATORY features an AGN-201 reactor which has been recently modified to operate at powers up to 1000 watts. The Laboratory provides facilities and equipment for teaching and research in nuclear physics, radio-chemistry, and reactor physics.

LECTURE SERIES

During the third and fourth terms, the eighth period on Wednesdays is scheduled for presentation of a lecture series in King Hall for all students, sponsored by the Director of Programs.

It is the purpose of this series to present talks on international affairs and naval professional and technical subjects, to inform as well as to challenge the thinking of the officer students in areas outside of their immediate academic pursuits.

COMPUTER FACILITY



SCIENCE AND ENGINEERING BUILDINGS

CURRICULAR OFFICES and PROGRAMS

CURRICULA AT THE POSTGRADUATE SCHOOL

Curriculum:	*Group:*	*Length:*	*Academic Associate or Counselor:*
Advanced Mathematics			Prof. Stewart
Advanced Science			
Chemistry	RC	3 yrs.	Prof. Kinney
Hydrodynamics	RH	3 yrs.	Prof. Pucci
Mathematics (Applied)	RM	3 yrs.	Prof. Pulliam
Metallurgy	RMT	3 yrs.	Prof. Buerger
Physics (General)	RP	3 yrs.	Prof. Frey
Physics (Nuclear)	RX	3 yrs.	Prof. Frey
Aeronautical Engineering			
General	AG	2 yrs.	Prof. Coates
Advanced*	AA	3 yrs.	Prof. Coates
Electronics and Communications Engineering			
Communications Engineering			
Basic	EB	2 yrs.	Prof. Ward
Advanced	CE	3 yrs.	Prof. Ward
Engineering Electronics			
Basic	EB	2 yrs.	Prof. Ward
Advanced	EA	3 yrs.	Prof. Ward
Information and Control	EI	3 yrs.	Prof. Ward
Underwater Acoustics	EW	3 yrs.	Prof. Ward
Special (CEC)	EY	12-18 mos.	Prof. Ward
Engineering Science	SA, SB, SC, SD	1 yr.	Prof. Olsen
Environmental Sciences			
Advanced Meteorology	MM	2 yrs.	Prof. Taylor
Advanced Air-Ocean Environment	ME	2 yrs.	Prof. Taylor
Oceanography	MO	2 yrs.	Prof. Taylor
General Air-Ocean Environment	MA	2 yrs.	Prof. Taylor
General Line and Baccalaureate			
General Line		1 yr.	Prof. La Cauza
Bachelor of Science	CA, CJ	2 yrs.	Prof. La Cauza
Bachelor of Arts	DA, DJ	2 yrs.	Prof. La Cauza
Naval Engineering			
Naval Engineering (Mechanical)	NH	2 yrs.	Prof. Pucci
Naval Engineering (Electrical)	NL	2 yrs.	Prof. Pucci
Mechanical Engineering (Advanced)	NA	3 yrs.	Prof. Pucci
Electrical Engineering (Advanced)	NE	3 yrs.	Prof. Pucci
Navy Management and Operations Analysis			
Naval Management	MN	1 yr.	Prof. Peterson
Management (Data Processing)	PM	1 yr.	Prof. Williams
Operations Analysis	RO	2 yrs.	Prof. Cunningham
Ordnance Engineering			
Nuclear Engineering (Effects)	RZ	2 yrs.	Prof. Handler
Weapons System Engineering			
(General)	WG	2 yrs.	Prof. Handler
(Chemistry)	WC	3 yrs.	Prof. Handler
(Materials)	WM	3 yrs.	Prof. Handler
(Air/Space Physics)	WP	3 yrs.	Prof. Handler
(Underwater Physics)	WU	3 yrs.	Prof. Handler
(Electronics)	WX	3 yrs.	Prof. Handler
(Special)	WS	2 yrs.	Prof. Handler

*Usually the third year is taken at a civilian university.

ADVANCED SCIENCE CURRICULA

Chemistry
Hydrodynamics
Metallurgy
General Physics
Nuclear Physics
Applied Mathematics

OBJECTIVE: To prepare selected officer personnel to deal with the problems of fundamental and applied research in the fields of general physics, nuclear physics, hydrodynamics, chemistry, metallurgy, and applied mathematics.

DESCRIPTION: Officers nominated for Advanced Science Curricula are selected from among those first-year students enrolled in technical curricula at the Postgraduate School who apply for the Advanced Science Program. Applicants are carefully screened and only those having a very good academic background and who appear to have an excellent chance of succeeding in their chosen field are nominated to the Chief of Naval Personnel.

Officers selected for Advanced Science Curricula complete their first year at the Postgraduate School and normally spend their second and third years of study at a selected civilian university. They may spend the summer prior to entering civilian universities on duty at the Office of Naval Research, Washington, D.C., or at one of the field offices, familiarizing themselves with the work of the Office of Naval Research in the basic sciences, or they may utilize the summer in preparing themselves for graduate school language requirements.

The curriculum at the civilian university for each officer is arranged from courses selected to suit the needs of the Navy, to develop the capabilities of the individual student and to meet the ultimate objective of his specialty.

The Advanced Science Curricula normally lead to the Master of Science degree for those officers meeting the requirements of the civilian universities for that degree and may, in exceptional cases for especially qualified officers, lead to a Doctor's degree.

AERONAUTICAL ENGINEERING CURRICULA

MELVIN EDWARD HIRSCHI, Commander, U.S. Navy; Curricular Officer; Naval War College, 1955; B.S., Univ. of New Mexico, 1958.

LAWRENCE CLEVLLAND CHAMBERS, Lieutenant Commander, U.S. Navy; Assistant Curricular Officer; B.S., USNA, 1952; B.S. Aero. Eng., USNPGS, 1959; M.S., Aero. Eng., Stanford Univ., 1960.

OBJECTIVE—To provide officers with advanced aeronautical education to meet Navy technical requirements in flight vehicles and their environmental fields. Curricula are edited to suit the field of the major, choosing fundamental or advanced material from mathematics, mechanics, physics, chemistry, metallurgy, structural analysis, aerodynamics, propulsion, electricity, electronics, environmental and vehicles dynamics; also the application of these sciences to flight vehicles and to space technology.

DESCRIPTION—The entrance requirement to the Aeronautical Engineering curricula, General and Graduate, is a Bachelor of Science degree, Naval Academy or its equivalent. The Naval Academy coverage in the basic prerequisite sciences in semester hours is Mathematics (20), Basic Engineering (30), Electrical Engineering (14), Physics (10) and Chemistry (8).

Students who can validate credit in the above fields at high scholarly standing may enter advanced courses starred below in the regular curriculum. These are best suited to higher education in subsystems of flight engineering. This graduate education is a revised form of the Graduate Curriculum AA shown, in its second year, with a third year either at this School or at one of the civilian institutions listed. It terminates in the Master or Engineer Degree, with designation, depending upon the subsystem.

The regular curricula complete the first year as shown, using courses marked by † to replace those above indicated by *. Thereafter selection is made: either to the Graduate Curriculum, AA, completed in a second and third year at Master Degree level; or to the General Curriculum, AG, completed in the second year with the B.S. (A.E.) Degree. Each curriculum has optional majors, as shown. After the first year, outstanding students in the AA Curriculum may qualify to work with the advanced flight systems engineering group.

FIRST YEAR AA( )4

First Term

†Ae 100C	Basic Aerodynamics	3- 2
*Ae 104C	Aerodynamics I	3- 2
Ae 204C	Solid Mechanics I	3- 2
*Ae 304C	Flight Kinematics	2- 2
Ae 404C	Thermodynamics I	3- 2
*Ma 221C	Differential Equations	3- 2
	†Electives (Ma, Mc, Ae) 4 to 8 credits	

Second Term

†Ae 101C	Technical Aerodynamics	3- 4
*Ae 105C	Aerodynamics II	3- 2
Ae 205C	Solid Mechanics II	3- 2
*Ae 305C	Flight Dynamics I	2- 2
Ae 405C	Thermodynamics II	3- 2
*Ae 109C	Aerodynamics Laboratory	0- 3
†Ma 221C	Differential Equations	3- 2
*EE 105C	Basic Electrical Phenomena	3- 2
Ae 001E	Aeronautical Lecture	0- 1

Third Term

†Ae 102C	Technical Aerodynamics Performance	4- 2
*Ae 106C	Aircraft Dynamics I	3- 2
Ae 206C	Structural Components I	3- 2
*Ae 306C	Flight Dynamics II	2- 2
Ae 406C	Thermodynamics III	3- 2
*Ae 209C	Structural Laboratory	0- 3
†EE 105C	Basic Electrical Phenomena	3- 2
*EE 106C	Basic Circuit Analysis I	3- 2
LP 101E	Lecture Program	0- 1

Fourth Term

†Ae 141B	Dynamics I	3- 2
*Ae 107B	Aircraft Dynamics II	3- 2
Ae 207C	Structural Components II	3- 2
*Ae 307C	Dynamics of Space Vehicles	2- 2
Ae 407C	Aircraft Propulsion	3- 2
Ae 409C	Aerothermodynamics Laboratory	0- 3
†EE 106C	Basic Circuit Analysis I	3- 2
	*Elective	
LP 102E	Lecture Program	0- 1

Summer intersessional period—Industrial tours to industry and military installations and courses in Naval Management.

GENERAL AERONAUTICAL ENGINEERING

SECOND YEAR AG( )3

First Term

Ae 108B	(3-2)	A	P	V
Ae 231C	(3-2)	A	P	V
Ae 214A	(4-0)	A	P	
Ae 151B	(2-0)	A		
Ae 161B	(0-4)	A		
Elect.	(3-2)	A	P	
EE 321C	(3-4)			V
EE 107C	(3-2)			V
Ae 309B	(0-3)	A	P	V

Second Term

Ae 501A	(4-0)	A	P	V
Ae 408B	(3-2)	A	P	V
Ae 232B	(2-2)	A	P	V
Ae 221B	(2-2)	A	P	V
Ae 152B	(2-0)	A		
Ae 162B	(0-4)	A		
EE 113B	(4-3)			V
EE 221B	(3-2)			V
Elect.	(3-2)		P	
Ae 001E	(0-1)	A	P	V

Third Term

Ae 502A	(4-0)	A	P	V
Ae 150B	(3-4)		P	
Ae 701A	(3-3)	A		V
EE 411B	(3-3)			V
EE 231C	(4-3)	A	P	
EE 222B	(3-2)			V
Elect.	(3-2)	A		
LP 101E	(0-1)	A	P	V

Fourth Term

Ae 508A	(3-2)	A	P	V
Ae 430A	(3-0)	A	P	
Ae 450A	(0-3)	A	P	
Ae 702A	(3-3)	A		V
Ae 153B	(2-0)	A		
Ae 163B	(0-4)	A		
EC 542A	(3-2)		P	
EE 498B	(3-4)		P	
EE 223A	(3-3)			V
Mc 403B	(3-0)			V
Elect.	(3-2)	A	P	V
LP 102E	(0-1)	A	P	V

AERO COURSE CODES:

100 Series Technical Aerodynamics
200 Series Structures
300 Series Flight Dynamics
400 Series Propulsion
500 Series Gas Dynamics
600 Series Advanced Structures
700 Series Guidance and Control Systems

GRADUATE AERONAUTICAL ENGINEERING

SECOND YEAR AA( )3

First Term

Ae 108B	(3-2)	A	P	S	V
Ae 231C	(3-2)	A	P	S	V
Ae 214A	(4-0)	A	P	S	
Ae 309B	(0-3)	A	P	S	V
EC 105C	(3-2)	A	P	S	
EE 321C	(3-4)				V
EE 107C	(3-2)				V
Ma Elect	(3-2)	A	P	S	

Second Term

Ae 232B	(2-2)	A	P	S	V
Ae 221B	(2-2)	A	P	S	V
Ae 511A	(4-0)	A	P	S	V
Ae 408B	(3-2)	A	P	S	V
Elective	(3-2)	A	P	S	
EE 113B	(4-3)				V
EE 221B	(3-2)				V
Ae 001E	(0-1)	A	P	S	V

Third Term

Ae 512A	(4-0)	A	P	S	V
Ae 215A	(4-0)				
Ae 601A	(4-0)	A	P	S	V
Ae 701A	(3-3)	A	P	S	V
Ma Elect	(3-0)	A	P	S	
EE 411B	(3-3)				V
EE 231C	(4-3)	A	P	S	
EE 222B	(3-2)				V
LP 101E	(0-1)	A	P	S	V

Fourth Term

Ae 513A	(4-0)	A	P	S	V
Ae 602A	(3-0)	A	P	S	V
Ae 431A	(4-0)	A	P		
Ae 451A	(0-3)	A	P		
Ae 702A	(3-3)			S	
EE 498B	(3-4)	A	P	S	
EC 112A	(3-2)		P		
EE 223A	(3-3)				V
EE 412A	(3-4)				V
Mc 403B	(3-0)				V
Mc 311C	(3-2)			S	
LP 102E	(0-1)	A	P	S	V

ELECTIVE Major Codes:

A Aero-Space Dynamics
P Propulsion
S Structures
V Avionics
M Aeromechanics
E Aeroelectricity
Z Aerophysics
X Aeroelectronics
Mt Aeromaterials

GRADUATE AERONAUTICAL ENGINEERING

THIRD YEAR CURRICULUM

Universities currently used in third year work and the fields in which they provide the strongest competence for advanced study are as follows:

CALIFORNIA INST. OF TECHNOLOGY, PASADENA, CAL.

Aerodynamics
Structures
Jet Propulsion

MASSACHUSETTS INST. OF TECHNOLOGY, CAMBRIDGE

Astronautics
Airborne Weapons Systems

UNIVERSITY OF MICHIGAN, ANN ARBOR, MICHIGAN

Aerodynamics
Aero-instrumentation
Propulsion
Structures
Nuclear Engineering

PRINCETON UNIVERSITY, PRINCETON, N. J.

Aerodynamics (flight mechanics)
Propulsion

IOWA STATE UNIV., AMES, IOWA

Nuclear Propulsion

COLLEGE OF AERONAUTICS, CRANFIELD, ENGLAND

Aerodynamics
Aircraft Design
Propulsion
Aircraft Electronics

STANFORD UNIVERSITY, STANFORD, CAL.

Aero- and Gasdynamics
Structures
Guidance and Control

U. S. NAVAL POSTGRADUATE SCHOOL

Flight Systems:
- Structures
- Propulsion
- Avionics-Guidance
- Avionics-Communication

Advanced Science:
- Aerophysics
- Aeromechanics
- Environmental Dynamics (Astronautics)
- Aeromaterials

ELECTRONICS AND COMMUNICATIONS ENGINEERING CURRICULA

DONALD FLEMING MILLIGAN, Commander, U.S. Navy; Curricular Officer, B.A., University of Kansas, 1947; Command Communications, USNPGS, 1953; U.S. Army Command and General Staff College, 1962.

PAUL RICHARD BYRD, Lieutenant Commander, U.S. Navy; Assistant Curricular Officer; B.S. Aeronautics, Miami University, Ohio, 1951; B.S. Communications Engineering, USNPGS, 1959.

OBJECTIVE—The objective of the Bachelor of Science program is to educate officers in the basic scientific and engineering fields related to electronics and communications and their application to the art of naval warfare.

The objective of the Master of Science program is to educate a selected group of academically qualified officers to develop a particular competence and ability in directing the development, evaluation, and operation of electronic and communications systems, as required by the Navy.

DESCRIPTION—All officers ordered for instruction in Electronics or Communications Engineering initially matriculate in a common basic curriculum for the first year and a half. At the end of the second and third terms of the first year, officers will be selected for more advanced curricula. This selection is based upon the Superintendent's appraisal of the individual's academic ability and is subject to final approval by the Chief of Naval Personnel. For properly qualified entering students, successful completion of the 2-year curricula leads to the award of a Bachelor of Science degree, and successful completion of the advanced curricula leads to the award of a Master of Science degree, in the chosen field of Electronics or Communications Engineering.

BASIC CURRICULUM (Common to all)

FIRST YEAR

First Term

EE 111C	Fields and Circuits	4- 4
Ma 150D	Vectors and Matrices	4- 1
Ma 230D	Calculus of Several Variables	4- 0
PH 105C	Mechanics	4- 0
		16- 5

Second Term

EE 112C	Circuit Analysis	4- 3
EE 211C	Electron Devices & Circuits I	4- 2
Ma 244C	Diff. Equations and Infinite Series	4- 0
PH 205C	Waves and Particles	4- 0
		16- 5

Third Term

EE 113B	Linear Systems Analysis	4- 3
EE 212C	Electron Devices & Circuits II	4- 3
Ma 271C	Complex Variables	4- 0
PH 604C	Structure of Atoms and Solids	4- 0
	or	
*PH 605B	Atomic Physics	4- 0
		16- 6

Fourth Term

EE 114B	Communication Theory	4- 0
EE 213C	Pulse and Wave Forming Circuits	4- 3
EE 811C	Electronic Computers	3- 3
	or	
*Ma 113C	Vector Analysis & Partial Diff. Equa.	4- 0
EE 731C	Electronic Measurements	3- 4
	or	
PH 705B	Solid State Physics	4- 2
		14-10
		or
		*16- 5

*Students eligible for MS curricula take these courses.

Fifth Term

Engineering Electronics and Communications Engineering students have leave period and take Mn 191C, Mn 210C and Sp 012D.

SECOND YEAR (Common to all 2-year students)

First Term

EE 611C	Electromagnetic Fields	4- 0
EE 214C	Electronic Communications Circuits I	4- 3
EE 116B	Communication Theory II	3- 2
EE 321C	Electro-mechanical Devices	3- 4
		14- 9

Second Term

EE 612C	Transmission of Electromagnetic Energy	3- 2
EE 215C	Electronic Communication Circuits II	4- 3
EE 216C	Special Electronic Devices	4- 2
EE 411B	Feedback Control Systems I	3- 3
		14-10

ENGINEERING ELECTRONICS

BS PROGRAM

For the last two terms of the second year, students in the two-year BS program are permitted to take approved elective courses best suited to their individual interests and naval experience. Four courses not exceeding 24 total hours per week are required for each term. For properly qualified entering students, successful completion of two years of work in this curriculum affords the opportunity to earn a Bachelor of Science degree in Engineering Electronics. A typical elective program for the final two terms would be as follows:

Third Term

EE 671B	Theory of Propagation	4- 0
EE 254B	Transistor Circuits	3- 3
EE 432B	Theory of Radar	3- 3
PH 450C	Underwater Acoustics (Required)	3- 2
		13- 8

Fourth Term

EE 455B	Sonar Systems	3- 3
EE 481B	Electronic Countermeasures	3- 3
EE 631B	Theory of Antennas	3- 3
EE 471B	Guidance and Navigation	3- 0
		12- 9

MS PROGRAM

Students selected for an MS program in Engineering Electronics will continue their studies in one of three options listed below. These options are designed to develop a particular competence in Advanced Electronics, Underwater Acoustics, or Information and Control Systems. The final six terms of these programs are a combination of required and elective courses. For the first six terms, students eligible for an MS program pursue the common basic curriculum, with some course substitutions as required, to prepare for this more advanced program.

Where elective courses are permitted, the selection must meet approval of the Curricular Officer and Academic Associate, as being consistent with the option major.

The third term of the third year may be spent in an industrial electronics laboratory. During this period, the student works as a junior engineer on a selected project which may form a part of, or be related to, his thesis.

OPTION I—ADVANCED ELECTRONICS

SECOND YEAR—GROUP EA

First Term

EE 214C	Electronic Communications Circuits I	4- 3
EE 621B	Electromagnetics I	3- 2
EE 811C	Electronic Computers	3- 3
Ma 321B	Probability	4- 2
		14-10

Second Term

EE 215C	Electronic Communication Circuits II	4- 3
EE 321C	Electromechanical Devices	3- 4
EE 571A	Statistical Communication Theory	3- 2
EE 622B	Electromagnetics II	4- 0
		14- 9

Third Term

EE 217B	Advanced Electronic Devices	4- 2
EE 433A	Radar Systems	4- 0
EE 411B	Feedback Control Systems I	3- 3
Ma 322A	Decision Theory and Classical Statistics	3- 2
		14- 7

Fourth Term

EE 253A	Microwave Tubes	3- 2
Ph 152B	Mechanics II	4- 0
EE 623A	Advanced Electromagnetic Theory	3- 0
EE 631B	Theory of Antennas	3- 3
		13- 5

THIRD YEAR—GROUP EA

First Term

EE 254B	Transistor Circuits	3- 3
EE 652A	Microwave Circuits and Measurements	3- 2
*EE 121A	Advanced Network Analysis	3- 2
	Thesis	0- 3
		9-10

Second Term

EE 122A	Network Synthesis I	3- 2
EE 541A	Signal Processing	4- 0
*EE 473A	Missile Guidance	3- 0
	Thesis	0- 3
		10- 5

Third Term

Industrial Tour.

Fourth Term

EE 941A	Thesis Seminar	0- 1
OA 121A	Survey of Operations Analysis	4- 2
EE 481B	Electronic Countermeasures	3- 3
*EE 671B	Theory of Propagation	4- 0
	Thesis	0- 2
		11- 8

*Typical Electives

OPTION II
UNDERWATER ACOUSTICS

SECOND YEAR—GROUP EW

First Term

Same as Option I.

Second Term

Same as Option I.

Third Term

EE 217B	Advanced Electron Devices	4- 2
EE 433A	Radar Systems	4- 0
Ma 322B	Decision Theory & Classical Statistics	3- 2
PH 431B	Fundamental Acoustics	4- 0
		15- 4

Fourth Term

EE 411B	Feedback Control Systems I	3- 3
EE 671B	Theory of Propagation	4- 0
Oc 110C	Introduction to Oceanography	3- 0
PH 432B	Underwater Acoustics	4- 3
		14- 6

THIRD YEAR—GROUP EW

First Term

EE 451A	Sonar Systems Engineering	4- 3
PH 461A	Transducer Theory and Design	3- 3
*EE 254B	Transistor Circuits	3- 3
	Thesis	0- 3
		10-12

Second Term

EE 122A	Network Synthesis I	3- 2
EE 541A	Signal Processing	4- 0
PH 433A	Propagation of Waves in Fluids	3- 0
	Thesis	0- 3
		10- 5

Third Term

Industrial Tour

Fourth Term

EE 941A	Thesis Seminar	0- 1
OA 121A	Survey of Operations Analysis	4- 2
PH 442A	Finite Amplitude Waves in Fluids	3- 0
*EE 481B	Electronic Countermeasures	3- 3
		10- 6

*Typical Electives

OPTION III INFORMATION AND CONTROL

SECOND YEAR—GROUP EI

First Term

Same as Option I.

Second Term

Same as Option I.

Third Term

EE 217B	Advanced Electron Devices	4- 2
EE 411B	Feedback Control Systems I	3- 3
EE 433A	Radar Systems	4- 0
Ma 322B	Decision Theory and Classical Statistics	3- 2
		14- 7

Fourth Term

EE 412A	Feedback Control Systems II	3- 4
EE 551A	Information Networks	3- 2
Ma 116B	Matrices and Numerical Methods	3- 2
Ma 423B	Advanced Digital Computer Programming	4- 0
		13- 8

THIRD YEAR—GROUP EI

First Term

*EE 121A	Advanced Network Analysis	3- 2
EE 413A	Sampled Data Control Systems	2- 2
EE 462A	Automation and System Control	3- 3
	Thesis	0- 3
		8-10

Second Term

EE 122A	Network Synthesis I	3- 2
EE 541A	Signal Processing	4- 0
*EE 461A	Systems Engineering	3- 2
	Thesis	0- 3
		10- 7

Third Term

Industrial Tour

Fourth Term

EE 941A	Thesis Seminar	0- 1
OA 121A	Survey of Operations Analysis	4- 2
*EE 254B	Transistor Circuits	3- 3
*EE 481B	Electronic Countermeasures	3- 3
	Thesis	0- 3
		10-12

*Typical Electives

COMMUNICATIONS ENGINEERING

BS PROGRAM

For the last two terms of the second year, students in the two-year Communications Engineering BS programs are permitted to take certain approved elective courses best suited to their individual interests and naval experience. Four courses not exceeding 24 hours per week are required for each term. For properly qualified entering students, successful completion of two years of work in this curriculum affords the opportunity to earn a Bachelor of Science degree in Communications Engineering. A typical program for the final two terms would be as follows:

SECOND YEAR

Third Term

PH 450C	Underwater Acoustics	3- 2
*EE 631B	Theory of Antennas	3- 3
*EE 254B	Transistor Circuits	3- 3
EE 422B	Modern Communications I	3- 3
		12-11

Fourth Term

*EE 471B	Guidance and Navigation	3- 0
*EE 671B	Theory of Propagation	4- 0
*EE 821B	Computer Systems Technology	3- 3
*EE 481B	Electronic Countermeasures	3- 3
		13- 6

*Typical Electives

MS PROGRAM

Communications Engineering students selected for an MS program will follow the curriculum outlined below. For the first six terms, students eligible for this program will pursue a common basic curriculum, with some course substitutions as required to prepare them for an advanced program.

Where elective courses are permitted, the selection must meet approval of the Curricular Officer and Academic Associate, as consistent with the major field of study.

The third term of the third year may be spent in an industrial laboratory. During this period, the student works as a junior engineer on a selected project which may form a part of or be related to his thesis.

COMMUNICATIONS ENGINEERING ADVANCED

SECOND YEAR—GROUP CE

First Term

Same as Engineering Electronics Options.

Second Term

Same as Engineering Electronics Options.

Third Term

EE 217B	Advanced Electron Devices	4- 2
EE 422B	Modern Communications I	3- 3
EE 433A	Radar Systems	4- 0
Ma 322A	Decision Theory and Classical Statistics	3- 2
		14- 7

Fourth Term

EE 411B	Feedback Control Systems I	3- 3
EE 631B	Theory of Antennas	3- 3
EE 671B	Theory of Propagation	4- 0
*EE 253A	Microwave Tubes	3- 2
		13- 8

*Typical Electives

THIRD YEAR—GROUP CE

First Term

EE 462A	Automation and System Control	3- 3
EE 652A	Microwave Circuits and Measurements	3- 2
MN 210C	Principles of Economics	4- 0
OA 111B	Principles of Operations Analysis	4- 2
	Thesis	0- 3
		14-10

Second Term

EE 122A	Network Synthesis I	3- 2
EE 541A	Signal Processing	4- 0
MN 412A	Managerial Economics	4- 0
OA 112A	Advanced Methods in Operations Analysis	4- 0
		15- 2

Third Term

Industrial Tour.

Fourth Term

EE 941A	Thesis Seminar	0- 1
*Ma 423B	Advanced Digital Computer Programming	4- 0
*MN 473A	Quantitative Decision Making	3- 0
*MN 480A	Facilities Planning	3- 0
	Thesis	0- 2
		10- 3

*Typical Electives

SPECIAL ELECTRONICS CURRICULUM FOR SELECTED CEC OFFICERS

Objective—To prepare selected CEC officers for special duties requiring a technical capability for planning electronic facilities and accomplishing the engineering studies required in the development of plans and specifications for their construction.

Prerequisite—BSEE degree from an accredited institution and at least an overall grade average of B.

description—For properly qualified entering students, successful completion of this curriculum affords the opportunity to earn a Master of Science degree in Engineering Electronics. The curriculum can be modified both as to length and content depending upon the individual student's background. A typical curriculum is outlined below.

ENGINEERING ELECTRONICS—GROUP EY

First Term

EE 113B	Linear Systems Analysis	4- 3
EE 621B	Electromagnetics I	3- 2
EE 811C	Electronic Computers	3- 3
EE 321C	Electromechanical Devices	3- 4
		13-12

Second Term

EE 114B	Communication Theory I	4- 0
EE 411B	Feedback Control Systems I	3- 3
EE 122A	Network Synthesis I	3- 2
EE 622B	Electromagnetics II	4- 0
		14- 5

Third Term

EE 217B	Advanced Electron Devices	4- 2
MA 321B	Probability	4- 2
	One Elective	3- 3
	Thesis	0- 3
		11-10

Fourth Term

EE 253A	Microwave Tubes	3- 2
EE 571A	Statistical Communication Theory	3- 2
MA 322A	Decision Theory & Classical Statistics	3- 2
	Thesis	0- 3
		9- 9

Fifth Term

During intersessional period, student will work on thesis and participate in CEC workshop seminar.

SECOND YEAR

First Term

EE 433A	Radar Systems	4- 0
EE 652A	Microwave Circuits and Measurements	3- 2
	One Elective	3- 3
	Thesis	0- 2
		10- 7

ENGINEERING SCIENCE CURRICULA

BRUNO MUSSETTO, Commander, U.S. Navy; Curricular Officer; B.S., Mechanical Engineering, Swarthmore, 1946; B.S., Electrical Engineering, USNPGS, 1961.

WILLIAM D. MCCLARY, Lieutenant Commander, U.S. Navy; Assistant Curricular Officer; B.A., Southeastern Oklahoma State College, 1948; M.Ed., Univ. of Oklahoma, 1954.

OBJECTIVE—To provide post-commissioning education in the fields of Mathematics, Physics and Engineering, designed to update and build on undergraduate education and to prepare students for advanced functional training such as Naval Tactical Data Systems; Polaris and other missiles; instructor duty on school staffs; test pilot schools.

HIGH ACADEMIC BACKGROUND

First Term

Ma 230D	Calculus of Several Variables	4- 0
Ma 120D	Vector and Matrices	3- 1
PH 151C	Mechanics I	4- 0
EE 111C	Fields and Circuits	4- 4
		15- 5

Second Term

Ma 073C	Differential Equations	5- 0
PH 152B	Mechanics II	4- 0
PH 240C	Optics and Spectra	3- 3
EE 112C	Circuit Analysis	4- 3
		16- 6

Third Term

Ma 311C	Introduction to Probability and Statistics	4- 0
Ma 126B	Numerical Methods for Digital Computers	3- 2
PH 630B	Elementary Atomic Physics	4- 0
EE 231C	Electronics I	4- 3
		15- 5

Fourth Term

Ma 421C	Introduction to Digital Computers	4- 1
OA 101C	Elements of Operations Analysis	3- 1
PH 621B	Elementary Nuclear Physics	4- 0
EE 232C	Electronics II	4- 3
		15- 5

AVERAGE ACADEMIC BACKGROUND

First Term

Ma 071D	Calculus I	5- 0
PH 021C	Mechanics	4- 0
CH 106D	Principles of Chemistry I	3- 2
Mt 021C	Elements of Materials Science I	3- 2
		15- 4

Second Term

Ma 072D	Calculus II	3- 0
Ma 081C	Introduction to Vector Analysis	2- 0
PH 022C	Fluid Mechanics Wave Motion and Thermodynamics	4- 0
CH 107D	Principles of Chemistry II	3- 2
Mt 022C	Elements of Materials Science II	3- 2
		15- 4

Third Term

Ma 073C	Differential Equations	5- 0
Ma 311C	Introduction to Probability and Statistics	4- 0
PH 023C	Electricity and Magnetism	4- 0
EE 111C	Fields and Circuits	4- 4
		17- 4

Fourth Term

Ma 421C	Introduction to Digital Computers	4- 1
OA 101C	Elements of Operations Analysis	3- 1
PH 024C	Electromagnetic Radiation and Optics	4- 0
EE 112C	Circuit Analysis	4- 3
		15- 5

FAIR ACADEMIC BACKGROUND (UPPER)

First Term

Ma 031D	College Algebra and Trigonometry	5- 0
PH 016D	General Physics Mechanics	4- 0
CH 106D	Principles of Chemistry I	3- 2
		12- 2

Second Term

Ma 051D	Calculus and Analytic Geometry I	5- 0
PH 017D	General Physics Thermodynamics Sound and Light	4- 0
CH 107D	Principles of Chemistry II	3- 2
Mr 010D	Meteorology	3- 0
		15- 2

Third Term

Ma 052D	Calculus and Analytic Geometry II	5- 0
Oc 110C	Introduction to Oceanography	3- 0
Mt 021C	Elements of Materials Science I	3- 2
PH 018D	General Physics Electricity and Magnetism	4- 0
		15- 2

Fourth Term

Ma 053D	Calculus and Analytic Geometry III	3- 0
PH 019C	Modern Physics	4- 0
Mt 022C	Elements of Materials Science II	3- 2
Ma 081C	Introduction to Vector Analysis	2- 0
Ma 411C	Digital Computers and Military Applications	4- 0
		16- 2

FAIR ACADEMIC BACKGROUND (LOWER)

First Term

Ma 031D	College Algebra and Trigonometry	5- 0
CH 001D	Introductory General Chemistry I	4- 3
PH 001D	General Physics I	4- 0
		13- 3

Second Term

Ma 051D	Calculus and Analytic Geometry I	5- 0
CH 002D	Introductory General Chemistry II	3- 3
PH 002D	General Physics II	4- 0
Mr 010D	Meteorology	3- 0
		15- 3

Third Term

Ma 052D	Calculus and Analytic Geometry II	5- 0
PH 003D	General Physics III	4- 0
Mt 021C	Elements of Materials Science I	3- 2
Oc 110C	Introduction to Oceanography	3- 0
		15- 2

Fourth Term

Ma 053D	Calculus and Analytic Geometry III	3- 0
Ma 081C	Introduction to Vector Analysis	2- 0
PH 004D	General Physics IV	4- 0
Mt 022C	Elements of Materials Science II	3- 2
Ma 411C	Digital Computers and Military Applications	4- 0
		16- 2

From those Engineering Science students who are available for two or more years of Postgraduate School study, a number will be transferred into other technical curricula at the end of their second term. Such transfers will be based upon academic performance, availability of openings in the technical curricula, and application by the students. The two-term curricula for these students are as follows:

HIGH ACADEMIC BACKGROUND

First Term

Ma 120D	Vectors and Matrices	3- 1
Ma 230D	Calculus of several variables	4- 0
PH 151C	Mechanics I	4- 0
EE 111C	Fields and Circuits	4- 4
		15- 5

Second Term

Ma 073C	Differential Equations	5- 0
PH 152B	Mechanics II	4- 0
EE 112C	Circuit Analysis	4- 3
PH 240C	Optics and Spectra	3- 3
		16- 6

AVERAGE ACADEMIC BACKGROUND

First Term

Ma 071D	Calculus I	5- 0
PH 021C	Mechanics	4- 0
CH 106D	Principles of Chemistry I	3- 2
EE 111C	Fields and Circuits	4- 4
		16- 6

Second Term

Ma 072D	Calculus II	3- 0
Ma 081C	Introduction to Vector Analysis	2- 0
PH 022C	Fluid Mechanics Wave Motion and Thermodynamics	4- 0
CH 107D	Principles of Chemistry II	3- 2
EE 112C	Circuit Analysis	4- 3
		16- 5

ENVIRONMENTAL SCIENCES CURRICULA

JULIUS FREDERICK STEUCKERT, Captain, U.S. Navy; Curricular Officer; B.S., USNA, 1940; B.S., Aerological Engineering, USNPGS, 1948.

SAMUEL WOODWORTH SELTRIDGE, JR., Commander, U.S. Navy; Assistant Curricular Officer; B.S., USNA, 1944; M.S., USNPGS, 1960.

ADVANCED METEOROLOGY CURRICULUM

OBJECTIVE—To prepare officers to become qualified meteorologists with a working knowledge of Oceanography as applied to naval operations and to enable them, through advanced study, to conduct independent research.

FIRST YEAR

First Term

Ma 120D	Vectors and Matrices with Geometric Applications	3- 1
Ma 230D	Calculus of Several Variables	4- 0
Mr 200C	Introduction to Meteorology	3- 0
Oc 110C	Introduction to Oceanography	3- 0
Ph 196C	Review of General Physics	4- 2
Mr 001D	Weather Codes and Elementary Analysis	0- 3
		17- 6

Second Term

Ma 240C	Elementary Differential Equations	2- 0
Ma 251C	Elementary Infinite Series	3- 0
Mr 201C	Elementary Weather-Map Analysis	0- 9
Mr 211C	Elementary Weather-Map Analysis	3- 0
Mr 410C	Meteorological Instruments	2- 2
Mr 413B	Thermodynamics of Meteorology	3- 2
		13-13

Third Term

Ma 261B	Vector Mechanics	5- 0
Ma 332B	Statistics I	3- 0
Mr 202C	Weather-Map Analysis	0- 6
Mr 212C	Introduction to Weather Elements	3- 0
Mr 321A	Dynamic Meteorology I	3- 0
Oc 220B	Descriptive Oceanography	3- 0
LP 101E	Lecture Program I	0- 1
		17- 7

Fourth Term

Ma 125B	Numerical Methods for Digital Computers	2- 2
Ma 333B	Statistics II	2- 2
Mr 203C	Forecasting Weather Elements and Mesometeorology	0- 6
Mr 213C	Forecasting Weather Elements and Mesometeorology	2- 0
Mr 322A	Dynamic Meteorology II	3- 0
Oc 260B	Sound in the Ocean	3- 0
LP 102E	Lecture Program II	0- 1
		12-11

Fifth Term

Ma 421C	Introduction to Digital Computers	4- 1
		4- 1

During intersessional period, students are instructed in various aspects of Meteorology and Oceanography as applied to naval operations. Visits to naval and civilian installations are also conducted.

SECOND YEAR

First Term

Ma 128B	Numerical Methods in Partial Differential Equations	3- 1
Mr 204B	Upper-Air and Surface Prognosis	0- 6
Mr 214B	Upper-Air and Surface Prognosis	3- 0
Mr 323A	Dynamic Meteorology III	3- 0
Mr 412A	Physical Meteorology	3- 0
Mr 521B	Synoptic Climatology	2- 2
Ma 420E	Computer Operations (five weeks)	1- 1
		15-10

Second Term

Mr 205B	The Middle Atmosphere	0- 6
Mr 215B	The Middle Atmosphere	3- 0
Mr 228B	Tropical and Southern Hemisphere Meteorology	3- 0
Mr 324A	Dynamical Prediction	3- 3
Oc 201B	Ocean Waves and Tides	3- 1
		12-10

Third Term

Mr 208B	Tropical and Southern Hemisphere Meteorology	0- 6
Mr 422A	The Upper Atmosphere	4- 0
Oc 611B	Ocean Wave Forecasting	3- 6
LP 101E	Lecture Program I	0- 1
	Thesis I	0- 8
		7-21

Fourth Term

Mr 206C	Naval Weather Service Operations	1- 9
Oc 619B	Oceanographic Forecasting	3- 4
Mr 810B	Seminar in Meteorology and Oceanography	2- 0
Mr 415B	Radar Meteorology	2- 0
	or	
Mr 325A	Energetics of General Circulation	2- 0
LP 102E	Lecture Program II	0- 1
	Thesis II	0- 8
		8-22

For properly qualified entering students, this curriculum affords the opportunity to qualify for the Master of Science degree in Meteorology.

ADVANCED AIR-OCEAN ENVIRONMENT CURRICULUM

Objective—To provide advanced education in Oceanography and Meteorology with emphasis on interaction between the atmosphere and oceans. Special naval applications of this curriculum include forecasting weather and sea conditions for submarine operations, antisubmarine warfare, polar operations, surface shipping and air operations; high-speed digital computer operation and techniques are included.

FIRST YEAR

Terms I through III same as ADVANCED METEOROLOGY CURRICULUM.

Fourth Term

Ma 125B	Numerical Methods for Digital Computers	2- 2
Ma 333B	Statistics II	2- 2
Mr 203C	Forecasting Weather Elements and Mesometeorology	0- 6
Mr 213C	Forecasting Weather Elements and Mesometeorology	2- 0
Mr 322A	Dynamic Meteorology II	3- 0
Oc 700B	Oceanographic Instruments and Observations	2- 2
LP 102E	Lecture Program II	0- 1
		11-13

Fifth Term

Ma 421C	Introduction to Digital Computers	4- 1
Oc 720B	Field Experience in Oceanography	0- 4
		4- 5

During intersessional period, students are instructed in various aspects of Meteorology and Oceanography as applied to naval operations. Visits to naval and civilian installations are also conducted.

SECOND YEAR

First Term

Mr 412A	Physical Meteorology	3- 0
Mr 521B	Synoptic Climatology	2- 2
Oc 211A	Ocean Waves	3- 0
Oc 253A	Dynamic Oceanography III	3- 0
Oc 260B	Sound in the Ocean	3- 0
Ma 420E	Computer Operations (five weeks)	1- 1
		15- 3

Second Term

Mr 217B	Interpretive Weather Forecasting and Prognosis	2- 6
Oc 611B	Ocean Wave Forecasting	3- 6
Oc 320B	Introduction to Geological Oceanography	3- 2
Oc 420B	Introduction to Biological Oceanography	3- 2
		11-16

Third Term

Oc 212A	Tides and Tidal Currents	3- 0
Oc 213A	Shallow-Water Oceanography	3- 1
Oc 615B	Oceanographic Forecasting I	3- 4
	Elective of additional OC Course	
LP 101E	Lecture Program I	0- 1
	Thesis I	0- 8
		9-14

Fourth Term

Mr 810B	Seminar in Meteorology and Oceanography	2- 0
Oc 612B	Arctic Oceanography	3- 0
Oc 617B	Oceanographic Forecasting II	3- 4
LP 102E	Lecture Program II	0- 1
	Thesis II	0- 8
		8-13

For properly qualified entering students, this curriculum affords an opportunity to qualify for the Master of Science degree.

GENERAL AIR-OCEAN ENVIRONMENT CURRICULUM

OBJECTIVE—To provide education in Oceanography and Meteorology with emphasis on interaction between the atmosphere and oceans. Special naval applications of this curriculum include forecasting weather and sea conditions for submarine operations, anti-submarine warfare, surface shipping and air operations.

FIRST YEAR

First Term

Ma 051D	Calculus and Analytic Geometry I	5- 0
Mr 200C	Introduction to Meteorology	3- 0
Oc 110C	Introduction to Oceanography	3- 0
Ph 190D	Survey of Physics I	3- 0
Mr 001D	Weather Codes and Elementary Analysis	0- 3
		14- 3

Second Term

Ma 052D	Calculus and Analytic Geometry II	5- 0
Mr 201C	Elementary Weather-Map Analysis	0- 9
Mr 211C	Elementary Weather-Map Analysis	3- 0
Mr 410C	Meteorological Instruments	2- 2
Ph 191D	Survey of Physics II	3- 0
		13-11

Third Term

Ma 053D	Calculus and Analytic Geometry III	3- 0
Ma 081C	Introduction to Vector Analysis	2- 0
Mr 202C	Weather-Map Analysis	0- 6
Mr 212C	Introduction to Weather Elements	3- 0
Mr 402C	Introduction to Meteorological Thermodynamics	3- 2
Oc 220B	Descriptive Oceanography	3- 0
LP 101E	Lecture Program I	0- 1
		14- 9

Fourth Term

Ma 381C	Elementary Probability and Statistics	4- 2
Mr 203C	Forecasting Weather Elements and Mesometeorology	0- 6
Mr 213C	Forecasting Weather Elements and Mesometeorology	2- 0
Mr 301B	Elementary Dynamic Meteorology I	4- 0
Oc 700B	Oceanographic Instruments and Observations	2- 2
LP 102E	Lecture Program II	0- 1
		12-11

Fifth Term

Ma 412C	Small Scale Digital Computers	3- 2
Oc 720B	Field Experience in Oceanography	0- 4
		3- 6

During intersessional period, students are instructed in various aspects of Meteorology and Oceanography as applied to naval operations. Visits to naval and civilian installations are also conducted.

SECOND YEAR

First Term

Mr 403B	Introduction to Micrometeorology	4- 0
Mr 204B	Upper-Air and Surface Prognosis	0- 6
Mr 214B	Upper-Air and Surface Prognosis	3- 0
Mr 302B	Elementary Dynamic Meteorology II	4- 0
Mr 521B	Synoptic Climatology	2- 2
Oc 260B	Sound in the Ocean	3- 0
		16- 8

Second Term

Mr 205B	The Middle Atmosphere	0- 6
Mr 215B	The Middle Atmosphere	3- 0
Mr 228B	Tropical and Southern Hemisphere Meteorology	3- 0
Oc 611B	Ocean Wave Forecasting	3- 6
Oc 201B	Ocean Waves and Tides	3- 1
		12-13

Third Term

Oc 241B	Elementary Dynamic Oceanography	3- 0
Mr 208B	Tropical and Southern Hemisphere Meteorology	0- 6
Oc 615B	Oceanographic Forecasting I	3- 4
LP 101E	Lecture Program I	0- 1
	Research Problem	0- 6
		6-17

Fourth Term

Mr 206C	Naval Weather Service Operations	1- 9
Mr 810B	Seminar in Meteorology and Oceanography	2- 0
Oc 612B	Arctic Oceanography	3- 0
Oc 617B	Oceanographic Forecasting II	3- 4
LP 102E	Lecture Program II	0- 1
		9-14

For properly qualified entering students, this curriculum affords an opportunity to qualify for a Bachelor of Science degree in Environmental Science.

OCEANOGRAPHY CURRICULUM

OBJECTIVE—To provide officers with an education in physical oceanography with particular emphasis on naval operations, and to enable them through advanced study to conduct independent research.

FIRST YEAR

First Term

Ma 120D	Vectors and Matrices	3- 1
Ma 230D	Calculus of Several Variables	4- 0
Mr 200C	Introduction to Meteorology	3- 0
Oc 110C	Introduction to Oceanography	3- 0
Ph 196C	Review of General Physics	4- 2
Mr 001D	Weather Codes and Elementary Analysis	0- 3
		17- 6

Second Term

Ma 240C	Elementary Differential Equations	2- 0
Ma 251C	Elementary Infinite Series	3- 0
Mr 201C	Elementary Weather-Map Analysis	0- 9
Mr 211C	Elementary Weather-Map Analysis	3- 0
Mr 410C	Meteorological Instruments	2- 2
Mr 413B	Thermodynamics of Meteorology	3- 2
		13-13

Third Term

Mr 261B	Vector Mechanics	5- 0
Ma 322B	Statistics I	3- 0
Oc 220B	Descriptive Oceanography	3- 0
Oc 320B	Introduction to Geological Oceanography	3- 2
Oc 420B	Introduction to Biological Oceanography	3- 2
LP 101E	Lecture Program I	0- 1
		17- 5

Fourth Term

Ma 125B	Numerical Methods for Digital Computers	2- 2
Ma 333B	Statistics II	2- 2
Oc 211A	Ocean Waves	3- 0
Oc 251A	Dynamic Oceanography I	3- 0
Oc 700B	Oceanographic Instruments and Observations	2- 2
LP 102E	Lecture Program II	0- 1
		12- 7

Fifth Term

Ma 421C	Introduction to Digital Computers	4- 1
Oc 720B	Field Experience in Oceanography	0- 4
		4- 5

During intersessional period, students are instructed in various phases of Oceanography as it applies to naval operations. Visits to naval and civilian installations are also conducted.

SECOND YEAR

First Term

Ma 128B	Numerical Methods in Partial Differential Equations	3- 1
Oc 212A	Tides and Tidal Currents	3- 0
Oc 611B	Ocean Wave Forecasting	3- 6
Oc 252A	Dynamic Oceanography II	3- 0
Oc 260B	Sound in the Ocean	3- 0
		15- 7

Second Term

Oc 213A	Shallow-Water Oceanography	3- 1
Oc 520B	Introduction to Chemical Oceanography	3- 2
Oc 253A	Dynamic Oceanography III	3- 0
Oc 615B	Oceanographic Forecasting I	3- 4
		12- 7

Third Term

Oc 820A	Special Topics in Oceanography	3- 0
Oc 340A	Marine Geophysics	2- 0
Oc 617B	Oceanographic Forecasting II	3- 4
LP 101E	Lecture Program I	0- 1
	Thesis I	0- 8
		8-13

Fourth Term

Oc 613B	Arctic Oceanography	3- 4
Oc 810B	Seminar in Oceanography	2- 0
	Elective	3- 0
	Thesis II	0- 8
LP 102E	Lecture Program II	0- 1
		8-13

This curriculum affords the opportunity to qualify for the degree of Master of Science in Oceanography, with a particular capability in physical oceanography. Students entering the curriculum with the baccalaureate in geology, biology, or chemistry may follow a modified curriculum, including preparation of a thesis in geological, biological, or chemical oceanography, which will qualify them for the same degree but with a capability in one of those three fields.

GENERAL LINE and BACCALAUREATE CURRICULA

JOHN DICK, Commander, U.S. Navy, Curricular Officer; BS, University of Minnesota, 1940

FRANK EMILIO LA CAUZA (1929)*, Academic Associate; BS, Harvard University, 1923; MS, 1924; AM, 1929

HOWARD W. CARR, Commander, U.S. Navy, Assistant Curricular Officer

JANET L. HERSLEY, Lieutenant Junior Grade, U.S. Navy Administrative Officer.

*The year of joining the Postgraduate School faculty is indicated in parentheses.

OBJECTIVES:

BACCALAUREATE CURRICULA: To raise the educational level, broaden the mental outlook, and increase the professional and scientific knowledge of naval officers who do not have a baccalaureate degree.

The Baccalaureate curricula provide specialized study to meet the professional needs of the commissioned officer. The different educational backgrounds and personal needs of the students are accommodated by providing two baccalaureate curricula. The Bachelor of Science program gives emphasis to the physical environment, without neglecting the social. The Bachelor of Arts program emphasizes the social environment without neglecting the physical.

GENERAL LINE CURRICULUM: To provide instruction of about nine and one-half months duration which will prepare those foreign officers enrolled for more responsible duties in their respective operating forces, as well as with combined staffs of allied forces.

GENERAL LINE CURRICULUM

REQUIRED COURSES

NW 102C	Operational Communications	3- 0
NW 191D	Tactics and CIC	3- 2
NW 193D	Anti-submarine Warfare	3- 0
NW 201C	Operational Planning	3- 0
NW 202C	Amphibious Operations	3- 0
NW 203D	Naval Aviation Survey	3- 0
NW 391D	Ordnance-Weapons Systems	3- 0
NW 393D	Missiles and Space Operations	3- 0
NW 395D	Mine Warfare	3- 0
NW 402C	Marine Piloting and Radar Navigation	2- 2
NW 404C	Logistics and Naval Supply	3- 0
NW 406C	Command Seamanship	3- 0
NW 501C	Marine Engineering	4- 0
NW 502C	Damage Control and ABC Warfare Defense	4- 0
EE 101D	Electrical Fundamentals	3- 2
Ma 010D	Basic Algebra and Trigonometry I	4- 0
PH 006D	Survey of Physics	5- 0
EE 205D	Electronics Fundamentals	3- 2
PH 600D	Nucleonics Fundamentals	3- 0
SP 001D	Elementary Speech	2- 0
		63- 8

ELECTIVE COURSES

NW 403C	Celestial Navigation	3- 0
NW 405D	Personal Affairs	3- 0
EE 301D	Electrical Machinery	3- 2
Ma 011D	Basic Algebra and Trigonometry II	3- 0
Ma 016D	Survey of Analytic Geometry and Calculus	4- 0
Ma 017D	Elementary Calculus	3- 0
Mr 010D	Meteorology	3- 0
GV 102C	International Relations I	3- 0
GV 103C	International Relations II	3- 0
GV 120C	Military Law I*	3- 0
GV 121C	Military Law II*	3- 0
GV 122C	International Law	4- 0
MN 191C	Organization and Management	4- 0

*Permission must be obtained from the Chairman of the Government and Humanities Department before an allied student may take either Military Law course.

BACCALAUREATE CURRICULA

The Baccalaureate Curricula include the Naval Professional courses of the General Line Curriculum and, in addition, sufficient coverage in the Humanities and Science Engineering areas to adequately support Bachelor of Science and Bachelor of Arts degrees. From one to two calendar years are allowed for those enrolled to complete the program. Students pursuing these curricula carry an average load of 18 credit hours.

To be eligible for enrollment an officer must have acceptable advanced standing of 45 semester hours which can be applied toward completion of the prescribed course of study. This must include a minimum of five term hours of college-level mathematics.

The Baccalaureate Curricula meet the general degree requirements of the Postgraduate School. The BS Curriculum consists of 216 term hours distributed in the following academic areas: 119 (55%) in Science Engineering; 54 (25%) in Naval Professional; 43 (20%) in Government and Humanities. The Bachelor of Arts Curriculum consists of 216 term hours distributed as follows: 119 (55%) in Government and Humanities; 54 (25%) in Naval Professional; 43 (20%) in Science-Engineering.

The Baccalaureate Curricula schedules are shown below. Students are required to complete the courses listed there, or equivalents, either before admission to the curriculum or as part of it. Furthermore, it will be necessary to satisfy a basic English and Grammar requirement through attainment of satisfactory scores on a standard examination administered on arrival.

*BACHELOR OF SCIENCE

CURRICULUM SCHEDULE

First Term

CH 001D	Introduction to General Chemistry I	4- 3
EN 101C	Advanced Writing for Naval Officers	3- 2
Ma 031D	College Algebra and Trigonometry	5- 0
MN 010D	Introduction to Economics	4- 0
		16- 5

Second Term

CH 002C	Introduction to General Chemistry II	3- 3
GV 102C	International Relations I	3- 0
Ma 051D	Calculus and Analytic Geometry I	5- 0
NW 201C	Operational Planning	3- 0
PY 010D	Psychology I	3- 0
		17- 3

Third Term

GV 103C	International Relations II	3- 0
Ma 052D	Calculus and Analytic Geometry II	5- 0
Mt 021C	Elements of Material Science I	3- 2
PH 011D	General Physics I	4- 3
NW 301C	Ordnance Weapon System	3- 0
		18- 5

Fourth Term

GV 142C	International Communism	4- 0
Ma 053D	Calculus and Analvtic Geometry III	3- 0
Ma 081C	Introduction in Vector Analysis	2- 0
NW 102C	Operational Communications	3- 0
NW 202C	Amphibious Operations	3- 0
PH 012D	General Physics II	4- 3
		19- 3

Fifth Term

GV 120C	Military Law I	3- 0
HI 102C	U. S. History II	4- 0
ME 561C	Mechanics I	4- 0
NW 404C	Logistics and Naval Supply	3- 0
PH 013D	General Physics III	3- 3
SP 010D	Public Speaking	2- 0
		19- 3

Sixth Term

NW 205C	Naval Warfare Seminar	3- 0
		3- 0

Seventh Term

EE 111C	Fields and Circuits	4- 4
GV 121C	Military Law II	3- 0
HI 104C	European History	4- 0
ME 562C	Mechanics II	4- 0
SP 011D	Conference Procedures	2- 0
		17-4

Eighth Term

EE 112C	Circuits Analysis	4- 3
NW 101C	Tactics and CIC	3- 2
NW 501C	Marine Engineering	4- 0
PH 014D	General Physics IV	4- 2
		15- 7

Ninth Term

EE 231C	Electronics I	4- 3
NW 203D	Naval Action Survey OR	
NW 204C	Aviator's Aviation	3- 0
NW 401C	Leadership	4- 0
NW 402C	Marine Piloting and Radar Navigation	2- 2
NW 502C	Damage Control and ABC Warfare Defense	4- 0
		17- 5

Tenth Term

EE 232C	Electronics II	4- 3
NW 103C	Anti-Submarine Warfare	4- 0
NW 302C	Nuclear Weapons	3- 0
NW 303C	Missiles and Space Operations	6- 0
NW 406C	Command Seamanship	3- 0
		20- 3

*BACHELOR OF ARTS

CURRICULUM SCHEDULE

First Term

EN 101C	Advanced Writing for Naval Officers	3- 2
GV 010D	U. S. Government	4- 0
Ma 021D	Introduction to Algebraic Technique	5- 0
MN 010D	Introduction to Economics	4- 0
SP 010D	Public Speaking	2- 0
		18-2

Second Term

GV 102C	International Relations I	3- 0
HI 103C	European History I	3- 0
Ma 023D	Calculus and Finite Mathematics II	5- 0
NW 501C	Marine Engineering	4- 0
PY 010D	Psychology I	3- 0
SP 011D	Conference Procedures	2- 0
		20- 0

Third Term

GV 103C	International Relations II	3- 0
HI 104C	European History II	4- 0
Ma 022D	Calculus and Finite Mathematics I	5- 0
MN 113C	Intermediate Economics	4- 0
PH 001D	General Physics I	4- 0
		20- 0

Fourth Term

EN 012D	Expository Logic	3- 0
GV 140C	Dev. of Western Political Thought	4- 0
HI 101C	U. S. History I	4- 0
LT 010D	Appreciation of Literature	3- 0
NW 404C	Logistics and Naval Supply	3- 0
PH 002D	General Physics II	4- 0
		21- 0

Fifth Term

GV 120C	Military Law I	3- 0
HI 102C	U. S. History II	4- 0
LT 102C	British Literature I	3- 0
MN 114C	International Economics	4- 0
PH 003D	General Physics III	4- 0
		18- 0

Sixth Term

NW 205C	Naval Warfare Seminar	3- 0
		3- 0

Seventh Term

GV 121C	Military Law II	3- 0
GV 122C	International Law	4- 0
LT 103C	British Literature II	3- 0
NW 101C	Tactics and CIC	3- 2
PH 004D	General Physics IV	4- 0
		17- 2

Eighth Term

GV 104C	American Diplomacy	4- 0
LT 101C	American Literature	3- 0
NW 201C	Operational Planning	3- 0
NW 203D	Naval Aviation Survey OR	
NW 204C	Aviator's Aviation	3- 0
NW 302C	Nuclear Weapons	3- 0
NW 406C	Command Seamanship	3- 0
		19- 0

Ninth Term

GV 142C	International Communism	4- 0
NW 103C	Anti-submarine Warfare	4- 0
NW 303C	Missiles and Space Operations	6- 0
NW 502C	Damage Control and ABC Warfare Defense	4- 0
		18- 0

Tenth Term

GV 141C	American Traditions	3- 0
NW 102C	Operational Communications	3- 0
NW 202C	Amphibious Operations	3- 0
NW 301C	Ordnance-Weapon Systems	3- 0
NW 401C	Leadership	4- 0
NW 402C	Marine Piloting and Radar Navigation	2- 2
		18- 2

*Electives may be substituted for courses for which exemptions are granted.

Note 1: The above are for an August input; for a January input, leave will occur during the 4th instead of the 6th term with a slight modification in the schedule.

Note 2: 216 term hours are required for graduation. The difference between the number of hours listed above and the total required for graduation is made up by advanced credits and exemptions.

Note 3: It is planned to delete Naval Aviation Survey and Aviator's Aviation from the curricula schedules and replace these courses with Accident Prevention and Crash Investigation and two terms of Aerodynamics. These will be required for aviators only and will total 10 term hours.

NAVAL MANAGEMENT AND OPERATIONS ANALYSIS CURRICULA

George M. McGee, Commander, U.S. Naval Reserve; Curricular Officer; B.A., St. Joseph's College, 1937; M. S. George Washington University, 1961.

William A. Wright, Commander, U.S. Naval Reserve; Assistant Curricular Officer; A. B. Harvard University, 1937.

Frank C. Hebert, Lieutenant Commander, U.S. Navy; Assistant Curricular Officer; B.A., USNPGS, 1963.

NAVAL MANAGEMENT CURRICULUM

Objective—To provide officers with increased education in management which will improve their capabilities for organizing, planning, directing, coordinating and controlling activities in which the resources of men, money, and materials are combined to accomplish Navy objectives.

Description—The curriculum is of twelve months duration at the graduate level commencing in August. All officers, regardless of designator, are required to participate in the "core" courses. These courses provide the foundation and tools of management and lead into the electives, which permit limited specialization in fields of interest to sponsoring bureaus and agencies.

Classroom instruction is supplemented by a guest lecturer series which affords the officer an opportunity to hear discussions of management topics by senior military officers, business executives, and prominent educators. Through the medium of a field trip to visit military installations and industrial concerns, the officer is able to discuss management philosophies and problems with leading executives in their own environment.

First Term

MN 210C	Principles of Economics	4- 0
MN 221C	Principles of Accounting	3- 0
MN 270C	Mathematics for Management	4- 0
MN 452B	Management Psychology	4- 0
	or	
MN 460A	Material Management	3- 0
		14- 0
		or 15- 0

Second Term

MN 412A	Managerial Economics	4- 0
MN 422A	Managerial Accounting	3- 0
MN 471A	Probability and Statistics I	4- 2
MN 452B	Management Psychology	4- 0
	or	
MN 460A	Material Management	3- 0
		14- 2
		or 15- 2

Third Term

MN 423A	Budgeting and Control	3- 0
MN 472A	Probability and Statistics II	4- 2
MN 481A	Computers and Data Processing	4- 0
MN 490A	Organization Theory and Administration	5- 0
EN 011D	Thesis Writing	2- 0
		18- 2

Fourth Term

MN 440A	Industrial Management	4- 0
MN 453A	Personnel Administration and Industrial Relations	4- 0
	Electives	3- 0 to 8- 0
		11- 0 to 16- 0

Fifth Term

MN 491A	Management Policy	4- 0
	Electives	6- 0 to 12- 0
	Individual Research	0- 8
		10- 8 to 16- 8

Elective Courses

MN 413A	Micro-Economic Theory	4- 0
MN 415A	National Income and International Trade	4- 0
MN 424A	Internal Control and Auditing Seminar	3- 0
MN 425A	Comptrollership Seminar	4- 0
MN 426A	Cost Accounting and Cost Analysis	3- 0
MN 432A	Systems Analysis	4- 0
MN 455A	Personnel Administration Seminar	3- 0
MN 456A	Labor Relations	4- 0
MN 461A	Procurement and Contract Administration	4- 0
MN 462A	Scientific Inventory Management	3- 0
MN 473A	Quantitative Decision Making	3- 0
MN 480A	Facilities Planning	3- 0
MN 492A	Government and Business	4- 0
MN 495A	Organization and Management Seminar	3- 0

MANAGEMENT (DATA PROCESSING) CURRICULUM

Objective—To provide officers with a comprehensive education in computer theory and practice so that they will gain an appreciation of the capabilities and limitations of digital computers in several areas of application and develop their ability to analyze data processing systems and effectively manage computer-based installations.

Description—The curriculum is of twelve months duration at the graduate level commencing in August. Classroom instruction is supplemented by a guest lecturer series which affords the officer an opportunity to hear discussions of management topics by senior military officers, business executives, and prominent educators. Through the medium of field trips to visit military installations and industrial concerns, the officer is able to discuss management and electronic data processing philosophies and problems with leading executives in their own environment.

First Term

MN 490A	Organization Theory and Administration	5- 0
MN 210C	Principles of Economics	4- 0
Ma 141D	Review of Analytic Geometry and Calculus	5- 0
Ma 427C	Programming I—Introduction	3- 1
		17- 1

Second Term

MN 453A	Personnel Adminstration and Industrial Relations	4- 0
MN 460A	Material Management	3- 0
Ma 140B	Linear Algebra and Matrix Theory	4- 0
Ma 315B	Introduction to Probability and Statistics	4- 2
Ma 428B	Programming IIa	3- 1
		18-3

Third Term

MN 381A	Data Processing Management	4- 0
OA 111B	Principles of Operations Analysis	4- 2
Ma 146B	Numerical Analysis and Digital Computers	4- 1
Ma 316B	Applied Statistics I	3- 2
		15- 5

Fourth Term

MN 382A	Computer Applications	4- 0
MN 322A	Managerial Accounting	4- 0
Ma 317B	Applied Statistics II	3- 0
Ma 429A	Programming IIb	3- 0
		14- 0

Fifth Term

MN 432A	Systems Analysis	4- 0
MN 461A	Procurement and Contract Administration	4- 0
MN 462A	Scientific Inventory Management	3- 0
OA 112A	Advanced Methods of Operations Analysis	4- 0
	Thesis	0- 8
		15- 8

ELEMENTS OF MANAGEMENT CURRICULUM

The Course "Elements of Management" is of four weeks' duration, presented once a year in the summer. It is a basic survey course in management designed for selected officers who may be sponsored by Bureaus and Offices of the Navy and who will be attending the workshop seminars.

The curriculum is designed to:

1. Acquaint the officer with the principles of management and administration.

2. Examine current problems of management within the Naval Establishment and general approaches to the solution of these problems.

3. Familiarize the officer with the modern practice and method of management in civilian activities with emphasis on relationship to their applications within the Naval Establishment.

No special preparation or qualification for this course is required.

In conjunction with this program, the Navy Management and Operations Analysis Curricula acts as host to Bureaus and Offices which desire to sponsor special programs and workshop seminars. The classroom program may be expected to form an excellent base for further discussion of special problems.

CURRICULUM

MN 090D	Principles of Organization and Management	15 Hours
MN 053D	Personnel Administration	15 Hours
MN 040D	Industrial Management	15 Hours
MN 020D	Financial Management	15 Hours

OPERATIONS ANALYSIS CURRICULUM

Objective—To develop the analytical ability of officers by providing a sound scientific background and education in scientific and analytical methods so that they may formulate new work in operations analysis, apply the results of operations research studies with greater effectiveness, and solve problems in operations analysis which arise both in the fleet and ashore.

Description—The normal tenure of this curriculum is two years. Classroom work is augmented by a guest lecturer series which permits officers to gain first-hand information as to practical applications of operations research principles and techniques. During the intersessional period officers are assigned individually as working members to various industrial or military organizations which are engaged in operations research of military problems.

A third year of study is offered to officers who are particularly well qualified. The selection normally will be predicated upon the expressed desire of the individual, the Superintendent's appraisal of his academic ability, and his availability.

FIRST YEAR

First Term

Ma 180C	Vectors, Matrices and Vector Spaces	3- 1
Ma 181D	Partial Derivatives and Multiple Integrals	4- 1
Ma 301C	Basic Probability and Set Theory	4- 0
OA 001E	Orientation in Operations Analysis Curriculum	0- 1
OA 891E	Seminar I	0- 2
PH 241C	Radiation	3- 3
		14- 8

Second Term

Ma 182C	Differential Equations and Vector Analysis	5- 0
Ma 302B	Second Course in Probability	3- 2
OA 291B	Introduction to Operations Analysis	4- 0
OA 892E	Seminar II	0- 2
PH 141B	Analytical Mechanics	4- 0
		16- 4

Third Term

Ma 193C	Set Theory and Integration	2- 0
Ma 303B	Theory and Techniques in Statistics I	3- 2
OA 292B	Methods of Operations Research	4- 0
OA 421B	Introduction to Digital Computers	5- 0
OA 893E	Seminar III	0- 2
PH 142B	Analytical Mechanics	4- 0
LP 101E	Lecture Program	0- 1
		18- 5

Fourth Term

Ma 196B	Matrix Theory	3- 0
Ma 304B	Theory and Techniques in Statistics II	3- 0
OA 391B	Games of Strategy	3- 2
OA 293B	Search Theory	4- 0
OA 393B	Introduction to War Gaming	3- 0
OA 894E	Seminar IV	0- 2
LP 102E	Lecture Program	0- 1
		16- 5

SECOND YEAR

First Term

Ma 183B	Fourier Series and Complex Variables	4- 0
OA 211A	Linear Programming	4- 1
OA 891E	Seminar I	0- 2
OA 899E	Military Science Seminar	0- 1
PH 360B	Electricity and Magnetism	4- 0
	Elective (Required)	3- 0
	Elective (Optional)	
		14- 5

Second Term

OA 212A	Dynamic Programming	3- 1
OA 234A	Queueing Theory and Reliability Theory	3- 0
OA 892E	Seminar II	0- 2
PH 630B	Elementary Atomic Physics	4- 0
	Elective (Required)	4- 0
	Elective (Optional)	
		13- 3

Third Term

OA 235A	Decision Criteria	3- 0
OA 893E	Seminar III	0- 2
PH 424B	Fundamental Acoustics	4- 0
PH 621B	Elementary Nuclear Physics	4- 0
	Thesis	0- 4
	Elective (Required)	3- 0
	Elective (Optional)	
LP 101E	Lecture Program	0- 1
		14- 7

Fourth Term

PH 425B	Underwater Acoustics	3- 2
OA 894E	Seminar IV	0- 2
	Elective (Required)	3- 0
	Thesis	0- 8
	Elective (Optional)	
LP 102E	Lecture Program	0- 1
		6-13

ELECTIVE SEQUENCES

Operations Analysis Option

OA 213A	Inventory Control	3- 0
OA 214A	Graph Theory	3- 0
OA 202A	Econometrics	3- 0
OA 236A	Utility Theory	3- 0
OA 225A	Air Warfare	3- 0
OA 296A	Development of Weapons Systems	3- 0
OA 392A	Decision Theory	3- 0
OA 394A	War Gaming II	3- 0

Mathematics Option

Ma 305A	Design of Experiments	3- 1
Ma 306A	Selected Topics in Advanced Statistics I	3- 1
Ma 307A	Stochastic Processes I	3- 0
Ma 308A	Stochastic Processes II	3- 0
Ma 416B	Numerical Analysis and Digital Computers	4- 1
Ma 428B	Programming IIa	3- 1
Ma 429A	Programming IIb	3- 0
Ma 709A	Functions of Real Variables	3- 0
Ma 710A	Functions of Real Variables	3- 0
Ma 355A	System Reliability and Life Testing	3- 0

Modern Physics Option

PH 366B	Electromagnetism	4- 0
PH 670B	Atomic Physics I	3- 0
PH 671B	Atomic Physics II	3- 3
PH 621B	Elementary Nuclear Physics	4- 0
PH 622B	Nuclear Physics Laboratory	0- 3

NOTE 1. If the above option is elected, delete PH 630B from the second year.

NOTE 2. If justified by sufficient interest, a Physics Option could be offered in Acoustics, Optics, or Electromagnetism as an alternative to the above option in Modern Physics.

Management Option

MN 490A	Organization Theory and Administration	5- 0
MN 413A	Micro Economic Theory	4- 0
OA 202A	Econometrics	3- 0
MN 473A	Quantitative Decision Making	3- 0

NAVAL ENGINEERING CURRICULA

EDGAR ROBERT MEYER, Captain, U.S. Navy, Curricular Officer; B.S., USNA, 1943; M.S., Massachusetts Institute of Technology, 1948.

ERNEST FISCHBEIN, Lieutenant Commander, U.S. Navy, Assistant Curricular Officer; B.A., Brooklyn College, 1949; M.A., Brooklyn College, 1953.

OBJECTIVE—To provide selected officers with advanced marine and electrical engineering education to meet the requirements of the Navy for officers with technical and administrative competence related to modern naval machinery and engineering plants. The specific areas of study are designed to include, within the various curricula, the fundamental and advanced theories of mathematics, thermodynamics, mechanics, dynamics, electrical power, circuits and feedback control, metallurgy, structures, nuclear physics and nuclear power.

DESCRIPTION—All students initially enter a common Naval Engineering (General) Curriculum. After completion of two terms, students are selected to pursue studies in a specialty of either Mechanical or Electrical Engineering. Upon completion of the first year of study, a limited number of students in each specialty are further selected to follow an advanced three year year curricula in their specialty (Mechanical or Electrical Engineering).

The criteria for selection are academic performance, assigned quotas, tour availability, and student preference. The Curricula are:

Naval Engineering (Mechanical)	2 year curriculum
Naval Engineering (Electrical)	2 year curriculum
Mechanical Engineering (Advanced)	3 year curriculum
Electrical Engineering (Advanced)	3 year curriculum

For properly qualified students, the two year curricula lead to the award of a designated Bachelor of Science degree and the three year curricula lead to the award of a designated Master of Science degree.

NAVAL ENGINEERING (GENERAL)

OBJECTIVE—This is a two-term, common-core program followed by all officer students entering the Naval Engineering Curricula. The objective is to educate officers in the basic sciences and engineering principles as a foundation for more advanced studies in either an electrical or mechanical engineering specialty.

FIRST YEAR

First Term

EE 111C	Fields and Circuits	4- 4
Ma 230D	Calculus of Several Variables	4- 0
Ma 120D	Vectors and Matrices	3- 1
ME 501C	Mechanics I	4- 0
		15- 5

Second Term

EE 112C	Circuit Analysis	4- 3
Ma 240C	Elementary Differential Equations	2- 0
Ma 251C	Elementary Infinite Series	3- 0
ME 502C	Mechanics II	4- 0
CH 103D	General Chemistry	4- 2
		17- 5

NAVAL ENGINEERING (MECHANICAL)

Objective—To support the aim of the basic objective to the extent practicable within a two year period by providing officer students with a sound science-engineering basis for assuming increased technical and administrative responsibilities related to naval machinery, with primary emphasis on Mechanical Engineering aspects.

FIRST YEAR

First and Second Terms

Same as Naval Engineering (General)

Third Term

Mt 201C	Introductory Physical Metallurgy	3- 2
Ma 416C	Numerical Methods and Fortran Programming	4- 1
ME 510C	Mechanics of Solids I	4- 2
ME 111C	Engineering Thermodynamics I	5- 0
LP 101E	Lecture Program I	0- 1
		16- 6

Fourth Term

EE 321C	Electromechanical Devices	3- 4
Mt 202C	Ferrous Physical Metallurgy	3- 2
ME 411C	Mechanics of Fluids	4- 2
ME 112C	Engineering Thermodynamics II	5- 0
LP 102E	Lecture Program II	0- 1
		15- 9

Intersessional Period—Courses in "Management" and "Art of Presentation" at USNPGS.

SECOND YEAR

First Term

ME 221C	Gas Dynamics and Heat Transfer	4- 2
ME 504B	Advanced Dynamics	4- 0
ME 521C	Mechanics of Solids II	4- 0
ME 711B	Mechanics of Machinery	3- 2
		15- 4

Second Term

ME 222C	Thermodynamics Laboratory	1- 4
ME 522B	Mechanics of Solids III	4- 0
ME 223B	Marine Power Plant Analysis	2- 4
PH 620B	Elementary Atomic Physics	4- 0
		11- 8

Third Term

ME 217B	Internal Combustion Engines	3- 2
ME 722B	Mechanical Vibrations	3- 2
EE 231C	Electronics I	4- 3
PH 621B	Elementary Nuclear Physics	4- 0
LP 101E	Lecture Program I	0- 1
		14- 8

Fourth Term

Ma 351B	Probability and Statistics	4- 2
ME 240B	Nuclear Power Plants	4- 0
ME 622B	Experimental Mechanics	2- 2
ME 820C	Machine Design	2- 4
LP 102E	Lecture Program II	0- 1
		12- 9

MECHANICAL ENGINEERING (ADVANCED)

Objective—To further the aim of the basic objective by providing officer students with a broad background of science-engineering studies in a three-year program designed to prepare them for assuming increased technical and administrative responsibilities related to naval machinery, with primary emphasis on Mechanical Engineering aspects.

FIRST YEAR

Same as Naval Engineering (Mechanical)

SECOND YEAR

First Term

Ma 113B	Vector Analysis and Partial Differential Equations	4- 0
Ma 270C	Complex Variables	3- 0
ME 211B	Thermodynamics of Compressible Flow	3- 0
ME 222C	Thermodynamics Lab	1- 4
ME 511A	Mechanics of Solids II	5- 0
		16- 4

Second Term

ME 412A	Advanced Mechanics of Fluids	4- 2
ME 512A	Mechanics of Solids	4- 0
ME 711B	Mechanics of Machinery	3- 2
PH 620B	Elementary Atomic Physics	4- 0
		15- 4

Third Term

ME 230B	Marine Power Plant Analysis	2- 4
ME 310B	Heat Transfer	4- 2
ME 503A	Advanced Dynamics	4- 0
Mt 301A	High Temperature Materials	3- 0
PH 637B	Nuclear Physics I	3- 0
LP 101E	Lecture Program I	0- 1
		16- 7

Fourth Term

Ma 280B	LaPlace Transformations	2- 0
ME 212A	Advanced Thermodynamics	3- 0
ME 712A	Mechanical Vibrations	3- 2
ME 811B	Machine Design I	3- 2
PH 638B	Nuclear Physics II	3- 3
LP 102E	Lecture Program II	0- 1
		14- 8

Intersessional Period—A four to six weeks tour at selected industrial or research activities.

THIRD YEAR

First Term

EE 231C	Electronics I	4- 3
ME 612A	Experimental Mechanics	3- 2
ME 812B	Machine Design II	3- 4
PH 651A	Reactor Theory I	3- 0
		13- 9

Second Term

EE 498B	Dynamics of Linear Systems	3- 4
ME 217B	Internal Combustion Engine	3- 2
PH 652A	Reactor Theory II	3- 0
	Thesis	0- 4
		9-10

Third Term

ME 241A	Nuclear Propulsion Systems I	4- 0
	Thesis	0-16
LP 101E	Lecture Program I	0- 1
		4-17

Fourth Term

ME 242A	Nuclear Propulsion Systems II	3- 2
ME 910E	Naval Architecture Seminar	3- 0
	Thesis	0- 4
EE 491B	Nuclear Reactor Instrumentation and Control	3- 3
*Mt 402B	Nuclear Reactor Materials and Effects of Radiation	3- 0
LP 102E	Lecture Program II	0- 1
		12-10

*Elective

NAVAL ENGINEERING (ELECTRICAL)

Objective—To support the aim of the basic objective to the extent practicable within a two year period by providing officer students with a sound science-engineering basis for assuming increased technical and administrative responsibilities related to naval machinery, with primary emphasis on Electrical Engineering aspects.

FIRST YEAR

First and Second Terms

Same as Naval Engineering (General)

Third Term

EE 131C	Polyphase Circuits	3- 2
EE 311C	Electric Machinery I	3- 4
Ma 416C	Numerical Methods and Fortran Programming	4- 1
Mt 201C	Introductory Physical Metallurgy	3- 2
LP 101E	Lecture Program I	0- 1
		13-10

Fourth Term

EE 312C	Electrical Machinery II	3- 4
EE 711C	Electrical Measurements	2- 3
ME 510C	Mechanics of Solids I	4- 2
Mt 202C	Ferrous Physical Metallurgy	3- 2
LP 102E	Lecture Program II	0- 1
		12-12

Intersessional Period—Courses in "Management" and "Art of Presentation" at USNPGS.

SECOND YEAR

First Term

EE 221B	Applied Electronics I	3- 3
EE 611C	Electromagnetic Fields	4- 0
Ma 271C	Complex Variables	4- 0
ME 111C	Engineering Thermodynamics	5- 0
		16- 3

Second Term

EE 113B	Linear Systems Analysis	4- 3
EE 222B	Applied Electronics II	3- 3
ME 132C	Engineering Thermodynamics II	4- 2
PH 620B	Elementary Atomic Physics	4- 0
		15- 8

Third Term

EE 114B	Communication Theory I	4- 0
EE 411B	Feedback Control Systems I	3- 3
ME 210C	Applied Thermodynamics	3- 2
PH 621B	Elementary Nuclear Physics	4- 0
LP 101E	Lecture Program I	0- 1
		14- 6

Fourth Term

EE 223A	Electronic Control and Measurement	3- 3
EE 261B	Nonlinear Magnetic Devices	3- 3
Mr 351B	Probability and Statistics	4- 2
ME 240B	Nuclear Power Plants	4- 0
LP 102E	Lecture Program II	0- 1
		14- 9

ELECTRICAL ENGINEERING (ADVANCED)

Objective—To further the aim of the basic objective by providing officer students with a broad background of science-engineering studies in a three-year program designed to prepare them for assuming increased technical and administrative responsibilities related to naval machinery, with primary emphasis on Electrical Engineering aspects.

FIRST YEAR

Same as Naval Engineering (Electrical).

SECOND YEAR

First Term

EE 221B	Applied Electronics I	3- 3
Ma 113B	Vector Analysis and Partial Differential Equations	4- 0
Ma 271C	Complex Variables	4- 0
ME 111C	Engineering Thermodynamics	5- 0
		16- 3

Second Term

EE 113B	Linear Systems Analysis	4- 3
EE 222B	Applied Electronics II	3- 3
ME 132C	Engineering Thermodynamics	4- 2
PH 620B	Elementary Atomic Physics	4- 0
		15- 8

Third Term

EE 114B	Communication Theory I	4- 0
EE 411B	Feedback Control Systems I	3- 3
ME 210C	Applied Thermodynamics	3- 2
PH 621B	Elementary Nuclear Physics	4- 0
LP 101E	Lecture Program I	0- 1
		14- 6

Fourth Term

EE 223A	Electronic Control and Measurement	3- 3
EE 261B	Non-linear Magnetic Devices	3- 3
EE 412A	Feedback Control Systems II	3- 4
ME 240B	Nuclear Power Plants	4- 0
LP 102E	Lecture Program II	0- 1
		13-11

Intersessional Period—A four to six weeks tour at selected industrial or research activities.

THIRD YEAR

First Term

EE 121A	Advanced Network Analysis	3- 2
EE 491B	Nuclear Reactor Instrumentation and Control	3- 3
EE 621B	Electromagnetics I	3- 2
Ma 351B	Probability and Statistics	4- 2
		13- 9

Second Term

EE 122A	Network Synthesis I	3- 2
EE 492A	Nuclear Reactor Power Plant Control	3- 4
EE 622B	Electromagnetics II	4- 0
	Thesis	0- 4
		10-10

Third Term

EE 315B	Marine Electrical Design I	2- 4
EE 931A	Seminar	0- 1
	Thesis	0-12
LP 101E	Lecture Program I	0- 1
		2-18

Fourth Term

EE 316A	Marine Electrical Design II	2- 4
EE 413A	Sampled Data Control Systems	2- 2
EE 931A	Seminar	0- 1
	Thesis	0- 8
LP 102E	Lecture Program II	0- 1
		4-16

ORDNANCE ENGINEERING CURRICULA

Donald Roy Schaffer, Commander, U.S. Navy; Curricular Officer and Instructor Ordnance Seminars; B.S.E.E., USNPGS, 1959; M.S., Aero and Astronautics, Massachusetts Institute of Technology, 1960.

NUCLEAR ENGINEERING (EFFECTS) CURRICULUM

(GROUP RZ)

Objective—To educate selected officers in such portions of the fundamental sciences as will furnish an advanced technical understanding of the phenomenology of the blast, thermal, nuclear, and biological aspects of nuclear weapons effects, including their employment and defensive situations.

Description—This curriculum is sponsored by the Defense Atomic Support Agency as a joint-service course for selected officers of the Army, Navy, Air Force, Marine Corps, and Coast Guard and affords the opportunity to qualify for the Master of Science degree in Physics. For those not academically qualified for the Master of Science degree a thesis is not required and certain elective sequences may be chosen in lieu of the thesis during the second year.

For a limited number of exceptionally well-qualified students a third year of instruction may be granted. These students are selected at the end of the first year. The second and third-year curriculum is then tailored to the individual needs, consistent with the requirements of the DASA and the parent service.

FIRST YEAR

First Term

CH 106D	Principles of Chemistry I	3- 2
Ma 120D	Vectors and Matrices	3- 1
Ma 230D	Calculus of Several Variables	4- 0
Ma 251C	Elementary Infinite Series	3- 0
		13- 3

Second Term

CH 109D	General and Organic Chemistry	3- 2
Ma 241C	Elementary Differential Equations	3- 0
Ma 260C	Vector Analysis	3- 0
PH 151C	Mechanics I	4- 0
PH 240C	Optics and Spectra	3- 3
		16- 5

Third Term

Ma 271C	Complex Variables	4- 0
PH 152B	Mechanics II	4- 0
PH 365B	Electricity and Magnetism	4- 0
PH 530B	Thermodynamics	3- 0
PH 635B	Atomic Physics I	5- 0
LP 101E	Lecture Program I	0- 1
		20- 1

Fourth Term

PH 153A	Mechanics III	4- 0
PH 366B	Electromagnetism	4- 0
PH 541B	Kinetic Theory and Statistical Mechanics	4- 0
PH 636B	Atomic Physics II	4- 3
PH 750E	Physics Seminar	0- 1
LP 102E	Lecture Program II	0- 1
		16- 5

Intersessional Period—Field Trip to Sandia Base for specially tailored Weapons Employment Course given by the Special Weapons Training Group of the Field Command, DASA.

SECOND YEAR (RZ)

First Term

EC 591A	Blast and Shock Effects	3- 0
EE 291C	Electronics I (Nuclear)	3- 3
Ma 351B	Probability and Statistics	4- 2
PH 350B	Special Topics in Electromagnetism (Non-MS students)	4- 0
PH 367A	Special Topics in Electromagnetism (MS students)	4- 0
PH 637B	Nuclear Physics I	3- 0
PH 750E	Physics Seminar	0- 1
	Thesis (or elective)	0- 3
		17- 9

Second Term

BI 800C	Fundamentals of Biology	6- 0
EE 292C	Electronics II (Nuclear)	3- 3
PH 639A	Nuclear Physics II	4- 3
PH 750E	Physics Seminar	0- 1
	Thesis (or elective)	0- 6
		13-13

Third Term

BI 801B	Animal Physiology	6- 0
ME 547C	Statics and Strength of Materials	5- 0
PH 441B	Shock Waves in Fluids	4- 0
PH 750E	Physics Seminar	0- 1
	Thesis (or elective)	0- 6
LP 101E	Lecture Program I	0- 1
		15- 8

Fourth Term

BI 802A	Radiation Biology	6- 0
CH 551A	Radiochemistry	2- 4
ME 548B	Structural Theory	5- 0
PH 750E	Physics Seminar	0- 1
	Thesis (or elective)	0- 6
LP 102E	Lecture Program II	0- 1
		13-12

ELECTIVE COURSES
SECOND YEAR (RZ)

Digital Computer Sequence.

Term	Course		
2	Ma 116B	Matrices and Numerical Methods	3- 2
3	Ma 421C	Introduction to Digital Computers	4- 1
4	Ma 423B	Advanced Digital Computer Programming	4- 0
4	ME 240B	Nuclear Power Plants	4- 0
			15- 3

WEAPONS SYSTEMS ENGINEERING CURRICULA

Basic Objective—To provide selected officers with an advanced technical education on a broad foundation encompassing the basic scientific and engineering principles underlying the field of weapons. The specific areas of study and the level to be attained are formulated for each curriculum to insure a sound basis for technical competence and for such subsequent growth as may be required for the operation, maintenance, design, development or production of advanced weapons systems.

Description—All officers ordered for instruction in Weapons Systems Engineering initially matriculate in the 2-year General Curriculum. At the end of the first year, officer students will be selected for the 3-year Advanced Weapons Systems Engineering Curricula within the quotas assigned by the Chief of Naval Personnel. This selection is based on the expressed choice of the individual and the Superintendent's appraisal of his academic ability. For properly qualified entering students, the 2-year General Curriculum leads to the award of a Bachelor's degree and the 3-year Curricula lead to the award of a Master's degree in a scientific or engineering field. A 2-year Special Curriculum is offered to selected officer students of allied countries.

WEAPONS SYSTEMS ENGINEERING (GENERAL) CURRICULUM
(GROUP WG)

Objective—To support the aims of the basic objective to the maximum extent practicable within the 2-year period with emphasis on the fundamentals of Weapons Systems Engineering.

FIRST YEAR (COMMON TO ALL)

First Term

CH 106D	Principles of Chemistry I	3- 2
EE 111C	Fields and Circuits	4- 4
Ma 120D	Vectors and Matrices	3- 1
Ma 230D	Calculus of Several Variables	4- 0
		14- 7

Second Term

CH 107D	Principles of Chemistry II	3- 2
EE 112C	Circuit Analysis	4- 3
Ma 240C	Elementary Differential Equations	2- 0
Ma 251C	Elementary Infinite Series	3- 0
Ma 260C	Vector Analysis	3- 0
		15- 5

Third Term

EC 611C	General Thermodynamics	3- 2
EE 231C	Electronics I	4- 3
Ma 271C	Complex Variables	4- 0
OR 241E	Ordnance Seminar	0- 2
PH 151C	Mechanics I	4- 0
LP 101E	Lecture Program I	0- 1
		15- 8

Fourth Term

EE 232C	Electronics II	4- 3
EE 321C	Electromechanical Devices	3- 4
OR 242E	Ordnance Seminar	0- 2
PH 152B	Mechanics II	4- 0
PH 265C	Physical Optics	4- 2
LP 102E	Lecture Program II	0- 1
		15-12

Intersessional Period—Enrollment in Mn 191C, Mn 210C and Sp 012D at the U.S. Naval Postgraduate School.

SECOND YEAR (WG)

First Term

CH 407B	Physical Chemistry	3- 2
EE 113B	Linear Systems Analysis	4- 3
EE 611C	Electromagnetic Fields	4- 0
Ma 421C	Introduction to Digital Computers	4- 1
OR 243E	Ordnance Seminar	0- 2
		15- 8

Second Term

EC 571A	Explosives Chemistry	3- 2
EE 411B	Feedback Control Systems I	3- 3
EE 612C	Transmission of Electromagnetic Energy	3- 2
PH 450C	Underwater Acoustics	3- 2
		12- 9

Third Term

EE 419B	Non-Linear and Sampled Systems	3- 4
EE 234C	Pulse Techniques and High Frequency Tubes	3- 3
Ma 351B	Probability and Statistics	4- 2
PH 630B	Elementary Atomic Physics	4- 0
LP 101E	Lecture Program I	0- 1
		14-10

Fourth Term

EC 542A	Reaction Motors	3- 2
EE 431C	Introduction to Radar	3- 3
Ma 352B	Applied Engineering Statistics	2- 2
PH 621B	Elementary Nuclear Physics	4- 0
PH 622B	Nuclear Physics Laboratory	0- 3
LP 102E	Lecture Program II	0- 1
		12-11

This curriculum affords the opportunity to qualify for the degree of Bachelor of Science in Electrical Engineering.

ADVANCED WEAPONS SYSTEMS ENGINEERING (CHEMISTRY) CURRICULUM

(GROUP WC)

Objective—To further the aims of the basic objective by providing officer students with a broad background of selected science-engineering studies oriented toward the weapons systems dependent upon chemical energy for propulsion or explosive applications, with Chemistry as the major field of study and Electrical Engineering as the principal minor field.

FIRST YEAR (COMMON TO ALL)

Same as WEAPONS SYSTEMS ENGINEERING (GENERAL)

SECOND YEAR (WC)

First Term

CH 108C	Inorganic Chemistry	3- 4
CH 231C	Quantitative Analysis	2- 4
EE 113B	Linear Systems Analysis	4- 3
OR 243E	Ordnance Seminar	0- 2
PH 365B	Electricity and Magnetism	4- 0
		13-13

Second Term

CH 311C	Organic Chemistry I	3- 2
CH 433B	Physical Chemistry I	4- 3
Ma 421C	Introduction to Digital Computers	4- 1
PH 670B	Atomic Physics I	3- 0
		14- 6

Third Term

CH 312C	Organic Chemistry II	3- 2
CH 444B	Physical Chemistry II	3- 3
Ma 351B	Probability and Statistics	4- 2
PH 671B	Atomic Physics II	3- 3
LP 101E	Lecture Program I	0- 1
		13-11

Fourth Term

CH 150A	Inorganic Chemistry, Advanced	4- 3
CH 313B	Organic Chemistry III	3- 2
CH 470A	Chemical Thermodynamics	3- 0
CH 800A	Chemistry Seminar	0- 1
Ma 352B	Applied Engineering Statistics	2- 2
LP 102E	Lecture Program II	0- 1
		12- 9

THIRD YEAR (WC)

First Term

CH 328A	Physical Organic Chemistry I	4- 0
CH 467A	Quantum Chemistry I	3- 0
CH/EC	Elective	3- 2
	Thesis	0- 4
		10- 6

Second Term

CH 329A	Physical Organic Chemistry II	3- 0
EE 234C	Pulse Techniques and High Frequency Tubes	3- 3
CH/EC	Elective	3- 2
	Thesis	0- 6
		9-11

Third Term

EC 542A	Reaction Motors	3- 2
EE 411B	Feedback Control Systems I	3- 3
CH/EC	Elective	3- 2
LP 101E	Lecture Program I	0- 1
	Thesis	0- 6
		9-14

Fourth Term

EE 419B	Non-Linear and Sampled Systems	3- 4
CH/EC	Elective	3- 2
PH 521B	Elementary Nuclear Physics	4- 0
LP 102E	Lecture Program II	0- 1
	Thesis	0- 5
		10-12

Successful completion of this curriculum leads to the degree of Master of Science in Chemistry.

ADVANCED WEAPONS SYSTEMS ENGINEERING (MATERIALS) CURRICULUM

(GROUP WM)

Objective—To further the aims of the basic objective by providing officer students with a broad background of selected science-engineering studies oriented toward those aspects of Weapons Systems having to do with the nature, characteristics, and behavior of component materials, with Materials Science as the major field of study.

FIRST YEAR (COMMON TO ALL)

Same as WEAPONS SYSTEMS ENGINEERING (GENERAL)

SECOND YEAR (WM)

First Term

Cr 271A	Crystallography and X-ray Techniques	3- 2
EE 113B	Linear Systems Analysis	4- 3
Mt 201C	Introductory Physical Metallurgy	3- 2
OR 243E	Ordnance Seminar	0- 2
PH 365B	Electricity and Magnetism	4- 0
		14- 9

Second Term

CH 443B	Physical Chemistry I	4- 3
Ma 421C	Introduction to Digital Computers	4- 1
Mt 202C	Ferrous Physical Metallurgy	3- 2
PH 670B	Atomic Physics I	3- 0
		14- 6

Third Term

CH 444B	Physical Chemistry II	3- 3
Ma 351B	Probability and Statistics	4- 2
Mt 205A	Advanced Physical Metallurgy	3- 4
PH 671B	Atomic Physics II	3- 3
LP 101E	Lecture Program I	0- 1
		13-13

Fourth Term

Mt 206A	Advanced Physical Metallurgy	3- 4
Ma 352B	Applied Engineering Statistics	2- 2
Mt 222A	Mechanical Properties of Solids	3- 0
PH 730B	Physics of the Solid State	4- 2
LP 102E	Lecture Program II	0- 1
		12- 9

Intersessional Period—Six-week Summer Industrial Experience Tour.

THIRD YEAR (WM)

First Term

CH 581A	Properties of Ceramic Materials	4- 0
	Elective	3- 2
Mt 301A	High Temperature Materials	3- 0
	Thesis	0- 4
		10- 6

Second Term

EC 591A	Blast and Shock Effects	3- 0
EE 234C	Pulse Techniques and High Frequency Tubes	3- 3
Mt 304A	Special Topics in Materials Science	4- 0
	Thesis	0- 6
		10- 9

Third Term

EC 542A	Reaction Motors	3- 2
EE 411B	Feedback Control Systems I	3- 3
LP 101E	Lecture Program I	0- 1
	Elective	3- 2
	Thesis	0- 6
		9-14

Fourth Term

EC 521A	Plastics and High Polymers	3- 2
EE 419B	Non-Linear and Sampled Systems	3- 4
LP 102E	Lecture Program II	0- 1
	Elective	3- 2
	Thesis	0- 6
		9-15

Successful completion of this curriculum leads to the degree of Master of Science in Materials Science.

ADVANCED WEAPONS SYSTEMS ENGINEERING (AIR/SPACE PHYSICS) CURRICULUM

(GROUP WP)

Objective—To further the aims of the basic objective by providing officer students with a broad background of selected science-engineering studies underlying air and space weapons systems, with Physics as the major field of study and Electrical Engineering as the principal minor field.

FIRST YEAR (COMMON TO ALL)

Same as WEAPONS SYSTEMS ENGINEERING (GENERAL)

SECOND YEAR (WP)

First Term

CH 407B	Physical Chemistry	3- 2
Ma 116B	Matrices and Numerical Methods	3- 2
OR 243E	Ordnance Seminar	0- 2
PH 154A	Celestial Mechanics	4- 0
PH 365B	Electricity and Magnetism	4- 0
		14- 6

Second Term

EE 113B	Linear Systems Analysis	4- 3
Ma 421C	Introduction to Digital Computers	4- 1
PH 366B	Electromagnetism	4- 0
PH 670B	Atomic Physics I	3- 0
		15- 4

Third Term

EE 234C	Pulse Techniques and High Frequency Tubes	3- 3
Ma 351B	Probability and Statistics	4- 2
PH 367A	Special Topics in Electromagnetism	4- 0
PH 671B	Atomic Physics II	3- 3
PH 750E	Physics Seminar	0- 1
LP 101E	Lecture Program I	0- 1
		14-10

Fourth Term

Ma 352B	Applied Engineering Statistics	2- 2
PH 541B	Kinetic Theory and Statistical Mechanics	4- 0
PH 637B	Nuclear Physics I	3- 0
PH 730B	Physics of the Solid State	4- 2
PH 750E	Physics Seminar	0- 1
LP 102E	Lecture Program II	0- 1
		13- 6

INTERSESSIONAL PERIOD—Field assignment at a representative ordnance or industrial installation.

THIRD YEAR (WP)

First Term

Ae 171A	Aerodynamics I	3- 2
PH 638B	Nuclear Physics II	3- 3
PH 654A	Plasma Physics I	4- 0
PH 750E	Physics Seminar	0- 1
	Thesis	0- 4
		10-10

Second Term

Ae 172A	Aerodynamics II	3- 2
PH 655A	Plasma Physics II	3- 0
PH 750E	Physics Seminar	0- 1
	Elective	3- 2
	Thesis	0- 6
		9-11

Third Term

Ae 513A	Compressibility I	4- 0
EE 411B	Feedback Control Systems I	3- 3
PH 750E	Physics Seminar	0- 1
LP 101E	Lecture Program I	0- 1
	Elective	3- 2
	Thesis	0- 6
		10-13

Fourth Term

Ae 514A	Compressibility II	3- 2
EE 419B	Non-Linear and Sampled Systems	3- 4
PH 750E	Physics Seminar	0- 1
LP 102E	Lecture Program II	0- 1
	Elective	3- 2
	Thesis	0- 6
		9-16

This curriculum affords the opportunity to qualify for the degree of Master of Science in Physics.

ADVANCED WEAPONS SYSTEMS ENGINEERING (UNDERWATER PHYSICS) CURRICULUM

(GROUP WU)

OBJECTIVE—To provide students with a broad background of science-engineering studies underlying Underwater Weapons Systems with Physics as the major field of study and Electrical Engineering as the principal minor field.

FIRST YEAR (COMMON TO ALL)

Same as WEAPONS SYSTEMS ENGINEERING (GENERAL)

SECOND YEAR (WU)

First Term

CH 407B	Physical Chemistry	3- 2
Ma 116B	Matrices and Numerical Methods	3- 2
OR 243E	Ordnance Seminar	0- 2
PH 365B	Electricity and Magnetism	4- 0
PH 431B	Fundamental Acoustics	4- 0
		14- 6

Second Term

EE 113B	Linear Systems Analysis	4- 3
PH 366B	Electromagnetism	4- 0
PH 432B	Underwater Acoustics	4- 3
PH 670B	Atomic Physics I	3- 0
		15- 6

Third Term

Ma 351B	Probability and Statistics	4- 2
PH 367A	Special Topics in Electromagnetism	4- 0
PH 471A	Acoustics Research	0- 3
PH 671B	Atomic Physics II	3- 3
LP 101E	Lecture Program I	0- 1
		11- 9

Fourth Term

Ma 352B	Applied Engineering Statistics	2- 2
Ma 421C	Introduction to Digital Computers	4- 1
Oc 110C	Introduction to Oceanography	3- 0
PH 480E	Acoustics Seminar	0- 1
PH 541B	Kinetic Theory and Statistical Mechanics	4- 0
PH 621B	Elementary Nuclear Physics	4- 0
LP 102E	Lecture Program II	0- 1
		17- 5

INTERSESSIONAL PERIOD: Industrial Experience Tour.

THIRD YEAR (WU)

First Term

OA 121A	Survey of Operations Analysis	4- 2
PH 161A	Fluid Mechanics	3- 0
	Elective	3- 2
	Thesis	0- 4
		10- 8

Second Term

PH 162A	Advanced Hydrodynamics	3- 0
PH 433A	Propagation of Waves in Fluids	3- 0
PH 480E	Acoustics Seminar	0- 1
	Elective	3- 2
	Thesis	0- 6
		9- 9

Third Term

EC 542A	Reaction Motors	3- 2
EE 411B	Feedback Control Systems	3- 3
EE 234C	Pulse Techniques and High Frequency Tubes	3- 3
LP 101E	Lecture Program I	0- 1
	Thesis	0- 6
		9-15

Fourth Term

EE 419B	Non-Linear and Sampled Systems	3- 4
	Elective	3- 0
PH 442A	Finite Amplitude Waves in Fluids	3- 0
PH 480E	Acoustics Seminar	0- 1
LP 102E	Lecture Program II	0- 1
	Thesis	0- 6
		9-12

Successful completion of this curriculum leads to the degree of Master of Science in Physicis.

ADVANCED WEAPONS SYSTEMS ENGINEERING (ELECTRONICS) CURRICULUM

(GROUP WX)

Objective—To provide students with a broad background of science-engineering studies underlying modern weapons control systems with primary emphasis on electronics control systems and method of digital computation.

FIRST YEAR (COMMON TO ALL)

Same as WEAPONS SYSTEMS ENGINEERING (GENERAL)

SECOND YEAR (WX)

First Term

EE 113B	Linear Systems Analysis	4- 3
EE 233B	Communications Circuits and Systems	4- 3
EE 621B	Electromagnetics I	3- 2
PH 630B	Elementary Atomic Physics	4- 0
		15- 8

Second Term

EE 114B	Communication Theory	4- 0
EE 213C	Pulse and Waveforming Circuits	4- 3
Ma 116B	Matrices and Numerical Methods	3- 2
EE 622B	Electromagnetics II	4- 0
		15-5

Third Term

EE 411B	Feedback Control System I	3- 3
EE 253A	Microwave Tubes	3- 2
EE 811C	Electronic Computers	3- 3
Ma 351B	Probability and Statistics	4- 2
LP 101E	Lecture Program I	0- 1
		13-11

Fourth Term

EE 412A	Feedback Control Systems II	3- 4
EE 433A	Radar Systems	4- 0
EE 551A	Information Networks	3- 2
Ma 352B	Applied Engineering Statistics	2- 2
LP 102E	Lecture Program II	0- 1
		12- 9

Intersessional Period—Field Assignment at a representative ordnance or industrial installation.

THIRD YEAR (WX)

First Term

EE 413A	Sampled Data Control Systems	2- 2
EE 462A	Automation and System Control	3- 3
	Elective	3- 2
	Thesis	0- 4
		8-11

Second Term

EE 461A	Systems Engineering	3- 2
EE 473A	Missile Guidance Systems	3- 0
	Elective	3- 2
	Thesis	0- 6
		9-10

Third Term

EC 542A	Reaction Motors	3- 2
EE 761B	Control System Components	2- 2
LP 101E	Lecture Program I	0- 1
	Elective	3- 2
	Thesis	0- 6
		8-13

Fourth Term

EE 122A	Network Synthesis I	3- 2
EE 821B	Computer Systems Technology	3- 3
LP 102E	Lecture Program II	0- 1
	Elective	3- 0
	Thesis	0- 6
		9-12

Successful completion of this curriculum leads to the degree of Master of Science in Electronics.

WEAPONS SYSTEMS (SPECIAL) CURRICULUM

(GROUP WS)

Objective—To provide selected foreign officers with a technical education in the principal science-engineering fields of Electrical Engineering, Physics, and Chemistry underlying weapons systems.

FIRST YEAR

First Term

CH 106C	Principles of Chemistry I	3- 2
EE 111C	Fields and Circuits	4- 4
Ma 120D	Vectors and Matrices	3- 1
Ma 230D	Calculus of Several Variables	4- 0
		14- 7

Second Term

CH 107C	Principles of Chemistry II	3- 2
EE 112C	Circuit Analysis	4- 3
Ma 240C	Elementary Differential Equations	2- 0
Ma 251C	Elementary Infinite Series	3- 0
Ma 260C	Vector Analysis	3- 0
		15- 5

Third Term

EC 611C	General Thermodynamics	3- 2
EE 231C	Electronics I	4- 3
Ma 270C	Complex Variables	3- 0
PH 151C	Mechanics I	4- 0
LP 101E	Lecture Program I	0- 1
		14- 6

Fourth Term

EE 232C	Electronics II	4- 3
EE 321C	Electromechanical Devices	3- 4
PH 152B	Mechanics II	4- 0
PH 270B	Physical Optics	4- 2
LP 102E	Lecture Program II	0- 1
		15-10

Intersessional Period—Enrollment in MN 191C, MN 210C and SP 012D, at the U.S. Naval Postgraduate School.

SECOND YEAR (WS)

First Term

CH 407B	Physical Chemistry	3- 2
EE 113B	Linear Systems Analysis	4- 3
EE 611C	Electromagnetic Fields	4- 0
Ma 412C	Introduction to Digital Computers	4- 1
		15- 6

Second Term

EC 591A	Blast and Shock Effects	3- 0
EE 411B	Feedback Control Systems I	3- 3
EE 234C	Pulse Techniques and High Frequency Tubes	3- 3
PH 450C	Underwater Acoustics	3- 2
		12- 8

Third Term

EE 419B	Non-Linear and Sampled Systems	3- 4
Ma 351B	Probability and Statistics	4- 2
PH 630B	Elementary Atomic Physics	4- 0
PH 631B	Atomic Physics Laboratory	0- 3
LP 101E	Lecture Program I	0- 1
		11-10

Fourth Term

EC 521A	Plastics and High Polymers	3- 2
Ma 352B	Applied Engineering Statistics	2- 2
PH 621B	Elementary Nuclear Physics	4- 0
PH 622B	Nuclear Physics Laboratory	0- 3
LP 102E	Lecture Program II	0- 1
	Elective	3- 0
		12- 8

This curriculum affords the opportunity to qualify for the degree of Bachelor of Science in Electrical Engineering.

CURRICULA CONDUCTED AT CIVILIAN INSTITUTIONS

Curriculum	*Length*	*Institution*	*Liaison Official*	*Curricular Supervisory Control Authority*
Business Administration	2 yrs.	Harvard	CO, NROTC	BUWEPS
		Stanford	CO, NROTC	BUWEPS
Civil Engineering (Advanced)	1-2 yrs.	Georgia Tech.	CO, NROTC	BUDOCKS
		M.I.T.	CO, NROTC	BUDOCKS
Typical Options:		Princeton	CO, NROTC	BUDOCKS
Structures		Purdue	CO, NROTC	BUDOCKS
Soil Mechanics		R.P.I.	CO, NROTC	BUDOCKS
Sanitary Engineering		Stanford	CO, NROTC	BUDOCKS
Waterfront Facilities		Tulane	CO, NROTC	BUDOCKS
Facilities Planning		Cal. (Berkeley)	CO, NROTC	BUDOCKS
Construction Engineering		U. of Colo.	CO, NROTC	BUDOCKS
Civil Engineering Administration		U. of Ill.	CO, NROTC	BUDOCKS
		U. of Mich.	CO, NROTC	BUDOCKS
		U. of Minn.	CO, NROTC	BUDOCKS
		U. of Wash.	CO, NROTC	BUDOCKS
Electrical Engineering (CEC)	15-24 mos.	U. of Mich.	CO, NROTC	BUDOCKS
Engineering Electronics (CEC)	12-18 mos.	U. of Mich.	CO, NROTC	BUDOCKS
Financial Management	1 yr.	Geo. Wash. U.	Senior Officer Student	USNPGS
Geodesy	2 yrs.	Ohio St. U.	CO, NROTC	USNPGS
International Relations	1 yr.	American U.	Senitor Officer Student	USNPGS
		Cal. (Berkeley)	CO, NROTC	USNPGS
		Harvard	CO, NROTC	USNPGS
Law (Army Judge Advocate Officers Advanced Course)	9 mos.	U. of Virginia	CO, NROTC	JAG
Management and Industrial Engineering	1 yr.	R.P.I.	CO, NROTC	USNPGS
Mechanical Engineering (CEC)	1 yr.	R.P.I.	CO, NROTC	BUDOCKS
Metallurgical Engineering	9 mos.	Carnegie Tech.	Senior Officer Student	USNPGS
Naval Construction and Engineering	3 yrs.	M.I.T.	CO, NROTC	BUSHIPS
		Webb Inst.	Senior Officer Student	BUSHIPS
Nuclear Engineering (Advanced)	14 mos.	M.I.T.	CO, NROTC	BUSHIPS
Nuclear Power Engineering (CEC)	15-20 mos.	Cal. (Berkeley)	CO, NROTC	BUDOCKS
		U. of Mich.	CO, NROTC	BUDOCKS
Oceanography	2 yrs.	U. of Miami (Florida)	CO, NROTC	USNPGS
		A & M College of Texas		
Petroleum Administration and Management	1 yr.	S.M.U.	Senior Officer Student	JAG
Petroleum Engineering (CEC)	1 yr.	U. of Texas	CO, NROTC	BUDOCKS
	1 yr.	industry		
Petroleum Management	16 mos.	U. of Kansas	CO, NROTC	BUSANDA
Political Science	2 yrs.	Fletcher School of Law and Diplomacy, Tufts	CO, NROTC	USNPGS
		Stanford	CO, NROTC	USNPGS
Procurement Management	1 yr.	U. of Mich.	CO, NROTC	BUSANDA
Public Relations	1 yr.	Boston U.	CO, NROTC, Harvard	CHINFO
Religion	9 mos.	Various		Chief of Chaplains
Retailing	1yr.	Pittsburgh	Senior Officer Student	BUSANDA
Subsistence Technology	1 yr.	Mich. State	Senior Officer Student	BUSANDA
Systems Inventory Management	2 yrs.	Harvard	CO, NROTC	BUSANDA
Textile Technology	18 mos.	N. Car. State	Senior Officer Student	BUSANDA
Transportation Management	1 yr.	Mich. State	CO, NROTC	BUSANDA

CURRICULA AT OTHER INSTITUTIONS

The curricula listed in this section are conducted entirely at civilian educational institutions. Quotas for enrollment must be approved by the Chief of Naval Personnel. The table indicates the duration of each curriculum, the location, and the curricular supervisory control authority as set forth in BUPERS INSTRUCTION 1520.50A. Administration of officer students in connection with educational matters is exercised by the Superintendent, U. S. Naval Postgraduate School, through the Commanding Officer, NROTC Unit, or through the Senior Officer Student at those institutions where no NROTC Unit is established.

The information on courses is taken from college catalogues, but is subject to change from year to year. Changes depend on scheduling problems at the educational institutions and on the academic backgrounds of students. Further detailed information can be obtained from the catalogue of the institution concerned, or by writing to the institution.

BUSINESS ADMINISTRATION

At Harvard University

Objective—To give emphasis to the following areas of study: (1) recognition of problems, (2) realistic administrative follow-through on decisions, (3) an understanding and realistic handling of human relations, (4) administrative powers in general, (5) the relationship of business to the government and to the public welfare, (6) the integration of business functions, and (7) the point of view of the Chief Executive and the directors responsible for over-all operations so as to give the student an effective start in the development of his managerial skills and an appreciation of the responsibilities of a business administrator.

Course length: Two years
Degree attainable: Master of Business Administration
Typical Curriculum:

First Year (All courses required)

Administrative Practices
Business Responsibilities in the American Society
Control
Finance
Marketing
Production
Written Analysis of Cases

Second Year (10 half-year courses required)

Business Policy (Required)
Courses in General Business Management
Courses in Industrial and Financial Accounting
Courses in Production/Manufacturing
Courses in Finance/Investment
Courses in Advanced/International Economics
Courses in Personnel Administration/Human Relations
Courses in Marketing/Sales/Merchandising
Courses in Transportation
Courses in Military Management
Courses in Taxation
Courses in Foreign Operations
Courses in Probability and Statistics for Business Decisions
Courses in Industrial Procurement

At Stanford University

Objective—To give the student a foundation in the following areas: (1) the external environment of the commercial firm, (2) the internal and organizational environment of the firm, (3) quantitative methods and tools of control, and (4) the management of major functions; to give the student an opportunity to apply the knowledge, skills, and attitudes acquired to the solution of action-oriented problems involving the entire commercial enterprise.

Course length: Two years
Degree attainable: Master of Business Administration
Typical Curriculum:

Required—First Year

Business Economics
Management Accounting
Business Statistics
Business Organization and Management
Business Finance
Marketing Management
Psychological Aspects of Business
Manufacturing I
Human Elements in Business
Legal Process in Business
Employment Relationships

Required—Second Year

Manufacturing II
Business Policy Formulation and Administration

Electives—Second Year

Courses in Industrial and Financial Accounting, Audit, Comptrollership
Courses in Production/Manufacturing
Courses in Finance/Investment/Banking
Courses in Personnel Administration/Industrial Relations
Courses in Marketing/Sales
Courses in Transportation
Courses in Insurance/Risk Management
Courses in Advanced Economics/International Trade
Courses in Research/Small Business Management
Courses in Business Information Systems Data Processing
Courses in Purchasing

CIVIL ENGINEERING (ADVANCED)

At: Georgia Institute of Technology
Massachusetts Institute of Technology
Princeton University
Purdue University
Rensselaer Polytechnic Institute
Stanford University
Tulane University
University of California (Berkeley)
University of Colorado
University of Illinois
University of Michigan
University of Minnesota
University of Washington

Objective—To educate officers for civil engineering duties. Options are available in all major fields of civil engineering. Typical options are: construction engineering, structures, soil mechanics, sanitary engineering, waterfront facilities, facilities planning, and civil engineering administration. Officers without previous civil engineering education would undertake a two-year curriculum; officers holding a Bachelor of Civil Engineering degree would undertake a one-year curriculum. This program is to qualify line officers (1100) for civil engineering duties and to provide advanced education for Civil Engineering Corps officers (5100).

Course length: One to two years
Degree attainable: Master of Science in Civil Engineering
Typical Curriculum: (For two-year Structures Option)

First Year:

- Contracts and Specifications
- Structural Analysis I and II
- Reinforced Concrete I and II
- Hydraulics
- Mechanical Behavior of Materials I
- Mathematics
- Highway and Airport Engineering
- Digital Computation Methods
- Building Construction
- Structural Design
- Structural Mechanics

Second Year:

- Advanced Mathematics
- Water Supply and Sewerage
- Indeterminate Structures
- Prestressed Concrete
- Analytical Solution of Structural Problems
- Long Span Structures
- Construction Methods and Estimates
- Limit Design of Steel Structures
- Structural Analysis for Terminal Loadings
- Advanced Indeterminate Structures
- Thesis

ELECTRICAL ENGINEERING (CEC)

At University of Michigan

Objective—To provide advanced education for selected CEC officers in electrical engineering with emphasis on power plants and electrical utility distribution.

Course length: 15-24 months
Degree attainable: Master of Science in Engineering Engineering

ENGINEERING ELECTRONICS (CEC)

At University of Michigan

Objective—To provide advanced education for selected CEC officers in the field of electronics with options in communication engineering, computer engineering, engineering systems and design, electromagnetic field theory, and microwave engineering.

Course length: 12 to 18 months
Degree attainable: Master of Science in Engineering Electronics

FINANCIAL MANAGEMENT

At George Washington University

Objective—To develop in officers of mature judgment and a broad background of professional experience the ability to interpret and analyze operational statistics for the purpose of developing standards of performance; to provide a periodic review of operations in order to denote areas of management which are not meeting standards; to review budget estimates; and to plan programs for the improvement of management economy and efficiency through better organization, administration and procedures and better utilization of manpower, materials, facilities, funds and time. The course is designed to give graduates a working knowledge of managerial controls adequate for assignment to financial management duties as a normal preparation for command and executive billets in the shore establishment and leads to degree Master of Business Administration.

Course length: One year
Degree attainable: Master of Science in Business Administration
Typical Curriculum:

Undergraduate Courses:

- General Accounting
- Management Communication
- Industrial and Governmental Economics
- Statistical Decision Making

Graduate Courses:

- Cost Accounting
- Managerial Accounting
- Internal Control and Audit
- Financial Management
- Seminar in Marketing
- Management Engineering
- Business Organization and Management
- Reading and Conference in Financial Management
- Human Relations in Business
- Research Seminar in Comptrollership
- Research Seminar
- Governmental Budgeting

GEODESY

At Ohio State University

Objective—To prepare officers for assignment to duties at the Oceanographic Office, on geodetic survey expeditions, and on fleet staffs. The curriculum presents a fundamental theoretical knowledge of geodesy, cartography, and photogrammetry, particularly as applied to hydrographic surveying and the compilation and production of charts and maps.

Course length: Two Years
Degree attainable: Master of Science in Geodesy

INTERNATIONAL RELATIONS

At: American University
University of California (Berkeley)
Harvard University

Objective—To provide a broad understanding of the forces and factors in international relations to equip officers to meet responsibilities involving knowledge of the international situation, including awareness of the role of sea power in world affairs.

Course length: One year
Degree attainable: Master's Degree

LAW

(Army Judge Advocate Officers Advanced Course)
At University of Virginia

Objective—To prepare more experienced Law Specialists (1620) for advanced staff responsibilities in the various legal fields. The course encompasses all branches of military law with emphasis on the administration of the Uniform Code of Military Justice, military affairs, civil affairs arising out of the operation of or litigation of military law, military reservations, international law including the laws of war, procurement and contract law, and legal assistance to military personnel.

Course length: Nine months

MANAGEMENT AND INDUSTRIAL ENGINEERING

At Rensselaer Polytechnic Institute

Objective—To prepare selected officers for managerial and industrial engineering billets in the Navy's industrial organization. The curriculum majors in industrial engineering and its application to managerial problems.

Course length: One year
Degree attainable: Master of Science in Management Engineering
Typical Curriculum:

Summer:

Review of Quantitative Methods
Statistical Methods
Law in Management and Engineering
Data Processing

Fall:

Cost Finding and Control
Analytical Methods in Management
New Product Problems
Production Planning
Industrial Relations

Spring:

Administrative Practice and Behavior
Organization Planning and Development
Financial Planning and Control
Seminar in Management
Production Control (Elective)
Management or Marketing (Elective)

MECHANICAL ENGINEERING (CEC)

At Rensselaer Polytechnic Institute

Objective—To provide advanced education for selected CEC officers in mechanical engineering with emphasis on power plants, heating and ventilation.

Course length: One year
Degree attainable: Master of Science in Mechanical Engineering

METALLURGICAL ENGINEERING

At Carnegie Institute of Technology

Objective—To obtain the maximum possible metallurgical background in a short program designed specifically for the graduate of the Naval Construction and Engineering Curriculum.

Course length: Nine months
Degree attainable: Bachelor of Science in Metallurgy

NAVAL CONSTRUCTION AND ENGINEERING

At: Massachusetts Institute of Technology
Webb Institute of Naval Architecture

Objective—To qualify selected officers for duty assignments in the fields of naval construction and marine engineering. The curricula are arranged to provide a broad capability in naval architecture and an exceptional capability in one option or specialty. Options are available in the following areas: hull design and construction, marine electrical engineering, electronics engineering and ship propulsion engineering. Selection of options is made after completion of the first summer term. Exceptional students are encouraged to pursue advanced work at the doctoral level. Successful completion of this curriculum leads to "Engineering Duty" designation (1400).

Course length: Three years
Degree attainable: Master of Science in Naval Architecture and Marine Engineering and the Degree of Naval Engineer
Typical Curriculum at M.I.T.:
(Hull Design and Construction Option)

First Summer:

Strength of Materials and Dynamics
Applied Hydrostatics
Review of Mathematics

First Year:

Structural Mechanics
Fluid Mechanics
Thermodynamics
History of Naval Ships
Advanced Calculus for Engineers
Naval Structural Engineering
Heat Transfer
Introduction to Nuclear Physics
Principles of Naval Architecture
Naval Ship General Arrangements I
Introduction to Probability and Random Variables

Second Summer:

Digital Computer Program Systems
Advanced Calculus for Engineers

Second Year:

Advanced Hydromechanics I and II
Properties of Metals
Naval Structural Theory I and II
Naval Ship Propulsion I
Mechanical Vibration
Naval Ship General Arrangements II
Naval Structural Analysis
Advanced Mechanics
Properties of Metals
Electives: Experimental Hydrodynamics
Naval Structural Design I
Naval Electrical Engineering

Third Summer:
Industrial Tour

Third Year:
Advanced Structural Mechanics
Experimental Stress Analysis
Principles of Ship Design
Principles of Naval Ship Design
Hydroacoustics
Naval Ship Propulsion II
Electives: Naval Structural Design II
Buckling of Structures
Plasticity
Thesis

NUCLEAR ENGINEERING (ADVANCED)

At Massachusetts Institute of Technology

Objective—To qualify officers for the technical direction of nuclear power development in the Navy. Graduates of this program can normally expect to be assigned duties within the nuclear power development program under the direction of the Bureau of Ships.

Course length: 14 months
Degree attainable: Master of Science

NUCLEAR POWER ENGINEERING (CEC)

At: University of California (Berkeley)
University of Michigan

Objective—To provide education for selected CEC officers in nuclear power engineering. Graduates of this curriculum will normally be assigned duties in the shore nuclear power program under the technical direction of the Bureau of Yards and Docks.

Course length: 15 to 20 months
Degree attainable: Master of Science

OCEANOGRAPHY

At University of Washington

Objective— To prepare officers for assignment to billets requiring comprehensive theoretical and practical foundation in the various aspects of oceanography. Students may specialize in physical, biological, chemical or geological oceanography. Prerequisites for this program include college general chemistry and general physics, and mathematics through differential and integral calculus. NOTE: Upon completion of the above course, officer students normally undergo an additional training period of six months at the Oceanographic Office, Washington, D. C., under the supervision of the Oceanographer.

Course length: 18 months
Degree attainable: Master of Science in Oceanography

PETROLEUM ADMINISTRATION AND MANAGEMENT

(Gas, Oil and Water Rights)

At Southern Methodist University

Objective—To provide Law Specialists (1620) with a study of government regulations in oil and gas law taxation problems, and special research and study of the evolution of law concerning water rights, current law affecting these rights, and technical problems attendant thereto so as to prepare them for assignment to billets concerned with the administration and management of the Naval Petroleum and Oil Shale Reserves and with the special problems in the field of water rights.

Course length: One year
Degree attainable: Master of Laws in Oil and Gas

PETROLEUM ENGINEERING (CEC)

At University of Texas
and in the petroleum industry

Objective—To prepare selected CEC officers for assignments to duty involving the administration and operation of Naval Petroleum and Oil Shale Reserves. The curriculum provides the student with a knowledge of petroleum development and production procedures, geology, petroleum economics and reservoir engineering.

Course length: One year of academic work followed by up to one year in the field with a major oil company
Degree attainable: Master of Science in Petroleum Engineering

PETROLEUM MANAGEMENT

At University of Kansas

Objective—To provide officers of the Supply Corps with graduate level education in the functional proficiency field of petroleum management and administration.

Course length: Sixteen months
Degree attainable: Master of Science

Typical Curriculum:

Fall:
Financial Accounting and Control I
Personnel Management
Material and Energy
Development of Oil and Gas Lands
Theoretical Principles of Petroleum Production

Spring:
Financial Accounting and Control II
Statistical Methods
Legal Aspects of Business
Field Practice in Natural Gas
Appraisal of Oil and Gas Properties

Summer:
Special Problems in Business Administration
Chemical Engineer Research

POLITICAL SCIENCE

At: The Fletcher School of Law and Diplomacy, Tufts University
Stanford University

Objective—To equip a limited number of intellectually mature officers with a broad professional background in international relations in order that they may provide professional advice and assistance in the formulation and execution of national policy. Studies should be specifically directed toward obtaining sound knowledge and understanding in:

(1) The theory of international politics, economics, law, and U. S. diplomatic history.

(2) The politics, geography and history of one of the following regions of the world: Europe, Asia, Africa, Western Hemisphere.

(3) The history, role and importance of world-wide and regional international organizations.

(4) Development and execution of U.S. political, military and economic policy as it pertains to U.S. foreign relations.

Course length: Two years
Degree attainable: Master of Arts

PROCUREMENT MANAGEMENT

At University of Michigan

OBJECTIVE—To provide officers of the Supply Corps with graduate level education in the field of military and commercial procurement.

Course length: One year
Degree attainable: Master of Business Administration

PUBLIC RELATIONS

At Boston University

OBJECTIVE—To provide advanced qualifications of officers in the field of public relations. Officers selected for this program must have previous education or experience in public information and public relations. The curriculum will be made up from regular course offerings of the university and will be based on an officer student's background and particular interest within the curricular area.

Course length: One year
Degree attainable: Master of Arts in Public Relations

RELIGION

At: Harvard University
Yale University
Catholic University
University of Chicago
University of Notre Dame
Fordham University
Union Theological Seminary

OBJECTIVE—To broaden the education of officer students in such fields as psychology, theology, homiletics, counseling, hospital ministry and education.

Course length: 9 months

RETAILING

At Graduate School of Retailing,
University of Pittsburgh

OBJECTIVE—To provide officers of the Supply Corps with graduate level education in the functional proficiency field of retailing. Emphasis is placed on consumer markets, sales promotion, merchandise and merchandising, and the management functions associated therewith.

Course length: One year
Degree attainable: Master of Business Administration

Typical Curriculum:

Fall:

Managerial Economics
Managerial Accounting
Seminar in Accounting
Administration and Human Behavior

Winter:

Managerial Account Planning
Management of Human Resources
Advertising Fundamentals
Elementary Business Statistics
Marketing Management

Spring:

Seminar in Retailing
Management of Financial Resources
Administrative Decision Making
Business and Society
Research in Business Economics

SUBSISTENCE TECHNOLOGY

At Michigan State University

OBJECTIVE—To provide officers of the Supply Corps with graduate level education in the field of food management.

Course length: One year
Degree attainable: Master of Business Administration

SYSTEMS INVENTORY MANAGEMENT

At Harvard University

OBJECTIVE—To provide officers of the Supply Corps with a well-grounded education at the graduate level in the scientific methods of inventory management.

Course length: Two years
Degree attainable: Master of Business Administration
Typical Curriculum:

First Year: (Required)

Administrative Practices
Control
Finance
The Manager and The American Economy
Marketing
Production
Written Analysis of Cases

Second Year: (Required)

Management Information Systems
Business Logistics
Financial Accounting I and II
Seminar in Military Marketing and Project Management

Second Year: (Electives) (Four to be selected)

Cost Administration
Industrial Procurement
Managing Technological Change
Planning and Controlling Production
*Analysis of Quantitative Data I and II
*Probability and Statistics for Business Decisions I and II
*Topics in Operations Analysis I and II
*Management Economics

*Prerequisite—Mathematics through Differential Calculus.

TEXTILE TECHNOLOGY

At North Carolina State College

Objective—To provide officers of the Supply Corps with graduate level education in the functional proficiency field of textile management.

Course length: 18 months

Degree attainable: Master of Textile Technology

Typical Curriculum:

- Technology Seminar
- Textile Testing II
- Textile Quality Control
- Complex Woven Structures
- Fabric Analytics and Characteristics
- Yarn Manufacture
- Synthetics IV
- Fabric Development and Construction
- Principles of Accounting
- Introduction to Production Costs
- Management Policy and Decision Making
- Management of Industrial Relations

TRANSPORTATION MANAGEMENT

At Michigan State University

Objective—To provide officers of the Supply Corps with graduate level education in the functional proficiency field of transportation management.

Course length: One year

Degree attainable: Master of Business Administration

Typical Curriculum:

- Basic Accounting II
- Financial Management
- Basic Marketing
- Basic Statistics I
- Accounting for Financial and Profit Management II
- Problems in Business Economics
- Basic Statistics II
- Transportation Policy
- Accounting for Financial and Profit Management III
- Human Problems in Administration
- Social Problems in Administration
- Marketing Management
- Transportation Seminar

LA MESA VILLAGE

ACADEMIC DEPARTMENTS
and
COURSE DESCRIPTIONS

DEPARTMENT OF AERONAUTICS

Richard William Bell, Professor of Aeronautics; Chairman (1951)*, A.B., Oberlin College, 1939; Ae.E., California Institute of Technology, 1941; Ph.D., 1958.

Eric John Andrews, Professor of Aeronautics (1959); Honors B.S., Aero. Eng., Univ. of London, 1936.

Wendell Marois Coates, Fellow, Professor of Aeronautics (1931); A.B., Williams College, 1919; M.S., University of Michigan, 1923; D.Sc., 1929.

Nicholas Cosmo Gallinaro, Ensign, U.S. Naval Reserve; Instructor in Aeronautics (1963); B.S., Tufts Univ., 1962.

Theodore Henry Gawain, Professor of Aeronautics (1951); B.S., Univ. of Pennsylvania, 1940; D.Sc., Massachusetts Institute of Technology, 1944.

Ulrich Haupt, Associate Professor of Aeronautics (1954); Dipl. Ing., Institute of Technology, Darmstadt, 1934.

Richard Moore Head, Professor of Aeronautics (1949)**; B.S., California Institute of Technology, 1942; M.S., 1942; M.S., 1943; Ae.E., 1943; Ph.D., 1949.

George Judson Higgins, Professor of Aeronautics (1942); B.S., in Eng. (AeE.), Univ. of Michigan, 1923; AeE., 1934.

Charles Horace Kahr, Jr., Professor of Aeronautics (1947); B.S., Univ. of Michigan, 1944; M.S., 1945.

Henry Lebrecht Kohler, Professor of Aeronautics (1943); B.S. in M.E., Univ. of Illinois, 1929, M.S. in M.E., Yale University, 1930; M.E., 1931.

Donald Wright MacKenzie, Lieutenant, U.S. Naval Reserve; Instructor in Aeronautics (1963); B.M.E., Cornell Univ., 1953; M.S., Lehigh Univ., 1957.

James Avery Miller, Associate Professor of Aeronautics (1963); B.S. in M.E., Stanford Univ., 1955; M.S. in M.E., Stanford Univ., 1957; Ph.D., Illinois Institute of Technology, 1963.

Roy Earl Reichenbach, Associate Professor of Aeronautics (1962); B.M.E., Ohio State University, 1956; M.S., 1956; Ph.D., California Institute of Technology, 1960.

James Herbert Starnes, Jr., Lieutenant Junior Grade, U.S. Naval Reserve; Instructor in Aeronautics (1963); B.S., Georgia Institute of Technology, 1961; M.S., Georgia Institute of Technology, 1963.

Ried W. Stone, Commander, U.S. Navy; Instructor in Aeronautics (1962); B.A., Univ. of Iowa, 1939; M.S., Aero. Eng., Univ. of Minnesota, 1950.

Alfred Francis Vachris, Jr., Lieutenant Junior Grade, U.S. Naval Reserve; Instructor in Aeronautics (1963); B.S., Univ. of Notre Dame, 1962; M.S., Polytechnic Institute of Brooklyn, 1963.

Michael Hans Vavra, Professor of Aeronautics (1947); Dipl. Ing., Swiss Federal Institute of Technology, 1934; Ph.D., Univ. of Vienna, 1958.

Robert Leslie Whitelaw, Associate Professor of Aeronautics (1963); B.S., Univ. of Toronto, 1940.

*The year of joining the Postgraduate School faculty is indicated in parentheses.

**On leave of absence at National Aeronautics and Space Administration.

DEPARTMENTAL REQUIREMENTS FOR DEGREES IN AERONAUTICAL ENGINEERING

The following is a summary of the minimum academic requirements for the award of these degrees as determined by the Aeronautics Department. Any curriculum toward these degrees must also be consistent with the general minimum requirements as determined by the Academic Council.

BACHELOR OF SCIENCE IN AERONAUTICAL ENGINEERING

This degree normally requires a minimum of 96 term hours of upper division courses in residence at the Postgraduate School (unless reduced by validated advanced credit) of which at least 70 term hours are in aeronautics courses. The following requirements must be met:

Subject:	*Approximate Term Hours*
Aerodynamics and aircraft dynamics	21
Solid mechanics and structural design	21
Thermodynamics and propulsion	18
Methods for Digital and Analog Computers	4
Basic Electric Fields And Circuits	8

Every candidate's undergraduate record, at the Naval Postgraduate School, or as validated from other institutions, must include:

a. Basic mathematics through differential equations, including adequate preparatory coverage.

b. Basic coverage in physics and chemistry to at least 12 term hours or the equivalent in each field.

MASTER OF SCIENCE IN AERONAUTICAL ENGINEERING

This degree requires a minimum of 56 graduate level term hours in residence at the Postgraduate School (unless reduced by validated advanced credit) of which at least 36 graduate level hours are to be in aeronautics courses. These requirements include term hours allotted to research. Not less than one-half of the remainder of the stated numbers required must be taken in A level courses. The following specific requirements will be met:

a. *Propulsion:* at least one graduate lecture course in the Ae 400 series.

b. *Gas dynamics:* at least a two-term lecture sequence in the Ae 500 series.

c. *Structures:* at least a two-term lecture sequence in the Ae 600 series.

d. *Systems engineering:* at least one lecture course in the Ae 700 series.

e. *Computers:* unless previously satisfied, one course in the use of digital analog computers.

f. *Options:* specialization in one of the available options such as 1) Flight Systems; 2) Propulsion; 3) Structures; 4) Flight test and evaluation; 5) Gas dynamics; or 6) Other recognized specialty in aeronautics.

g. *Research and thesis:* at least 10, but not more than 15, graduate term hours in Ae 000 (Research), plus an acceptable thesis (this requirement may be waived upon recommendation of the Chairman, Aeronautics Department).

AERONAUTICAL ENGINEER

This degree requires a minimum of 115 graduate level term hours in residence at the Postgraduate School (unless reduced by validated advanced credit) of which at least 65 graduate level hours are to be in aeronautics courses. These requirements include term hours allotted to research. Not less than one-half of the remainder of the stated number required must be taken in A level courses. Specific requirements to be met are the same as outlined in items a through f of the M. S. program. Additional requirements are:

a. *Major:* at least 3 additional graduate aeronautics lecture courses of the major option, and 2 additional graduate aeronautics lecture courses in support of that option; final coverage in the option to be approved by the Chairman, Aeronautics Department.

b. *Research and thesis:* at least 15 but not more than 20 graduate term hours in Ae 000 (Research), plus an acceptable thesis.

AERONAUTICS

Ae 001E AERONAUTICAL LECTURE SERIES (0-1). Lectures on general aeronautical engineering subjects by prominent authorities from the Navy Department, research laboratories and the industry.

Ae 010C AERONAUTICAL SEMINAR (0-1). Discussion of aeronautical developments and reports on progress in research by faculty and students.

Ae 099C AERODYNAMICS (4-3). Basic aerodynamics for ordnance application. Properties of fluids; equations of basic hydro-aerodynamics; viscous fluids and boundary layers; dynamic lift and drag of bodies; elementary study of compressible flows. Laboratory is in subsonic wind tunnel. TEXTS: Same as Ae 100. PREREQUISITE: Engineering Mechanics.

Ae 100C BASIC AERODYNAMICS (3-2). Properties of fluids; statics and dynamics; theory of lift; propellers; viscous flows; vortices; boundary layers; separation phenomena surface friction; dynamics of compressible fluids. The laboratory includes experimental work in the wind tunnel, technical analysis and report writing. TEXTS: DODGE and THOMPSON, *Fluid Mechanics;* ROUSE, *Elementary Fluid Mechanics;* PAO, *Fluid Mechanics.*

Ae 101C TECHNICAL AERODYNAMICS (3-4). Aerodynamic flows and pressures about flight vehicle components; surface friction; wake drag; airfoil sections; three-dimensional airfoil theory; induced drag; high lift devices. The laboratory periods include wind tunnel experiments, analysis and technical report writing. TEXTS: DWINNELL, *Principles of Aerodynamics;* POPE, *Wind Tunnel Testing.* PREREQUISITE: Ae 100.

Ae 102C TECHNICAL AERODYNAMICS PERFORMANCE (4-2). The aerodynamic characteristics of the aircraft; propeller and jet engine; sea level performance; performance at altitudes; range and endurance; special performance problems; charts. The laboratory periods are devoted to computations and performances analysis. TEXTS: DWINNELL, *Principles of Aerodynamics;* PERKINS and HAGE, *Airplane Performance, Stability and Control;* POPE, *Wind Tunnel Testing.* PREREQUISITE: Ae 101.

Ae 104C AERODYNAMICS I (3-2). Flow kinematics in gas or fluid, scalar and vector determination of states of translation, rotation, stress and strain, dynamic equations. Potential flows, description by complex variables, transformations of patterns, the force field on airfoils, coefficients and characteristics. TEXT: Under study. PREREQUISITE: Validated advanced credit in basic B.S. mathematics and engineering.

Ae 105C AERODYNAMICS II (3-2). The finite wing, spanwise lift distribution, vortex systems and induced effects. Viscosity, surface friction, drag. TEXT: Under study. PREREQUISITE: Ae 104.

Ae 106C AIRCRAFT DYNAMICS I (3-2). Performance of aircraft and their propulsive systems; an advanced version of Ae 102. TEXT: Under study. PREREQUISITE: Ae 105.

Ae 107B AIRCRAFT DYNAMICS II (3-2). Forces and couples on the airplane or its components; design characteristics for stability and control. TEXT: Under study. PREREQUISITE: Ae 106.

Ae 108B AIRCRAFT DYNAMICS III (3-2). Continuation of stability and control study. Principles of automatic control. TEXT: Under study. PREREQUISITE: Ae 107.

Ae 109C AERODYNAMICS LABORATORY (0-3). The subsonic windtunnel, its basic equipment, instrumentation, and use for engineering experimentation. TEXT: Under study. PREREQUISITE: Ae 104, can be taken simultaneously.

Ae 141B DYNAMICS I (3-2). The forces and moments on the flight vehicle and its parts; C.G. location, effect on static stability; neutral points; maneuver points; free control stability; control effectiveness and design; maneuverability. The laboratory work consists of wind tunnel experimentation and analysis. TEXTS: HIGGINS, *USNPGS Notes;* PERKINS, *Aircraft Stability and Control;* HAMLIN, *Flight Testing;* ETKIN, *Dynamics of Flight.* PREREQUISITE: Ae 102.

Ae 142B DYNAMICS II (3-4). The Euler equations of motion; aerodynamic derivatives; longitudinal motion analysis; lateral motion analysis; effect of control freedom and of controls and response coupling; spins. The laboratory work consists of wind tunnel experimentation in dynamics. TEXTS: Same as Ae 141. PREREQUISITE: Ae 141.

Ae 150B FLIGHT TEST PROCEDURES (3-4). Technical aerodynamics of airplanes including performance, longitudinal stability, lateral-directional stability and flight test methods and aircraft evaluation. Test flying by students in naval aircraft, data reduction and flight test report writing. TEXTS: DOMMASCH, SHERBY *and* CONNOLLY, *Airplane Aerodynamics;* NATC Patuxent, *Flight Test Manual;* NavAer publications.

Ae 151B FLIGHT TESTING AND EVALUATION I (2-0). Technical longitudinal stability and control of aircraft, related test methods and aircraft evaluation. TEXTS: Same as Ae 150. PREREQUISITE: Ae 141.

Ae 152B FLIGHT TESTING AND EVALUATION II (2-0). Theoretical lateral-directional control of aircraft, related test methods and aircraft evaluation. TEXTS: Same as Ae 150. PREREQUISITE: Ae 141.

Ae 153B FLIGHT TESTING AND EVALUATION III (2-0). The technical aerodynamics of airplanes, especially performance and test methods. TEXTS: Same as Ae 150. PREREQUISITE: Ae 142.

Ae 161B FLIGHT TESTING AND EVALUATION LABORATORY I (0-4). Flight program accompanying Ae 151. Test flying in naval aircraft by aviator students; stalls; static and dynamic longitudinal stability; static and maneuvering neutral points; control effectiveness; trim changes; Mach effects.

Ae 162B FLIGHT TESTING AND EVALUATION LABORATORY II (0-4). Flight program accompanying Ae 152. Test flying in naval aircraft by aviator students; rate of roll; adverse yaw; control effectiveness with asymmetric power, static and dynamic lateral-directional stability; over-all qualitative evaluation of aircraft.

Ae 163B FLIGHT TESTING AND EVALUATION LABORATORY II (0-4). Flight program accompanying Ae 153. Test flying in naval aircraft by aviator students and reduction of resulting data; airspeed calibration; level flight performance and fuel consumption; climb performance.

Ae 171A AERODYNAMICS I (3-2). Edited to the interests of ordnance curricula. Properties of gases from viewpoint of kinetic theory; dynamic equations for real fluids in vector form; circulation; potential flow, perfect fluid equations, two-dimensional flows, theory of lift, vortices, viscous fluids; dimensional analysis, incompressible laminar boundary layer. TEXT: Class notes. PREREQUISITES: Required Ma and Ph.

Ae 172A AERODYNAMICS II (3-2). Continuation of Ae 171. Karman integral relation, turbulent boundary layer, transition, separation; airfoil section characteristics; laws of vortex motion, finite wing span theory, induced drag; engineering consequences and applications. TEXT: Class notes. PREREQUISITE: Ae 171.

Ae 173A COMPRESSIBLE FLUIDS I (4-0). Essentially the coverage in Ae 513, edited in the interests of ordnance curricula. TEXTS: Same as Ae 513. PREREQUISITE: Ae 172.

Ae 174A COMPRESSIBLE FLUIDS II (3-2). A continuation of Ae 173, edited from the same viewpoint, with coverage similar to Ae 514. TEXTS: Same as Ae 514. PREREQUISITE: Ae 173.

Ae 175A MISSILE DYNAMICS (3-2). Generalized force fields on flight vehicles, in continuation of this sequence. Equations of motion, trim, performance, range, static and dynamic stability, controllability, practical design problems and analysis of a particular missile. TEXT: same as Ae 141. PREREQUISITE: Ae 174.

Ae 200C STRUCTURAL MECHANICS I (3-2). Survey of basic mechanics for application to the structure of flight vehicles. Topics are: Force systems, deformations, truss analysis, section properties, shear and bending moment diagrams, graphical and diagrammatic methods. Problem work supplements theory. TEXTS: BEER and JOHNSTON, *Statics;* NILES and NEWELL, *Airplane Structures;* TIMOSHENKO, *Strength of Materials, Vol. I.* PREREQUISITE: Engineering Mechanics (Statics).

Ae 201C STRUCTURAL MECHANICS II (4-2). A continuation of Ae 200. The two-dimensional state of stress, stress-strain relations; design of struts, circular shafts, thin cylinders, beams; load distribution; energy principles, impact; bending deflections by diagrammatic methods. Problem work and laboratory tests supplement theory. TEXTS: TIMOSHENKO, *Strength of Materials;* PEERY, *Aircraft Structures;* NILES and NEWELL, *Airplane Structures;* SHANLEY, *Strength of Materials.* PREREQUISITE: Ae 200.

Ae 202C STRUCTURAL COMPONENTS I (4-2). Stress and structural analysis of frame or engine components used in flight vehicles. Extended discussion of statically indeterminate systems under transverse or axial loads, bending, torsion; thermal effects; curved bars and frames; columns. Problem work and laboratory tests supplement theory. TEXTS: Same as Ae 201 and TIMOSHENKO, *Strength of Materials, Part II.* PREREQUISITE: Ae 201.

Ae 203C STRUCTURAL COMPONENTS II (4-2). A continuation of Ae 202. Flight framework is analyzed under characteristic loading, unsymmetrical bending, shear flow in open and closed sections, shear resistant webs, diagonal tension fields. Torsion of non-circular sections, membrane analogy Problem work and laboratory tests supplement theory. TEXTS: Same as Ae 202. PREREQUISITE: Ae 202.

Ae 204C SOLID MECHANICS I (3-2). Applied mechanics of rigid and deformable solids in equilibrium; an advanced version of Ae 200. TEXT: Under study. PREREQUISITE: Validated advanced credit in basic B.S. mathematics and engineering.

Ae 205C SOLID MECHANICS II (3-2). General stress-strain relations at a point. Bending stresses and transverse shear. Energy principles. Deflections of statically determinate systems. TEXT: Under study. PREREQUISITE: Ae 204.

Ae 206C STRUCTURAL COMPONENTS I (3-2). Extended analysis of statically indeterminate systems such as beams, frames, trusses. Matrix formulation of structures problems. Column discussions. TEXT: Under study. PREREQUISITE: Ae 205.

Ae 207C STRUCTURAL COMPONENTS II (3-2). Analysis of bending and shear effects in flight vehicles. Unsymmetrical bending; shear flows; tension field webs; torsion of non-circular sections. TEXT: Under study. PREREQUISITE: Ae 206.

Ae 209C STRUCTURAL LABORATORY (0-3). Fundamentals of experimental stress analysis. Electronic and optical instrumentation methods. TEXT: Under study. PREREQUISITE: Ae 205.

Ae 214A STRUCTURAL COMPONENTS III (4-0). Columns and beam-columns. Lateral and torsional buckling of beams. Axially symmetrical plates. General theory of plates; moments, stresses, curvatures, equilibrium. TEXTS: SECHLER, *Elasticity in Engineering;* TIMOSHENKO, *Strength of Materials, Vol. II.* PREREQUISITE: Ae 203.

Ae 215A ADVANCED STRUCTURES (4-0). Elasticity equations, energy methods. Matrix formulations in structural analysis, built up wing applications. Selected topics in vibrations, stability, plasticity. TEXTS: Same as Ae 214, others depend upon topics. PREREQUISITE: Ae 214.

Ae 221B STRUCTURAL PERFORMANCE (2-2). Static and dynamic tests of aircraft and missile components in the Aeronautical Structures Laboratory. Electronic and optical instrumentation methods, evaluation of strain measurements, demonstration of stress distribution in various structures. TEXTS: LEE, *An Introduction to Experimental Stress Analysis;* PERRY and LISSNER, *Strain Gage Primer;* Notes. PREREQUISITE: Ae 203.

Ae 231C STRUCTURAL DESIGN I (3-2). Design and analysis of a flight vehicle. Preliminary layout, aerodynamic and structural characteristics, military specifications, design criteria and load factors. TEXTS: Same as Ae 207; Selected Publications. PREREQUISITE: Ae 207.

Ae 232B STRUCTURAL DESIGN II (2-2). A continuation of Ae 231. Structural design of vehicle components, survey of design problems in airplanes, missiles and rockets. TEXTS: Same as Ae 231. PREREQUISITE: Ae 231.

Ae 304C FLIGHT KINEMATICS (2-2). Kinematics of the vehicle in air or space; coordinate systems, scalar and vector forms, transformation of orthogonal systems, matrices; applications to flight record analysis and other aeronautical problems. TEXT: Under study. PREREQUISITE: Validated advanced credit in basic B.S. mathematics and engineering.

Ae 305C FLIGHT DYNAMICS I (2-2). Dynamics of particles and rigid bodies, inertial systems. Kepler's Laws, Newtonian mechanics, potential fields. Dynamic equations for the flight vehicle, in air or space; selected flight applications. TEXT: Under study. PREREQUISITE: Ae 304.

Ae 306C FLIGHT DYNAMICS II (2-2). Continuation of Ae 305. Oscillating systems; vibration, free, damped, forced; response curves, resonance; applications to aeronautical systems acting as rigid or as elastic bodies, and with one or more degrees of freedom; matrix applications: TEXT: Under study. PREREQUISITE: Ae 305.

Ae 307C DYNAMICS OF SPACE VEHICLES (2-2). This course parallels Ae 106 and 107 for the vehicle in space, with negligible air drag. TEXT: Under study. PREREQUISITE: Ae 306.

Ae 309B DYNAMICS OF SPACE VEHICLES (0-3). Wind-tunnel experimentation to determine forces and couples on complete model aircraft. Methods of data processing and prediction of full scale performance. TEXT: Under study. PREREQUISITE: Ae 307, or Ae 107 simultaneously.

Ae 401C THERMODYNAMICS I (AERONAUTICAL) (4-2). Fundamentals of thermodynamics edited especially for application to aerothermodynamics and aircraft propulsion. Topics include fundamental laws, energy concepts, terminology and symbolism, properties of ideal and real gases, vapors, property relationships, theoretical cycles and elementary compressible flow. TEXTS: KEENAN and KEYS, *Thermodynamic Properties of Steam;* KEENAN and KAYE, *Gas Tables;* DOOLITTLE, *Thermodynamics for Engineers;* USNPGS Notes. PREREQUISITE: Ae 100.

Ae 402C THERMODYNAMICS II (AERONAUTICAL) (3-2). A continuation of Ae 401. The latter half of the course includes an introduction to heat transfer by conduction, radiation and convection. TEXTS: KEENAN and KAYE, *Gas Tables;* DOOLITTLE, *Thermodynamics for Engineers.* PREREQUISITE: Ae 401.

Ae 404C THERMODYNAMICS I (3-2). Basic concepts and fundamental laws of thermal energy; an advanced version of Ae 401. TEXTS: LEE and SEARS, *Thermodynamics;* KEENAN and KAYE, *Gas Tables;* KEENAN and KEYS, *Thermodynamic Properties of Steam.* PREREQUISITE: Earlier B.S. engineering thermodynamics.

Ae 405C THERMODYNAMICS II (3-2). Continuation of Ae 404 to include one dimensional isentropic and diabatic compressible flow. TEXT: Same as Ae 404. PREREQUISITE: Ae 404.

Ae 406C THERMODYNAMICS III (3-2). An extension of Ae 405 to include combustion and heat transfer. TEXTS: LEE and SEARS, *Thermodynamics;* JACOB and HAWKINS, *Elements of Heat Transfer and Insulation.* PREREQUISITE: Ae 405.

Ae 407C AIRCRAFT PROPULSION (3-2). Application of air-breathing machinery to aircraft propulsion. Performance of propellers, turbo-fan and turbojet engines and components in relation to vehicle performance. TEXT: HESSE, *Jet Propulsion,* USNPGS Notes. PREREQUISITE: Ae 406C

Ae 408B AIRCRAFT PROPULSION II (3-2). Supersonic and Hypersonic vehicle propulsion. Ramjets and unconventional propulsion machinery. TEXT: Under study. PREREQUISITE: Ae 407C.

Ae 409C AEROTHERMODYNAMICS LABORATORY (0-3). Laboratory experiments pertinent to Ae 404 and Ae 405.

Ae 411B AIRCRAFT ENGINES (4-2). Combustion of liquid fuels in air. Chemical and physical aspects of ignition, flame propagation and stabilization in steady flow. Piston engine performance as affected by environment and mechanical design. Propeller design, performance and operation. TEXTS: LICHTY, *Internal Combustion Engines;* TAYLOR *and* TAYLOR, *Internal Combustion Engines;* NELSON, *Airplane Propeller Principles;* FRASS, *Aircraft Power Plants;* USNPGS Notes. PREREQUISITE: Ae 402.

Ae 412B THERMODYNAMICS LABORATORY (0-3). Laboratory experiments and computations involving air flow, combustion, gas analysis and heat transfer as applied to aircraft propulsion machinery. Familiarization with and use of specialized instrumentation. PREREQUISITE: To be accompanied by Ae 411.

Ae 421B AIRCRAFT PROPULSION (3-2). Steady flow machinery as applied to aircraft propulsion cycles, compressor and turbine performance characteristics and matching for off-design operation. Turbojet, turboprop and turbo-fan performance in flight. Ramjet engine performance analysis. TEXT: HESSE, *Jet Propulsion.* USNPGS Notes. PREREQUISITE: Ae 411.

Ae 422A PERFORMANCE OF PROPULSION SYSTEMS (4-2). Application of air-breathing and rocket engines to the propulsion of manned aircraft and missiles. Theory and performance of advanced systems for space propulsion: TEXT: To be specified. PREREQUISITE: Ae 421.

Ae 423A ADVANCED PROBLEMS IN PROPULSION (4-2). Selected problems investigated and reported individually by students. Subject matter varies following developments in technology. TEXT: To be specified. PREREQUISITE: Ae 421.

Ae 430A PRINCIPLES OF TURBOMACHINES (3-0). General relations for flows with energy changes, relative and absolute motions: energy equations and momentum theorems. Operating principles and performance of compressors, pumps, and turbines. TEXTS: SHEPHERD, *Principles of Turbomachinery;* VAVRA, *Aerothermodynamics.* PREREQUISITE: Ae 421 and 508 simultaneously.

Ae 431A AEROTHERMODYNAMICS OF TURBOMACHINES I (4-0). Rational course on flows of elastic fluids in turbomachines. Fundamental relations for arbitrary applications to rotating machinery of axial and centrifugal type. TEXT: VAVRA, *Aerothermodynamics.* PREREQUISITE: Ae 513.

Ae 432A AEROTHERMODYNAMICS OF TURBOMACHINES II (4-0). Continuation of Ae 431, with special emphasis on practical design criteria for applications to jet engines, rocket motor turbo-pumps, and space power plants. TEXT: VAVRA, *Aerothermodynamics.* PREREQUISITES: Ae 431, Ae 451.

Ae 433A ADVANCED PROPULSION SYSTEMS (4-0). Application of fluid dynamics, thermodynamics and stress analysis to propulsion systems for different flight vehicles using conventional and exotic fluids. Heat transfer elements, effects of temperature. Off-design performance, matching and control. TEXT: VAVRA, *Aerothermodynamics.* PREREQUISITES: Ae 432, Ae 452.

Ae 434A SPACE POWER PLANTS (3-0). Power plants for propulsion and generation of electrical energy for space vehicles with chemical, nuclear, and solar heat sources and radiative heat sinks. TEXT: CORLISS, *Propulsion Systems for Space Flight;* KREITH, *Radiation Heat Transfer;* VAVRA, *Aerothermodynamics.* PREREQUISITES: Ae 440, Ae 460.

Ae 440A DESIGN OF TURBOMACHINERY (4-0). Analysis and design of elements of turbomachines. Centrifugal and thermal stresses in blades and disks, vibratory analysis, critical speed, stress analysis, and modern design concepts. TEXT: USNPGS Notes. PREREQUISITES: Ae 431, Ae 451 or Ae 430, Ae 450.

Ae 450A PROPULSION LABORATORY I (0-3). Course given in conjunction with Ae 430. Measurements and analysis of flows in compressors and turbines, cascade test rigs and flow channels. Performance of jet engines and rocket motors. TEXTS: VAVRA, *Aerothermodynamics;* VAVRA and GAWAIN, *Compressor Test Rig.* PREREQUISITES: Same as Ae 430.

Ae 451A PROPULSION LABORATORY II (0-3). Course given in conjunction with Ae 431. Same coverage as Ae 450, with special emphasis on correlation of tests results with theory. TEXTS: Same as Ae 450. PREREQUISITES: Same as Ae 431.

Ae 452A PROPULSION LABORATORY III (0-3). Course given in conjunction with and to supplement Ae 432. Determination of off-design performance of turbomachines. Three-dimensional flow phenomena. TEXT: Same as Ae 432. PREREQUISITE: Same as Ae 432.

Ae 453A PROPULSION LABORATORY IV (0-3). Course given in conjunction with and to supplement extension of Ae 433 with advanced methods and instrumentation. Data reduction with electronic computer. Heat transfer and control tests. TEXT: Same as Ae 433. PREREQUISITE: Same as Ae 433.

Ae 454A LABORATORY SEMINAR I (1-4). Advanced individual test assignments to supplement course Ae 434. TEXT: Same as Ae 434. PREREQUISITE: Same as Ae 434.

Ae 460A PROPULSION DESIGN LABORATORY (0-2). Course given in conjunction with Ae 440. Test of disk and bladings in Hotspin Test Unit, evaluation of centrifugal and thermal stresses, vibration tests on electric shaker, work on critical speed test rig, bearing and seal tests. TEXT: Same as Ae 440. PREREQUISITE: Same as Ae 440.

Ae 501A HYDRO-AERO MECHANICS I (4-0). Dynamic equations for real fluids in vector and tensor form, circulation, rotational flow, potential flow, perfect fluid equations, complex variables and conformal mapping, two-dimensional airfoil theory. TEXTS: KUETHE AND SCHETZER, *Foundation of Aerodynamics;* ABBOTT and VON DOENHOFF, *Theory of Wing Sections;* Instructor's Notes. PREREQUISITE: Ae 101.

Ae 502A HYDRO-AERO MECHANICS II (4-0). Continuation of Ae 501. Laws of vortex motion, finite span wing theory, hydrodynamics of viscous fluids, pipe flow, boundary-layer, equations, Blasius' solution, Karman integral relation, turbulent boundary-layer, transition. TEXTS: Same as Ae 501. PREREQUISITE: Ae 501.

Ae 508A COMPRESSIBILITY (3-2). One dimensional gas dynamics; channel flow, normal and oblique shock waves, Prandtl-Meyer expansion, three-dimensional flow equations; Crocco's theorem, linearized potential flow and application to air foils and bodies of revolution, method of characteristics. TEXTS: Same as Ae 502. PREREQUISITE: Ae 502.

Ae 511A HYDRO-AERO MECHANICS ADVANCED I (4-0). This course provides a more advanced coverage of the material in Ae 501. TEXTS: Same as Ae 501, also VAVRA, *Aerothermodynamics.*

Ae 512A HYDRO-AERO MECHANICS ADVANCED II (4-0). This course provides a more advanced coverage of the material in Ae 502. TEXTS: Same as Ae 502.

Ae 513A COMPRESSIBILITY I (4-0). One dimensional gas dynamics; channel flow, normal and oblique shock waves, Prandtl-Meyer expansion, three dimensional flow equations, Crocco's theorem, two- and three-dimensional linearized theory, method of characteristics. TEXTS: LIEPMANN and ROSHKO, *Elements of Gas Dynamics;* Instructor's Notes. PREREQUISITE: Ae 512.

Ae 514A COMPRESSIBILITY II (3-2). Similarity laws for transonic and hypersonic flows, viscous shear and heat transfer, continuum magneto-aerodynamics; basic equations including Maxwell's relations, applications to plasmas, ionized boundary layers and magnetic nozzles. Wind tunnel and shock tube tests are conducted in conjunction with class discussion. TEXTS: Same as Ae 513. PREREQUISITE: Ae 513.

Ae 521A MAGNETOAERODYNAMICS (4-0). Dynamic equations for continuous media and classical equations for electromagnetic fields as applied to ionized gases moving in a magnetic field; propagation of small disturbances, Alfven waves, fast and slow waves, shock waves; particular solutions of the magnetoaerodynamic equations; motion of charged particles, drift, anisotropic Ohm's law, applications. TEXTS: Instructor's notes. PREREQUISITE: Ae 514 or Ae 508.

Ae 601A METHODS IN ELASTICITY (4-0). Formal systems in stress and strain, the generalized Hooke's Law and compatibility. Classical boundary value problems. Plane stress and strain; Airy stress function. Variational concepts; minimum potential and complementary energies. Eigenvalue solutions. Problems in elastic stability. TEXTS: WANG, *Applied Elasticity;* SECHLER, *Elasticity in Engineering.* PREREQUISITE: Ae 215.

Ae 602A STATIC AEROELASTICITY (3-0). Problems involving the coupling of aerodynamic and elastic forces without inertia coupling: the divergence of lifting surfaces and control reversal. Two-dimensional examples, related integral and differential equations, solutions for finite wings including the effect of sweep, semi-rigid solutions, iterative methods, matrix forms. TEXTS: BROADBENT, *The Elementary Theory of Aeroelasticity;* FUNG, *The Theory of Aeroelasticity;* BISPLINGHOFF, ASHLEY, HALFMAN, *Aeroelasticity.* PREREQUISITE: Ae 601.

Ae 603A AEROELASTICITY (FLUTTER) AND VIBRATION. (4-0). Problems involving coupling of inertia forces with elastic and/or aerodynamic forces. Free and forced vibrations, effect of damping, several degrees of freedom. Torsional vibration, critical speeds. Impact. Fundamental non-stationary wing theory. Flutter of a two-dimensional airfoil and of a cantilever wing. TEXTS: Same as Ae 602. PREREQUISITE: Ae 602.

Ae 604A THERMOELASTICITY (3-1). Analysis and design of structures at elevated temperatures. Temperature distribution, elastic and inelastic thermal stresses in aeronautical structures, thermal effects on deflections, stiffness and flutter. TEXT: GATEWOOD, *Thermal Stresses.* PREREQUISITE: Ae 601.

Ae 605A PLATES AND SHELLS (4-0). Plates and shells from viewpoint of application to flight vehicles. Flat plates in bending and transverse load, curvature and twist of middle surface, bending and twisting moments, shearing forces, equilibrium equations, stresses; strain energy under lateral loading, and under loads in middle surface, plate stability; axially symmetrical shells, shell geometry, equilibrium, critical stresses; discontinuities, flanges, cutouts; selected design applications. TEXTS: TIMOSHENKO, *Theory of Plates and Shells;* NACA and NASA Technical Notes, USNPGS Notes. PREREQUISITE: Ae 601.

Ae 610A AERONAUTICAL STRUCTURES SEMINAR (3-0). Selected topics in advanced structural design of flight vehicles from aeroelasticity, thermoelasticity, dynamic loading and vibration, plasticity, stability, non-linear problems, structural systems. TEXTS: Depend upon topic. PREREQUISITE: Some coursework in Ae 600 sequence.

Ae 623A STATIC AND DYNAMIC AEROELASTICITY (4-0). Static aeroelastic phenomena; divergence and control reversal. Finite wing examples; integrals, differential equation formulations with solutions from semi-rigid, iterative, and matrix methods. Free and forced vibration, effect of damping. Flutter mechanism. Non-stationary wing theory. Applications to two- and three-dimensional lifting surfaces. TEXTS: FUNG, *The Theory of Elasticity;* BISPLINGHOFF and ASHLEY, *Principles of Aeroelasticity;* SCANLON and ROSENBAUM, *Aircraft Vibration and Flutter.* PREREQUISITE: Ae 601.

Ae 701A AERONAUTICAL SYSTEMS ENGINEERING (3-3). Power controls and stability augmentation; block diagram concept; transfer function; basic references for automation; single axis and multi-axis autocontrols; inter-axis maneuver coupling; time modulated control; command flight, remote controlled reference systems; systems concepts and applications to vehicles and their sub-systems. TEXTS: EKIN, *Dynamics of Flight;* PERKINS and HAGE, *Airplane Performance, Stability and Control.* PREREQUISITE: Ae 142.

Ae 702A ADVANCED DYNAMICS (3-3). Aeroelastic effects on stability and control, vehicle dynamics and interaction with augmentation devices and automatic controls. Automatic power plant control for deck recovery; precision velocity control by cut-off in ballistic vehicles, vector jet stabilization techniques. TEXTS: Same as Ae 701; Instructor's notes. PREREQUISITE: Ae 701.

DEPARTMENT OF ELECTRICAL ENGINEERING

CHARLES HARRY ROTHAUGE, Professor of Electrical Engineering; Chairman (1949)*; B.E., Johns Hopkins Univ., 1940; D. Eng., 1949.

ROY STANLEY GLASGOW, Dean Emeritus and Professor of Electrical Engineering (1949); B.S., Washington Univ., 1918; M.S., Harvard, 1922; E.E., Washington Univ., 1925; D.Sc., (Hon.), Washington Univ., 1961.

GEORGE ROBERT GIET, Fellow, Professor of Electronics (1925); A.B., Columbia Univ., 1921; E.E., 1923.

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GEORGE HEINEMANN MARMONT, Professor of Electronics (1959); B.S., California Institute of Technology, 1934; Ph.D., 1940.

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JAMES MURRAY, Instructor in Electrical Engineering (1962); B.Sc., (Honours), Univ. of Edinburgh, 1962.

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HERBERT LEROY MYERS, Assistant Professor of Electrical Engineering (1951); B.S., Univ. of Southern California, 1951.

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FRED GEHERT REA, Lieutenant Junior Grade, U.S. Navy, Instructor in Electronics (1962); B.E.E., Cornell Univ., 1961; M.E.E., 1962.

ABRAHAM SHEINGOLD, Professor of Electronics (1946); B.S., College of the City of New York, 1936; M.S., 1937.

WILLIAM CONLEY SMITH, Professor of Electrical Engineering (1946); B.S., Ohio Univ., 1935; M.S., 1939.

DONALD ALAN STENTZ, Associate Professor of Electronics (1949); B.S., Duke Univ., 1949; M.S., USNPGS, 1958.

ROBERT DENNEY STRUM, Assistant Professor of Electrical Engineering (1958); B.S., Rose Polytechnic Institue, 1946.

GEORGE JULIUS THALER, Professor of Electrical Engineering (1951); B.E., Johns Hopkins Univ., 1940; D.Eng., 1947.

HAROLD ARTHUR TITUS, Associate Professor of Electronics (1962); B.S., Kansas Univ., 1952; M.S., Stanford Univ., 1957; Ph.D., 1962.

JOHN BENJAMIN TURNER, JR., Associate Professor of Electronics (1955); B.S., Univ. of Arkansas, 1941; M.S., Univ. of California, 1948.

JOHN ROBERT WARD, Associate Professor of Electrical Engineering (1962); B.Sc., Univ. of Sydney, 1949; B.E., 1952; Ph.D., 1958.

MILTON LUDELL WILCOX, Associate Professor of Electrical Engineering (1958); B.S., Michigan State Univ., 1938; M.S., Univ. of Notre Dame, 1956.

*The year of joining the Postgraduate School Eaculty has been indicated in parentheses.

**Absent on leave.

DEPARTMENTAL REQUIREMENTS FOR DEGREES IN ELECTRICAL ENGINEERING

In addition to meeting the minimum specific academic requirements for these degrees as given below, candidates must also satisfy the general degree requirements as determined by the Academic Council.

BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING

BACHELOR OF SCIENCE IN ENGINEERING ELECTRONICS

BACHELOR OF SCIENCE IN COMMUNICATIONS ENGINEERING

It is required that candidates for these degrees satisfy the following requirements while in residence at the Naval Postgraduate School except in the case of candidates entering the school with advanced standing, when due allowance will be made for advanced transfer credits.

Discipline	*Subject*	*Approximate Term Hrs.*
Electrical Engineering	Eields and Circuits	17
	Electron Devices and Circuits	16
	Electromagnetic Theory	4
	Communication Theory	4
	Electromechanical Devices	5
	Eeedback Control Theory	4
	Electronic Computers	4
		54
Mathematics	Vector Algebra	4
	Calculus	4
	Differential Equations and Series	4
	Complex Variables	3
		15
Physics	Properties of Matter	8

In addition to the above 77 term hours, approximately 28 elective term hours will be required in upper division courses. At least 15 of those term hours will normally be elected in the candidate's degree option (Electrical Engineering, Engineering Electronics or Communications Engineering).

MASTER OF SCIENCE IN ELECTRICAL ENGINEERING

MASTER OF SCIENCE IN ENGINEERING ELECTRONICS

Each student's program must include a total of at least 45 term hours in A or B level courses beyond the requirements for the B.S. degree. At least 20 of these credits shall be in A level courses.

Of the above 45 credits at least 20 must be directed towards a specialty within the candidate's degree option, and in addition at least 22 non-specialty credits must be distributed as follows:

Advanced Circuits	4 term hours
Advanced Devices	4 term hours
Advanced Mathematics	6 term hours
Electives other than Electrical Engineering or Mathematics	8 term hours

In addition candidates must present an acceptable thesis.

BIOLOGY

BI 800C FUNDAMENTALS OF BIOLOGY (6-0). The fundamental principles of the living cell covered from a biochemical and biophysical standpoint. Specialization of cell function, as exemplified in certain animal and plant tissues and organ systems. Genetics and its relation to properties of cell nucleus. Related topics, including the evolutionary progress.

BI 801B ANIMAL PHYSIOLOGY (6-0). A general course in animal physiology, emphasizing human functional aspects. PREREQUISITE: BI 800C.

BI 802A RADIATION BIOLOGY (6-0). Eundamental processes of energy transfer from radiation to living matter. Biochemical, physiological and genetic effects of radiation. Methods of experimental radiation biology. PREREQUISITES: PH 637B, PH 638A, BI 800C, BI 801B.

BI 822A SPECIAL TOPICS IN RADIATION BIOLOGY (2-0). Study of important current topics in radiation biology. PREREQUSITE: Appropriate biological background.

BI 823A SPECIAL TOPICS IN RADIATION BIOLOGY II. (2-0). A continuation of BI 822A. A study of important current topics in radiation biology.

ELECTRICAL ENGINEERING

EE 101D ELECTRICAL FUNDAMENTALS (3-2). A presentation of basic electrical phenomena. Topics include: DC circuits and components, magnetism, electromagnetism, instruments, AC circuits and components, resonance, transformers, batteries, and power sources.

EE 105C BASIC ELECTRICAL PHENOMENA (3-2). The first of a series of three courses designed to present the fundamentals of fields and circuits. An introduction to the theory of electric and magnetic fields presented in a unified manner which satisfies the prerequisites for circuits, electronics, and machinery. PREREQUISITE: Ordinary Differential Equations.

EE 106C BASIC CIRCUIT ANALYSIS I (3-2). The circuit concept is developed by the complete analysis of simple circuits. Sinusoidal steady-state solution by phasor methods is introduced. Matrix methods are used in the analysis of multi-loop and multinode circuits. PREREQUISITE: EE 105C.

EE 107C BASIC CIRCUIT ANALYSIS II (3-2). A continuation of EE 106. Poles and zeros are defined. Driving point, transfer, and hybrid parameters of 2-port networks; polar, logarithmic, and rectangular plots; network theorems; Fourier series; and balanced polyphase circuits are studied. PREREQUISITE: EE 106C.

EE 111C FIELDS AND CIRCUITS (4-4). An introduction to the theory of electric and magnetic fields is presented as a foundation for the study of circuits, electronics, and machinery. The basic circuit elements are defined by the application of this theory. Response of simple circuits and power and energy relations are considered. Sinusoidal steady-state solution by phasor methods is introduced. PREREQUISITE: Differential and Integral Calculus (may be concurrent).

EE 112C CIRCUIT ANALYSIS (4-3). A continuation of EE 111C. Sinusoidal analysis is continued. Poles and zeros are defined. Matrix methods are introduced. Driving point, transfer, and hybrid parameters of 2-port networks; polar, logarithmic and rectangular plots; network theorems; Fourier series; and balanced polyphase networks are studied. PREREQUISITE: EE 111C.

EE 113B LINEAR SYSTEMS ANALYSIS (4-3). The basic theory of circuit analysis is continued with a thorough study of transient phenomena in linear systems. Laplace transform methods are studied with illustrations in electrical, mechanical, and electromechanical systems. Fourier integral methods for solutions of system response and spectral analysis are considered. Real convolution and its application to inversion techniques in both Laplace and Fourier solutions is illustrated. Methods of analysis in both the time and frequency domain are compared. The analog computer is used to simulate linear systems in the laboratory. PREREQUISITES: EE 112C or EE 107C. Complex Variable Theory (may be concurrent).

EE 114B COMMUNICATION THEORY I (4-0). In this introductory course the following concepts and their mathematical formulations are presented: Information measure; sampling; pulse encoding methods; frequency and time multiplexing; amplitude, frequency and phase modulation. In addition, a comparison of modulation methods is presented. PREREQUISITE: EE 113B.

EE 116B COMMUNICATION THEORY II (3-2). A continuation of EE 114B. Noise sources and methods of measurement are treated. Statistical methods for handling noise and random signals are presented, followed by a study of detection problems in radar and pulse transmission systems. Correlation functions and their application to communication systems are introduced. PREREQUISITE: EE 114B.

EE 121A ADVANCED NETWORK ANALYSIS (3-2). Network topology, signal flow graphs, sensitivity, and general linear, scattering, and immittance descriptions are considered. Additional topics are chosen from the following partial list: Potential analog, time varying linear system analysis, response of linear systems to random signals, analytic properties of network functions. PREREQUISITE: EE 113B.

EE 122A NETWORK SYNTHESIS I (3-2). Basic principles of system synthesis as exemplified in the synthesis of passive electric networks. Energy relations in such networks and the fundamental properties of physically realizable driving point immittances are studied. Synthesis of one-port networks, in various forms, is illustrated, as is the ladder development of 2-port networks. PREREQUISITE: EE 113B.

EE 123A NETWORK SYNTHESIS II (3-0).Two-port synthesis is continued from EE 122A, with emphasis on series and parallel realizations, lattice networks, and resistively terminated networks. N-port synthesis, synthesis through matrix methods, and linear graph theory methods of synthesis are introduced. Other advanced topics in modern active and passive synthesis will be discussed. PREREQUISITE: EE 122A.

EE 131C POLYPHASE CIRCUITS (3-2). Analysis of polyphase circuits with balanced and unbalanced loading. Power and energy measurements in polyphase circuits. Analysis of polyphase circuits with unbalanced voltages using symmetrical components. Fault currents and voltages determined by the application of sequence networks. PREREQUISITE: EE 112C or EE 107C.

EE 205D ELECTRONICS FUNDAMENTALS (3-2). A qualitative approach to the fundamentals of electronics. Topics include: vacuum tubes, gas-filled tubes, cathode-ray tubes, transistors, rectifiers, amplifiers, oscillators, modulators, detectors, receivers, transmitters, antennas and propagation. PREREQUISITE: EE 101D.

EE 211C ELECTRON DEVICES AND CIRCUITS I (4-2). The study of the physical processes in electron devices is introduced by a consideration of charge-carrier motion in vacuum and in solids. The operational characteristics of diodes, control grid vacuum tubes, and transistors are derived and vacuum tube amplifiers are introduced. PREREQUISITE: EE 111C or EE 106C.

EE 212C ELECTRON DEVICES AND CIRCUITS II (4-3). The topics studied include transistor amplifiers, frequency response of cascaded untuned amplifier stages, and compensated, tuned, and feedback amplifiers. PREREQUISITE: EE 211C.

EE 213C PULSE AND WAVEFORMING CIRCUITS (4-3). The topics studied include sinusoidal oscillators, basic pulse techniques, relaxation oscillators, bistable and monostable switching circuits and pulse amplifiers. PREREQUISITE: EE 212C or EE 232C or EE 222B.

EE 214C ELECTRONIC COMMUNICATION CIRCUITS I (4-3). Power supplies, tuned and untuned power amplifiers, modulation techniques and circuits, and communication transmitters will be studied. PREREQUISITE: EE 213C.

EE 215C ELECTRONIC COMMUNICATION CIRCUITS II (4-3). Topics covered include tuned voltage amplifiers, frequency converters, detectors, automatic gain control, and noise suppressors. These circuits are then integrated into a radio receiving system. PREREQUISITE: EE 214C.

EE 216C SPECIAL ELECTRONIC DEVICES (4-2). The topics studied include particle dynamics, micro-wave devices, variable resistance and variable reactance devices, and a brief survey of quantum electronics. PREREQUISITES: EE 214C and PH 604C or equivalent.

EE 217B ADVANCED ELECTRON DEVICES (4-2). The topics studied include particle dynamics, electron beam techniques and devices, microwave devices, variable resistance and reactance devices, and quantum-electronic devices. PREREQUISITES: EE 214C and PH 705B or equivalent.

EE 221B APPLIED ELECTRONICS I (3-3). The topics studied include. Charge motion in a vacuum and in solids; diodes and diode circuits; transistors and multielectrode vacuum tubes, with applications to simple amplifier circuits; gaseous tubes. PREREQUISITE: EE 112C or EE 107C.

EE 222B APPLIED ELECTRONICS II (3-3). Topics included are: Tuned, feedback and power amplifiers; amplifier frequency response; oscillators; power supplies; non-linear circuits and modulation. PREREQUISITE: EE 221B.

EE 223A ELECTRONIC CONTROL AND MEASUREMENT (3-3). Analysis and design of electronic circuits of control, measurement, data transmission and processing. Topics included are: Vacuum tube voltmeters, DC amplifiers, pulse shaping and switching circuits, oscillators and time base generators, counting and time interval measuring circuits, frequency measurement and control circuits, motor speed and generator voltage control systems. PREREQUISITES: EE 222B or EE 232C, and EE 113B (may be concurrent).

EE 231C ELECTRONICS I (4-3). The topics studied include: Charge motion in a vacuum and in solids; diodes and diode circuits; transistors and multielectrode vacuum tubes, with applications to simple amplifier circuits; gaseous tubes. PREREQUISITE: EE 112C or EE 107C.

EE 232C ELECTRONICS II (4-3). Topics included are: Tuned, feedback and power amplifiers: amplifier frequency response; oscillators; power supplies; non-linear circuits and modulation. PREREQUISITE: EE 231C.

EE 233B COMMUNICATION CIRCUITS AND SYSTEMS (4-3). The following topics are studied: amplitude and frequency modulation and detection, pulse modulation methods, frequency conversion and synthesis, transmitting and receiving systems, multiplexing techniques. PREREQUISITE: EE 232C or EE 222B.

EE 234C PULSE TECHNIQUES AND HIGH FREQUENCY TUBES (3-3). A study of clipping, differentiating, integrating, clamping, and coupling circuits, relaxation oscillators, and pulse amplifiers, using both tubes and transistors. Following this is a study of microwaves tubes most commonly employed in radar systems. PREREQUISITE: EE 232C or EE 222B.

EE 253A MICROWAVE TUBES (3-2). A study of the theory and operating principles of various microwave tubes, such as traveling-wave tubes, klystrons, plasma devices, crossed-field devices. Topics to be studied will include: formation and control of electron beams, slow-wave structures, interaction between beams and waves, and coupled mode theory. PREREQUISITE: EE 622B.

EE 254B TRANSISTOR CIRCUITS (3-3). Following a brief review of the transistor physics and circuits analysis, the topics include: high frequency and noise models, broadband low-pass amplifiers, bandpass amplifiers, oscillators, and negative resistance devices. PREREQUISITE: EE 212C or EE 222B or EE 232C.

EE 255A QUANTUM ELECTRONICS (3-2). A review of the general laws of radiation and energy levels in atoms and solids. Principles of masers and lasers. Applications and current problems in the development of quantum electronic devices. PREREQUISITES: EE 622B and PH 705B.

EE 261B NONLINEAR MAGNETIC DEVICES (3-3). An introduction to the use of the saturable reactor as a nonlinear circuit element. Pulse, storage, counting circuits as used in data processing and digital computer technology, as well as power modulation applications are considered. Piecewise linear analysis techniques are used to develop the theory of magnetic amplifiers. The transfer function of the amplifier with and without feedback is derived. PREREQUISITES: EE 113B and EE 212C or EE 222B or EE 232C.

EE 291C ELECTRONICS I (NUCLEAR) (3-3). This is the first of two courses designed to give the Nuclear Engineering student an appreciation of electronic equipment used in this science. Topics are: Steady state circuit analysis, transient concepts, and the basic theory of vacuum and semiconductor diodes, control type tubes, and transistors. PREREQUISITES: Mathematics through calculus.

EE 292C ELECTRONICS II (NUCLEAR) (3-3). This course considers vacuum tube and transistor circuits, such as power supplies, voltage amplifiers, feedback circuits, pulse amplifiers, and pulse shaping circuits. Basic concepts are then applied to a variety of special circuits, including: Integral and differential discriminators, coincidence and anti-coincidence circuits, count-rate meters, and scalers. PREREQUISITE: EE 291C.

EE 301D ELECTRIC MACHINERY (3-2). The fundamentals and applications of electrical machinery. Topics include: external characteristics of shunt and compound generators: shunt, series and compound motors; alternators, induction and synchronous motors; parallel operation of alternators and generators. PREREQUISITE: EE 101D.

EE 311C ELECTRIC MACHINERY I (3-4). A study of electromagnetically coupled circuits, fixed or in relative motion. The principles common to translational and rotational electromechanical energy conversion devices are presented. These principles are applied to transformers and rotating machinery in the steady-state and dynamic modes. PREREQUISITE: EE 112C or EE 107C.

EE 312C ELECTRIC MACHINERY II (3-4). A continuation of electric machine study. Types studied are synchronous and asynchronous motors and generators, direct current motors and generators and AC and DC control machines. PREREQUISITE: EE 311C.

EE 315B MARINE ELECTRICAL DESIGN I (2-4). This is the first of two courses covering the synthesis and design of power systems and their components. The design of a transformer will be studied, in relation to both steady-state and transient performance. Protective devices and power distribution concepts will be introduced. PREREQUISITE: EE 312C.

EE 316A MARINE ELECTRICAL DESIGN II (2-4). The distribution problem will be continued with respect to unbalanced loading, fault analysis and circuit protection. The design of a motor or a generator will be studied, with consideration given to starting conditions, unbalance, motor-generator operation and stability. PREREQUISITE: EE 315B.

EE 321C ELECTROMECHANICAL DEVICES (3-4). The basic theory and operating characteristics of control machines under steady state and transient conditions. Transformers, synchros, induction motors, DC motors, DC generators, and rotary amplifiers are covered in sufficient detail to develop the concepts required in control application. PREREQUISITE: EE 112C or EE 107C.

EE 331C ELECTRICAL MACHINERY (3-3). A one term course covering the principles and applications of AC and DC machines. DC motors and generators, alternators, and both single and poly-phase synchronous and induction motors are covered. Electromechanical energy conversion principles are emphasized. Dynamic and steady-state performance is treated. PREREQUISITES: EE 112C or EE 107C.

EE 411B FEEDBACK CONTROL SYSTEMS I (3-3). The mathematical theory of linear feedback control systems is considered. Topics include: writing system equations; relationship between time and frequency domain characteristics; analysis using root locus concepts and using polar and logarithmic plots; stability using Nyquist's criterion, Routh's criterion, and root locus; performance criteria and sensitivity. Laboratory work includes simulation of control systems on the analog computer and testing and evaluation of physical systems. PREREQUISITES: EE 113B, EE 321C, and EE 212C or EE 222B or EE 232C.

EE 412A FEEDBACK CONTROL SYSTEMS II (3-4). Elements of design of control systems are considered, using both frequency response and s-plane methods. The fundamental methods of analysis of nonlinear control systems are presented. The phase plane and describing function methods are studied. The relay servo is introduced. PREREQUISITE: EE 411B.

EE 413A SAMPLED DATA CONTROL SYSTEMS (2-2). A study of the response of control systems to discontinuous information. The basic theory of sampling, quantizing and data reconstruction is studied. The Z-transformation and the z-plane are presented. The system transient performance and the design of compensation is presented. PREREQUISITE: EE 412A.

EE 414A STATISTICAL DESIGN OF CONTROL SYSTEMS (2-2). Statistical concepts and random signals are studied. The consideration of statistical analysis and design of linear and nonlinear systems with stationary and non-stationary signal characteristics. The design of the optimum filter is studied. PREREQUISITE: EE 412A.

EE 415A LINEAR CONTROL SYSTEM SYNTHESIS (3-0). The synthesis of linear control systems is studied. Performance criteria, advanced root locus methods and Mitrovic's method are presented. The analysis and synthesis of multiloop systems are studied, using determinantal and signal flow methods. PREREQUISITE: EE 412A.

EE 416A NONLINEAR CONTROL SYSTEMS (3-1). Phase space and state-space concepts are studied. Quasi-optimum, dual-mode and relay-control systems are presented. Optimum control methods are presented. Lyapunov's method is studied. PREREQUISITE: EE 412A.

EE 419B NON-LINEAR AND SAMPLED SYSTEMS (3-4). A terminal course in control system theory intended for students not pursuing a control option. Phase plane methods, relay control systems, and sampled-data systems are studied. PREREQUISITE: EE 411B.

EE 422B MODERN COMMUNICATIONS (3-3). A study of modern communications techniques, with emphasis on the application of theory to modern communication systems. The systems studied include frequency shift radio teletype, single-sideband and multiplex techniques. PREREQUISITE: EE 116 B or EE 571A.

EE 431C INTRODUCTION TO RADAR (3-3). A one-term course designed for students not majoring in electronics. The course includes a study of search, fire-control, and radar-guidance systems with particular emphasis on pulse, FM, doppler, and mono-pulse systems. PREREQUISITES: EE 234C and EE 612C.

EE 432B THEORY OF RADAR (3-3). A one-term course designed for students majoring in electronics. The course includes a study of pulse, FM, doppler, and mono-pulse radar systems, moving target indication, data presentation, and track-while-scan systems. PREREQUISITES: EE 116B, EE 216C, and EE 612C.

EE 433A RADAR SYSTEMS (4-0). Following a brief discussion of the radar range equation, this course introduces the student to the basic concepts of pulse, CW, FM-CW, MTI, pulse-doppler, conical scan, and mono-pulse radars. Finally, some of the important aspects of radar antennas and propagation characteristics are studied. PREREQUISITE: EE 622B, Ma 321B.

EE 451A SONAR SYSTEMS ENGINEERING (4-3). A study of the theory and engineering practices of active and passive sonar systems. Emphasis is placed on the new developments in modern underwater sound systems including communications, instrumentation, and the tactical use of these systems. PREREQUISITE: Ph 432A.

EE 455B SONAR SYSTEMS (3-3). A study of sonar theory including the active and passive systems, transducers, and characteristics of the transmission medium. PREREQUISITES: Ph 450 B and EE 215C.

EE 461A SYSTEMS ENGINEERING (3-2). An introduction to the engineering of large scale systems. The primary aim of this course is to increase the student's awareness of the complex interactions of various disciplines and the main recurring problems in systems engineering. Examples from large scale military weapons systems will be studied. PREREQUISITE: EE 571A.

EE 462A AUTOMATION AND SYSTEM CONTROL (3-3). A study of basic techniques and problems encountered in large computer-centered information and control systems. Typical functional requirements for tactical data systems. Analysis of data input functions, data processing functions and data utilization functions. Laboratory work is devoted to solution of problems arising from the integration of electronic computers and radar displays. Interaction between engineering design, programming and system analysis is stressed. PREREQUISITES: EE 811C, EE 433A and Ma 116A or equivalent.

EE 471B GUIDANCE AND NAVIGATION (3-0). A study of the principles underlying systems of guidance and navigation. The principal topics are: Radio, radar, infra-red, inertial and celestial techniques. PREREQUISITES: PH 105C, EE 215C, and EE 411B.

EE 473A MISSILE GUIDANCE SYSTEMS (3-0). Fundamentals of missile guidance systems: Radio, radar, infra-red, inertial and celestial techniques. PREREQUISITES: EE 411B, EE 433A and PH 152B.

EE 481B ELECTRONIC COUNTERMEASURES (3-3). A study of radio-frequency radiation, and the characteristics of devices used for detecting and interfering with these radiations. The course includes active and passive systems, spectrum analyzers, noise problems, antennas, direction-finding systems, frequency scanning and memory systems, and data processing and display. PREREQUISITES: Need-to-Know through Secret, EE 116B and EE 215C.

EE 491B NUCLEAR REACTOR INSTRUMENTATION AND CONTROL (3-3). The basic principles and methods of nuclear reactor control are presented. The treatment of the elementary reactor with temperature and poisoning feedback is given using linear feedback control system analysis. The requirements for stable operation and accuracy of automatic neutron flux control are analyzed and demonstrated, using a reactor kinetics simulator. PREREQUISITE: EE 498B or equivalent.

EE 492A NUCLEAR REACTOR POWER PLANT CONTROL (3-4). The elementary thermodynamics of the plant control loop is established and the transfer functions obtained. The dynamic performance of the basic plant is analyzed under various load conditions. Automatic plant control stability and performance using external reactor control systems are investigated. PREREQUISITE: EE 491B.

EE 498B DYNAMICS OF LINEAR SYSTEMS (3-4). This course is intended for non-EE majors. The differential equations of some typical physical systems will be derived, and Laplace transform and pole-zero concepts will be used for their solution. Both time and frequency domains will be covered. The transfer function concept will be introduced, and the discussion will be extended to feedback systems. PREREQUISITE: EE 107C or EE 112C.

EE 541A SIGNAL PROCESSING (4-0). Application of statistical decision theory to the detection of signals in noise. Ambiguity diagrams for signals and also transducer arrays. Signal processing in detection and tracking systems. PREREQUISITES: EE 411B, EE 571A, and EE 811C.

EE 551A INFORMATION NETWORKS (3-2). Adaptations of symbolic logic for the analysis of binary information networks using relay, vacuum tubes, transistors, or magnetic cores. Abstract models for switching networks. Combinational and sequential circuits. Logical design of arithmetic and control elements. Dynamic simulation. Transfer function synthesis. Frequency domain treatment of analog and digital computer programs. PREREQUISITES: EE 811C, EE 113B, and EE 212C or EE 222B or EE 232C.

EE 571A STATISTICAL COMMUNICATION THEORY (3-2). This course is a more advanced sequel to EE 114B than EE 116B. It includes a study of noise sources and a mathematical treatment of noise and random signals based on statistical methods. Transmission of such signals through linear and nonlinear networks is analyzed. Statistical decision theory applications to signal detection and interpretation are illustrated by selected problems. PREREQUISITES: EE 114B and Ma 321B.

EE 611C ELECTROMAGNETIC FIELDS (4-0). An introduction to electromagnetic field theory. Following a review of electric and magnetic fields, Maxwell's equations are presented for time-varying fields. PREREQUISITE: EE 112C or EE 107C.

EE 612C TRANSMISSION OF ELECTROMAGNETIC ENERGY (3-2). Starting with the wave equation, this course develops classical transmission line theory, plane wave propagation, and transmission of energy through rectangular and cylindrical waveguides. Microwave components such as obstacles, couplers, and cavity resonators are discussed. PREREQUISITES: EE 611C and EE 113B.

EE 621B ELECTROMAGNETICS I (3-2). Classical transmission line theory is developed and illustrated in laboratory exercises. The theory of static electric and magnetic fields is presented, and solutions of boundary value problems are obtained by means of scalar and vector potentials. PREREQUISITES: Ma 113B and EE 112C or EE 107C.

EE 622B ELECTROMAGNETICS II (4-0). The time-varying Maxwell equations and general boundary conditions are presented. Solutions to the wave equation in unbounded regions are studied. Maxwell's equations are applied to systems of guided waves and cavity resonators. PREREQUISITES: EE 621B and EE 113B.

EE 623A ADVANCED ELECTROMAGNETIC THEORY (3-0). Solutions to boundary value problems utilizing series solutions, transform tneory, and variational techniques. PREREQUISITE: EE 622B.

EE 631B THEORY OF ANTENNAS (3-3). This course is intended to make the student familiar with the more common types of antennas and feed systems. The attack is essentially an engineering approach, applying to practical systems the mathematics and field theory presented in earlier courses. The laboratory is directed to the measurement of field intensities, antenna patterns, input impedance and feed systems. PREREQUISITE: EE 612C.

EE 652A MICROWAVE CIRCUITS AND MEASUREMENTS (3-2). A study of microwave components as circuit elements. Topics to be studied will include: waveguides as transmission lines, waveguide impedance concepts, matrix formulation for obstacles in waveguides, and resonant cavities as microwave circuit elements. PREREQUISITE: EE 622B.

EE 671B THEORY OF PROPAGATION (4-0). Properties of the atmosphere and its effect on the propagation of surface, space, and sky waves. Additional topics include: Coverage prediction, frequency selection, noise, and tropospheric and ionospheric scatter. PREREQUISITE: EE 612C.

EE 711C ELECTRICAL MEASUREMENTS (2-3). An introduction to the measurement of the fundamental quantities; current, voltage, capacitance, inductance and magnetic properties of materials. Alternating current bridges, their components and accessories; measurement of circuit components at various frequencies; theory of errors and treatment of data. PREREQUISITE: EE 112C.

EE 721A ELECTRICAL MEASUREMENT OF NON-ELECTRICAL QUANTITIES (3-3). The measurement of pressure, speed, acceleration, vibration, strain, heat, sound, light, time, displacement and other non-electrical quantities by electrical means. Consideration of special measurement problems encountered in development of missiles and missile guidance systems. PREREQUISITE: EE 212C or EE 222B or EE 232C.

EE 731C ELECTRONIC MEASUREMENTS (3-4). A study of the theory and techniques of electronic measurement of voltage, current, power, impedance, phase, and frequency. Accuracy and precision are stressed. Measurement instruments studied include: vacuum tube voltmeters, square-law devices, bolometers, directional couplers, r-f bridges. PREREQUISITES: EE 212C or EE 222B or EE 232C, and EE 612C or EE 622B.

EE 761B CONTROL SYSTEM COMPONENTS (2-2). A number of control system components will be chosen for study from the following partial list: Gyroscopic devices, accelerometers, resolvers, hydraulic devices, pneumatic devices, digital-analog and analog-digital coders and de-coders. PREREQUISITE: EE 412A.

EE 811C ELECTRONIC COMPUTERS (3-3). Basic principles of digital, analog, and incremental computers. Fundamentals of digital computer programming. Machine language, assembly language and compiler language. Elements of numerical analysis. Boolean algebra, logical design. Principles of system simulation. PREREQUISITES: EE 112C or EE 107C, and Ordinary Differential Equations.

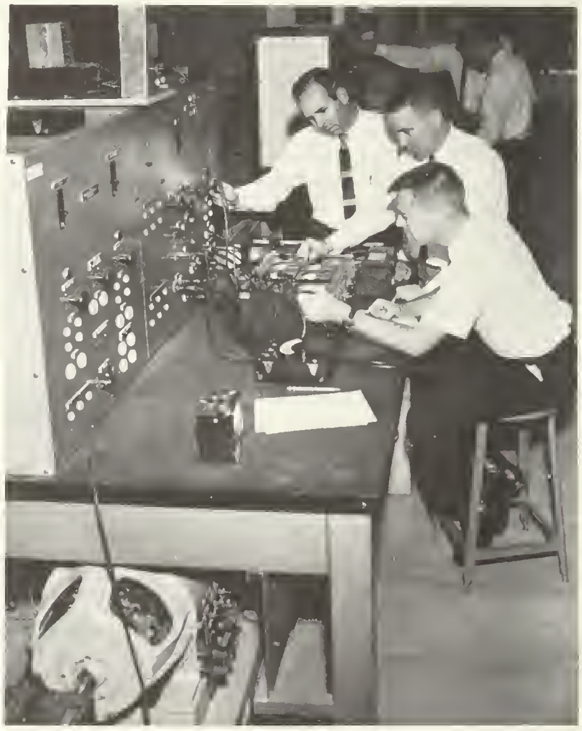
EE 821B COMPUTER SYSTEMS TECHNOLOGY (3-3). A course, primarily for the student not specializing in data processing, in the fundamental methods, concepts, and techniques underlying modern naval computer-oriented systems, such as NTDS and the OPCONCEN. Formulation of operational requirements. Evaluation of engineering techniques. Programming methods for large-scale command-control systems. Differing requirements of tactical versus strategic problems. The laboratory work provides the opportunity for the student to gain familiarity with methods for implementing user and command functions in a typical system environment. PREREQUISITE: 811C.

EE 911A INFORMATION PROCESSING SEMINAR (0-2). Discussion and reports on related topics of current interest in the field of information processing. PREREQUISITE: EE 462A or EE 551A.

EE 921A SPECIAL TOPICS IN CONTROL THEORY (0-2). An analysis of current developments in control systems, as disclosed by papers in current technical journals. PREREQUISITE: EE 412A.

EE 931A THESIS SEMINAR (0-1). In these seminar sessions, advanced students will present papers on their thesis work, which will then be discussed by other students and faculty. Some topics may be presented by faculty members.

EE 941A THESIS SEMINAR (0-1). Similar to EE 931A except that the topics will be more specifically related to the areas of electronics, signal processing, communications, information processing and general systems analysis.



LABORATORY

EE 271C ELECTRONIC DEVICES AND CIRCUITS I (4-2). The topics include DC and AC circuit theory, introductory principles of electronic devices and circuits, physical processes in vacuum, gaseous and semiconductor and tube devices. PREREQUISITES: Basic calculus and physics.

EE 272C ELECTRONIC DEVICES AND CIRCUITS II (4-2). The study of electronic circuits. Included topics are electronic devices as circuit elements, analysis of linear amplifiers, large-signal amplifiers and basic applications of electronic circuits. PREPREQUISITE: EE 271.

EE 552B LOGICAL DESIGN AND CIRCUITRY (4-0). Symbolic logic and the analysis of basic logical circuits; qualitative description of basic electronic and semi-conductor devices; construction of computer circuits using tubes, transistors, etc. Models for switching networks, synthesis of combinational and sequential switching circuits. Logical design of arithmetic and control elements. Memory devices, conventional and exotic. Machine-aided logical design.

RUSSELL BRANNON BOMBERGER, Associate Professor of English (1958); B.S., Temple Univ., 1955; M.A., Univ. of Iowa, 1956; M.S., Univ. of Southern California, 1960; M.A., Univ. of Iowa, 1961; Ph.D., Univ. of Iowa, 1962.

WILLIAM J. DAVIS, Lieutenant Commander, U.S. Navy; Instructor in Military Law; B.S., Univ. of Colorado, 1947; LL.B., Southern Methodist Univ., 1953.

WILLARD D. HOOT, Commander, U.S. Navy; Instructor in International Law; B.A., Penn State, 1939; LL.B., Univ. of Michigan, 1942; Army JAG School, Univ. of Virginia, 1956.

BOYD FRANCES HUFF, Associate Professor of Government and History (1958); B.A., Univ. of Washington, 1938; M.A., Brown Univ., 1941; Ph.D., Univ. of California, 1955.

ROBERT N. LASS, Lieutenant Commander, U.S. Naval Reserve; Visiting Professor of English; B.A., 1935; M.A., 1937; Ph.D., Univ. of Iowa, 1942.

RICHARD V. MONTAG, Lieutenant Commander, U.S. Naval Reserve; Visiting Assistant Professor of Political Science; A.B., College of St. Charles Borromeo, 1949; M.A., Ohio State, 1952.

CARL E. POHLHAMMER, Lieutenant Junior Grade, U.S. Naval Reserve; Instructor in History, B.A., San Jose State, 1954; M.A., Univ. of California, 1957.

BURTON MACLYNN SMITH, Associate Professor of Speech (1955); B.A., Univ. of Wisconsin, 1936; M.A., 1937.

STEPHEN J. WAYNE, Lieutenant Junior Grade, U.S. Naval Reserve; Instructor in Political Science; B.A., Univ. of Rochester, 1961; M.A., Columbia Univ., 1963.

*The year of joining the Postgraduate School faculty is indicated in parenthesis.

DEPARTMENTAL REQUIREMENTS FOR DEGREE IN GOVERNMENT AND HUMANITIES BACHELOR OF ARTS

1. Minimum requirements for the degree Bachelor of Arts with major in Political Science (International Relations) includes a total of 86 terms hours of specified courses, plus an additional 33 term hours of electives in Government and Humanities. Specific upper division courses required for the major are distributed as follows:

Bachelor of Arts as determined by the Academic Council.

ENGLISH

EN 001D ENGLISH GRAMMAR FOR ALLIED OFFICERS (3-0). A review of the basic principles of English grammar and exercise in the writing of papers. Designed especially for Allied Officers.

EN 011D THESIS WRITING (2-0). A study of the principles and techniques of research writing specially designed for students in the Management Curricula.

EN 101C ADVANCED WRITING FOR NAVAL OFFICERS (3-2). Study of, and extensive practice in, the techniques of expository, informative, and persuasive writing adapted especially to the needs of the Naval officer. PREREQUISITE: Freshman English or permission of Chairman of Department.

EN 102C REASONING AND RESEARCH REPORTING (4-0). A study of the principles of inductive and deductive logic as they are applied in the preparation of research reports.

EN 103C SEMINAR IN RESEARCH TECHNIQUES (1-0). A study of the principles and techniques of research writing.

EN 120C THE ENGLISH LANGUAGE (3-0). Lectures and exercises on the English language; its history, vocabulary, and usage.

GEOGRAPHY

GY 101C POLITICAL GEOGRAPHY (3-0). A study of world areas, regions, and countries; peoples, their distribution and political organizations.

GOVERNMENT

GV 010D U.S. Government (4-0). A study of the structure and powers of the Federal Government, its relation to the individual states, and its military aspects.

GV 102C INTERNATIONAL RELATIONS I (3-0). The first part of a two-term analytical study of the basic concepts, factors and problems of international politics. Part I is focused on the nature and power of the modern sovereign state and its political and economic modes of acting in its relations with other states.

GV 103C INTERNATIONAL RELATIONS II (3-0). A continuation of the analytical study of international politics. Part II is focused on military factors in the relations of states, the nature and problems of alliances, and with the nature and problems of international organization. PREREQUISITE: For Baccalaureate students GV 102C.

GV 104C AMERICAN DIPLOMACY (4-0). An analysis of the major problems of the United States foreign relations in Europe, Latin America, and the Far East from 1900 to the Korean conflict.

GV 106C COMPARATIVE GOVERNMENT (4-0). An analytical and comparative study of the form and functioning of the major types of contemporary government with emphasis on the policy-making process. PREREQUISITE: GV 010D.

GV 108C THEORY AND PRINCIPLES OF INTERNATIONAL RELATIONS (4-0). A seminar in the scope and theories of International Relations and techniques of research in the field; the analysis of problems.

GV 110C GOVERNMENT AND POLITICS OF MAJOR ASIAN STATES (4-0). The international, internal, and military problems of the major Asian states, exclusive of Communist China.

GV 111C GOVERNMENT AND POLITICS OF SOUTHEAST ASIA (4-0). The international, internal, and military problems of the southeast Asian states and of Australia and New Zealand.

GV 112C LATIN AMERICA (4-0). A study of contemporary Latin America with emphasis on the problems and objectives of the constituent states, their regional and international relationships.

GV 113C THE ATLANTIC COMMUNITY (4-0). A study of the states in the Atlantic Community; their political, economic, military, ideological, and sociological relations, both regional and international.

GV 114C THE MIDDLE EAST (4-0). A study of political, economic, social, cultural and strategic aspects of the contemporary Middle East and its role in international relations.

GV 115C THE SINO-SOVIET BLOC (4-0). An analysis of the international relations of Communist China, Soviet Russia, and their respective satellites with emphasis on their military significance to the United States.

GV 116C AFRICA SOUTH OF THE SAHARA (4-0). A study of contemporary Africa south of the Sahara with emphasis on emerging political institutions and analysis of major developing economic, social and cultural patterns.

GV 120C MILITARY LAW (3-0). The principles of Military Law as included in the Uniform Code of Military Justice, the Manual for Courts-Martial and the Manual of the Judge Advocate General. Topics include: jurisdiction; charges and specifications; substantive law; and the law of evidence.

GV 121C MILITARY LAW (3-0). Procedural aspects of Military Law and relations with civil authorities in legal matters. Topics include: non-judicial punishment; courts of inquiry; investigations; summary and special courts-martial; trial techniques; civil and criminal process. PREREQUISITE: GV 120C.

GV 122C INTERNATIONAL LAW (4-0). A survey of the basic principles of international law with emphasis on jurisdiction and the rules of warfare. Case and problem discussions.

GV 130C AMERICAN PARTY POLITICS (3-2). The nature and functions of political parties; origin, development, structure, internal management and control; relation of parties and pressure groups to legislation and administration; analyses of voting behavior and participation in politics. PREREQUISITE: GV 010D.

GV 131C POLICY-MAKING PROCESSES OE U.S. GOVERNMENT (3-2). A seminar in the structure and functioning of American political institutions with particular emphasis upon the forces which shape and condition the decision-making processes in Congress, the Executive branch and the Judicial system.

GV 132C AMERICAN CONSTITUTIONAL DEVELOPMENT (3-0). An examination of the United States Constitution and its development through the years as interpreted by Supreme Court decisions and by Congressional and Presidential traditions and practices. Constitutional issues such as federalism, civil-military relations, public v. private interests, and civil rights will be discussed.

GV 140C DEVELOPMENT OF WESTERN POLITICAL THOUGHT (4-0). An historical and analytical study of major Western political thought from Plato to Rousseau with emphasis on the antecedents of modern democratic and totalitarian philosophies. Readings from original sources.

GV 141C AMERICAN TRADITIONS AND IDEALS (3-0). The traditions, ideals and values of our civilization and the role of the military in implementing the image of America in the world. PREREQUISITE: HI 101C or HI 102C.

GV 142C INTERNATIONAL COMMUNISM (4-0). A study of communism: the development of its theory, strategy and tactics; their application to the conquest and consolidation of power; success and failures; comparison with other totalitarian systems; contrast with principles and processes of democracy.

GV 150C GREAT ISSUES (3-0). Seminar on the issues confronting the United States correlating the knowledge gained in previous courses in order to develop responses to the challenges facing the United States. PREREQUISITE: Permission of Chairman of Department.

GV 199C DIRECTED STUDIES (2-0 to 4-0). Independent study in Government in subjects in which formal course work is not offered. PREREQUISITE: Permission of Chairman of Department.

HISTORY

HI 101C U.S. HISTORY (1763-1865) (4-0). The Development of the Federal Union from the American Revolution to the end of the Civil War.

HI 102C U.S. HISTORY (1865-present) (4-0). The development of the American nation from the reconstruction crisis to the present.

HI 103C EUROPEAN HISTORY (1871-1919) (3-0). The international, internal and military development of the major European states in the period before World War I.

HI 104C EUROPEAN HISTORY (1919-present) (4-0). The international, internal, and military development of the major European states since World War I.

HI 199C DIRECTED STUDIES (2-0 to 4-0). Independent study in History in subjects in which formal course work is not offered. PREREQUISITE: Permission of Chairman of Department.

LITERATURE

LT 010D APPRECIATION OF LITERATURE (3-0). An introduction to the understanding and enjoyment of literature expressing the enduring problems of mankind. Style and structure will be considered as well as content. Some attention will be paid to genres and periods of literature.

LT 101C MASTERPIECES OF AMERICAN LITERATURE (3-0). A study of those ideas which have shaped American cultural life and reflect American thinking.

LT 102C MASTERPIECES OF BRITISH LITERATURE (3-0). A study of the significant ideas of selected British thinkers as they pertain to social and cultural life.

LT 103C MASTERPIECES OF BRITISH LITERATURE (continued) (3-0).

LT 104C, LT 105C MASTERPIECES OF EUROPEAN LITERATURE (3-0, 3-0). A study of the significant ideas of European writers. Plays, novels, short stories, essays, and criticisms will be read and discussed. 104 covers the period from early times to the end of the Renaissance. 105 covers the period from the Renaissance to the present time.

LT 106C, LT 107C, LT 108C MASTERPIECES OF RUSSIAN LITERATURE (3-0, 2-0, 2-0). A study of selected Russian and Soviet writers to demonstrate the role of literature in Russian and Soviet life and culture. 106, a survey of Russian literature from the early period through the 19th century, exclusive of the novel (3-0). 107, a study of the Russian novel of the 19th century (2-0). 108, a study of Soviet literature (2-0).

LT 109C PHILOSOPHICAL TRENDS IN MODERN LITERATURE (3-0). An examination of modern literature expressing social, psychological, and cultural problems in order to show how literature reflects the aspirations and the frustrations of modern man. PREREQUISITE: Permission of Chairman of Department.

LT 110C THE LITERATURE OF NORTHERN EUROPE (2-0). A study of selected writers of Germany, Scandinavia, and the British Isles, with particular reference to the dramatists such as Hauptmann, Ibsen, Strindberg, and Shaw to demonstrate their influence on the social and philosophical thinking of their times.

LT 111C THE AMERICAN NOVEL (2-0). A study of the novel in the United States from Charles Brockden Brown to William Faulkner.

PSYCHOLOGY

PY 010D INTRODUCTION TO PSYCHOLOGY (3-0). A survey of principles underlying human behavior with emphasis on the application of these principles to human relations and problems of social adjustment.

PY 101C APPLIED PSYCHOLOGY (3-0). A study of group dynamics, rating procedures, criminology, and personality formation and adjustment; individual projects are assigned. PREREQUISITE: PY 010D.

SPEECH

SP 010D PUBLIC SPEAKING (2-0). Practice in speaking effectively on subjects and in situations dealing with subjects pertinent to Naval officers. This course is offered to Allied officers as SP 001D.

SP 011D CONFERENCE PROCEDURES (2-0). Theory and practice in group dynamics applied to conferences, emphasizing completed staff work in group problem solving.

SP 012D ART OF PRESENTATION (2-0). Practice in Navy staff briefing with utilization of visual aids.

SP 101C ADVANCED SPEECH (2-0). A study through practice of techniques in obtaining desired audience response. PREREQUISITE: SP 010D.

MANAGEMENT DEPARTMENT

HERMAN PAUL ECKER (1957)*, Chairman, Professor of Management; B.A., Pomona College, 1948; M.A., Claremont Graduate School, 1949.

SHERMAN WESLEY BLANDIN, JR., Commander, SC, U.S. Navy; Instructor in Management; B.S., USNA, 1944; B.T.E., Georgia Institute of Technology, 1952; M.S., 1953.

WILLIAM HOWARD CHURCH, Professor of Management (1956); B.A., Whittier College, 1933; M.S.P.A., Univ. of Southern California, 1941.

JAMES BARRIE COWIE, Assistant Professor of Management (1963); B.S., (honors) Glasgow Univ., 1958; C.I.A. Glasgow Univ., 1959.

LESLIE DARBYSHIRE, Professor of Management (1962); B.A., Univ. of Bristol, 1950; D.B.A., Univ. of Washington, 1957.

H. ARTHUR HOVERLAND, Associate Professor of Management (1963); B.S., Miami Univ. of Ohio, 1951; M.S., Univ. of Illinois, 1954; Ph.D., Univ. of Michigan, 1963.

WALTER ERNEST MARQUARDT, JR., Lieutenant Commander, CEC, U.S. Navy; Instructor in Management; B.S., USNA, 1949; B.C.E., Rensselaer Polytechnic Institute, 1961; M.S., 1957.

CLAIR ALTON PETERSON, Associate Professor of Management (1962); B.B.A., Univ. of Minnesota, 1951; Ph.D., Massachusetts Institute of Technology, 1961.

JOHN DAVID SENGER, Associate Professor of Management (1957); B.S., Univ. of Illinois, 1945; M.S., 1948.

CLARENCE B. STEPHENSON, Commander, U.S. Navy; Instructor in Management; B.S., USNA, 1944; M.E.A., George Washington Univ., 1958; M.B.A., 1959.

*The year of joining the Postgraduate School faculty is indicated in parentheses.

DEPARTMENTAL REQUIREMENTS FOR DEGREES IN MANAGEMENT BACHELOR OF SCIENCE IN MANAGEMENT

1. Award of the degree Bachelor of Science in Management requires completion of the Postgraduate School's general requirements for the baccalaureate degree, and, in addition, 48 term hours of Management courses at or above the C level. Of these 48 hours, the student must complete at least eight term hours of work in each of the fields Quantitative Methods and Financial Management, and five term hours of Economics.

2. Each student's curriculum must be approved by the Chairman of the Management Department prior to his admission to candidacy.

3. A final cumulative grade point average of 1.0 both in Management subjects and over-all must be achieved.

BACHELOR OF SCIENCE

1. In addition to satisfying the Postgraduate School's general requirements for a baccalaureate degree, the degree Bachelor of Science with major in Business Administration requires a minimum of 40 term hours in general and functional Management ccurses at or above the C level.

2. The following requirements must be met:

Subject	*Term Hours*
Organization and Management	4
Principles of Accounting	4
Budgeting & Comptrollership	4
Managerial Accounting	4
Industrial Management	4
Economic Analysis	4
Human Relations	4
Personnel Management	4
Material Management	3
Management Statistics	4
Electronic Data Processing	3
	42

3. The student must achieve a grade point average of at least 1.0 in subjects of the major.

MASTER OF SCIENCE IN MANAGEMENT

1. The degree Master of Science in Management requires the completion of a minimum of 60 term hours, not including the research paper, of courses distributed between A and B level. A minimum of 48 hours must be A level. All students are required to register for research and must present an acceptable research paper.

2. The following core course requirements must be successfully completed for a student to earn the degree M.S. in Management:

Subject	*Term Hours*
Organization and Management	5
Financial Management	8
Management Psychology	4
Quantitative Methods	8
Economics	5
Material Management	3
Personnel Administration	4
Industrial Management	4
Business and Government	4
Management Policy	3
Electronic Data Processing	3
	51

3. Students will be expected to select a sub-specialty from the following elective options:

a. Material Management
b. Personnel Management
c. Financial Management
d. Research and Development and Program Management
e. Systems Analysis

MASTER OF SCIENCE IN MANAGEMENT (DATA PROCESSING)

1. The degree Master of Science in Management (Data Processing) requires the completion of a minimum of 60 term hours, not including the thesis, of courses distributed between the A and B level. A minimum of 24 hours must be A level. All students are required to register for research and must present an acceptable thesis.

2. Core course requirements must be successfully completed or validated by advanced credit in the following areas:

Discipline	*Term Hours*
Management	11
Mathematics	8
Data Processing	20
Operations Research	5
Statistics	12
	56

3. In addition to the core requirements, students will be expected to elect options pertinent to their future assignments. A minimum of 12 hours of A or B level work beyond the core program will be required.

MANAGEMENT

MN 010D INTRODUCTION TO ECONOMICS (4-0). A study of the operation of the American economy, its structural and institutional aspects, resources, technology, financial and monetary institutions, labor organizations and the role of government.

*MN 020D FINANCIAL MANAGEMENT (1-0). Survey of accounting principles, government budgeting, and appropriation accounting.

*MN 040D PRODUCTION MANAGEMENT (1-0). Survey of the application of management control to production processes.

*MN 053D PERSONNEL MANAGEMENT (1-0). Survey of individual and group behavior as applied to organization structures.

*MN 090D PRINCIPLES OF ORGANIZATION AND MANAGEMENT (1-0). Survey of various management principles and practices that contribute to effective achievement of managerial goals.

MN 113C INTERMEDIATE ECONOMICS (4-0). An analysis of demand, supply, the pricing of commodities, the theory of national income determination, pricing of productive services and economic dynamics.

MN 114C INTERNATIONAL ECONOMICS (4-0). Discussion of theories of international trade, tariff policy, exchange rates and trade control. Analysis of international economic problems and international economic organizations.

MN 120C PRINCIPLES OF ACCOUNTING (4-0). A beginning course in the elements of accounting which develops the mechanics of bookkeeping through the accounting cycle and introduces the basic principles of assets and equities, income and expense, preparation of financial statements and the external and internal use of financial statements.

MN 121C MANAGERIAL ACCOUNTING (4-0). Further develops the internal use of the accounting system as a management tool. Considers financial statements analysis, introducing cost accounting as a control device and establishes the place of accounting in management decision making in industry and in government. PREREQUISITE: MN 120.

MN 122C BUDGETING AND COMPTROLLERSHIP (4-0). Introduces budgeting as a control concept in industry; discusses application to the military departments including budget formulation, programming, budget execution. Develops the concepts of internal audit and comptrollership in industry and as applied to the Navy.

MN 152C HUMAN RELATIONS (4-0). The historical background of the American worker and the growth of the modern human relations movement are examined. Such topics as individual differences among workers, communication, motivation, interpersonal relationships and the role of the manager as a leader are investigated. Emphasis is placed on the implications of human relations for the naval officer.

MN 153C PERSONNEL ADMINISTRATION (4-0). The broad area of personnel management is covered, with particular emphasis on recruitment and selection, training, promotion, performance evaluation, and the role of the labor union in both industry and the Federal Government.

MN 163C MATERIAL MANAGEMENT (4-0). This course consists of a broad overview of major and item material management and support functions as performed in the Department of Defense, the Defense Supply Agency, and the military departments, as well as an analysis of selected techniques employed in requirements determination, procurement, and inventory management of secondary items in support of the operating forces and military industrial activities.

MN 170C MANAGEMENT STATISTICS (4-0). Basic course in the methods and theory of statistical analysis as applied to management decision making. The course includes probability theory, data collection, sampling distributions, discrete and continuous distribution functions, testing of hypotheses, and the use of control charts.

MN 191C ORGANIZATION AND MANAGEMENT (4-0). An introduction to the principles and practices of management. The formal aspects of organizational structure, e.g., hierarchy and control and control spans are analyzed together with alternative ways of accomplishing objectives. The role of the planning and control functions is studied in addition to the tools of analysis available to managers.

MN 210C PRINCIPLES OF ECONOMICS (4-0). A study of two major economic problems; the determination of the level of national output and the allocation of resources via the price system. In the first section, the determinants of saving and investments and the roles of monetary and fiscal policy are analyzed. The remainder of the course is devoted to price determination in the product and factor markets.

**Offered as a special summer course to visiting officers.*

MN 221C PRINCIPLES OF ACCOUNTING (3-0). An introduction to principles and concepts of commercial-industrial accounting; such as financial statements, accounting cycle, accounting theory, chart of accounts, accounting terminology. The course is designed to familiarize the student with management tools made available through the accounting function.

MN 270C MATHEMATICS FOR MANAGEMENT (4-0). This course is designed to provide the mathematical background needed to understand modern managerial tools and techniques. Specific areas covered include a review of algebra, probability, and a survey of calculus.

MN 322A MANAGERIAL ACCOUNTING (4-0). Surveys accounting principles including financial accounting, cost accounting and standard costs by study of commercial-industrial accounting practices; illustrates application in the Navy through the Industrial Fund concept; introduces the subjects of governmental budgeting, internal audit and control and comptrollership. Offered principally for students of the Management (Data Processing) Curriculum.

MN 381A DATA PROCESSING MANAGEMENT (4-0). This course is intended to provide a knowledge of alternative data processing systems from unit record equipment to complex computer systems. Consideration is given to the effective installation and utilization of the most suitable system for representative Data Processing tasks. The role of the manager of such a system is emphasized.

MN 382A COMPUTER APPLICATIONS (4-0). This course discusses the application of computer systems to data processing and scientific problems. This is a continuation of MN 381A.

MN 400A INDIVIDUAL RESEARCH (0-8). The student is expected to formulate a problem or select a topic considered by the faculty to be of interest and importance to management. The investigation will be undertaken independently under the supervision of one or more staff members.

MN 401A INDIVIDUAL STUDY (3-0). Designed to give the student an opportunity to continue advanced study in some aspect of management. Consent of advisor must be secured.

MN 412A MANAGERIAL ECONOMICS (4-0). General economic principles applied to managerial decision making. Practical tools which can be used to improve the allocation of the firm's resources are studied. Specific subjects include forecasting demand, cost analysis, and capital budgeting.

MN 413A MICRO-ECONOMIC THEORY (4-0). This course is designed to provide more intensive study in economic analysis with principle emphasis on value and distribution theory. Analysis is made of the behavior of business firms in their pricing, production, purchasing, and employment policies, and the relationship of the individual firm to the general pricing process. PREREQUISITE: MN 210C.

MN 415A NATIONAL INCOME AND INTERNATIONAL TRADE (4-0). The first half of the course is devoted to the determinants of the level of national income—including savings, investment, and the interest rate. The second half is devoted to the basic theory of international trade and current foreign trade issues.

MN 416A ADVANCED ECONOMIC ANALYSIS (4-0). A comprehensive survey of the tools of economic analysis. An investigation is made of the basis of choice by individual economic agents—the behavior of the firm, the structure of industry and the functioning of the economy. Basic concepts in model building, different types of economic models, problems and techniques of quantifying models are employed.

MN 422A MANAGERIAL ACCOUNTING (3-0). Develops the managerial uses of accounting for decision making purposes in industry. Illustrates the application of commercial accounting to the Navy through the Navy Industrial Fund. Topics include job order cost accounting, standard costs variance analysis, capital budgeting decisions, budgetary control.

MN 423A BUDGETING AND CONTROL (3-0). Covers the budget formulation cycle in the government with emphasis on programming-decision making techniques employed in the Department of Defense; budget execution and accounting for appropriated funds in the Navy Department. Introduces the concepts of internal audit and control and comptrollership in the Navy.

MN 424A INTERNAL CONTROL AND AUDITING SEMINAR (3-0). Develops the concepts and principles of internal control and audit with emphasis on current practice in industry and current organization for audit in the Navy. Discussion of cases from industry and the Navy relating to audit practices, audit reports and utilization and the resulting problems posed to military managers.

MN 425A COMPTROLLERSHIP SEMINAR (4-0). Develops the comptrollership function in industry and in the military services, including detailed analysis of placement in the organization, operating tasks, staff role and anticipated future trends. Discussion of a broad range of cases to illustrate current practice and problems.

MN 426A COST ACCOUNTING AND COST ANALYSIS (3-0). Develops the concepts of cost allocation, cost estimation, variable versus fixed costs, flexible budgets and variance analysis. Introduces the military application of cost accounting for control and weapons procurement decision-making.

MN 432A SYSTEMS ANALYSIS (4-0). This course covers the application of economic concepts, probability theory, and statistics to problems of choice among various weapons systems. Approximately half of the course is devoted to the theoretical problems involved in optimum resource allocation; the remaining time is devoted to study of current weapons choice problems. PREREQUISITE: MN 413A.

MN 440A INDUSTRIAL MANAGEMENT (4-0). A practical, quantitative approach to organizational problems of measurement, determination of goals and decision making. The course is taught with reference to a series of problems developing the role of quantitative data and techniques in management planning and control, production, industrial economics and military logistics problems.

MN 452B MANAGEMENT PSYCHOLOGY (4-0). Basic psychological concepts are examined, with particular emphasis given those aspects of major importance to the manager. Current theories applicable to such topics as communication, authority, motivation, and leadership are studied and discussed. Attention is given to aiding the manager in developing sound interpersonal relationships both in the military and Civil Service organizations.

MN 453A PERSONNEL ADMINISTRATION AND INDUSTRIAL RELATIONS (4-0). Current personnel practices in industry are examined. The background, philosophy, and regulations of Civil Service are discussed, with emphasis given industrial relations aspects of administration. Throughout the course comparisons are made between the personnel management techniques of the Federal Government and of civilian industrial organization.

MN 455A PERSONNEL ADMINISTRATION SEMINAR (3-0). A combination of directed reading and individual student presentations in specialized areas is utilized. The student is given the opportunity to pursue an area of interest, prepare a paper on the selected topic, and make a presentation to the class and the instructor for their critical comment.

MN 456A LABOR RELATIONS (4-0). The nature of labor problems is defined; union history and government studied; the processes of collective bargaining, the economics of the labor market; and governmental regulation of wages and unions examined. Particular emphasis is placed on employee-management relations in the Federal Service in view of the changing status of collective bargaining in this area.

MN 460A MATERIAL MANAGEMENT (3-0). This course presents the functions of material planning, requirements determination, procurement, distribution, and control applied to the introduction, development, and supply support of major military programs. A broad overview is given of the various organizations of the Department of Defense in the material management field.

MN 461A PROCUREMENT AND CONTRACT ADMINISTRATION (4-0). The elements of the procurement cycle are discussed, including the requirements determination, legal, fiscal, technical, production, facilities, inspection, and termination factors involved. The various military procurement laws and regulations are reviewed and analyzed to determine their effect upon the Navy material logistics systems.

MN 462A SCIENTIFIC INVENTORY MANAGEMENT (3-0). The basic concepts and formulae used to develop material demand forecasting systems and variable inventory levels are reviewed and discussed. The scientific approach to basic inventory decisions is stressed. Opportunities are provided to study and analyze several approaches which introduce mathematical inventory theory as applied to the Navy Supply System.

MN 471A PROBABILITY AND STATISTICS I (4-2). An introduction to management statistics. Emphasis is placed on the application of decision theory under uncertainty in practical business and economic situations. It includes probability, expected value, utility, binomial and normal distributions, and tests of hypotheses. TEXT: Schlaifer, *Introduction to Statistics for Business Decisions.*

MN 472A PROBABILITY AND STATISTICS II (4-2). A continuation of MN 471A. It includes sampling techniques, determination of optimal sample size, tests of significance, measures of variability, confidence intervals, and regression and correlation analysis.

MN 473A QUANTITATIVE DECISION MAKING (3-0). The course explores the application of science to decision making involving a survey of applicable tools of quantitative analysis. The instruction treats management decision making problems from over-all system point-of-view with primary emphasis on interaction of separate elements of an enterprise; examining flows of information, money, materials, manpower and capital equipment. The course stresses practical applications of mathematical and statistical tools.

MN 480A FACILITIES PLANNING (3-0). The course includes analysis of the problems involved in development of requirements and programming and procurement of long lead-time support facilities. The complexity of the process brought about by technological change, modification of strategic and tactical concepts, limited budgets and the executive-legislative relationship, are examined.

MN 481A COMPUTERS AND DATA PROCESSING (4-0). An introduction to digital computers, the main emphasis on the principles involved in effective implementation of computer systems. Specific programming problems from the managerial area.

MN 490A ORGANIZATION THEORY AND ADMINISTRATION (5-0). A critical appraisal of the current state of management theory with a view to developing generalizations and operational skills of value to the military manager. Interdisciplinary contributions to the study of management are evaluated.

MN 491A MANAGEMENT POLICY (4-0). An attempt is made to synthesize the various functional areas of management into a composite whole. Stress is placed on the operation of top management rather than on component parts in the processes of analysis, decision-making, action and control in achieving various goals.

MN 492A GOVERNMENT AND BUSINESS (4-0). Public policies of national government are affecting the economic, political and social order; role of government in our society; responsiveness of national government to various interest groups; defense policy, its effect upon the Navy; the budgetary process in the formulation of the National Strategy; interaction of regulatory agencies with Defense.

MN 495A ORGANIZATION AND MANAGEMENT SEMINAR (3-0). A research and discussion approach to the problem areas of the theory of organization, their structure and behavior. Particular attention is given to consequences of changes in organizational environments and internal technologies.

DEPARTMENT OF MATHEMATICS AND MECHANICS

Warren Randolph Church, Professor of Mathematics and Mechanics; Chairman (1938)*; B.A., Amherst, 1926; M.A., Univ. of Pennsylvania; 1930; Ph.D., Yale Univ., 1935.

Charles Henry Rawlins, Jr., Professor Emeritus of Mathematics and Mechanics (1922); Ph.B., Dickinson College, 1910; M.A., 1913; Ph.D., Johns Hopkins Univ., 1916.

Horace Crookham Ayres, Professor of Mathematics and Mechanics (1958); B.S., Univ. of Washington, 1931; M.S., 1931; Ph.D., Univ. of California, 1936.

Willard Evan Bleick, Professor of Mathematics and Mechanics (1946); M.E., Stevens Institute of Technology, 1929; Ph.D., Johns Hopkins Univ. 1933.

Jack Raymond Borsting, Associate Professor of Mathematics (1959); B.A., Oregon State College, 1961; M.A., Univ. of Oregon, 1952; Ph.D., 1959.

Walter Scott Brainerd, Lieutenant, U.S. Navy; Instructor of Mathematics (1963); B.A., Univ. of Colorado, 1958; M.A., Univ. of Maryland, 1961.

Richard Crowley Campbell, Professor of Mathematics and Mechanics (1948); B.S., Muhlenberg College, 1940; M.A., Univ. of Pennsylvania, 1942.

Samuel Campbell Colwell, III, Lieutenant, U.S. Naval Reserve; Instructor in Mathematics (1961); B.A., Duke Univ., 1958.

Donald MacAllister Fairbairn, Ensign, U.S. Naval Reserve; Instructor of Mathematics (1964); B.S., George Peabody College, 1963.

Frank David Faulkner, Professor of Mathematics and Mechanics (1950); B.S., Kansas State Teachers College, 1940; M.S., Kansas State College, 1942.

Joseph Giarratana, Professor of Mathematics and Mechanics, (1946); B.S., Univ. of Montana, 1928; Ph.D., New York Univ., 1936.

Eugene H. Hanson, Commander, U.S. Naval Reserve; Visiting Professor of Mathematics (1962); B.S., Denison Univ., 1925; M.A., Ohio State Univ., 1933; Ph.D., 1935.

Herbert J. Hauer, Assistant Professor of Mathematics and Mechanics (1963); B.S., Queens College, 1949; M.A., Univ. of California, 1955.

Walter Jennings, Professor of Mathematics and Mechanics (1947); B.A., Ohio State Univ., 1932; B.S., 1932; M.A., 1934.

William Joseph Kennedy, Jr., Lieutenant Junior Grade, U.S. Naval Reserve; Instructor of Mathematics (1963); B.A., Whitman College, 1960.

Uno Robert Kodres, Associate Professor of Mathematics and Mechanics (1963); B.A., Wartburg College, 1954; M.S., Iowa State Univ., 1956; Ph.D., 1958.

Harold Joseph Larson, Assistant Professor of Mathematics (1962); B.S., Iowa State Univ., 1956; M.S., 1957; Ph.D., 1960.

Brooks Javins Lockhart, Professor of Mathematics and Mechanics (1948); B.A., Marshall Univ., 1937; M.S., West Virginia Univ., 1940; Ph.D., Univ. of Illinois, 1943.

Kenneth Robert Lucas, Associate Professor of Mathematics (1958); B.S., Washburn Univ., 1949; Ph.D., Kansas Univ., 1957.

Herman Bernhard Marks, Associate Professor of Mathematics (1961); B.S., Southern Methodist Univ., 1950; M.A., Univ. of Texas, 1959.

Aladuke Boyd Mewborn, Professor of Mathematics and Mechanics (1946); B.S., Univ. of Arizona, 1927; M.S., 1931; Ph.D., California Institute of Technology, 1940.

Paul Robert Milch, Assistant Professor of Mathematics (1963); B.S., Brown Univ., 1958.

Eugene Bryant Mitchell, Commander, U.S. Navy; Instructor of Mathematics (1962); B.S., Univ. of South Carolina, 1946; Naval Engineer, Massachusetts Institute of Technology, 1952.

Robert R. Pearson, Lieutenant, U.S. Naval Reserve; Instructor in Mathematics (1963); B.A., Univ. of Connecticut, 1959.

Robert Merlin Pickrell, Commander, U.S. Navy; Instructor of Mathematics (1963); B.S., U.S. Naval Academy, 1945.

John Philip Pierce, Professor of Mathematics (1948); B.S., in E.E., Worcester Polytechnic Institute, 1931; Master of E.E., Polytechnic Institute of Brooklyn, 1937.

Francis McConnell Pulliam, Professor of Mathematics and Mechanics (1949); B.A., Univ. of Illinois, 1937; M.A., 1938; Ph.D., 1947.

Robert Richard Read, Associate Professor of Mathematics (1961); B.S., Ohio State Univ., 1961; Ph.D., Univ. of California, 1957.

Paul C. Rogers, Lieutenant Commander, U.S. Naval Reserve; Visiting Assistant Professor of Mathematics (1961); B.N.S., College of the Holy Cross, 1945; M.A., Boston Univ., 1948.

George Donald Schmieg, Ensign, U.S. Naval Reserve; Instructor of Mathematics (1963); B.A., Univ. of South Dakota, 1963.

Peter D. Smith, Lieutenant Junior Grade, U.S. Navy; Instructor in Mathematics (1962); B.A., College of the Holy Cross, 1960.

Harold Stuart Starrett, Jr., Lieutenant Junior Grade, U.S. Naval Reserve; Instructor of Mathematics (1963); B.M.E., Georgia Institute of Technology, 1962; M.S.M.E., 1964.

Elmo Joseph Stewart, Professor of Mathematics (1955); B.S., Univ. of Utah, 1937; M.S., 1939; Ph.D., Rice Institute, 1953.

Charles Chapman Torrance, Professor of Mathematics and Mechanics (1946); M.E., Cornell Univ., 1922; M.A., 1927; Ph.D., 1931.

Thomas Augustus Van Sant, Lieutenant Junior Grade, U.S. Naval Reserve; Instructor in Mathematics (1962); B.A., St. John's College, 1958; B.E.S., Johns Hopkins Univ., 1960.

Marion Cammack Wicht, Commander, U.S. Naval Reserve; Visiting Professor of Mathematics and Mechanics (1963); B.S., Mississippi Southern Univ., 1935; M.A., Vanderbilt Univ., 1936; Ph.D., Auburn Univ., 1957.

Douglas George Williams, Professor of Mathematics (1961); M.A., (honors), Univ. of Edinburgh, 1954.

WALTER MAX WOODS, Associate Professor of Mathematics (1961); B.S., Kansas State Teachers College, 1951; M.S., Univ. of Oregon, 1957; Ph.D., Stanford Univ., 1961.

PETER WILLIAM ZEHNA, Associate Professor of Mathematics (1961); B.A., Colorado State College, 1950; M.A., 1951; M.A., Univ. of Kansas, 1956; Ph.D., Stanford Univ., 1959.

* The year of joining the Postgraduate School is indicated in parentheses.

DEGREES WITH MAJOR IN MATHEMATICS

Officer students may, under special conditions, be offered the opportunity to qualify for either a Bachelor of Science or Master of Science degree with major in mathematics. Any interested student should consult the Chairman of the Department of Mathematics and Mechanics for an evaluation of his previous work to determine his potential for obtaining either degree and to consider the possibility of scheduling the necessary work. Evaluation of courses presented upon entering the Postgraduate School for credit towards these degrees must be completed prior to entering a program leading to these degrees. The requirements in mathematics for these degrees are given below. They provide, on the bachelor's or master's level, a working knowledge of one field of mathematics and a well-rounded background in three of the major fields of mathematics.

1. Requirements for the degree of *Bachelor of Science* with major in Mathematics.

   a. Of the total term hours specified in the general requirements for the degree of Bachelor of Science, a student majoring in mathematics must complete at least 36 term hours of approved course work in mathematics beyond the calculus, and must have an average QPR of 1.25 or better in these 36 term hours.

   b. These 36 term hours in mathematics must include at least 6 hours of approved course work in each of three fields of mathematics and two of these fields must be analysis and algebra.

   c. Each student majoring in mathematics will set up in advance, in consultation with the Chairman of the Department, and approved by him, a mathematics curriculum fitted to his aims, aptitudes, preparation, and interests. This original curriculum may, however, be modified as work progresses, but only in consultation with and with the approval of the Chairman of the Department.

2. Requirements for the degree of *Master of Science* with major in Mathematics.

   a. A student pursuing a program leading to a Master of Science degree with major in mathematics must have completed work which would qualify him for a Bachelor of Science degree with major in mathematics as defined in paragraph 1. A student whose background does not satisfy this requirement may take course work to eliminate this deficiency while simultaneously pursuing the Master of Science Program. However, course work pursued to eliminate this deficiency cannot be counted toward satisfying either the general or departmental requirements for the degree of Master of Science.

   b. Of the total term hours specified in the general requirements for the degree of Master of Science, a student majoring in mathematics must complete at least 24 term hours of approved A or B level course work in mathematics, and must have an average QPR of 2.125 or better in these 24 term hours. These 24 term hours must include at least 6 hours in each of the fields of analysis and algebra. Each student majoring in mathematics will set up in advance, in consultation with the Chairman of the Department, and approved by him, a mathematics curriculum fitted to the student's aims, aptitudes, preparation and interests. This original curriculum may, however, be modified as work progresses, but only in consultation with and with approval of the Chairman of the Department.

   c. A student pursuing a program leading to the degree of Master of Science with major in mathematics will be required to write a thesis in Mathematics. The nature of the thesis may but need not be an original contribution to knowledge. The purpose of the thesis is to demonstrate the student's ability to recognize a problem, define that problem, investigate and successfully complete various facets of the problem and then be able to document and present his work on the problem. For the completion of the thesis the student will be given 8 hours credit, which will be in addition to the required 24 hours.

   d. In addition to the above requirements, a student must pass a written comprehensive examination in mathematics. This examination is given twice each year and normally a student will take this examination within the year preceding the award of the Master of Science degree.

3. The thesis director, topic, and subject of specialization shall be chosen, with the consent of the chairman of the department, as early as possible (but in all events, not later than two terms prior to the time for granting the degree). Minor departures from the preceding requirements may be authorized by the Chairman of the Department of Mathematics and Mechanics.

MATHEMATICS

Ma 000E, Ma 001E PROBLEM SESSION (0-1). Non-credit problem session to supplement other courses.

Ma 010D BASIC ALGEBRA AND TRIGONOMETRY I (4-0). Review of arithmetic processes. The real number system. Engineering notation and the slide rule. Algebraic operations. Linear equations. Graph. Laws of exponents. Quadratic equations; the quadratic formula. Logarithms. Definition of trigonometric functions. Solution of the right triangle. TEXT: ANDRES, MISER *and* REINGOLD, *Basic Mathematics for Engineers.* PREREQUISITE: None.

Ma 011D BASIC ALGEBRA AND TRIGONOMETRY II (3-0). Vectors. Exponential and logarithmic equations. Trigonometric identities. Determinants and systems of linear equations. Quadratic and higher order equations. Straight line and conic section. TEXT: ANDRES, MISER *and* REINGOLD, *Basic Mathematics for Engineers.* PREREQUISITE: Ma 010D.

Ma 015D ALGEBRA AND TRIGONOMETRY REFRESHER (4-0). Review of simple algebraic processes. Slide rule. Functional notation and graphs. Trigonometric functions and their graphs. Right triangle, and vectors. Exponents, radicals and logarithms. Linear equations. Quadratic equations. Straight line. TEXT: ANDRES, MISER *and* REINGOLD, *Basic Mathematics for Engineers.* PREREQUISITES: Previous courses in college algebra and trigonometry or equivalent.

Ma 016D SURVEY OF ANALYTIC GEOMETRY AND ELEMENTARY CALCULUS (4-0). Concepts of function, limit, continuity. Analytic geometry of the straight line and conic sections. Elements of the differential and integral calculus with emphasis on polynomials and the simpler transcendental functions. Applications are stressed throughout. TEXT: DENBOW *and* GOEDICKE, *Foundations of Mathematics.* PREREQUISITE: Recent course in algebra and trigonometry.

Ma 017D ELEMENTARY CALCULUS (3-0). A continuation of Ma 016D. Theorem of the Mean. Differentiation and integration of transcendental functions. Polar coordinates. Differentials. Applications. TEXTS: GRANVILLE, SMITH *and* LONGLEY, *Elements of Differential and Integral Calculus.* PREREQUISITE: Ma 016D or its equivalent.

Ma 021D INTRODUCTION TO ALGEBRAIC TECHNIQUES (5-0). Algebraic techniques are developed from the postulates for integers. TEXT: EULENBERG *and* SUNKO, *Introducing Algebra.* PREREQUISITE: None.

Ma 022D CALCULUS AND FINITE MATHEMATICS I (5-0). The concept of function is introduced with polynomials and rational functions used for examples. The basic ideas of differentiation and integration are presented. Introductory concepts of set theory are considered. TEXTS: McBRIEN, *Introductory Analysis;* KEMENY, SNELL, THOMPSON, *Introduction to Finite Mathematics.* PREREQUISITE: Ma 021D.

Ma 023D CALCULUS AND FINITE MATHEMATICS II (5-0). Basic concepts of probability and matrix theories; elementary logic; linear programming; applications in social sciences are stressed. TEXT: KEMENEY, SNELL, THOMPSON, *Introduction to Finite Mathematics.* PREREQUISITE: Ma 021D.

Ma 024D CALCULUS AND FINITE MATHEMATICS III (3-0). A continuation of Ma 023D; Markov chains; linear programming; strictly and non-strictly determined games; matrix games; applications to behavioral science problems. TEXT: KEMENEY, SNELL, THOMPSON, *Introduction to Finite Mathematics.* PREREQUISITE: Ma 023D.

Ma 030D INTERMEDIATE ALGEBRA (5-0). The set of real numbers and postulates for the development of the algebra of real numbers. Proofs of some elementary theorems for the algebra of the real numbers. Applications of the postulates and theorems to addition, subtraction, multiplication, division and factorization of algebraic expressions. Application to word problems, first degree equations and equations of higher degree. Functions, graphs and inequalities. Exponents and logarithms. Sequences, series and the binomial theorem. Complex numbers. TEXT: DUBISH, HOWES *and* BRYANT, *Intermediate Algebra.* PREREQUISITE: None.

Ma 031D COLLEGE ALGEBRA AND TRIGONOMETRY (5-0). Brief review of algebraic fundamentals. Slide rule and logarithmic methods of computation. Algebra of complex numbers, quadratic equations. Systems of equations, determinants: Cramer's rule. Binomial Theorem. Mathematical induction. Trigonometric functions of the general angle. Identities. Solution of right and oblique triangles. Elements of the theory of equation. TEXT: BETTINGER, ENGLUND, *Algebra and Trigonometry.* PREREQUISITES: Previous courses in College Algebra and Trigonometry.

Ma 035D ALGEBRA AND ELEMENTARY TRIGONOMETRY (5-0). Algebraic fundamentals. Slide rule. Logarithms. Function concepts. Rectangular coordinates. Linear equations and graphs. Quadratic equations. Complex numbers in rectangular form. Systems of linear equations. Determinants. Trigonometric functions of the general angle. Applications, graphs, radians. Simple identities. TEXT: HART, *First Year College Mathematics,* Brief Edition. PREREQUISITES: Previous courses in Elementary Algebra and Plane Geometry.

Ma 036D TRIGONOMETRY, ANALYTIC GEOMETRY, ELEMENTARY CALCULUS (5-0). A continuation of Ma 035C. Demoivres Theorem and roots of complex numbers. Double and half angle identities. The general triangle. Fundamentals of plane analytic geometry. Theory of equations. Concepts of function, limit, continuity. The derivative. Derivatives of algebraic and transcendental functions with applications. TEXTS: HART, *First Year College Mathematics,* Brief Edition; THOMAS, *Calculus and Analytic Geometry.* PREREQUISITE: Ma 035D.

Ma 037D ANALYTIC GEOMETRY: ELEMENTARY CALCULUS (5-0). A continuation of Ma 036C. Fundamentals of plane analytic geometry. Differentials. Curvature. Radius and circle of curvature. Theorem of mean value and its applications. Integration of standard elementary forms. Constant of integration. TEXT: GRANVILLE, *Elements of the Differential and Integral Calculus.* PREREQUISITE: Ma 036D.

Ma 038D CALCULUS (5-0). This course is a continuation of Ma 037D and includes the following topics: Integration as a process of summation, formal integration by various devices, reduction formulas, introduction to infinite series, partial differentiation, and multiple integrals. TEXT: GRANVILLE, SMITH *and* LONGLEY, *Elements of the Differential and Integral Calculus.* PREREQUISITE: Ma 037D.

Ma 039C DIFFERENTIAL EQUATIONS (3-0). For students with some previous work in infinite series. Ordinary differential orders with constant coefficients. Systems of linear equations. Series solutions. Fourier series. TEXTS: COHEN, *Differential Equations;* GOLOMB *and* SHANKS, *Elements of Differential Equations.* PREREQUISITE: Ma 038D or the equivalent.

Ma 041D REVIEW OF ALGEBRA, TRIGONOMETRY, ANALYTIC GEOMETRY (5-0). Basic algebraic operations; Trigonometric functions; equations of lines and conics; complex numbers, theory of algebraic equations; matrix notation for linear equations, matrix algebra. TEXT: ALLENDOEFER *and* OAKLEY, *Fundamentals of Freshman Mathematics.* PREREQUISITE: Previous courses in algebra, trigonometry, analytic geometry.

Ma 051D CALCULUS AND ANALYTIC GEOMETRY I (5-0). Fundamentals of plane analytic geometry, concepts of function, limit, continuity. The derivative and differentiation of algebraic and trigonometric functions with applications. Derivatives of higher order. Differentials. Formal integration of elementary functions. Rolles' theorem, areas, volumes of revolution. TEXT: Thomas, *Calculus and Analytic Geometry.* PREREQUISITE: Ma 031D or its equivalent.

Ma 052D CALCULUS AND ANALYTIC GEOMETRY II (5-0). Selected topics from plane analytic geometry. Differentiation and integration of transcendental functions. Hyperbolic functions. Parametric equations. Formal integration. Numerical integration. Improper integrals. Polar coordinates. Plane vectors. TEXT: Thomas, *Calculus and Analytic Geometry.* PREREQUISITE: Ma 051D.

Ma 053D CALCULUS AND ANALYTIC GEOMETRY III (3-0). Partial derivatives, directional derivatives, total differential. Chain rule differentiation. Multiple integration and applications. Introduction to Infinite Series. TEXT: Thomas, *Calculus and Analytic Geometry.* PREREQUISITE: Ma 052D, Ma 081C must be taken concurrently.

Ma 061D REVIEW OF CALCULUS (5-0). Concept of functions, limit and continuity; differentiation, integration with applications; differentiation of function of several variables, directional derivatives. TEXT: Thomas, *Calculus and Analytic Geometry.* PREREQUISITE: Previous courses in calculus.

Ma 071D CALCULUS I (5-0). The calculus of functions of a single independent variable with emphasis on basic concepts. Derivatives, differentials, applications, Rolles' theorem and the mean value theorem. Definite integral with applications. Elementary transcendental functions. Topics from plane analytic geometry to be introduced as necessary. Polar coordinates. TEXT: Thomas, *Calculus and Analytic Geometry.* PREREQUISITES: Ma 031D or its equivalent, and previous work in calculus.

Ma 072D CALCULUS II (3-0). Advanced transcendental functions including hyperbolic functions. Methods of formal integration. Numerical methods. Improper integrals. Partial derivatives, directional derivatives. Total differential. Chain rule differentiation. Multiple integrals with applications. TEXT: Thomas, *Calculus and Analytic Geometry.* PREREQUISITES: Ma 071D, Ma 081C must be taken concurrently.

Ma 073C DIFFERENTIAL EQUATIONS (5-0). A continuation of Ma 072D. Series of constants; power series; Fourier series; first order ordinary differential equations; ordinary linear differential equations with constant coefficients; simultaneous solution of ordinary differential equation series solution of ordinary differential equations, including Bessel's Equation. TEXTS: Thomas, *Calculus and Analytic Geometry;* Kaplan, *Advanced Calculus;* Golomb *and* Shanks, *Elements of Ordinary Differential Equation.* PREREQUISITE: Ma 072D or Ma 061D.

Ma 081C INTRODUCTION TO VECTOR ANALYSIS (2-0). Vectors and their algebra. Solid analytic geometry using vector methods. Vector equations of motion. Differentiation and integration of vector functions. Space curves, arc length, curvature. Partial derivatives, directional derivatives and the gradient. Line integrals. TEXT: Thomas, *Calculus and Analytic Geometry.* PREREQUISITE: Ma 052D or Ma 071D, Ma 053 D or Ma 072D must be taken concurrently.

Ma 101B LINEAR ALGEBRA I (3-0). Systems of Linear Equations. Vector Spaces. Algebra of Matrices. Determinants. TEXT: Stoll, *Linear Algebra and Matrix Theory.* PREREQUISITE: Consent of Instructor.

Ma 102B LINEAR ALGEBRA II (3-0). Bilinear and Quadratic Forms. Linear Transformation on a Vector Space. Canonical Representations of a Linear Transformation. TEXT: Stoll, *Linear Algebra and Matrix Theory.* PREREQUISITE: Ma 101B.

Ma 103C PROJECTIVE GEOMETRY (3-0). Transformations in Euclidean geometry; invariants; perspectivities; Desargue's triangle theorem; principle of duality; homogeneous coordinates of points and lines; linear combinations of points and lines; cross ratio, a projective invariant; harmonic division, properties of complete quadrangles and complete quadrilaterals; projective transformations, the projective properties. TEXTS: Adler, *Modern Geometry;* Struik, *Analytic and Projective Geometry.* PREREQUISITE: Consent of Instructor.

Ma 104A ALGEBRAIC CURVES (3-0). An introduction to study of algebraic geometry is given by means of a solution of topics from the theory of curves, centering around birational transformations and linear series. TEXT: Walker, *Algebraic Curves.* PREREQUISITES: Ma 103C and Ma 105B or consent of Instructor.

Ma 105B FUNDAMENTALS OF MODERN ALGEBRA I (3-0). Concept of group; subgroups; composition of groups; basic theorems for Abelian groups. Rings; integral domains; ideals; polynomial rings; basis theorems for rings. TEXTS: Birkhoff *and* Maclane, *A Survey of Modern Algebra (Revised Edition);* Miller, *Elements of Modern Abstract Algebra.* PREREQUISITE: Ma 102B or consent of Instructor.

Ma 106B FUNDAMENTALS OF MODERN ALGEBRA II (3-0). Continuation of Ma 105A. Fields; field extensions; algebraic numbers; algebraic integers; root fields and their Galois groups; properties of the Galois group and its sub-groups; finite fields; insolvability of the quintic polynomial. TEXTS: Birkhoff *and* Maclane, *A Survey of Modern Algebra (Revised Edition);* Miller, *Elements of Modern Abstract Algebra.* PREREQUISITE: Ma 105B.

Ma 107B INTRODUCTION TO GENERAL TOPOLOGY (3-0). Review of usual topology in *En* fundamentals of point set topology, e.g., compactness, connectivity, homeomorphism, etc. Hausdorff, metrizable, regular spaces, and embedding theorems. Applications. TEXT: Spencer *and* Hall, *Elementary* Topology. PREREQUISITE: Ma 109B or consent of Instructor.

Ma 109B FUNDAMENTALS OF ANALYSIS I (3-0). Elements of set theory and topology in E*n*; vector valued functions, differentials and Jacobians; functions of bounded variation. TEXTS: Apostol, *Mathematical Analysis;* Rudin, *Principles of Mathematical Analysis.* PREREQUISITE: A course in differential and integral calculus.

Ma 110B FUNDAMENTALS OF ANALYSIS II (3-0). Theory of Reimann-Stieljes integration, multiple integrals, sequences and series of functions. TEXTS: Apostol, *Mathematical Analysis;* Rudin, *Principles of Mathematical Analysis.* PREREQUISITE: Ma 109B.

Ma 111A FUNDAMENTALS OF ANALYSIS III (3-0). Continuation of Ma 110B. Line and surface integrals, Stokes theorem, improper integrals, Fourier series and Fourier integrals. TEXT: APOSTOL, *Mathematical Analysis*. PREREQUISITES: Ma 109B and Ma 110B.

Ma 113B VECTOR ANALYSIS and PARTIAL DIFFERENTIAL EQUATIONS (4-0). Calculus of vectors; differential operators; line and surface integrals; Green's, Stokes, and divergence theorems. Separation of variables; boundary conditions; applications to heat flow. TEXTS: WYLIE, *Advanced Engineering Mathematics*; SPIEGEL, *Vector Analysis*. PREREQUISITES: Ma 120D, Ma 240C and Ma 251C.

Ma 116B MATRICES AND NUMERICAL METHODS (3-2). Finite differences, interpolation, numerical differentiation and integration; numerical solution of polynomial equations; numerical methods for initial value and boundary value problems involving ordinary and partial differential equations; solution of systems of linear algebraic equations; latent roots and characteristic vectors of matrices; numerical methods for inversion of matrices. TEXTS: JENNINGS, *First Course in Numerical Methods;* KUNZ, *Numerical Analysis;* MILNE, *Numerical Calculus*. PREREQUISITES: Ma 113B, or Ma 183C, or Ma 245C, or Ma 246C.

Ma 120D VECTORS and MATRICES WITH GEOMETRIC APPLICATIONS (3-1). Real number system. Algebra of complex numbers. Vector algebra. Points, lines and planes in vector and scalar notation. Quadric surfaces. Matrices, determinants, linear systems and linear dependence. Laboratory periods devoted to a review of essential topics in trigonometry and plane analytic geometry. TEXTS: AYRES, *Matrices;* BARNETT *and* FUJII, *Vectors;* RIDER, *First Year Mathematics for Colleges;* PULLIAM, *Matrices*. PREREQUISITE: A course in plane analytic geometry.

Ma 125B NUMERICAL METHODS FOR DIGITAL COMPUTERS (2-2). Numerical solution of systems of linear algebraic equations, polynominal equations, and systems of non-linear algebraic equations; finite differences, numerical interpolation, differentiation, integration; numerical methods for solving initial value and boundary value problems involving ordinary and partial differential equations. TEXTS: JENNINGS, *First Course in Numerical Methods;* KUNTZ, *Numerical Analysis;* MILNE, *Numerical Calculus*. PREREQUISITE: Ma 113B or Ma 183B, or Ma 245B or Ma 246B.

Ma 126B NUMERICAL METHODS FOR DIGITAL COMPUTERS (3-2). Lagrangian polynomial approximations to real functions. Introduction to best polynomial approximations in the sense of least squares. Minimax polynominal approximations. Numerical methods for solving equations and systems of equations. Difference calculus, numerical differentiation and integration. Selected numerical methods for solving initial value and boundary value problems involving ordinary and partial differential equations. The laboratory periods include sample problems solved on hand-operated keyboard calculators; emphasis is given to methods which are useful with large scale automatic digital computers. TEXTS: JENNINGS, *First Course in Numerical Methods;* MILNE, *Numerical Calculus;* KUNTZ, *Numerical Analysis*. PREREQUISITE: Ma 240C and Ma 250C or equivalent.

Ma 127B SCIENTIFIC COMPUTATION WITH DIGITAL COMPUTERS (3-2). Numerical methods for solution of scientific and engineering problems using a high speed digital computer; reduction of problems to mathematical language and the design of programs for their solution; computer evaluation of functions; systems of linear equations and differential equations; problem solving with a digital computer being used for demonstration. TEXTS: MILNE, *Numerical Calculus;* KUNTZ, *Numerical Analysis*. PREREQUISITE: Ma 073C or equivalent.

Ma 128B NUMERICAL METHODS IN PARTIAL DIFFERENTIAL EQUATIONS (3-1). Finite difference expressions for derivatives. Boundary value problems in ordinary differential equations. Iterative methods for solving systems of linear algebraic equations. Relaxation methods. Basic numerical methods for linear second order partial differential equations of Laplace, Poisson, heat-flow and the one-dimensional wave equation. Introduction to difference equations. Stability. Discretization and round-off errors. TEXTS: FORSYTHE *and* WASOW, *Finite-Difference Methods for Partial Differential Equations;* JENNINGS, *Introduction to Numerical Methods for Digital Computers;* KUNTZ, *Numerical Analysis;* MILNE, *Numerical Calculus*. PREREQUISITES: Ma 125B and Ma 421C.

Ma 140B LINEAR ALGEBRA AND MATRIX THEORY (4-0). Systems of linear equations, equalities and inequalities. Vector spaces, bases. Determinants and matrices. Linear transformations, bilinear and quadratic forms. Canonical representations. Geometrical interpretations. Latent roots and vectors of a matrix. TEXTS: STOLL, *Linear Algebra and Matrix Theory;* LANCZOS, *Applied Analysis*. PREREQUISITE: Ma 141D or the equivalent.

Ma 141D REVIEW OF ANALYTIC GEOMETRY AND CALCULUS (5-0). Cartesian coordinates; analytical geometry of straight line and second degree curves. Trigonometry. Concepts of function, limit and continuity. Differential and integral calculus. Functions of several variables. Algebra and the theory of equations. Inequalities. TEXT: THOMAS, *Calculus and Analytic Geometry*. PREREQUISITE: Previous course in analytic geometry and calculus.

Ma 146B NUMERICAL ANALYSIS AND DIGITAL COMPUTERS (4-1). Finite differences. Interpolation and function representation. Numerical differentiation and integration. Summation of series. Algebraic equations. Linear simultaneous algebraic equations. Matrices; latent roots and vectors. Ordinary differential equations, initial and two-point boundary value problems. (Computer methods will be emphasized throughout and laboratory periods will be used to evaluate some of the methods, using the School's computers). TEXTS: MILNE, *Numerical Calculus;* HARTREE, *Numerical Analysis;* N.P.L. HANDBOOK, *Modern Computing Methods*. PREREQUISITE: Ma 140B.

Ma 150D VECTORS AND MATRICES WITH GEOMETRIC APPLICATIONS (4-1). Real number system. Algebra of complex numbers. Vector algebra. Points, lines and planes in scalar and vector notation. Special Surfaces. Frenet-Serret formulae. Directional derivatives, gradient and curl. Determinants, matrices, linear systems and linear dependence. Laboratory periods devoted to review of essential topics in trigonometry and plane geometry. TEXTS: AYRES, *Matrices;* RIDER, *First Year Mathematics for Colleges;* SPIEGEL, *Theory and Problems of Vector Analysis;* BRAND, *Vector Analysis*. PREREQUISITE: A course in plane analytic geometry. Taken concurrently with Mc 101D unless specially arranged otherwise.

Ma 151C DIFFERENTIAL EQUATIONS (4-1). Review of calculus. Partial derivatives. Polar coordinates and change of variables. Elements of differential equations; first order; linear, total; systems of linear equations. TEXTS: GRANVILLE, SMITH *and* LONGLEY, *Elements of the Differential and Integral Calculus;* GOLOMB *and* SHANKS, *Elements of Ordinary Differential Equations.* PREREQUISITE: A course in differential and integral calculus.

Ma 158B SELECTED TOPICS FOR AUTOMATIC CONTROL (4-0). Analytic functions. Cauchy's theorem and formula. Taylor and Laurent series, residues, contour integration, conformal mapping. The Laplace transform and its use in solving ordinary differential equations; inversion integral. Systems of linear differential equations. Stability criteria. TEXTS: CHURCHILL, *Introduction to Complex Variables and Applications;* CHURCHILL, *Modern Operational Mathematics in Engineering.* PREREQUISITES: Ma 120D and Ma 151C.

Ma 170D CALCULUS FOR MANAGEMENT (4-0). Review of the real number system. Sets and the concepts of functions and relations. The geometry and calculus of some elementary functions of one or more variables. Applications using elementary economic models. TEXT: YAMANE, *Mathematics for Economists.* PREREQUISITE: A course in the calculus of functions of one variable.

Ma 180C VECTORS, MATRICES, AND VECTOR SPACES (3-1). Real number system. Algebra of complex numbers. Vector algebra. Points, lines, and planes in scalar and vector notation. Matrices, determinants, and linear systems. Abstract vector spaces. Laboratory periods devoted to a review of essential topics in trigonometry and analytic geometry. TEXTS: SPIEGEL, *Theory and Problems of Vector Analysis;* BROWNE, *Theory of Determinants and Matrices;* HADLEY, *Linear Algebra.* PREREQUISITE: Consent of Instructor.

Ma 181D PARTIAL DERIVATIVES AND MULTIPLE INTEGRALS (4-1). Review of elementary calculus. Hyperbolic functions. Infinite series. Partial and total derivatives. Directional derivatives and gradients and their physical interpretations. Jacobians. Leibnitz's Theorem for differentiating integrals. Line integrals. Double and triple integrals. Introduction to ordinary differential equations. TEXTS: GRANVILLE, *Smith and* LONGLEY, *Elements of the Differential and Integral Calculus;* KAPLAN, *Advanced Calculus;* COGAN, NORMAN *and* THOMPSON, *Calculus of Functions of One Argument;* Instructor's Notes. PREREQUISITES: A course in differential and integral calculus and Ma 120D to be taken concurrently.

Ma 182C DIFFERENTIAL EQUATIONS AND VECTOR ANALYSIS (5-0). Differential equations. Series solutions of ordinary differential equations. Systems of differential equations, including matrix methods. Vector differentiation. Vector integral relations. TEXTS: KAPLAN, *Advanced Calculus;* WYLIE, *Advanced Engineering Mathematics;* SPIEGEL, *Theory and Problems of Vector Analysis.* PREREQUISITE: Ma 181D.

Ma 183B FOURIER SERIES AND COMPLEX VARIABLES (4-0). Expansion of functions. Fourier series and solution of partial differential equations. Algebra of complex numbers. Analytic functions of a complex variable, and the elementary transcendental functions. Complex integration. Residues. TEXTS: CHURCHILL, *Fourier Series and Boundary Value Problems;* CHURCHILL, *Complex Variables.* PREREQUISITE: Ma 182C.

Ma 193C SET THEORY AND INTEGRATION (2-0). Set theoretic concepts. Basic concepts in the theories of Riemann, Lebesgue, and Stieltjes integrals with emphasis on applications to probability theory. TEXTS: MUNROE, *Introduction to Measure and Integration.* PREREQUISITE: Ma 181D or the equivalent.

Ma 196B MATRIX THEORY (3-0). Algebra of matrices; characteristic value of matrices; Hamilton-Cayley and Sylvester's theorems; Matrix methods in the solution of systems of differential equations. TEXTS: FRAZER, DUNCAN *and* COLLAR, *Elementary Matrices;* GASS, *Linear Programming.* PREREQUISITE: Ma 120D, or Ma 150D, or the equivalent.

Ma 220C PARTICLE DYNAMICS (2-2). Review of vector algebra and statics. Moment of a force about a point and about an axis. Axial and polar vectors. Reduction of a general force system and Poinsot's central axis. Centroids. Vector kinematics referred to a rotating coordinate frame. The Coriolis theorem and application to curvilinear coordinates. Potential energy and stability. Particle dynamics. TEXTS: BARNETT *and* FUJII, *Vectors;* BEER *and* JOHNSTON, *Vector Mechanics for Engineers.* PREREQUISITE: A previous course in mechanics.

Ma 221C DIFFERENTIAL EQUATIONS (3-2). Review of calculus. Partial derivatives. Polar coordinates and change of variables. Power and Fourier series. Elements of differential equations; first order, linear, total. Systems of linear equations. TEXTS: TAYLOR, *Advanced Calculus;* LEIGHTON, *Differential Equations.* PREREQUISITE: A course in differential and integral calculus.

Ma 230D CALCULUS OF SEVERAL VARIABLES (4-0). Review calculus of one variable. Taylor series, Leibnitz and L'Hospitals rules. Differential calculus of functions of several variables, directional derivatives, gradient vectors, geometry of tangent planes to surfaces. Double and triple integration in rectangular coordinates. TEXTS: GRANVILLE, SMITH, LANGLEY, *Elements of Differential and Integral Calculus;* TAYLOR, *Advanced Calculus.* PREREQUISITE: A previous course in calculus and Ma 120D or Ma 150D (may be taken concurrently).

Ma 240C ELEMENTARY DIFFERENTIAL EQUATIONS (2-0). Elements of differential equations including basic types of first order equations and linear equations of all orders with constant coefficients. Systems of linear equations. TEXT: LEIGHTON, *Introduction to the Theory of Differential Equations.* PREREQUISITE: Ma 230D, (may be taken concurrently).

Ma 241C ELEMENTARY DIFFERENTIAL EQUATIONS (3-0). A longer version of Ma 240C including more emphasis on first order equations. TEXT: GOLOMB *and* SHANKS, *Elements of Ordinary Differential Equations.* PREREQUISITE: Ma 230D, (May be taken concurrently).

Ma 244C ELEMENTARY DIFFERENTIAL EQUATIONS AND INFINITE SERIES (4-0). A combination of Ma 250C and Ma 240C given together in this order. TEXTS: COHEN, *Differential Equations;* TAYLOR, *Advanced Calculus.* PREREQUISITE: Ma 230D.

Ma 245B PARTIAL DIFFERENTIAL EQUATIONS (3-0). Solution of boundary value problems by separation of variables; Sturm-Liouville theory; Fourier Bessel series solution. TEXTS: CHURCHILL, *Fourier Series and Boundary Value Problems.* PREREQUISITES: Ma 251C and Ma 240C.

Ma 246B PARTIAL DIFFERENTIAL EQUATIONS (4-0). Series solution of linear differential equations, generalized orthogonal functions; solution of boundary value problems by separation of variables; Strum-Liouville theory; Fourier-Besssel series solutions. TEXT: CHURCHILL, *Fourier Series and Boundary Value Problems.* PREREQUISITES: Ma 250 C and Ma 240C.

Ma 248B DIFFERENTIAL EQUATIONS FOR OPTIMUM CONTROL (3-0). Methods in differential equations for calculating differentials based on the adjoint system of differential equations. Applications to problems in optimum control, particularly trajectories and minimum time problems. Numerical methods for determining and correcting trajectories, particularly optimum trajectories, on a digital computer. TEXT: USNPGS Notes. PREREQUISITES: Ma 240C or equivalent, and Ma 421C or consent of Instructor.

Ma 250C ELEMENTARY INFINITE SERIES (2-0). Sequences and series, convergence tests; power series, Taylor series expansions; uniform convergence; introduction to Fourier series. TEXT: TAYLOR, *Advanced Calculus.* PREREQUISITE: Ma 230D, (may be taken concurrently).

Ma 251C ELEMENTARY INFINITE SERIES (3-0). A longer version of Ma 250B including series solution of linear differentiation equations. Bessel and Legendre functions, generalized orthogonal functions. TEXT: TAYLOR, *Advanced Calculus.* HILDEBRAND, *Advanced Calculus for Engineers.* PREREQUISITES: Ma 230D and Ma 240C.

Ma 260C VECTOR ANALYSIS (3-0). Vector differential and integral calculus including differential geometry of lines and surfaces, line and surface integrals, change of variable formulas and curvilinear coordinates. TEXT: SPIEGEL, *Theory and Problems of Vector Analysis.* PREREQUISITES: Ma 120D and Ma 230D.

Ma 261B VECTOR MECHANICS (5-0). Line, surface and volume integrals, Green's divergence, and Stokes' theorems. Vector differential calculus, and the vector differential operators in rectangular and curvilinear coordinates. The integral theorems in vector form. The vector equations of motion. Irrotational, solenoidal and linear vector fields with applications to fluid mechanics in meteorology. Total differential equation and systems of total differential equations. TEXTS: SOKOLNIKOFF *and* SOKOLNIKOFF, *Higher Mathematics for Engineers and Physicists;* COHEN, *Differential Equations;* SPIEGEL, *Theory and Problems of Vector Analysis;* WEATHERBURN, *Advanced Vector Analysis.* PREREQUISITES: Ma 240C and Ma 251C.

Ma 270C COMPLEX VARIABLES (3-0). Analytic functions; series expansion; integration formulas; residue theory. TEXT: CHURCHILL, *Introduction to Complex Variables.* PREREQUISITES Ma 120D, Ma 230 D, Ma 250C.

Ma 271C COMPLEX VARIABLES (4-0). A longer version of Ma 270B including more emphasis on Contour integration are required for transform theory. TEXT: CHURCHILL, *Introduction to Complex Variables.* PREREQUISITES: Ma 120D, Ma 230D, Ma 250C.

Ma 280B LAPLACE TRANSFORMATIONS (2-0). Definitions and existence conditions; applications to systems involving linear difference, differential and integral equations; inversion integral. TEXT: CHURCHILL, *Modern Operational Mathematics in Engineering.* PREREQUISITES: Ma 240C, Ma 250C, and Ma 270C, (the latter may be taken concurrently).

Ma 301C BASIC PROBABILITY AND SET THEORY (4-0). Elements of set theory and set algebra. Axioms for a probability function and models for finite sample spaces. Random variables and their probability distributions. Families of distributions and their characteristics. Chebyshev's inequality and the law of large numbers. Normal family and normal approximations. TEXTS: MOSTELLER, *Probability with Statistical Applications;* PARZEN, *Modern Probability Theory and its Applications.* PREREQUISITE: A course in differential and integral calculus.

Ma 302B SECOND COURSE IN PROBABILITY (3-2). A continuation of Ma 301C. Jointly distributed random variables and the distribution of functions of random variables. Independence and conditional distributions. Sums of random variables and the Central Limit Theorem. TEXT: PARZEN, *Modern Probability Theory and its Applications.* PREREQUISITES: Ma 301C and Ma 181D or the equivalent.

Ma 303B THEORY AND TECHNIQUES IN STATISTICS I (3-2). Descriptive statistics. Point estimation. Principles of choice and properties of estimators. Methods for calculation. Confidence intervals. Applications. Testing hypotheses. Concepts of power, most powerful tests. Applications. TEXTS: MOOD *and* GRAYBILL, *Introduction to the Theory of Statistics;* BOWKER *and* LIEBERMAN, *Engineering Statistics.* PREREQUISITE: Ma 302B.

Ma 304B THEORY AND TECHNIQUES IN STATISTICS II (3-0). A continuation of Ma 303B. Regression and correlation. Least squares. Elements of analysis of variance. Multiple comparisons. Sequential sampling. Quality control; Sampling inspection. TEXTS: MOOD *and* GRAYBILL, *Introduction to the Theory of Statistics;* BOWKER *and* LIEBERMAN, *Engineering Statistics.* PREREQUISITE: Ma 303B.

Ma 305A DESIGN OF EXPERIMENTS (3-1). Theory of the general linear hypothesis. Analysis of variance. Planning of experiments. Randomized blocks and Latin Squares. Simple factorial experiments. Confounding. TEXTS: GRAYBILL, *An Introduction to Linear Statistical Models;* COX, *Planning of Experiments;* OSTLE, *Statistics in Research.* PREREQUISITE: Ma 304B or consent of Instructor.

Ma 306A SELECTED TOPICS IN ADVANCED STATISTICS I (3-1). Topics will be selected by instructor to fit the needs and background of the students. Areas of choice to include the fields of sequential analysis, non-parametric methods and multivariate analysis. The course may be repeated for credit if the topic changes. TEXT: To be announced. PREREQUISITE: Ma 304B, or consent of Instructor.

Ma 307A STOCHASTIC PROCESS I (3-0). Poisson and Wiener processes. Markov chains. Discrete and continuous parameter cases. Ergodic properties and passage probabilities. Birth and death processes and their application to queueing theory. TEXTS: PARZEN, *Stochastic Processes;* FULLER, *An Introduction to Probability Theory and its Applications.* PREREQUISITE: Ma 304B or consent of the Instructor.

Ma 308A STOCHASTIC PROCESS II (3-0). Orthogonal representation of stochastic processes. Stationary time series; harmonic analysis of the auto correlation function. Ergodic properties. Applications. TEXTS: PARZEN, *Stochastic Processes;* HANNAN, *Time Series Analysis.* PREREQUISITE: Ma 307A.

Ma 309A SELECTED TOPICS IN ADVANCED STATISTICS II (3-0). A continuation of Ma 306A. PREREQUISITE: Ma 306A.

Ma 311C INTRODUCTION TO PROBABILITY AND STATISTICS (4-0). An elementary treatment of probability with some statistical applications. Topics discussed are probability models, discrete and continuous random variables, moment properties, testing statistical hypotheses, and statistical estimation. TEXT: MOSTELLER, ROURKE *and* THOMAS, *Probability with Statistical Applications.* PREREQUISITE: Ma 015D or equivalent.

Ma 315B INTRODUCTION TO PROBABILITY AND STATISTICS (4-2). Elements of set theory. Foundations of probability and basic rules of computation. Sample space, random variable, discrete and continuous distribution functions. Classical distribution functions. Limit theorems, Markov chains. Applications in fields of particular interest to class. TEXT: MOSTELLER, *Probability with Statistical Applications;* HOEL, *Introduction to Mathematical Statistics.* PREREQUISITE: A previous course in calculus.

Ma 316B APPLIED STATISTICS I (3-2). Descriptive Statistics. Introduction to decision theory. Point estimation; principles of choice and properties of estimators; methods for calculation. Confidence intervals; applications. Testing hypotheses; concepts of power, most powerful tests; applications. TEXTS: HOEL, *Introduction to Mathematical Statistics;* SCHLAIFER, *Business Decisions.* PREREQUISITE: Ma 315B.

Ma 317B APPLIED STATISTICS II (3-0). A continuation of Ma 316B. Regression and correlation; least squares. Elements of Analysis of Variance; multiple comparisons. Sequential sampling. Non-parametric procedures. TEXTS: HOEL, *Introduction to Mathematical Statistics;* SCHLAIFER, *Business Decisions.* PREREQUISITE: Ma 316B.

Ma 321B PROBABILITY (4-2). Elements of set theory. Foundations of Probability and basic rules of computation. Sample space, random variable, discrete and continuous distribution functions. The classical distribution functions. Joint, marginal and conditional distribution functions. Characteristic functions. Limit theorems. Introduction to random processes. Applications to fields of interest of the class. Markov chains. TEXTS: HOEL, *Introduction to Mathematical Statistics;* DAVENPORT *and* ROOT, *Random Signals and Noise.* PREREQUISITES: Ma 244C and Ma 271C or the equivalent.

Ma 322A DECISION THEORY AND CLASSICAL STATISTICS (3-2). Testing statistical hypothesis, point estimation, interval estimation, regression analysis. Decision theoretic problem with specific attention given to minimax strategies. Bayes strategies, and admissability. TEXT: To be announced. PREREQUISITE: Ma 321B and consent of Instructor.

Ma 326A ADVANCED PROBABILITY I (3-0). Probability viewed as a measure. Sets, measures and integration. Convergence almost surely, in probability and in quadratic mean. Distribution functions and characteristic functions. TEXT: To be announced. PREREQUISITE: Consent of Instructor.

Ma 327A ADVANCED PROBABILITY II (3-0). Infinitely divisible laws. Strong and weak laws of large numbers. Classical central limit problems, modern central limit problems. TEXT: GNEDENKO *and* KOLMOGOROV, *Limit Theorems for Sums of Independent Random Variables.* PREREQUISITE: Consent of Instructor.

Ma 332B STATISTICS I (3-0). Introduction to probability theory. Derivation and properties of principal frequency functions of discrete and continuous random variables. Joint distributions and introduction to regression and correlation. TEXT: HOEL, *Introduction to Mathematical Statistics (3rd Edition).* PREREQUISITE: Ma 230D or the equivalent.

Ma 333B STATISTICS II (2-2). A continuation of Ma 332B. Applications of probability in statistics. Derived distributions. Estimators of parameters and their frequency functions. Mathematical expectation. Introduction to sampling theory. Applications in meteorology. TEXTS: WADSWORTH *and* BRYAN, *Introduction to Probability and Random Variables;* HOEL, *Introduction to Mathematical Statistics (2nd Edition);* BEST *and* PANOFSKY, *Some Applications of Statistics in Meteorology.* PREREQUISITE: Ma 332B or the equivalent.

Ma 351B PROBABILITY AND STATISTICS (4-2). Elements of set theory. Foundations of probability and basic rules of computation. Sample space, random variable, discrete and continuous distribution functions. Bayes Theorem. The classical distribution functions. Expectations, propagation of error. Joint, Marginal, and conditional distribution functions, least squares. Limit theorems. Derivation of Poisson process. Elements of hypothesis testing and estimation. TEXTS: LINDGREN *and* McELRATH, *Introduction to Probability and Statistics;* BOWKER *and* LIEBERMAN, *Engineering Statistics.* PREREQUISITE: Ma 230D.

Ma 352B APPLIED ENGINEERING STATISTICS (2-2). Tests of hypothesis and estimation. Analysis of variance. Statistical quality control, control charts. Sampling inspection. Reliability theory and applications. TEXT: BOWKER *and* LIEBERMAN, *Engineering Statistics;* OSTLE, *Statistics in Research,* PREREQUISITE: Ma 351B.

Ma 355A SYSTEM RELIABILITY AND LIFE TESTING (3-0). Reliability functions and their point and interval estimates under various sampling plans. Standard and accelerated life testing plans. Analysis of serial, parallel, and mixed systems. Analysis of reliability apportionment and inherent design reliability. Reliability growth models and methods for updating reliability estimates. Properties of functions with monotone failure rate. TEXTS: Lloyd *and* Lipow, *Reliability;* Barlowe, Hunter *and* Proschan, *Reliability.* PREREQUISITES: Ma 303B and Ma 304B, or Ma 321B and Ma 322A.

Ma 371C MANAGEMENT STATISTICS (4-0). Elements of probability theory with emphasis on random variables and their probability distributions. Distributions of estimators of parameters. Applications of these concepts as aids in decision making. TEXT: To be announced. PREREQUISITE: Ma 170D or equivalent.

Ma 381C ELEMENTARY PROBABILITY AND STATISTICS (4-2). Elements of the theory of probability. The classical probability distributions. Elements of statistical inference with applications in the field of the group. TEXTS: Mosteller, Rourke *and* Thomas, *Probability With Statistical Applications;* Panofsky *and* Brier, *Applications of Statistics to Meteorology* (Meteorology groups only). PREREQUISITE: Ma 181D or equivalent.

Ma 395B GAMES OF STRATEGY (3-2). Theory and applications of matrix games, including the minimax theorem, properties of optimal strategies, and solutions of some specific types of discrete games. Theory and applications of continuous games including games with convex kernels and games of timing. TEXTS: Karlin, *Mathematical Methods and Theory in Games, Programming and Economics Volume I and II.* McKinsey, *Introduction to the Theory of Games.* PREREQUISITE: Ma 196B or equivalent and Ma 301C or equivalent.

Ma 396A DECISION THEORY (3-0). Basic concepts. Bayes, admissible, minimax, and regret strategies. Principles of choice. Relation of statistical decision functions to the theory of games. Applications in the planning of operational evaluation trials. TEXTS: Chernoff *and* Moses, *Elementary Decision Theory;* Wald, *Statistical Decision Functions;* Tucker, *Introduction to Statistical Decision Function;* (USNPGS Thesis); Smith, *Application of Statistical Methods to Naval Operational Testing* (USNPGS Thesis). PREREQUISITES: Ma 304B, Ma 193C and Ma 395B. (The latter may be taken concurrently.)

Ma 397A THEORY OF INFORMATION COMMUNICATION (3-0). Markov chains; surprisal of events and uncertainty of distributions; characterization of uncertainty; noise and rate of information transmission; limit distributions connected with sequences from an ergodic Markov chain; Shannan-Fano coding; detection. TEXTS: Shannon *and* Weaver, *The Mathematical Theory of Communication;* Feller, *Probability Theory and its Applications;* Feinstein, *Foundations of Information Theory;* Khinchin, *Mathematical Foundations of Information Theory.* PREREQUISITES: Ma 120D or Ma 150D and Ma 321B.

Ma 398B SAMPLING INSPECTION AND QUALITY CONTROL (3-1). Attribute and variables sampling plans. MIL. STD., sampling plans with modifications. Multi-level continuous sampling plans and sequential sampling plans. Distribution of effort in related sampling plans. Quality control with emphasis on recent developments. TEXTS: Grant, *Statistical Quality Control;* Bowker *and* Lieberman, *Engineering Statistics;* articles from statistical journals. PREREQUISITE: Ma 304B or Ma 322A.

Ma 401B ANALOG COMPUTERS (4-0). Elementary analog devices which may be used to perform addition, multiplication, vector resolution, function generation, integration, etc. Combinations of such devices for solution of differential equations, systems of linear equations, algebraic equations, harmonic analysis, etc. Gimbal solvers. Digital differential analyzers. TEXTS: Soroka, *Analog Methods in Computation and Simulation;* Murray, *Theory of Mathematical Machines;* Reprints of articles from scientific periodicals. PREREQUISITE: Ma 240C or equivalent.

Ma 402B ANALOG COMPUTERS (2-0). Theory of D.C. Amplifiers, servos, plotters and function multipliers. Analog solution to simultaneous differential equations of any order. Solution of the Legendre, Bessel and Hermite equations. TEXT: Korn *and* Korn, *Analog Computers.* PREREQUISITE: Ma 240C or equivalent.

Ma 411C DIGITAL COMPUTERS AND MILITARY APPLICATIONS (4-0). Description of a general purpose digital computer. Programming fundamentals. The use of subroutines, assembly routines and compilers in programming. Applications such as war gaming, simulation of systems, logistics and data processing, demonstrations on a computer. TEXT: McCracken, *Digital Computer Programmings.* PREREQUISITE: Ma 073C or equivalent.

Ma 412C SMALL SCALE DIGITAL COMPUTERS (3-2). Octal and binary number systems. Description of general purpose digital computers. Operating characteristics and fundamentals of programming for the CDC-160A. Programming, with meteorological applications, and operation of the 160. Course designed for meteorology students who may be expected to program for, and operate similar equipment upon completion of study. TEXTS: Programming Manuals. PREREQUISITE: Ma 381C.

Ma 416C NUMERICAL METHODS AND FORTRAN PROGRAMMING (4-1). Numerical solutions of systems of linear and nonlinear algebraic equations; finite differences; numerical interpolation, differentiation; integration; numerical methods of solving initial value and boundary value problems. The first half of course is devoted to learning the Fortran language and writing programs of increasing complexity. In the last half of the course attention is focused mainly on the numerical methods, making use of already existing library subroutines to supplement theory with examples. TEXTS: Milne, *Numerical Calculus;* Kunz, *Numerical Analysis;* McCracken, *A Guide to Fortran Programming;* Jennings, *First Course in Numerical Methods.* PREREQUISITE: Calculus, Differential equations.

Ma 420E COMPUTER OPERATION (1-1). (For 5 wks.). This is a non-credit course designed for students whose course or thesis work requires a knowledge of computer operation. In a combination of lecture and laboratory periods details of operation of computer and peripheral equipment are covered as well as input-output techniques and power-on, power-off procedures. TEXTS: Programming Manuals. PREREQUISITE: Ma 421B or equivalent.

Ma 421C INTRODUCTION TO DIGITAL COMPUTERS (4-1). Octal and binary number systems. Description of general purpose digital computer. Operating characteristics and fundamentals of programming. Programming, using assembly routines and compilers. Engineering applications of digital computers. A *portion* of the laboratory period is devoted to operating the computers. TEXTS: McCRACKEN, *Digital Computer Programming;* McCRACKEN, *A Guide to Fortran Programming;* Programming Manuals. PREREQUISITES: None.

Ma 423B ADVANCED DIGITAL COMPUTER PROGRAMMING (4-0). Theory and design of sub-routines, assembly routines and compilers. Symbol manipulation. Problem oriented languages and control languages. TEXT: Selected Articles from Publications. PREREQUISITE: Ma 421C.

Ma 424B BOOLEAN ALGEBRA (3-0). Development of Boolean Algebra and its application to problems in logic. Information retrieval and related problems. TEXT: WHITESITT, *Boolean Algebra and its Application.* PREREQUISITE: Ma 421C.

Ma 426B ADVANCED NUMERICAL METHODS (4-1). Representations of functions and/or data by Chebyshev approximation, Continued Fractions, Economization of Series, Quadrature Methods and Multivariate Interpolation by least squares. Matrices and Linear Systems. Methods for Numerical Quadrature. Multiple Quadrature by Monte Carlo Methods. Numerical Solution of Differential Equations. TEXTS: RALSTON *and* WILF, *Mathematical Methods for Digital Computers;* LANCZOS, *Applied Analysis.* PREREQUISITES: Ma 116B and Ma 421C.

Ma 427C PROGRAMMING I — INTRODUCTION (3-1). General description of data processing equipment from card/tape ancillary equipment to large-scale digital computer systems. History and development of computing devices. Characteristics of a digital computer and its operation. Programming in a problem-oriented language, e.g., FORTRAN, ALGOL, COBOL; the particular choice depending on the availability of the system for the School's computers and the special interests of the class. TEXTS: McCRACKEN, *A Guide to FORTRAN Programming;* manufacturers' brochures and computer manuals. PREREQUISITE: None.

Ma 428B PROGRAMMING IIa (3-1). Binary and octal number systems. Programming in machine language for the CDC 1604. Use of USNPGS's SCRAP assembly routine. Problem solving and program planning techniques. Use of subroutines, program testing aids and monitor systems. Input/ouput considerations. Introduction to advanced topics such as parallel processing, time-sharing and satellite computers. TEXTS: CDC 1604 and SCRAP MANUALS. PREREQUISITE: Ma 427C.

Ma 429A PROGRAMMING IIb (3-0). Evaluation of different computer systems—hardware and software. Critical review of available programming languages, machine- and problem-oriented. Systems programming. Theory and construction of assembly and compiler programs. Executive routines and monitor systems. Large scale programming efforts, e.g., NTDS and SAGE system. Multi-computer configurations. TEXTS: Technical papers; computer programming manuals, etc. PREREQUISITE: Ma 428B.

Ma 441C INTRODUCTION TO DIGITAL COMPUTERS (3-0). Description of a general purpose digital computer. Command structure and commands. Flow charts and programming. Applications to problems in science, logic and data processing. TEXTS: McCRACKEN, *Digital Computer Programming;* McCRACKEN, *A Guide to Fortran Programming;* Programming manuals. PREREQUISITE: Consent of Instructor.

Ma 471C ELECTRONIC DATA PROCESSING AND MANAGEMENT CONTROL (3-0). Functional description of a general purpose digital computer; its control, memory, arithmetic and input-output units. Binary number system and representation of information in a computer or on magnetic tape. Use of computers to solve management problems associated with inventory control, personnel records, reports and assignments. TEXT: CANNING, *Electronic Data Processing for Business and Industry;* Programming Manuals. PREREQUISITE: Ma 371C.

Ma 501C THEORY OF NUMBERS (3-0). Divisibility, congruences, quadratic reciprocity, diophantine equations, continued fractions, partitions. TEXT: NIVEN *and* ZUCKERMAN, *An Introduction to the Theory of Numbers.* PREREQUISITE: Consent of Instructor.

Ma 502B DIFFERENTIAL GEOMETRY (3-0). Curves and surfaces. Parametric representation. Curvature. Principal normal. Binormal. Torsion. The Frenet formulas. Transformations of coordinates. Covariant and contravariant vectors. Symmetric and skew-symmetric tensors. Christoffel symbols. Reimannian tensor. Gaussian curvature Geodesics. TEXT: EISENHART, *An Introduction to Differential Geometry.* PREREQUISITE: Consent of Instructor.

Ma 503B FOUNDATION OF MATHEMATICS (3-0). Fundamental concepts of mathematics with some emphasis on the axiomatic method including consistency, completeness and independence of axioms in an axiom system. TEXT: To be announced. PREREQUISITE: Consent of instructor.

Ma 504C CALCULUS OF FINITE DIFFERENCES (3-0). Finite differences, factorial polynomials, sums, infinite products, Bernoulli numbers and polynomials, linear difference equations. TEXT: MILLER, *An Introduction to the Calculus of Finite Differences and Difference Equations.* PREREQUISITE: Consent of Instructor.

Ma 524A BOOLEAN ALGEBRA (3-0). A treatment of Boolean algebra as an abstract mathematical system. The interrelationships between Boolean algebra, set theory and logic are stressed through the algebra of sets and the statement calculus. Stone representation theorem for a Boolean algebra is covered in detail. TEXTS: STOLL, *Set Theory and Logic;* HALMOS, *Lectures on Boolean Algebra.* PREREQUISITE: Ma 705B or equivalent.

Ma 541B APPLIED MATHEMATICS (3-0). Green's function technique for solving Sturm-Liouville problems for ordinary differential equations as well as boundary and initial value problems for partial differential equations of mathematical physics are introduced. Operational calculus. TEXT: FRIEDMAN, *Techniques of Applied Mathematics.* PREREQUISITE: Consent of Instructor.

Ma 542B APPLIED MATHEMATICS (3-0). A continuation of Ma 541B. The material introduced in Ma 541B is studied more extensively. TEXT: FRIEDMAN, *Techniques of Applied Mathematics.* PREREQUISITE: Ma 541B.

Ma 546B SPECIAL FUNCTIONS (3-0). Special functions of mathematical physics. Orthogonal polynomials. Legendre functions. Bessel functions. Mathieu functions. Spherical harmonics. Recursion formulas, Rodrigues' formulas. Generating functions. Addition theorems. Relationship with hypergeometric differential equation. Expansion and orthogonality properties. TEXT: HOCHSTADT, *Special Functions of Mathematical Physics*. PREREQUISITE: Consent of Instructor.

Ma 548B PARTIAL DIFFERENTIAL EQUATIONS (3-0). The Cauchy problem for partial differential operators. Cauchy-Kowalewsky Theorems. Methods of characteristics. Well-posed problems for elliptic, hyperbolic and parabolic partial differential equations. TEXT: PETROVSKY, *Partial and Differential Equations*. PREREQUISITE: Consent of Instructor.

Ma 549B FOURIER BESSEL EXPANSIONS AND CALCULUS OF VARIATIONS (2-0). Partial differential equations, separation of variables, Sturm-Liouville systems, Fourier Bessel expansions, orthogonal functions, Bessel's inequality. Euler equations, Hamilton's principle, application to Physics. TEXTS: CHURCHILL, *Fourier Series and Boundary Value Problems;* COURANT, *Methods of Mathematical Physics, Vol. 1;* HILDEBRAND, *Methods of Applied Mathematics*. PREREQUISITE: Consent of Instructor.

Ma 555A INTEGRAL EQUATIONS (3-0). Fredholm integral equations of the first and second kinds. The Fredholm alternative. Volterra equations. Neumann series. Integral equations with symmetric kernels. Hilbert-Schmidt theory. Singular equations. Applications. TEXT: MIKHLIN, *Linear Integral Equations*. PREREQUISITE: Consent of Instructor.

Ma 571B THEORY OF FUNCTIONS OF A COMPLEX VARIABLE (3-0). Selected topics from the theory of functions of a real variable. Complex functions and analytic functions. Integration in the complex plane. Series of complex functions. Power series. Laurent series. PREREQUISITE: Consent of Instructor.

Ma 572B THEORY OF FUNCTIONS OF A COMPLEX VARIABLE (3-0). Singularities of complex functions. Residues and contour integration. Zeros of analytic functions, factors of and infinite product representations for analytic functions. Maximum modulus theorems for analytic and harmonic functions. Conformal mapping. PREREQUISITE: Ma 571B or Consent of Instructor.

Ma 573A THEORY OF FUNCTIONS OF A COMPLEX VARIABLE (3-0). Special functions of a complex variable. Analytic theory of differential equations. PREREQUISITE: Ma 572B or consent of Instructor.

Ma 576A LAPLACE TRANSFORMATIONS (3-0). Theory of the Laplace transform with particular reference to its properties as a function of a complex variable. Applications of the transform to difference, differential, integral equations of convolution type and boundary value problems. Sturm-Liouville systems. TEXT: To be announced. PREREQUISITE: Ma 573A or consent of Instructor.

Ma 701B SEMINAR IN ANALYSIS (2-0). Topics in analysis. Content of the course varies. Students will be allowed credit for taking the course more than one time. PREREQUISITE: Consent of Instructor.

Ma 705B SET THEORY (3-0). Elementary logic and methods of proof in mathematics; properties of sets and operations with sets; relations and functions from a set-theoretic point of view; equivalence of sets and their cardinality; infinite sets and their classification by cardinal numbers. TEXT: ZEHNA *and* JOHNSON, *Elements of Set Theory*. PREREQUISITE: Differential and integral calculus or consent of Instructor.

Ma 709A FUNCTIONS OF REAL VARIABLES (3-0). Review of set theory and real numbers. Topological and metric spaces, convergence of directed functions, continuity and semicontinuity. Functions of bounded variation, absolutely continuous functions, differentials. TEXT: ROYDEN, *Real Analysis*. PREREQUISITE: Ma 109B.

Ma 710A FUNCTIONS OF REAL VARIABLES (3-0). Continuation of Ma 709. Lebesque-Stieltjes integrals, measure and measurable function. Radon-Nikodym theorem, function spaces, L*p* spaces. TEXT: ROYDEN, *Real Analysis*. PREREQUISITE: Ma 709A.

Ma 711A INTRODUCTION TO FUNCTIONAL ANALYSIS (3-0). Linear spaces and functionals. Banach and Hilbert spaces. Weak and weak* topologies, completely continuous operators, spectral theorems. TEXT: To be announced. PREREQUISITE: Consent of Instructor.

Ma 740A CALCULUS OF VARIATIONS (3-0). Bliss's differential methods, adjoint differential equations. Euler equations, maximum principle. Weierstrass and Legendre conditions. Perturbation techniques, numerical procedures for determining solutions, and application to control problems. TEXTS: Selected papers and USNPGS Notes. PREREQUISITES: Ma 240C or the equivalent and Ma 412B or consent of Instructor.

Ma 751B TENSOR ANALYSIS I (3-0). The basic concepts of differential geometry. Definition of a tensor. Physical interpretations. The metric tensor. Covariant differentiation. Geodesics. TEXTS: BURINGTON *and* TORRANCE, *Higher Mathematics;* WEATHERBURN, *Riemannian Geometry and the Tensor Calculus*. PREREQUISITES: Ma 120D, Ma 181D, Ma 182C or the equivalent.

Ma 752A TENSOR ANALYSIS II (3-0). A continuation of Ma 751B. Introduction to special relativity theory, with emphasis upon axiomatic and philosophical foundations. Formulation of the laws of mechanics and electromagnetism in relativistic form. TEXT: BERGMAN, *Introduction to the Theory of Relativity*. PREREQUISITE: Ma 751B and a sound background in classical mechanics and electromagnetism.

Ma 753A TENSOR ANALYSIS III (3-0). A continuation of Ma 752A. Introduction to general relativity theory. Parallel displacement and the curvature tensor. TEXT: BERGMAN, *Introduction to the Theory of Relativity*. PREREQUISITE: Ma 752A.

Ma 801A SEMINAR IN ANALYSIS. Subject matter of this seminar will in general be left to the discretion of instructors; usually content will be special topics from the fields of functional analysis and partial differential equations. Number of hours subject to arrangement. PREREQUISITE: Consent of Instructor.

Ma 831B SEMINAR IN PROBABILITY AND STATISTICS. Content of the course varies. Students will be allowed credit for taking the course more than one time. PREREQUISITE: Consent of Instructor.

Ma 832A SEMINAR IN PROBABILITY AND STATISTICS. Content of the course varies. Students will be allowed credit for taking the course more than one time. PREREQUISITE: Consent of Instructor.

Ma 931B READING IN PROBABILITY AND STATISTICS. Content of the course varies. Students will be allowed credit for taking the course more than one time. PREREQUISITE: Consent of Instructor.

Ma 932B READING IN PROBABILITY AND STATISTICS. Content of the course varies. Students will be allowed credit for taking the course more than one time. PREREQUISITE: Consent of Instructor.

MECHANICS

Mc 101D ENGINEERING MECHANICS I (2-2). Review of statics, free-body diagrams; distributed forces; centroids; moments and products of inertia of areas; hydrostatics; friction, general principles of dynamics; dimensional analysis; kinematics of a particle; relative and absolute time rate of change of a vector; Cariolis acceleration. TEXT: Housner *and* Hudson, *Applied Mechanics;* Shames, *Engineering Mechanics.* PREREQUISITES: Ma 120D or Ma 150D (may be taken concurrently).

Mc 102D ENGINEERING MECHANICS II (2-2). Dynamics of a particle; impulse and momentum; work and energy; potential; conservation of energy; vibrating systems, free and forced, with and without damping; impact; dynamics of rigid bodies; moments and products of inertia; principal axes of inertia; the gyroscope. TEXT: Housner *and* Hudson, *Applied Mechanics;* Shames, *Engineering Mechanics.* PREREQUISITE: Mc 101D.

Mc 111C VECTOR MECHANICS I (4-0). Review of vector algebra and statics. Reduction of a general force system and Poinsot's central axis. Axial and polar vectors. Centroids. Vector kinematics referred to a rotating coordinate frame. The Coriolis theorem and its application to curvilinear coordinates. Potential energy and stability. Particle dynamics. Spherical pendulum. TEXTS: Housner *and* Hudson, *Applied Mechanics;* Beer *and* Johnston, *Vector Mechanics for Engineers;* Synge *and* Griffith, *Principles of Mechanics.* PREREQUISITE: A previous course in mechanics.

Mc 112C VECTOR MECHANICS II (4-0). Vector dynamics of rigid bodies. The instantaneous screw axis. Euler angles. Body and space centrodes. Ellipsoid of inertia and principal axes. Poinsot's force free motion and the forced precession of a gyro, with application to the earth. Dynamical stability of a gyro by complex variable. Elementary theory of missile stability. TEXTS: Housner *and* Hudson, *Applied Mechanics;* Beer *and* Johnston, *Vector Mechanics for Engineers;* Synge *and* Griffith, *Principles of Mechanics.* PREREQUISITE: Mc 111C.

Mc 201B METHODS IN DYNAMICS (2-2). The principles of linear momentum, angular momentum, work and energy, power and energy, conservation of energy, virtual work, and d'Alembert are developed and discussed in detail. This work is followed by a development and interpretation of Lagrange's equations of motion. Application of these various principles to obtain the differential equations of motion of dynamical systems is given particular attention. TEXTS: Synge *and* Griffith, *Principles of Mechanics;* Timoshenko *and* Young, *Advanced Dynamics.* PREREQUISITE: Mc 102D.

Mc 311C VIBRATIONS (3-2). Kinematics of vibrations; free and forced vibrations of systems with one degree of freedom; theory of vibration measuring instruments and of vibration insulation; systems with many degrees of freedom; normal modes of vibration; computation of fastest and slowest modes by matrix methods; vibrations of strings, beams, shafts and membranes. Rayleigh's method; Stodola's method; critical speeds; self-excited vibrations; effects of impact on elastic structures. TEXTS: Thompson, *Mechanical Vibrations (2nd edition);* Den Hartog, *Mechanical Vibrations (3rd edition);* Frankland, *Effects of Impact on Simple Elastic Structures* (TMB Report 481). PREREQUISITES: Mc 102D and a course in beam deflection theory.

Mc 402B MECHANICS OF GYROSCOPIC INSTRUMENTS (3-0). Review of the vector kinematics and dynamics involved in the angular motion of rigid bodies; steady, free and forced precession and general motion of a gyro; stability of a free gyro; the gyrocompass and gyropendulum; gyro angular velocity indicator; the stable platform; Shuler tuning of inertial guidance instruments. TEXTS: Synge *and* Griffith, *Principles of Mechanics (2nd edition);* Wrigley, *Shuler Tuning of Navigational Instruments;* Russell, *Inertial Guidance for Rocket-Propelled Missiles;* Draper, Wrigley *and* Hovorka, *Inertial Guidance.* PREREQUISITE: Mc 102D.

Mc 403B KINEMATICS OF GUIDANCE (3-0). Kinematics and geometry of guidance and interception systems; special coordinates; inertial reference frames; accelerometers; inertial guidance; Dovap; guidance of a ballistic missile and of an interceptor; perturbations and the adjoint differential equations in guidance and optimum control; introductory orbit theory. TEXTS: Locke, *Guidance; USNPGS Notes.* PREREQUISITE: A course in differential equations and Mc 102D.

Mc 404B MISSILE MECHANICS (3-0). A survey of ballistic missile dynamics including discussions of atmospheric structure; standard conditions; drag; stability derivatives; equations of yawing, swerving and angular motion; electronic digital integration of equations of motion; effects of variations from standard conditions; rocket motor thrust and torque; tricyclic motion; aeroballistic range measurements of stability derivatives; contributions of aerodynamic jump and drift to dispersion; dynamic wind tunnel tests; dynamic stability. TEXT: Classroom Notes. PREREQUISITE: A course in dynamics.

Mc 405B ORBITAL MECHANICS (3-0). Review of kinematics. Lagrange's equation of motion. The earth's gravitational field. Contral force motion. The two body problem. The determination of orbits. The three body problem. Perturbations. TEXTS: Thomson, *Introduction to Space Dynamics;* Vinti, *New Methods of Solution for Unretarded Satellite Orbits.* PREREQUISITE: Mc 102D.

DEPARTMENT OF MECHANICAL ENGINEERING

ROBERT EUGENE NEWTON, Professor of Mechanical Engineering; Chairman (1951)*; B.S. in M.E., Washington Univ., 1938; M.S., 1939; Ph.D., Univ. of Michigan, 1951.

DENNIS KAVANAUGH, Professor Emeritus of Mechanical Engineering (1926); B.S., Lehigh Univ., 1914.

JOHN EDISON BROCK, Professor of Mechanical Engineering (1954); B.S.M.E., Purdue Univ., 1938; M.S.E., 1941; Ph.D. Univ. of Minnesota, 1950.

GILLES CANTIN, Associate Professor of Mechanical Engineering (1960); B.A.Sc., Ecole Polytechnique (Montreal), 1950; M.Sc., Stanford Univ., 1960.

VIRGIL MORING FAIRES, Professor of Mechanical Engineering (1958); B.S. in M.E., Univ. of Colorado, 1922; M.S., 1925; M.E., 1926.

ERNEST KENNETH GATCOMBE, Professor of Mechanical Engineering (1946); B.S., Univ. of Maine, 1931; M.S., Purdue Univ., 1939; Ph.D., Cornell Univ., 1944.

CECIL DUDLEY GREGG KING, Associate Professor of Mechanical Engineering (1952); B.E., Yale Univ., 1943; M.S. in M.E., Univ. of California (Berkeley), 1952.

ROY WALTERS PROWELL, Professor of Mechanical Engineering (1946); B.S. in I.E., Lehigh Univ. 1936; M.S. in M.E., Univ. of Pittsburgh, 1943.

PAUL FRANCIS PUCCI, Associate Professor of Mechanical Engineering (1956); B.S. in M.E., Purdue Univ., 1949; M.S. in M.E., 1950; Ph.D., Stanford Univ. 1955.

HAROLD MARSHALL WRIGHT, Professor of Mechanical Engineering (1945); B.Sc. in M.E., North Carolina State College, 1930; M.M.E., Rensselaer Polytechnic Institute, 1931.

* The year of joining the Postgraduate School faculty is indicated in parenthesis.

DEPARTMENTAL REQUIREMENTS FOR DEGREES IN MECHANICAL ENGINEERING

Following is a statement of departmental minimum requirements for degrees in Mechanical Engineering. It is noted that candidates for these degrees must also satisfy general degree requirements as determined by the Academic Council.

BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

a. ENTRANCE REQUIREMENTS. Prior to entering an approved curriculum, a student must have successfully completed college courses as follows: Mathematics through integral calculus, one year of chemistry, and one year of physics. In addition, through completed course work or examination, the student must demonstrate a knowledge of the fundamentals of engineering graphics.

b. MECHANICAL ENGINEERING COURSES. Minimum credit of 65 term hours in mechanical engineering courses is required. These must include the following minimum numbers of term hours in the indicated areas. The minimum acceptable quality point ratio in these courses is 1.0.

Area	*Minimum Term Hours*
Energy Conversion (Includes thermodynamics, gas dynamics, heat transfer, internal combustion engines. Must include a course in power plants.)	18
Applied Mechanics (Includes statics, dynamics, fluid mechanics, and vibrations.)	15
Mechanics of Solids and Machine Design (Includes kinematics of machinery. Must include a course in machine design.)	15

c. OTHER SPECIFIC COVERAGE. The following minimum requirements must be met in each of the indicated disciplines.

MATHEMATICS—One course in each of the following subjects: vector algebra, differential equations, and digital computers.

ELECTRICAL ENGINEERING—15 term hours.

METALLURGY—6 term hours.

Some of these requirements may, with the consent of the department, be met by transfer credit.

d. UPPER DIVISION CREDIT. Minimum credit of 105 term hours in upper division or higher level courses is required.

e. DEPARTMENT APPROVAL. Any program leading to award of this degree must be approved by the department at least 3 terms before completion. In general, approved programs will require more than the minimum degree requirements in order to conform to the needs and objectives of the U.S. Navy.

MASTER OF SCIENCE IN MECHANICAL ENGINEERING

a. UNDERGRADUATE PREPARATION. A candidate shall have satisfied the requirements for the degree Bachelor of Science in Mechanical Engineering. Credit requirements in succeeding paragraphs must be met by courses in addition to those used to satisfy this requirement.

b. MECHANICAL ENGINEERING COURSES. Minimum credit of 20 term hours in A level courses in mechanical engineering is required.

c. COURSES IN OTHER DEPARTMENTS. A minimum of 12 term hours of graduate credit must be earned outside the major department.

d. A LEVEL COURSES. At least 24 term hours of A level courses must be included in the program. Courses used to meet the requirement of paragraph b may also be counted to meet this requirement.

e. THESIS. Completion of a thesis and its acceptance by the department are required. For this a maximum of 8 term hours of graduate credit may be allowed toward satisfaction of the school requirement for 48 term hours. The thesis credit may not be used to satisfy any of the requirements of paragraphs b and d. f. DEPARTMENT APPROVAL. Any program leading to award of this degree must be approved by the department at least 3 terms before completion. In general, approved programs will require more than the minimum degree requirements in order to conform to the needs and objectives of the U.S. Navy.

MECHANICAL ENGINEERING

ME 061D MECHANICS I (4-0). Forces and force systems, moments and couples, resultants, equilibrants, free body diagrams, equilibrium of a free body, simple structures, friction, first and second moments, centroids, basic concepts of kinematics. TEXT: FAIRMAN *and* CUTSHALL, *Engineering Mechanics*. PREREQUISITE: Ma 052D.

ME 062D MECHANICS II (4-0). Newton's laws, d'Alembert's principle, work and energy, impulse and momentum, rocket motion, Kepler's laws, artificial satellites and space vehicles. TEXT: FAIRMAN *and* CUTSHALL, *Engineering Mechanics*. PREREQUISITES. Ma 053D and ME 061D.

ME 111C ENGINEERING THERMODYNAMICS I (5-0). The laws and processes of transforming energy from one form to another; first law analysis; second law analysis and cycle analysis for reversible processes; transient flow; irreversible processes and available energy. Applications to ideal gas cases; internal combustion engines, gas turbines, turbojets, rockets. TEXT: FAIRES, *Thermodynamics*. PREREQUISITE: Ma 230D.

ME 112C ENGINEERING THERMODYNAMICS II (5-0). Continuation of ME 111C. Applications of thermodynamic principles to marine steam power plants; reversed cycles; gas-vapor mixtures; combustion with dissociation problems; general methods of handling imperfect gas problems. TEXT: FAIRES, *Thermodynamics*. PREREQUISITE: ME 111C.

ME 132C ENGINEERING THERMODYNAMICS II (4-2). Continuation of ME 111C. Applications of thermodynamic principles to marine power plant equipment, steam power plants and cycles, refrigeration and heat-pump systems, gas-vapor mixtures, methods of handling imperfect gases. TEXT: FAIRES, *Thermodynamics*. PREREQUISITE: ME 111C.

ME 142C THERMODYNAMICS (4-0). Survey of engineering thermodynamics with emphasis on the application of thermodynamic principles to marine nuclear power plants. Review of first and second laws of thermodynamics, and properties of two phase fluids. Power plant cycles. Steam turbines. Elementary fluid mechanics and heat transfer. TEXT: FAIRES, *Thermodynamics*. PREREQUISITE: PH 530B.

ME 210C APPLIED THERMODYNAMICS (3-2). Continuation of the application of thermodynamic principles, fluid mechanics and the thermodynamics of compressible flow, turbine blading, elements of heat transfer. Complementary laboratory experiments. PREREQUISITE: ME 132C.

ME 211B THERMODYNAMICS OF COMPRESSIBLE FLOW (3-0). The thermodynamic and dynamic fundamentals of compressible fluid flow. One-dimensional analyses including the effects of area change, friction, and heat transfer. TEXT: SHAPIRO, *Thermodynamics and Dynamics of Compressible Fluid Flow, Vol. I*. PREREQUISITES: ME 112C, ME 411C, and Ma 113B.

ME 212A ADVANCED THERMODYNAMICS (3-0). Imperfect gases and other advanced topics in thermodynamics; the mathematical development of property relations and their use with experimental data. TEXT: FAIRES, *Thermodynamics*. PREREQUISITES: ME 112C and Ma 113B.

ME 217B INTERNAL COMBUSTION ENGINES (3-2). Theoretical and real-fuel cycles, combustion processes for spark-ignition and compression-ignition engines. Combustion chambers, carburetion and fuel-injection phenomena. Factors affecting engine performance and design. TEXT: TAYLOR *and* TAYLOR, *Internal Combustion Engines*. PREREQUISITE: ME 112C.

ME 221C GASDYNAMICS AND HEAT TRANSFER (4-2). Fundamentals of one-dimensional compressible fluid flow including effects of area change, friction, and heat addition. Fundamentals of conduction, convection, and radiation heat transfer, including heat exchanger analysis. TEXT: GIEDT, *Principles of Engineering Heat Transfer*. PREREQUISITES: ME 112C and ME 411C.

ME 222C THERMODYNAMICS LABORATORY (1-4). Laboratory experiments applying thermodynamic principles to a gas turbine engine, refrigeration plant, air compressor, compressible flow metering and heat transfer. TEXT: FAIRES, *Thermodynamics*. PREREQUISITES: ME 112C and ME 411C.

ME 223B MARINE POWER PLANT ANALYSIS (2-4). Preliminary planning of marine power plants. Estimation of hull, main engine and auxiliary power requirements, inter-relationship of components, heat balances and flow diagrams, computation of ship and plant performance indices, preliminary investigation of major equipment items. PREREQUISITE: ME 221C or equivalent.

ME 230B MARINE POWER PLANT ANALYSIS (2-4). Preliminary planning of ship propulsion plants. Estimation of hull, main engine and auxiliary power requirements, inter-relationship of components, heat balances, computation of ship and plant performance indices, preliminary investigation of some major equipment items. PREREQUISITE: ME 211C or equivalent.

ME 240B NUCLEAR POWER PLANTS (4-0). Survey of nuclear power engineering. The reactor as a power source as affected by technical feasibility and economics. Elementary nuclear reactor physics. Engineering considerations in core design, including problems of core design, power removal and utilization and shielding. Discussion of reactor types. TEXT: KING, *Nuclear Power Systems*. PREREQUISITES: ME 210C or ME 221C; PH 621B.

ME 241A NUCLEAR PROPULSION SYSTEMS I (4-0). The first of a two course sequence covering engineering aspects of nuclear power reactors. Reactor types, characteristics, and criteria for selection. Advanced heat transfer, fluid mechanics and thermodynamics as applied to characteristic cycles. TEXT: GLASSTONE, *Principles of Nuclear Reactor Engineering*. PREREQUISITES: ME 310B and PH 652A.

ME 242A NUCLEAR PROPULSION SYSTEMS II (3-2). Reactor shielding. Elementary thermal core and plant design. Detailed study of existing reactor plants. TEXT: GLASSTONE, *Principles of Nuclear Reactor Engineering*. PREREQUISITE: ME 241A.

ME 310B HEAT TRANSFER (4-2). The fundamentals of heat transfer mechanisms: one and two dimensional conduction, free and forced convection, condensation, boiling, thermal radiation, transient and periodic systems, and heat exchanger analysis. Use of the thermal circuit, analog, numerical and graphical techniques. TEXT: Kreith, *Principles of Heat Transfer.* PREREQUISITES: ME 112C, ME 412A, and Ma 113B.

ME 411C MECHANICS OF FLUIDS (4-2). Mechanical properties of fluids, hydrostatics, buoyancy and stability analysis. Energy aspects of ideal and real fluid flow, flow metering and control. Impulse-momentum principles and analysis. Dimensional analysis and similitude. Elements of hydrodynamic lubrication. Analysis of fluid machinery and fluid systems. Laboratory experiments and problem work. TEXT: Streeter, *Fluid Mechanics.* PREREQUISITE: Ma 230D.

ME 412A ADVANCED MECHANICS OF FLUIDS (4-2). Potential flow theory. Linearized compressible flow. Oblique shock relations. Viscous flow and boundary layer theory. TEXTS: Shapiro, *Thermodynamics and Dynamics of Compressible Flow, Vols. I and II.* PREREQUISITES: ME 411C, Ma 113B.

ME 501C MECHANICS I (4-0). Laws of statics. Force systems, equilibrium, simple structures, distributed forces, friction, virtual work. Basic concepts of kinematics. TEXT: Beer *and* Johnston, *Vector Mechanics.* PREREQUISITE: Ma 120C (may be concurrent).

ME 502C MECHANICS II (4-0). Kinematics, Newton's laws, kinetics of particles. Work and energy, impulse and momentum. Moment of inertia of mass. Kinetics of rigid bodies. TEXT: Beer *and* Johnston, *Vector Mechanics.* PREREQUISITES: ME 501C and Ma 240C (may be concurrent).

ME 503A ADVANCED DYNAMICS (4-0). Restatement of laws of mechanics. Particle kinetics in different coordinate systems. Effects of earth's rotation. Tensor of inertia. General motion of a rigid body. Gyroscopes. Numerical procedures. Generalized coordinates and Lagrange's equations. TEXTS: Yeh *and* Abrams, *Mechanics of Solids, Vol. I;* Synge *and* Griffith, *Principles of Mechanics.* PREREQUISITE: ME 502C.

ME 504B ADVANCED DYNAMICS (4-0). Restatement of laws of mechanics. Particle kinetics in different coordinate systems. Effects of earth's rotation. Tensor of inertia. General motion of a rigid body. Gyroscopes. Numerical procedures. Generalized coordinates and Lagrange's equations. TEXTS: Yeh *and* Abrams, *Mechanics of Solids, Vol. I;* Timoshenko *and* Young, *Advanced Dynamics.* PREREQUISITE: ME 502C.

ME 510C MECHANICS OF SOLIDS I (4-2). Stress, strain, Hooke's law, tension and compression, shearing stresses, connections, thin vessels, torsion, statics of beams, stresses in beams, deflections of beams, combined loadings and combined stresses, columns. Strain energy, impact, simple indeterminate structures. Supporting laboratory work. TEXT: Timoshenko *and* Young, *Elements of Strength of Materials.* PREREQUISITES: Ma 230C and ME 501C.

ME 511A MECHANICS OF SOLIDS II (5-0). Further elastic analysis of statically indeterminate structures, beam columns, curved beams, unsymmetrical bending, shear center, beams on elastic foundations, plates and shells, thick-walled cylinders, rotating discs, and elementary thermal stresses. TEXTS: Timoshenko, *Strength of Materials, Vols. I and II.* PREREQUISITES: ME 510C and Ma 240C.

ME 512A MECHANICS OF SOLIDS III (4-0). Elements of theory of elasticity. Stress tensor and theories of failure. Torsion of non-circular sections. Plastic analysis. Matrix methods in structural analysis. Brittle fracture. TEXTS: Timoshenko, *Strength of Materials, Vol. II;* Timoshenko *and* Goodier, *Theory of Elasticity;* Parker, *Brittle Behavior of Engineering Structures.* PREREQUISITES: Ma 113B and ME 511A.

ME 521C MECHANICS OF SOLIDS II (4-0). Statically indeterminate problems in bending, symmetrical beams of variable cross section, beams of two materials, unsymmetrical bending, thick-walled cylinders, rotating disks, curved bars, beams with combined axial and lateral loads. TEXTS: Timoshenko, *Strength of Materials, Vols. I and II.* PREREQUISITES: ME 510C and Ma 240C.

ME 522B MECHANICS OF SOLIDS III (4-0). Stress concentration, deformations beyond the elastic limit, mechanical properties of materials, strength theories, impact, fatigue, torsion of non-circular sections, thin plates and shells. TEXT: Timoshenko, *Strength of Materials, Vol. II.* PREREQUISITE: ME 521C.

ME 547C STATICS AND STRENGTH OF MATERIALS (5-0). Review of principles of statics, statics of determinate structures, pin-connected trusses. Stress, strain, Hooke's law, tension and compression, shearing stresses. Connections, thin vessels, torsion. Statics of beams, flexural stresses and deformations, numerical procedures. Simple indeterminate structures. Combined loadings and combined stresses. Columns. TEXT: Timoshenko *and* Young, *Elements of Strength of Materials.* PREREQUISITE: PH 151C.

ME 548B STRUCTURAL THEORY (5-0). Fundamental concepts. Stability and determinacy of simple trusses and frames. Space frames. Hyperstatic structures. Energy methods. Slope deflection and moment distribution. Dynamic disturbance. Systems with one, two and many degrees of freedom. TEXTS: McCormac, *Structural Analysis;* Rogers, *Dynamics of Framed Structures.* PREREQUISITES: ME 547C and Ma 240C.

ME 561C MECHANICS I (4-0). Forces and force systems, moments and couples, resultants, equilibrants, free body diagrams, equilibrium of a free body, simple structures, friction, first and second moments, centroids, basic concepts of kinematics. TEXT: Meriam, *Mechanics.* PREREQUISITE: Ma 052D.

ME 562C MECHANICS II (4-0). Newton's laws, d'Alembert's principle, work and energy, impulse and momentum, rocket motion, Kepler's laws, artificial satellites and space vehicles. TEXT: Meriam, *Mechanics.* PREREQUISITES: ME 561C and Ma 053D.

ME 612A EXPERIMENTAL MECHANICS (3-2). Fundamentals of mechanical measurements, resistance strain gages, transducers and instrumentation systems, dynamic response characteristics, brittle lacquer, photoelasticity, analog methods, model theory. Complementary laboratory experiments. TEXTS: Beckwith *and* Buck, *Mechanical Measurements;* Perry *and* Lissner, *Strain Gage Primer;* Lee, *An Introduction to Experimental Stress Analysis.* PREREQUISITES: ME 512A and ME 712A.

ME 622B EXPERIMENTAL MECHANICS (2-2). Fundamentals of mechanical measurements, resistance strain gages, transducers and instrumentation systems, dynamics response characteristics. Complementary laboratory experiments. TEXTS: BECKWITH *and* BUCK, *Mechanical Measurements;* PERRY *and* LISSNER, *Strain Gage Primer.* PREREQUISITES: ME 522B and ME 722B.

ME 711B MECHANICS OF MACHINERY (3-2). Algebraic analysis of the motion of cam followers; design of cams. Velocities and acceleration of machine parts. Kinematics of gearing. Synthesis. Dynamic forces on machine members. TEXT: FAIRES, *Kinematics.* PREREQUISITE: ME 502C.

ME 712A MECHANICAL VIBRATIONS (3-2). Undamped and damped, free and forced vibrations for one, two and many degrees of freedom. Vibration isolation and absorbers. Instrumentation. Methods of Rayleigh, Stodola, Holzer. Applications to multi-cylinder engines. Laboratory experiments illustrate basic principles of vibration and its control. TEXTS: DEN HARTOG, *Mechanical Vibrations;* THOMSON, *Mechanical Vibrations,* PREREQUISITES: Ma 280B, ME 711B and ME 511A.

ME 713A ADVANCED DYNAMICS OF MACHINERY (3-0). Special topics such as: shock and vibration mounts, torsional vibrations of crank shafts, vibration absorbers, special bearings, gear lubrication, sleeve bearings with pulsating loads, oil film whirl, turbine blade vibrations, nonlinear vibration problems. Additional matrix methods. TEXTS: DEN HARTOG, *Mechanical Vibrations;* KARMAN *and* BIOT, *Mathematical Methods in Engineering.* PREREQUISITE: ME 712A.

ME 722B MECHANICAL VIBRATIONS (3-2). Free and forced vibrations, with and without damping for one, two and many degrees of freedom. Vibration isolation and absorbers, torsional vibration, instrumentation. Laboratory experiments illustrate basic principles of vibration and its control. TEXTS: DEN HARTOG, *Mechanical Vibration;* THOMSON, *Mechanical Vibrations.* PREREQUISITES: Ma 113B, ME 711B and ME 521C.

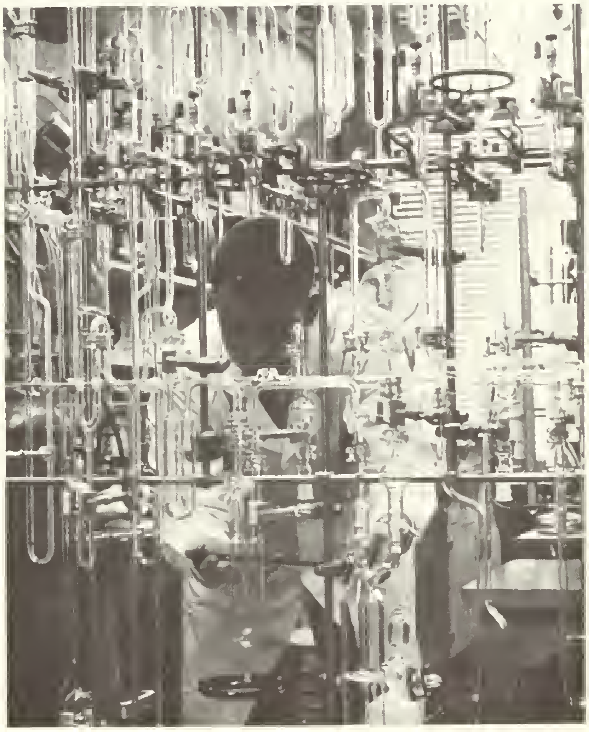
ME 811B MACHINE DESIGN I (3-2). First of a two-course sequence. Studies of fits, tolerances, allowances, material selection, stress concentration, bearings, shafting, screws, belts, chains, brakes, clutches and cams. TEXT: FAIRES, *Design of Machine Elements.* PREREQUISITES: ME 512A and ME 711B.

ME 812B MACHINE DESIGN II (3-4). Continuation of ME 811B; springs, gearing, and advanced design problems. Machine design projects of a comprehensive nature. TEXT: FAIRES, *Design of Machine Elements.* PREREQUISITES: ME 811B and ME 712A.

ME 820C MACHINE DESIGN (2-4). Studies of fits, tolerances, allowances, stress concentration, material selection, bearings, gears, shafting, cams, springs, screws, brakes and clutches. TEXT: FAIRES, *Design of Machine Elements.* PREREQUISITES: ME 522B and ME 711B.

ME 900A ADVANCED TOPICS IN MECHANICAL ENGINEERING (4-0). Investigation of selected advanced Mechanical Engineering topics. PREREQUISITE: Department approval.

ME 910E NAVAL ARCHITECTURE SEMINAR (3-0). Seminar discussions of various phases of naval architecture. Typical discussion subjects will be: drydocking, launching procedures and calculations, elements of ship resistance, action of ship propulsion devices, hull efficiencies and some aspects of small craft design. PREREQUISITE: ME 223B or ME 230B.



CHEMISTRY LABORATORY

DEPARTMENT OF METALLURGY AND CHEMISTRY

GILBERT FORD KINNEY, Professor of Chemical Engineering; Chairman (1942)*; A.B., Arkansas College, 1928; M.S., Univ. of Tennessee, 1930; Ph.D., New York Univ., 1935.

NEWTON WEBER BUERGER, Professor of Metallurgy (1942); B.S., Massachusetts Institute of Technology, 1933; M.S., 1934; Ph.D., 1939.

PETER MCLAUCHLIN BURKE, Assistant Professor of Metallurgy (1960); B.S., Stanford University, 1956; M.S., 1957.

JOHN ROBERT CLARK, Professor of Metallurgy (1947); B.S., Union College, 1935; Sc.D., Massachusetts Institute of Technology, 1942.

JOHN HENRY DUFFIN, Associate Professor of Chemical Engineering (1962); B.S., Lehigh University, 1940; Ph.D., Univ. of California, 1959.

ALFRED GOLDBERG, Associate Professor of Metallurgy (1953); B.Eng., McGill Univ., 1946; M.S., Carnegie Institute of Technology, 1947; Ph.D., Univ. of California, 1955.

WILLIAM WISNER HAWES, Professor of Metallurgy and Chemistry (1952); B.S., Ch.E., Purdue Univ., 1924; Sc.M., Brown Univ., 1927; Ph.D., 1930.

CARL ADOLPH HERING, Professor of Chemical Engineering (1946); B.S., Oregon State College, 1941; M.S., Cornell Univ., 1944.

GEORGE DANIEL MARSHALL, JR., Professor of Metallurgy (1946); B.S., Yale Univ., 1930; M.S., 1932.

GEORGE HAROLD MCFARLIN, Professor of Chemistry (1948); B.A., Indiana Univ., 1925; M.A., 1926.

C. DEAN NEWNAN, JR., Lieutenant Commander, U.S. Naval Reserve (1963); B.S., Univ. of California, 1943; B.S., in Ch.E., Univ. of Illinois, 1947.

ROBERT HUDSON RANDALL, Lieutenant Junior Grade, U.S. Naval Reserve (1963); B.A., Los Angeles State College, 1960.

RICHARD ALAN REINHARDT, Associate Professor of Chemistry (1954); B.S., Univ. of California, 1943; Ph.D., 1947.

MELVIN FERGUSON REYNOLDS, Professor of Chemistry (1946); B.S., Franklin and Marshall College, 1932; M.S., New York Univ., 1935; Ph.D., 1937.

CHARLES FREDERICK ROWELL, Assistant Professor of Chemistry (1962); B.S., Syracuse Univ., 1956; M.S., Iowa State Univ., 1959; Ph.D., Oregon State Univ., 1964.

CHARLES DAVID SCHMULBACH, Lieutenant, U.S. Naval Reserve, Visiting Assistant Professor of Chemistry (1963); B.S., Univ. of Illinois, 1951; Ph.D., 1958.

JOHN WILFRED SCHULTZ, Associate Professor of Chemistry (1958); B.S., Oregon State College, 1953; Ph.D., Brown Univ., 1957.

JAMES EDWARD SINCLAIR, Associate Professor of Chemistry (1946); B.S., Ch.Eng., Johns Hopkins Univ., 1945; M.S., USNPGS, 1956.

GLENN HOWARD SPENCER, Associate Professor of Chemistry (1962); B.S., Univ. of California, 1953; Ph.D., Univ. of Washington, 1958.

WILLIAM MARSHALL TOLLES, Assistant Professor of Chemistry (1962); B.A., Univ. of Connecticut, 1958; Ph.D., Univ. of California, 1962.

JAMES WOODROW WILSON, Professor of Chemical Engineering (1949); B.A., Stephen F. Austin State, 1935; B.S., in Ch.E., Univ. of Texas, 1939; M.S., in Ch.E., Texas A. and M. College, 1941.

*The year of joining the Postgraduate School faculty is indicated in parentheses.

DEPARTMENTAL REQUIREMENTS FOR DEGREES IN CHEMISTRY

BACHELOR OF SCIENCE IN CHEMISTRY

1. A specific curriculum should be consistent with the general minimum requirements for a Bachelor of Science degree as determined by the Academic Council.

2. A major in chemistry should include a minimum of 54 term hours in chemistry (of which 11 term hours are elective), 21 term hours of physics (through general and modern physics), 18 term hours of mathematics (through calculus), and 15 term hours of elective upper division courses in engineering, mathematics, or science (including chemistry). At least 108 of the term hours must be of upper division level.

3. The following specific requirements must be met. Courses marked with an asterisk must include laboratory work.

Discipline	*Subject*	*Approximate Term Hours*
Chemistry	General*	8
	Inorganic*	5
	Analytical*	4
	Organic*	12
	Physical*	14
		43
Physics	General*	16
	Modern (Atomic)	5
		21
Mathematics	College Algebra & Trigonometry	5
	Analytical Geometry & Calculus	13
		18

4. The 11 elective term hours in chemistry must be fulfilled by taking at least upper division courses in chemistry or chemical engineering.

5. In addition to the general requirement of an overall 1.0 grade point average, an overall chemistry grade point average of 1.0 is required.

MASTER OF SCIENCE IN CHEMISTRY

1. To obtain the degree, Master of Science in Chemistry, the student must have completed work equivalent to the following: Two terms of General Chemistry, one term of Intermediate Inorganic Chemistry or Inorganic Qualitative Analysis, one term of Quantitative or Instrumental Analysis, one term of Thermodynamics, two terms of Physical Chemistry, three terms of

Organic Chemistry, one term of Elementary Differential Equations and four terms of Physics.

2. In addition the student must successfully complete the following:

a. One course at the A level in each of the following areas: Chemical Thermodynamics, Inorganic Chemistry, Physical-Organic Chemistry, and Quantum Chemistry. Minimum Total term hours—12.

b. Two or more courses at the A level in the general area chosen for specialization. These courses must have a total of not less than six term hours of lecture and must be approved by the Department of Metallurgy and Chemistry. Minimum Total term hours—6.

c. A thesis demonstrating ability to perform independent and original work.

d. Sufficient supporting courses in science, mathematics and engineering to meet school requirements.

MASTER OF SCIENCE IN MATERIALS SCIENCE

1. The following is a statement of departmental minimum requirements for the degree of Master of Science in Materials Science. It is noted that the candidates for this degree must also satisfy the general degree requirements determined by the Academic Council. A candidate shall previously have satisfied the requirements for a Bachelor's degree with a major in science or engineering. Credit requirements in succeeding paragraphs must be met by courses in addition to those used to satisfy this requirement.

2. A minimum credit of 20 term hours in A level courses in Materials Science is required. These shall include at least one course each in the areas of metals, of ceramics, and of plastics. A minimum of 12 term hours of graduate credit must be earned outside the major department. A total of at least 24 term hours of A level courses must be included in the program.

3. Completion of a thesis and its acceptance by the department are required. A maximum of eight term hours of graduate credit may be allowed towards satisfaction of the School requirement for 48 term hours, but the thesis credit may not be used to satisfy the requirements of paragraph 2.

4. Any program leading to award of this degree must be approved by the Department of Metallurgy and Chemistry at least three terms before completion. In general, approved programs will require more than minimum degree requirements in order to conform to the needs and objectives of the United States Navy.

CHEMICAL ENGINEERING

EC 105C AEROMATERIALS (3-2). Review of selected principles in inorganic, organic and physical chemistry and their application to problems in aero materials. TEXT: Popovich *and* Hering, *Fuels and Lubricants*. PREREQUISITE: None.

EC 112A FUELS, COMBUSTION, HIGH TEMPERATURE THERMODYNAMICS (3-2). A brief survey of the organic and physical chemistry necessary for a study of the problems associated with fuels. The nature of conventional fuels and of high-energy fuels, their limitations, and possible future development. Also methods of reaction rate control. TEXTS: Popovich *and* Hering, *Fuels and Lubricants*, and Penner, *Chemical Problems in Jet Propulsion*. PREREQUISITES: Physical Chemistry and Thermodynamics.

EC 113A PROPELLANTS AND FUELS (3-2). This course deals with special topics and problems of current interest in rocket propellants, liquid fuels and nuclear fuels as related to propulsion. TEXT: *Assigned reading in current journals*. PREREQUISITE: EC 542.

EC 122D FUEL AND OIL CHEMISTRY (4-2). A study of fuels and lubricants from an engineering aspect. Topics discussed include combustion and lubrication theory, properties of fuels and lubricants and occurrence and refining of petroleum. TEXT: Popovich *and* Hering, *Fuels and Lubricants*.

EC 521A PLASTICS AND HIGH POLYMERS (3-2). A study of the general nature of plastics and high polymers, their applications and limitations as engineering materials. Also, correlation between properties and chemical structure. In the laboratory plastics are made, molded, tested and identified. TEXT: Kinney, *Engineering Properties and Applications of Plastics*. PREREQUISITE: Ch 103 or Ch 107.

EC 542A REACTION MOTORS (3-2). A study of the fundamentals of Rocket Motors. The subject matter includes the basic mechanics of Jet Propulsion engines, properties of solid and liquid propellants, the design and performance parameters of rocket motors. In the laboratory periods representative problems are solved. TEXT: Sutton, *Propulsion Elements*. PREREQUISITE: EC 611 or consent of instructor.

EC 543A ROCKET PROPELLANTS (2-0). A study of solid and liquid rocket propellants and their ballistic, chemical and physical properties. PREREQUISITE: EC 542A.

EC 544A ROCKET MOTOR LAB. (0-3). Laboratory work in reaction motors illustrating and applying principles that were presented in EC 542A. Experiments include the static firing of rocket motors and the analysis of the data, combustion and burning rate studies on propellants, evaluation of propellant characteristics, the formulation of small amounts of solid propellants. PREREQUISITE: EC 542A.

EC 571A EXPLOSIVES CHEMISTRY (3-2). Chemical and physical properties of explosives are related to modes of behavior and physical principles of use. Basic principles of testing and evaluation of explosives. Trends in new developments are surveyed. Independent exploratory work in the laboratory in such areas as manner of initiation, sensitivity, brisance, power, heats of explosion and combustion. TEXT: Cook, *Science of High Explosives*. PREREQUISITES: Thermodynamics and Physical Chemistry.

EC 591A BLAST AND SHOCK EFFECTS (3-0). Generation of blast and shock waves by explosions, propagation of shock waves in air, scaling laws for explosions, shock and blast loads on structures, damage and damage mechanisms, thermal and ionizing radiation effects, principles of protection against damage. TEXT: Kinney, *Shocks in Air*. PREREQUISITES: Physical Chemistry and Thermodynamics.

EC 611C GENERAL THERMODYNAMICS (3-2). A treatment of the laws of classical thermodynamics with emphasis on the analysis of processes by use of the thermodynamic state functions. Applications are made to simple systems, but principles developed provide a foundation for specialized material. TEXTS: ZEMANSKY, *Heat and Thermodynamics,, 4th Ed.*; KIEFER, KINNEY *and* STUART, *The Principles of Engineering Thermodynamics.* PREREQUISITES: Ch 107 or Ch 103.

EC 614A ADVANCED ENGINEERING THERMODYNAMICS (3-2). Thermodynamic properties of real (non-ideal) gases, the application of thermodynamic methods to the analysis of processes involving non-conventional fluids, the construction and use of thermodynamic diagrams for non-ideal gases and mixtures. TEXTS: WEBER *and* MEISSNER, *Thermodynamics for Chemical Engineers;* KIEFER, KINNEY *and* STUART, *The Principles of Engineering Thermodynamics.* PREREQUISITE: EC 611C or equivalent.

EC 624A THERMODYNAMICS OF COMPRESSIBLE FLOW (3-2). The subject matter includes a thermodynamic analysis of different types of flow and shock front behavior. In the lab period representative flow problems are solved and a flow chart for the adiabatic shock in the flow of an ideal gas is constructed. TEXT: KIEFER, KINNEY *and* STUART. *Principles of Engineering Thermodynamics.* PREREQUISITE: EC 611C or equivalent.

EC 711B CHEMICAL ENGINEERING CALCULATIONS (3-2). Engineering problems involving mass and energy relations in chemical and physical-chemical processes. TEXT: HOUGEN, ETC., *Chemical Process Principles, Part I.* PREREQUISITE: Ch 103 or Ch 107.

EC 721B UNIT OPERATIONS I (3-2). An introduction to the study of the unit operations of chemical engineering. Selection of and primary emphasis on particular unit operations will be made on the basis of current student specialties. TEXT: SMITH *and* McCABE, *Unit Operations of Chemical Engineering.* PREREQUISITE: Physical Chemistry.

EC 722B UNIT OPERATIONS II (3-2). A continuation of EC 721B with emphasis on mass transfer operation. TEXT: SMITH *and* McCABE, *Unit Operations of Chemical Engineering.* PREREQUISITE: EC 721B.

EC 741A HEAT TRANSFER (3-2). The fundamentals of heat transfer by conduction, convection and radiation and their application to problems in ordnance. In the laboratory periods problems illustrating these principles are solved. TEXTS: SCHENCK, *Heat Transfer Engineering;* McADAMS, *Heat Transmission.* PREREQUISITE: Consent of instructor.

EC 750A APPLIED MATHEMATICS IN CHEMICAL ENGINEERING (3-2). The differential equations describing various chemical engineering processes are derived and solved using analytic and numeric techniques. Electronic computers will be used to obtain solutions to problems. TEXT: SHERWOOD, MICKLEY *and* REED, *Applied Mathematics in Chemical Engineering.* PREREQUISITE: EC 721B.

EC 760A CHEMICAL ENGINEERING KINETICS (3-2). Rate equations are postulated for various chemical reactions and the application of these equations studied using electronic computers. Chemical reactors will be designed using rate equations obtained. Design variations will be studied by using computers. TEXT: SMITH, *Chemical Engineering Kinetics.* PREREQUISITE: EC 721B.

EC 770A PROCESS CONTROL FOR CHEMICAL ENGINEERS (3-2). Various control elements used in chemical plants are studied, their differential equations set up and their response to transient and periodic inputs determined. The equations of combinations of control elements are set up and studied for their response behavior using feedback. TEXT: ECKMAN, *Automatic Process Control.* PREREQUISITE: EC 721B.

CHEMISTRY

CH 001D INTRODUCTORY GENERAL CHEMISTRY I (4-3). The first term of a two term course in elementary chemistry for students who have not had college chemistry. A study of the principles which govern the physical and chemical behavior of matter with sufficient descriptive chemistry to illustrate these principles. Laboratory experiments will be related to the lecture material. TEXTS: SIENKO *and* PLANE, *Chemistry;* RITTER, *An Introductory Laboratory Course in Chemistry.*

CH 002D INTRODUCTORY GENERAL CHEMISTRY II (3-3). The second term of the sequence described under CH 001D. Particular emphasis on the properties of compounds as related to the periodic table is used to organize the study. PREREQUISITE: CH 001D.

CH 103D GENERAL CHEMISTRY (4-2). A survey of the principles governing the chemical behavior of matter. Descriptive chemistry is limited almost entirely to the compounds of carbon on the assumption that students will have had college chemistry. TEXT: PAULING, *General Chemistry.* PREREQUISITE: College Chemistry.

CH 106D PRINCIPLES OF CHEMISTRY I (3-2). The first course of a two-term sequence. A study of the fundamental principles of chemistry governing the physical and chemical behavior of matter. Current theories of atomic structure and chemical bonding are particularly emphasized. Also studied are the states of matter, chemical kinetics, and chemical equilibria. Elementary physical chemistry experiments are performed in the laboratory. TEXT: SIENKO *and* PLANE, *Chemistry.* PREREQUISITE: College Chemistry.

CH 107D PRINCIPLES OF CHEMISTRY II (3-2). A continuation of CH 106D. The principles of chemistry are applied to the study of the chemical properties of the elements and their compounds. Special attention is given to the compounds of carbon. Laboratory experiments are used to illustrate the chemical behavior of matter. TEXT. SIENKO *and* PLANE, *Chemistry.* PREREQUISITE: CH 106D.

CH 108C INORGANIC CHEMISTRY (3-4). An intensive treatment at an intermediate level of the chemistry of the common ions in aqueous solution. The course will supplement general chemistry and will emphasize facility in the use of equilibria, kinetics, and structure in correlating the chemistry of the more familiar elements. TEXTS: CLIFFORD, *Inorganic Chemistry of Qualitative Analysis;* KING, *Qualitative Analysis and Electrolytic Solutions.* PREREQUISITE: CH 107D.

CH 109D GENERAL AND ORGANIC CHEMISTRY (3-2). This course provides a continuation of the chemical principles begun in CH 106D and also provides the minimal coverage of organic chemistry for students who will take courses in biology. TEXTS: Sienko *and* Plane, *Chemistry;* Hart *and* Schuetz, *A Short Course in Organic Chemistry.* PREREQUISITE: CH 106D.

CH 150A INORGANIC CHEMISTRY, ADVANCED (4-3). Applications of thermodynamics, chemical kinetics, and reaction mechanisms to inorganic systems. Structures of inorganic species. Aqueous solution chemistry of selected elements. A systematic approach to the chemistry of the halogens is studied in the laboratory. TEXT: Gould, *Inorganic Reactions and Structure.* PREREQUISITES: CH 108C; CH 231C; CH 444B (may be taken concurrently).

CH 231C QUANTITATIVE ANALYSIS (2-4). A study of the principles and calculations of quantitative analysis, accompanied by typical volumetric and gravimetric determinations in the laboratory. TEXT: Pierce *and* Haenisch, *Quantitative Analysis.* PREREQUISITE: CH 107D.

CH 302C SURVEY OF ORGANIC CHEMISTRY (4-2). A brief introduction to organic substances and their reactions, accompanied by the preparation of some representative examples. TEXT: Hart *and* Schuetz, *A Short Course in Organic Chemistry.* PREREQUISITE: CH 107D.

CH 311C ORGANIC CHEMISTRY I (3-2). The first term of a three-term study of the chemistry of organic compounds with appropriate laboratory supplementation. TEXT: Cram *and* Hammond, *Organic Chemistry.* PREREQUISITE: CH 107D.

CH 312C ORGANIC CHEMISTRY II (3-2). A continuation of CH 311C. The study of organic chemistry is pursued further with the emphasis in the laboratory on synthetic techniques. TEXT: Cram *and* Hammond, *Organic Chemistry.* PREREQUISITE: CH 311C.

CH 313B ORGANIC CHEMISTRY III (3-2). The final term in a three-term sequence. The discussion of organic chemistry is extended to the areas of current advances in both organic and biochemistry as applications of the material in the two earlier terms. PREREQUISITE: CH 312C or the permission of the instructor.

CH 320A ADVANCED ORGANIC CHEMISTRY I (3-2). First of a two-term sequence in which modern synthetic techniques are discussed and the application of kinetic and steric control considered. PREREQUISITE: CH 313B.

CH 321A ADVANCED ORGANIC CHEMISTRY II (3-2). Continuation of CH 320A. PREREQUISITE: CH 320A.

CH 323A THE CHEMISTRY OF HIGH POLYMERS (3-0). A treatment of the principal classes of natural and synthetic high polymers, including preparation, structure, and properties. TEXT: Golding, *Polymers and Resins.* PREREQUISITE: CH 313B.

CH 324A QUALITATIVE ORGANIC CHEMISTRY (2-4). Identification of organic compounds on the basis of physical properties, solubility, classification reactions, and the preparation of derivatives. TEXT: Shriner, Fuson *and* Curtin, *Identification of Organic Compounds.* PREREQUISITE: CH 313B.

CH 325A QUANTITATIVE ORGANIC ANALYSIS (1-4). The quantitative estimation of organic compounds based on the use of reactions of the functional groups. TEXT: Fritz *and* Hammond, *Quantitative Organic Chemistry.* PREREQUISITE: CH 313B.

CH 327A NATURAL PRODUCTS (4-0). A limited introduction to the chemistry of steroids, terpenes, and alkaloids, with emphasis on the role of stereochemistry in the physiological and chemical properties of these systems. TEXT: Fieser *and* Fieser, *Steroids.* PREREQUISITE: CH 313B.

CH 328A PHYSICAL ORGANIC CHEMISTRY I (4-0). First term of a two-term sequence. In this term the tools available for the study of organic mechanisms are discussed and appropriate examples used. PREREQUISITE: CH 313B.

CH 329A PHYSICAL ORGANIC CHEMISTRY II (3-0). The techniques discussed in CH 328A are used in the study of organic reaction mechanisms as currently understood. PREREQUISITE: CH 328A.

CH 405B PHYSICAL CHEMISTRY (4-2). Not open to students who have had a course in thermodynamics at the USNPGS. A survey course, including such topics as properties of matter, thermochemistry, chemical equilibria, kinetics. TEXTS: Daniels *and* Alberty, *Physical Chemistry;* Daniels, *et al., Experimental Physical Chemistry.* PREREQUISITE: CH 107D or CH 103D.

CH 407B PHYSICAL CHEMISTRY (3-2). A one-term course in physical chemistry for students who have had thermodynamics. Gases, liquids, solids, solutions, thermochemistry, chemical equilibria and kinetics are studied. TEXTS: Daniels *and* Alberty, *Physical Chemistry;* Daniels, *et al., Experimental Physical Chemistry.* PREREQUISITES: CH 107D or CH 103D; and one term of thermodynamics.

CH 443B PHYSICAL CHEMISTRY I (4-3). The first term of a two-term sequence in physical chemistry. The sequence will include such topics as properties of matter, thermochemistry, chemical thermodynamics, chemical equilibria, kinetics, and electrochemistry. TEXTS: Daniels *and* Alberty, *Physical Chemistry;* Daniels, *et al., Experimental Physical Chemistry.* PREREQUISITES: CH 107D, EC 611.

CH 444B PHYSICAL CHEMISTRY II (3-3). The second term of the sequence begun by CH 443B. PREREQUISITE: CH 443B.

CH 454B INSTRUMENTAL METHODS OF ANALYSIS (3-3). A course designed to familiarize the student with modern instrumental techniques of chemical analysis. Emphasis is given to the theoretical basis of the various kinds of measurements made in the laboratory and the principles involved in the design and construction of analytical instruments. Laboratory experiments will deal with representative analytical problems. TEXT: Willard, Merritt *and* Dean, *Instrumental Methods of Analysis.* PREREQUISITE: CH 444B.

CH 464A ELECTROCHEMISTRY (3-0). A detailed treatment of modern electrochemistry and the structure of solutions. TEXT: Robinson *and* Stokes, *Electrolyte Solutions*. PREREQUISITE: CH 444B.

CH 466A CHEMICAL KINETICS (3-0). Experimental methods and interpretation of data. Mechanisms of reactions. Collision theory and activated-complex theory. TEXT: Frost *and* Pearson, *Kinetics and Mechanism*. PREREQUISITE: CH 444B.

CH 467A QUANTUM CHEMISTRY I (3-0). A study of the fundamental principles governing the quantum behavior of matter. Topics will include the Heisenberg uncertainty principle, the Pauli exclusion principle, and the use of quantum mechanics in describing the electronic structures of atoms and simple molecular systems. TEXT: Pauling *and* Wilson, *Introduction to Quantum Mechanics*. PREREQUISITE: CH 444B.

CH 468A QUANTUM CHEMISTRY II (3-0). The application of quantum mechanics to polyatomic molecules. Use will be made of valence-bond and molecular-orbital methods along with group theory in constructing approximate wave functions for describing typical molecular systems. The discussion will extend to current journal articles. PREREQUISITE: CH 467A.

CH 469A QUANTUM CHEMISTRY III (3-0). The application of quantum chemistry to prediction of molecular structure; theoretical and experimental methods. Modern uses of ultraviolet, visible, infrared, microwave, electron paramagnetic resonance, and nuclear magnetic resonance spectra. PREREQUISITE: CH 468A.

CH 470A CHEMICAL THERMODYNAMICS (3-0). Application of thermodynamics to real gases, non-electrolytes, electrolytic solutions, multicomponent solutions. Calculations of equilibria, estimation of thermodynamic quantities and brief discussion of calculations of thermodynamic properties from spectroscopic and other molecular data. TEXT: Lewis *and* Randall, *Thermodynamics, 2nd Ed*. PREREQUISITES: EC 611 and CH 444B.

CH 540A NUCLEAR CHEMISTRY I (3-0). An introduction to the reactions of nuclei. Behavior and properties of unstable species. TEXT: Friedlander *and* Kennedy, *Nuclear and Radiochemistry*. PREREQUISITE: CH 150.

CH 541A NUCLEAR CHEMISTRY II (3-4). A continuation of CH 540A with emphasis on techniques peculiar to chemical studies of radioactive materials; methods of isolation, purification and analysis of mixtures. TEXT: Friedlander *and* Kennedy, *Nuclear and Radiochemistry*. PREREQUISITE: CH 540A.

CH 551A RADIOCHEMISTRY I (2-4). Discussion of important aspects of radioactivity from standpoint of the chemical transformations which accompany it and which it may induce; techniques for measurement and study of ionizing radiation; methods of separation of unstable nuclides, identification and assay. TEXT: Friedlander *and* Kennedy, *Nuclear and Radiochemistry*. PREREQUISITES: CH 109D or CH 107D; and PH 638.

CH 552A RADIOCHEMISTRY II (3-4). A discussion of chemical properties and behaviors of unstable elements. Topics considered are the formation and decay schemes of the more important unstable nuclides, methods of isolation and purification and analysis of mixtures; exchange reactions; chemical reactions that take place in consequence of nuclear reactions. TEXT: Friedlander *and* Kennedy, *Nuclear and Radiochemistry*.

CH 553B RADIOCHEMISTRY (2-3). A descriptive course with emphasis on nuclear reactions. The laboratory includes detection techniques and activation analysis employing the nuclear reactor. PREREQUISITE: NONE.

CH 554A RADIOCHEMISTRY, ADVANCED (2-3). An advanced course in radiochemical techniques and applications offered to well-qualified students only. Experiments in analysis of complex mixtures of active nuclides; activation analysis. Consent of the instructor required. PREREQUISITE: CH 551A or CH 541A.

CH 580A APPLIED ELECTROCHEMISTRY (3-2). Basic principles of electrochemistry. Electrolytic solutions, half-cell reactions, practical aspects of primary and secondary cells. Not open to students who have completed CH 444B. TEXTS: Daniels *and* Alberty, *Physical Chemistry*; Vinal, *Storage Batteries*. PREREQUISITE: CH 405B or CH 407B.

CH 581A PROPERTIES OF CERAMIC MATERIALS (4-0). Occurrence, syntheses and properties of ceramic raw materials. Kinetic and phase equilibrium principles underlying the production of ceramics and glasses. Structure of typical ceramics and glasses. TEXT: Kingery, *Introduction to Ceramics*. PREREQUISITES: Physical Chemistry and Thermodynamics.

CH 800A CHEMISTRY SEMINAR (0-1). A departmental program in which invited speakers and resident faculty speak on current topics in chemistry and related areas. Mature students may be assigned topics from the literature or may be requested to report on their research. PREREQUISITE: Consent of the Instructor.

CH 850A SPECIAL TOPICS IN CHEMISTRY (Credit to be arranged). Pursuit of deeper understanding of some topic chosen by the student and the instructor; may involve directed reading and conference or a lecture pattern. May be repeated for credit with a different topic. PREREQUISITE: Permission of the Instructor.

CH 900E RESEARCH (0-2 to 0-10). Experimental investigation of original problems. PREREQUISITE: Consent of the professor in charge.

CRYSTALLOGRAPHY

Cr 271A CRYSTALLOGRAPHY AND X-RAY TECHNIQUES (3-2). The essential concepts of crystallography, the stereographic projection, modern x-ray diffraction and radiographic apparatus and techniques, the theory of x-ray diffraction, high temperature diffraction techniques. The laboratory work includes a study of crystal models for symmetry, forms, and combinations; the construction of stereographic projections; and actual practice in making and interpreting of x-ray diffraction photographs. TEXTS: Buerger, *Elementary Crystallography*; Azaroff *and* Buerger, *The Powder Method*. PREREQUISITE: CH 107D.

Cr 301B CRYSTALLOGRAPHY AND MINERALOGY (3-4). Designed primarily for the student who will continue with courses in mineralogy, geology, and petrology. The student is introduced to the fundamental concepts of crystallography, the stereographic projection, the theory of x-ray diffraction, and the application of x-ray powder methods as applied to identification of minerals. The laboratory work includes a study of crystal models, construction of stereographic projections, and determination of minerals by x-ray powder diffraction patterns. TEXT: Rogers, *Introduction to the Study of Minerals*. PREREQUISite: CH 107D.

GEOLOGY

Ge 101C PHYSICAL GEOLOGY (3-2). The study of the various geological phenomena. Topics discussed are: rock-forming minerals; igneous, sedimentary, and metamorphic rocks; weathering and erosion; stream sculpture; glaciation; surface and sub-surface waters; volcanism, dynamic processes; structural geology; and interpretation of topographic maps. The course stresses those topics of particular interest to the petroleum engineer. TEXT: Gilluly, *Principles of Geology*. PREREQUISITE: None.

Ge 201B CRYSTALLOGRAPHY AND GEOLOGY (3-0). A course directed towards the specific needs of the nuclear engineering groups. About half the time is spent on modern concepts of crystallography including atomic bonding, lattices, point groups, space lattices, x-ray diffraction theory and techniques, polymorphism and isomorphism. Minerals, rocks, and physical geology are then covered with special emphasis on dyamic principles and seismology. TEXTS: Dana *and* Hurlbut, *Manual of Mineralogy;* Gilluly, *Principles of Geology*. PREREQUISITES: PH 240; PH 635; CH 405B, CH 407B, or CH 444B.

Ge 241A GEOLOGY OF PETROLEUM (2-4). Seminars and discussion on the origin, accumulation, and structures which aid in the accumulation of petroleum, its general occurrence, and distribution. This course is supplemented by reading assignments in the current petroleum and petroleum geology journals. TEXT: Lalicker, *Principles of Petroleum Geology*. PREREQUISITE: Ge 101C.

Ge 401B PETROLOGY AND PETROGRAPHY (2-3). The various igneous rock series on the basis of physical chemical theories; the characteristics, structures and textures of igneous rocks; the metamorphic rocks, mineral alteration metamorphism and the resultant rock types. The laboratory work consists of the study of the various rocks in hand specimens, and in thin sections under the petrographic microscope. The course is supplemented by trips to nearby localities. TEXTS: Pirsson *and* Knopf, *Rocks and Rock Minerals;* Grout, *Petrography and Petrology*. PREREQUISITE: CR 301B.

METALLURGY

Mt 021C ELEMENTS OF MATERIALS SCIENCE I (3-2). An introduction to the science and application of materials for students in the one year science program. The subject matter covers many of the principles underlying the properties and behavior of materials, including atomic and crystal structure, mechanical properties and phase equilibria. PREREQUISITE: A course in general chemistry.

Mt 022C ELEMENTS OF MATERIALS SCIENCE II (3-2). A continuation of Mt 021C in which basic principles are applied in studying the properties, application, fabrication and corrosion of metals and other materials. PREREQUISITE: Mt 021C.

Mt 101C PRODUCTION METALLURGY (2-0). An introduction to the study of metallurgy including discussion of the nature of metal-bearing raw materials and the fundamental processes, materials and equipment of extractive metallurgy. TEXT: Hayward, *An Outline of Metallurgical Practice*. PREREQUISITE: Elementary General Chemistry (may be taken concurrently).

Mt 102C PRODUCTION OF STEEL (3-0). A discussion of the occurrence and composition of various iron ores, blast furnace products, the various methods of steel production, and the production of grey, white and malleable cast iron. TEXT: Bray, *Ferrous Process Metallurgy*. PREREQUISITE: General Chemistry.

Mt 103C PRODUCTION OF NON-FERROUS METALS (3-0). A discussion of the sources, the strategic importance of, and the methods of production of copper, zinc, lead, tin, aluminum, magnesium, and other metals of technical interest. TEXT: Bray, *Non-Ferrous Production Metallurgy*. PREREQUISITE: General Chemistry.

Mt 104C PRODUCTION METALLURGY (4-0). A condensation of the material of Mt 102C and Mt 103C into a one-term course. TEXTS: Bray, *Non-Ferrous Production Metallurgy;* Bray, *Ferrous Process Metallurgy*. PREREQUISITE: General Chemistry.

Mt 201C INTRODUCTORY PHYSICAL METALLURGY (3-2). An introduction to physical metallurgy. Topics include: (a) the nature and properties of metals, (b) a study of phase equilibria, (c) the correlation of microstructure and properties with phase diagrams, (d) mechanical properties and heat treatment, (e) descriptions of non-ferrous alloys of commercial importance. The laboratory experiments introduce methods available to the metallurgist for the study of metals and alloys. PREREQUISITE: A course in general chemistry.

Mt 202C FERROUS PHYSICAL METALLURGY (3-2). A continuation of Mt 201. Topics incude: (a) iron-carbon alloys, (b) effect of various heat treatments on the structure and properties of steel, (c) reaction rates and hardenability, (d) the effect of alloying elements on steel, (e) surface hardening methods, (f) cast irons, (g) characteristics and properties of various steels. The laboratory experiments include heat treatment, mechanical testing, and metallographic examination of ferrous alloys. TEXT: Clark *and* Varney, *Physical Metallurgy for Engineers*. PREREQUISITE: Mt 201C.

Mt 203B PHYSICAL METALLURGY (Special Topics) (2-2). A continuation of material presented in Mt 201C and Mt 202C, including a discussion of powder metallurgy, welding and casting, fatigue, properties of metals at low temperatures, and surveys of the alloys of aluminum and magnesium. TEXTS: Coonan, *Principles of Physical Metallurgy;* Heyer, *Engineering Physical Metallurgy;* Clark *and* Varney, *Physical Metallurgy for Engineers;* Woldman, *Metal Process Engineering*, PREREQUISITE: Mt 202C.

Mt 204A NON-FERROUS METALLOGRAPHY (3-3). An expansion of material introduced in Mt 201C and Mt 202C and Mt 203B with greater emphasis on the intrinsic properties of specific non-ferrous metals and alloys. PREREQUISITE: Mt 202C.

Mt 205A ADVANCED PHYSICAL METALLURGY (3-4). The subject matter includes equilibrium in alloy systems, the crystallography of metals and alloys, phase transformations and diffusion. The laboratory time is devoted to x-ray techniques used in metallurgical studies. TEXTS: BARRETT, *Structure of Metals;* CULLITY, *Elements of X-ray Diffraction;* RHINES, *Phase Diagrams in Metallurgy.* PREREQUISITES: Mt 202C, PH 620 or equivalent.

Mt 206A ADVANCED PHYSICAL METALLURGY (3-4). The subject matter is an extension of that offered in Mt 205A but is primarily concerned with dislocations and other imperfections and their influences on the physical properties of metals. TEXTS: COTTRELL, *Dislocations and Plastic Flow in Crystals;* READ, *Dislocations in Crystals.* PREREQUISITE: Mt 205A.

Mt 207B PHYSICS OF SOLIDS (3-0). A course for engineers intended as an introduction to the physics of solids. Topics discussed include introductory statistical mechanics, atomic structure and spectra, introductory quantum mechanics, binding and energy bands, crystal structure and imperfections in crystals. TEXT: SPROULL, *Modern Physics.* PREREQUISITE: Mt 202C.

Mt 212C PHYSICAL AND PRODUCTION METALLURGY (4-2). This course covers the same material as Mt 202C and includes in addition the production of iron and steel. One period each week is devoted to this latter topic. TEXTS: COONAN, *Principles of Metallurgy;* BRAY, *Ferrous Process Metallurgy;* CLARK *and* VARNEY, *Physical Metallurgy for Engineers.* PREREQUISITE: Mt 201C.

Mt 221B PHASE TRANSFORMATIONS (3-0). Kinetics, thermodynamics and mechanisms of nucleation and growth; solidification, precipitation, recrystallization, martensitic transformations, eutectoid transformations and order-disorder phenomena. PREREQUISITE: Mt 202C.

Mt 222A MECHANICAL PROPERTIES OF SOLIDS (3-0). Elements of elastic and plastic deformation; discussion of mechanical properties; deformation and fracture in single crystal and polycrystalline metals; the effect of temperature; the correlation of mechanical properties and phenomena with microstructures and imperfections. PREREQUISITE: Mt 202C.

Mt 301A HIGH TEMPERATURE MATERIALS (3-0). A course concerned with the effect of elevated temperatures on the properties of metals, especially as related to reaction motors, guided missiles, rockets, air frames and allied components. Methods of evaluating elevated temperature performance. Development of alloys, ceramics, cermets and refractory coatings for high temperature service. PREREQUISITE: Mt 202C.

Mt 302A ALLOY STEELS (3-3). A thorough study of the effects of the alloying elements, including carbon, commonly used in steel making, on the characteristics of steels in the annealed, the hardened and the hardened and tempered conditions. TEXT: E. C. BAIN, *The Alloying Elements in Steel.* PREREQUISITE: Mt 202C.

Mt 303A METALLURGY SEMINAR. Hours to be arranged. Papers from current technical journals will be reported on and discussed by students. PREREQUISITE: Mt 203B or Mt 205 A.

Mt 304A SPECIAL TOPICS IN MATERIALS SCIENCE (credit by arrangement). An advanced course in which theoretical and practical problems of materials properties, applications and fabrication are discussed. PREREQUISITE: Consent of Instructor.

Mt 307A HIGH TEMPERATURE STUDIES (0-3). A laboratory course designed to familiarize the student in the study of fundamentals at high temperatures. Students working in small groups will be given an opportunity to undertake some original investigation with the purpose of developing an understanding of problems involved and methods of analysis in high temperature studies of materials. PREREQUISITES: Mt 221B, Mt 222A or Mt 301A (may be taken concurrently).

Mt 401A PHYSICS OF METALS (3-0). A discussion of crystal chemistry and modern theories of the solid state. TEXTS: KITTRELL, *Solid State Physics;* selected references. PREREQUISITES: Mt 205A, PH 610 or PH 640.

Mt 402B NUCLEAR REACTOR MATERIALS — EFFECTS OF RADIATION (3-0). A course designed for students in nuclear engineering. Includes a study of materials of reactor construction; factors in materials selection; commercially available materials; liquid metal coolants; nature of radiation damage on materials. TEXTS: *The Reactor Handbook—General Properties Materials;* FINNISTON *and* HOWE, *Metallurgy and Fuels;* DRENES *and* VINEYARD, *Radiation Effects in Solids.* PREREQUISITE: Mt 207B, or equivalent.

Mt 501A WELDING METALLURGY (3-3). A study of the various materials equipment and processes employed for joining metals by both the plastic and the fusion welding methods, and of the mechanical, electrical, and metallurgical factors essential to successful welding. PREREQUISITE: Mt 203B.

Mt 900E RESEARCH (0-2 to 0-10). Experimental investigation of original problems. PREREQUISITE: Consent of Instructor.

CLOSED CIRCUIT TELEVISION

DEPARTMENT OF METEOROLOGY AND OCEANOGRAPHY

George Joseph Haltiner, Chairman, Professor of Meterology (1946)*; B.S., College of St. Thomas, 1940; Ph.M., Univ. of Wisconsin, 1942; Ph.D., 1948.

Hugh Wallick Albers, Lieutenant Commander, U.S. Navy; Instructor in Meteorology; B.S., USNA, 1949; B.S., USNPGS, 1955.

Frederick Francis Duggan, Jr., Lieutenant Commander, U.S. Navy; Instructor in Meteorology; B.S., USNA, 1950; M.S., USNPGS, 1960.

William Dwight Duthie, Professor of Meteorology (1945); B.A., Univ. of Washington, 1935; M.S., 1937; Ph.D., Princeton Univ., 1940.

Richard William Haupt., Commander, U.S. Navy; Instructor in Oceanography; B.S., Tulane Univ. 1947.

James Irvin Johnston, Lieutenant Commander, U.S. Navy; Instructor in Meteorology; B.S., Univ. of Washington, 1953; M.S., USNPGS, 1959.

Glenn Harold Jung, Associate Professor of Oceanography (1958); B.S., Massachusetts Institute of Technology, 1949; M.S., 1952; Ph.D., Texas Agricultural and Mechanical College, 1955.

Thomas Albert Le Dew, Lieutenant Commander, U.S. Navy; Instructor in Meteorology; B.S., USNA, 1950; M.S., USNPGS, 1955.

Frank Lionel Martin, Professor of Meteorology (1947); B.A., Univ. of British Columbia, 1936; M.A., 1938; Ph.D., Univ. of Chicago, 1941.

John Hood Powell, Lieutenant, U.S. Navy; Instructor in Meteorology; B.S., USNA, 1955; M.S., USNPGS, 1957.

Robert Joseph Renard, Associate Professor of Meteorology (1952); M.S., Univ. of Chicago, 1952.

Howard Rodwell Seay, Lieutenant Commander, U.S. Navy; Instructor in Meteorology; B.S., Univ. of Calif. at Los Angeles, 1946; M.S., USNPGS, 1953.

Samuel Woodworth Selfridge, Commander, U.S. Navy; Instructor in Meteorology; B.S., USNA, 1944; M.S., USNPGS, 1960.

Norman Marshall Stevenson, Lieutenant Commander, U.S. Navy; Instructor in Meteorology; M.S., USNPGS, 1960.

Charles Luther Taylor, Associate Professor of Meteorology (1954); B.S., Pennsylvania State Univ., 1942; M.S., 1947.

Warren Charles Thompson, Professor of Oceanography (1953); B.A., Univ. of Calif., at Los Angeles, 1943; M.S., Scripps Institution of Oceanography, 1948; Ph.D., Texas Agricultural and Mechanical College, 1953.

Willem van der Bijl, Associate Professor of Meteorology (1961); B.Sc., Free Univ. of Amsterdam, 1941; M.Sc., 1943; Ph.D., State Univ. Utrecht, 1952.

Jacob Bertram Wickham, Associate Professor of Oceanography (1951); B.S., Univ. of California, 1947; M.S., Scripps Institution of Oceanography, 1949.

* The year of joining the Postgraduate School Faculty is indicated in parentheses.

DEPARTMENTAL REQUIREMENTS FOR DEGREES IN METEOROLOGY AND OCEANOGRAPHY BACHELOR OF SCIENCE

Subject	*Term Hours Required* B.S. in Meteorology	B.S. in Environmental Science
I Meteorology		
a. Descriptive	6	3
b. Dynamic	8	12
c. Physical	13	
d. Synoptic	22	20
II Oceanography		
a. Descriptive	6	6
b. Dynamic		12
c. Field and Lab		16
III Electives	20	31
	75	100

Electives may be chosen from any of I or II plus mathematics courses covering the following subjects: Probability and Statistics, Vector Analysis, Digital Computation, and Differential Equations. A research paper is required.

MASTER OF SCIENCE

Subject	*Term Hours Required* M.S. in Meteorology	M.S. in Physical Oceanography
I Meteorology		
a. Dynamic	15	
b. Physical	11	
c. Synoptic	7	
II Oceanography		
a. Descriptive		12
b. Physical		20
c. Field and Lab		6
III Electives	29	18
	62	56

Electives may be chosen from any of I or II plus mathematics courses covering the following subjects: Probability and Statistics, Vector Analysis, Digital Computation, and Partial Differential Equations. At least 20 term hours must be A level Meteorology and Oceanography courses with the remainder not less than B level. An acceptable thesis is required. B.S. in Meteorology or equivalent in prerequisite to M.S. in Meteorology.

METEOROLOGY

Mr 001D WEATHER CODES AND ELEMENTARY ANALYSIS (0-3). Designed to acquaint Environmental Science students with weather codes and observations, stressing utility and application and to introduce the essential elements of meteorological analysis. TEXTS: WBAN Manual for Synoptic Codes; WBAN Manual for Radiosonde Code; WBAN Manual for Upper Wind Code; International Cloud Atlas. PREREQUISITE: none.

Mr 010D METEOROLOGY (3-0). The principles of meteorology and the effects of weather phenomena on naval operations. Included topics: structure of the atmosphere; weather elements; the station model, pressure and winds; theory of air masses and fronts; tropical storms; sources of weather information; sea and swell conditions; climatology and the principles of weather map analysis and forecasting. TEXT: DONN, *Meteorology with Marine Applications.* PREREQUISITE: None.

Mr 100D ELEMENTARY METEOROLOGY (3-0). Primarily designed to give non-meteorological officer students a survey of meteorology. Topics included are essentially the same as in Mr 200C; however, there is greater emphasis on large-scale and small-scale circulations. TEXT: PETTERSSEN, *Introduction to Meteorology.* PREREQUISITE: None.

Mr 200C INTRODUCTION TO METEOROLOGY (3-0). A general course which treats descriptively the composition and vertical structure of the atmosphere, physical processes, general circulation, air masses, fronts, cyclones and anticyclones. TEXT: Same as Mr 100D. PREREQUISITE: None.

Mr 201C ELEMENTARY WEATHER-MAP ANALYSIS (0-9). Laboratory course taught in conjunction with Mr 211C. Practice in upper-air and surface analysis stressing basic techniques and continuity. TEXT: Same as Mr 211C. PREREQUISITES: Mr 200C and a knowledge of weather codes and observations.

Mr 202C WEATHER-MAP ANALYSIS (0-4). Laboratory course taught in conjunction with Mr 212C. Practice in sea-level and frontal analysis, graphical arithmetic, analysis of upper-air soundings, and vertical space/time cross sections. Introduces local forecasting techniques and mesoscale synoptic analysis. TEXT: TEXT: Same as Mr 212C. PREREQUISITE: Mr 201C.

Mr 203C FORECASTING WEATHER ELEMENTS AND MESOMETEOROLOGY (0-6). Laboratory course taught in conjunction with Mr 213C. Practice in objective and quantitative forecasting techniques and mesoscale synoptic analysis. TEXT: Same as Mr 213C. PREREQUISITE: Mr 202C.

Mr 204B UPPER-AIR AND SURFACE PROGNOSIS (0-6). Laboratory course taught in conjunction with Mr 214B. Practice in prognosis of upper-air and surface charts using current and classical methods. Practice in graphical techniques and local forecasting. TEXT: Same as Mr 214B. PREREQUISITE: Mr 203C.

Mr 205B THE MIDDLE ATMOSPHERE (0-9). Laboratory course taught in conjunction with Mr 215B. Practice in hemispheric analysis and prognosis of contour, temperature and wind fields for constant-pressure surfaces and vertical cross sections up to 10 mb; tropopause and maximum-wind layer analysis. TEXT: Same as Mr 215B. PREREQUISITE: Mr 204B.

Mr 206C NAVAL WEATHER SERVICE ORGANIZATION AND OPERATION (1-9). Instruction and laboratory practice in the operational functions and responsibilities of the Naval Weather Service. TEXTS: Selected NavWeps, AWS and NWRF publications; departmental notes. PREREQUISITE: Mr 205B.

Mr 208B TROPICAL AND SOUTHERN HEMISPHERE METEOROLOGY (0-6). Laboratory course associated with Mr 228B. Southern hemispheric pressure analysis; low-latitude contour (isobar), streamline, and isotach analysis and forecasting with emphasis on tropical cyclones. TEXT: Departmental notes. PREREQUISITES: Mr 214B and Mr 228B.

Mr 211C ELEMENTARY WEATHER-MAP ANALYSIS (3-0). Objectives and techniques of surface and upper-air analysis, including contours (isobars), isotherms and fronts. TEXTS: BERRY, BOLLAY, *and* BEERS, *Handbook of Meteorology*; departmental notes. PREREQUISITES: Mr 001D and Mr 200C.

Mr 212C INTRODUCTION TO WEATHER ELEMENTS (3-0). Continuation of Mr 211C. Structure and behavior of extratropical cyclones; graphical arithmetic; stability analysis and air masses; space/time cross sections; extended analyses. TEXTS: Same as Mr 211C plus the NAWAC Manual, departmental notes. PREREQUISITE: Mr 211C.

Mr 213C FORECASTING WEATHER ELEMENTS AND MESOMETEOROLOGY (2-0). Continuation of Mr 212C. Objective forecasting techniques; quantitative forecasting of hydrometeors, temperature and wind; instability lines, tornadoes and severe weather. TEXTS: Departmental notes, various NavWeps, AWS and USWB publications. PREREQUISITE: Mr 212C.

Mr 214B UPPER-AIR AND SURFACE PROGNOSIS (3-0). Qualitative and quantitative application of mechanisms of pressure change and kinematics to surface and upper-air prognosis (up to 500 mb) of height, thickness and temperature fields. Manually applied graphical and numerical techniques; extended forecasting by weather-type methods. TEXTS: Same as Mr 213C plus PETTERSSEN, Vol 1, *Weather Analysis and Forecasting*, NavWeps 50-1P-548, the NAWAC Manual. PREREQUISITES: Mr 213C, Mr 301B or Mr 321A.

Mr 215B THE MIDDLE ATMOSPHERE (3-0). Objectives and techniques of high-tropospheric (above 500 mb) and stratospheric (to 10 mb) analysis and prognosis, including jet stream, maximum-wind layer and tropopause. Synoptic climatology; interpolation and extrapolation of height, temperature and wind data. TEXTS: Same as Mr 213C plus RIEHL, *Jet Streams of the Atmosphere.* PREREQUISITE: Mr 214B.

Mr 217B INTERPRETIVE WEATHER FORECASTING AND PROGNOSIS (2-6). Essential operational aspects of course material contained in Mr 214B, Mr 215B, and Mr 218B. TEXTS: Same as in Mr 214B and Mr 215B. PREREQUISITES: Mr 213C and Mr 322A.

Mr 228B TROPICAL AND SOUTHERN HEMISPHERE METEOROLOGY (3-0). Southern hemisphere synoptic meteorology; tropical synoptic models (with emphasis on the tropical cyclone); tropical forecasting. TEXT: RIEHL, *Tropical Meteorology.* PREREQUISITE: Mr 301B or Mr 321A.

Mr 301B ELEMENTARY DYNAMIC METEOROLOGY I (4-0). The equations of motion; trajectories and streamlines; thermal wind; mechanism of pressure changes and kinematics of pressure systems. TEXT: HALTINER *and* MARTIN, *Dynamical and Physical Meteorology.* PREREQUISITES: Mr 200C, Mr 402C, PH 191C and Ma 081C.

Mr 302B ELEMENTARY DYNAMIC METEOROLOGY II (4-0). A continuation of Mr 301B. Vorticity and circulation; dynamical forecasting by numerical methods; selected topics including fronts and frontogenesis. TEXT: Same as Mr 301B. PREREQUISITE: Mr 301B.

Mr 321A DYNAMIC METEOROLOGY I (3-0). The equations of motion; horizontal flow; geostrophic and gradient winds; vertical variation of wind and pressure systems; kinematics of pressure systems; continuity and tendency equations. TEXT: Same as Mr 301B. PREREQUISITES: Mr 413B, Ma 240 C and Ma 261B concurrently.

Mr 322A DYNAMIC METEOROLOGY II (3-0). A continuation of Mr 321A. Circulation theorems, vorticity equation and applications, solution of hydrodynamic equations by (a) perturbation methods, (b) by numerical integration; barotropic and baroclinic models; fronts and frontogenesis. TEXT: Same as Mr 301B. PREREQUISITES: Ma 125C concurrently and Mr 321A.

Mr 323A DYNAMIC METEOROLOGY III (TURBULENCE AND DIFFUSION) (3-0). Viscosity and turbulence; equations of motion for viscous and turbulent flows; wind in the friction layer; diffusion of momentum, heat, water, vapor, chemicals etc.; diurnal temperature variation; air-mass transformation; statistical properties of turbulence. TEXTS: Same as Mr 301B plus SUTTON, *Micrometeorology*. PREREQUISITES: Mr 322A and Ma 333B.

Mr 324A DYNAMICAL PREDICTION (3-3). The solution of the hydrodynamical equations for meteorological phenomena by analytical and numerical methods. Objective analysis. TEXT: THOMPSON, *Numerical Weather Analysis and Prediction*. PREREQUISITES: Mr 323A and Ma 128B.

Mr 325A ENERGETICS OF THE GENERAL CIRCULATION (2-0). The equations for energy and momentum balance in the atmosphere; zonal and eddy energy; diabatic heating and its conversion into kinetic energy. Models of the general circulation. Transport of enthalpy, momentum, kinetic energy, etc., using Fourier transforms. TEXTS: PFEFFER, *Dynamics of Climate*; departmental notes. PREREQUISITES: Mr 323A and Ma 128B.

Mr 335A THEORETICAL METEOROLOGY (3-0). Advanced topics in theoretical meteorology to fit the needs of the students. PREREQUISITE: Consent of the Instructor.

Mr 402C INTRODUCTION TO METEOROLOGICAL THERMODYNAMICS (3-2). A treatment of elementary thermodynamics and its application in meteorology, with particular emphasis on thermodynamic charts and diagrams. Theories of condensation and precipitation processes. Static stability and instability phenomena. TEXT: HALTINER *and* MARTIN, *Dynamical and Physical Meteorology*. PREREQUISITES: PH 191C and Ma 052D or equivalent.

Mr 403B INTRODUCTION TO MICROMETEOROLOGY (4-0). Properties of radiating matter in general; solar and terrestrial radiation and their effects on the temperature distribution; the heat budget; structure of the wind (in the friction layer) and its significance in turbulent transfer; air-mass modification; forecasting the micrometeorological variables and their use in diffusion from point and line sources. TEXT: Same as Mr 402C. PREREQUISITES: Mr 302B and Ma 381C or equivalent.

Mr 410C METEOROLOGICAL INSTRUMENTS (2-2). Principles of design and operation of meteorological instruments used in naval meteorology with special emphasis on new developments and requirements. Application of electronic meteorological instruments used by the fleet meteorologist. TEXTS: MIDDLETON *and* SPILHAUS, *Meteorological Instruments;* selected papers and departmental notes. PREREQUISITES: Ma 052D or equivalent and PH 196C or equivalent.

Mr 412A PHYSICAL METEOROLOGY (3-0). Solar and terrestrial radiation; absorption, scattering and diffuse reflection of solar radiation; terrestrial radiation and the atmosphere radiation chart; applications to air-mass modification and minimum-temperature forecasting; heat budget of earth-atmosphere system. TEXTS: Same as Mr 402C; departmental notes. PREREQUISITE: Mr 413B.

Mr 413B THERMODYNAMICS OF METEOROLOGY (3-2). The physical variables; equations of state; first law of thermodynamics; properties of gases; properties of water and moist air; theories of condensation and precipitation processes; thermodynamic diagrams; air-mass identification indices; geopotential determinations; altimetry; instability phenomena and criteria. TEXTS: Same as Mr 402C; departmental notes. PREREQUISITES: Ma 230D and PH 196C.

Mr 415B RADAR METEOROLOGY (2-0). Characteristics of radar sets; propagation of electromagnetic waves in standard and non-standard atmospheres; scattering by hydrometeors; attenuation; quantitative precipitation estimates; applications of radar in convective clouds, mesometeorology and larger-scale weather systems. TEXT: BATTAN, *Radar Meteorology*. PREREQUISITES: Mr 321A or Mr 301B; Ma 333B or Ma 381C.

Mr 420B UPPER-ATMOSPHERE PHYSICS (4-0). The fundamental laws of atmospheric flow; balloon and rocket research; sounding the atmosphere by acoustic and radio techniques; the ozonosphere; aerial tides and magnetic effects; solar, magnetic and ionospheric disturbances, meteors, cosmic rays and satellites. TEXT: MASSAY *and* BOYD, *The Upper Atmosphere;* FLEAGLE *and* BUSINGER, *An Introduction to Atmospheric Physics*; departmental notes. PREREQUISITES: PH 365B, PH 541B and PH 671B.

Mr 422A THE UPPER ATMOSPHERE (4-0). The composition of the upper atmosphere; temperature and wind structure as deduced from several lines of observation; variations of electron concentration in the iononsphere; terrestrial magnetic variations; solar disturbances and their effects in the upper atmosphere; the aurora. TEXTS: Same as Mr 420B, plus GOODY, *The Physics of the Stratosphere*. PREREQUISITES: Mr 323A, and Ma 333B or Ma 381C.

Mr 510C CLIMATOLOGY (2-0). The distribution with respect to season, geography, and orography of the major meteorological elements. Definitions of climatic zones and types according to Koeppen and their meteorological descriptions; micrometeorology; regional climatology of the oceans; climatology as a tool in objective forecasting. TEXT: LANDSBERG, *Physical Climatology*. PREREQUISITE: Mr 200C.

Mr 521B SYNOPTIC CLIMATOLOGY (2-2). The study and statistical evaluation of meteorological elements in relation to the macro- and microclimates; the Koeppen system; methods of presenting climatological data to non-meteorological personnel; construction and use of forecast registers; climatological techniques in objective forecasting. TEXT: Landsberg, *Physical Climatology*. PREREQUISITES: Mr 200C and Ma 381C or Ma 333B concurrently.

Mr 810B SEMINAR IN METEOROLOGY AND OCEANOGRAPHY (2-0). Students present original research or prepare summaries of recent findings in the fields of meteorology or oceanography and present synopses for group discussion. PREREQUISITES: Mr 422A or Mr 403B, Mr 521A, and Ma 333B or Ma 381C.

OCEANOGRAPHY

Oc 100D SURVEY OF OCEANOGRAPHY (3-0). A description of the marine environment; the topography of the sea floor; bottom sediments; distributions of temperature, salinity and biological materials; ocean-atmosphere interactions and their influence on currents, waves and the ocean thermal structure; methods of oceanographic observation and analysis. Intended as a terminal course for students not enrolled in environmental sciences curricula. TEXT: Departmental notes. PREREQUISITE: None.

Oc 110C INTRODUCTION TO OCEANOGRAPHY (3-0). A survey course treating physical and chemical properties of sea water, marine biology, and submarine geology; the heat budget of the oceans; water masses and the general circulation; currents, waves, and tides. TEXTS: Sverdrup, *Oceanography for Meteorologists;* Shepard, *Submarine Geology*. PREREQUISITE: None.

Oc 201B OCEAN WAVES AND TIDES (3-1). The properties of waves of small amplitude in all water depths; wave spectra and analysis; refraction; near-shore circulations; tide-producing forces, tides and tidal currents, and analysis of tidal records; internal waves. TEXT: departmental notes. PREREQUISITES: Oc 110C and PH 196C.

Oc 211A OCEAN WAVES (3-0). Various solutions of the hydrodynamical equations of motion for surface and internal waves, with particular attention to short gravity waves and their properties; generation of waves by wind: empirical and theoretical wind-wave spectra. TEXTS: Defant, *Physical Oceanography*; selected publications. PREREQUISITES: Ma 261B and Ma 333B.

Oc 212A TIDES AND TIDAL CURRENTS (3-0). Theories of the astronomical tides; the tide-producing forces; tidal oscillations in ocean basins; geographical variation of the tides; analysis and prediction of tides; tidal datum planes. Meteorological tides. Seiches. Tidal currents. TEXTS: Defant, *Physical Oceanography;* Marmer, *Tidal Datum Planes.* PREREQUISITE: Oc 211A.

Oc 213A SHALLOW-WATER OCEANOGRAPHY (3-1). Transformation of waves in shoal water; nearshore water circulation and littoral drift; beaches and coasts. TEXT: King, *Beaches and Coasts.* PREREQUISITES: Oc 110C and Oc 610B or Oc 611B (one of the latter may be taken concurrently).

Oc 220B DESCRIPTIVE OCEANOGRAPHY (3-0). Properties of sea water; water masses, currents and three-dimensional circulation in all oceans; distribution of temperature, salinity and oxygen; temperature-salinity relationship. TEXTS: Sverdrup, Johnson *and* Fleming, *The Oceans;* selected references. PREREQUISITE: Oc 110C.

Oc 241B ELEMENTARY DYNAMIC OCEANOGRAPHY (3-0). The equations of motion; geostrophic currents and their calculation by the indirect method; inertial motion; vorticity; frictional effects and wind-driven currents; dynamic models of the ocean circulation. TEXT: von Arx, *Introduction to Physical Oceanography.* PREREQUISITES: Oc 110C and Mr 302B.

Oc 251A DYNAMIC OCEANOGRAPHY I (3-0). Thermodynamics of the sea; absorption of electromagnetic radiation; the equations of relative motion, the hydrostatic equation; frictionless flow. TEXT: Defant, *Physical Oceanography.* PREREQUISITES: Oc 110C, Ma 240C and Ma 251C.

Oc 252A DYNAMIC OCEANOGRAPHY II (3-0). The deep thermohaline circulation, vertical current shear, topographic influences on currents; mass transport calculations; horizontal divergence and vertical motion. TEXT: Defant, *Physical Oceanography.* PREREQUISITES: Oc 251A or Mr 321A.

Oc 253A DYNAMIC OCEANOGRAPHY III (3-0). Turbulence and diffusion in the ocean; boundary layer flow; air-sea interface exchanges; convection, stability and the formation of mixed layers; the wind-driven circulation. TEXT: Defant, *Physcial Oceanography.* PREREQUISITES: Oc 252A or Mr 321A.

Oc 260B SOUND IN THE OCEAN (3-0). The oceanographic factors involved in sound ranging, including thermal gradients, sound absorption properties of sea water, sound scattering and reflection characteristics of the sea surface and sea floor, scattering properties of marine organisms, and ambient noise arising in the sea. TEXTS: Albers, *Underwater Acoustics Handbook;* departmental notes. PREREQUISITES: Oc 110C and PH 196C or equivalent.

Oc 320B INTRODUCTION TO GEOLOGICAL OCEANOGRAPHY (3-2). Physiography of the sea floor, especially continental shelves and slopes, submarine canyons, coral reefs, and the deep-sea floor; character and distribution of sediments and rates of deposition; structure and origin of the ocean basins. TEXTS: Shepard, *Submarine Geology (2nd ed.);* Kuenen, *Marine Geology.* PREREQUISITE: Oc 110C.

Oc 330A MARINE GEOLOGY AND GEOPHYSICS (3-0). Topography and sediments of the sea floor; gravity, magnetism, and seismicity of the oceans; acoustical studies at sea; structure of the sea floor; origin of the ocean basins. For students not majoring in the environmental sciences. TEXTS: Gilluly, Waters *and* Woodford, *Principles of Geology;* Shepard, *Submarine Geology (2nd ed.);* selected publications. PREREQUISITE: Oc 110C.

Oc 340A MARINE GEOPHYSICS (2-0). Geophysical measurements of the earth; gravity, magnetism and seismicity of the oceans; acoustical studies of the sea floor; earth's crust beneath the ocean basins. TEXT: selected publications. PREREQUISITE: OC 320B.

Oc 420B INTRODUCTION TO BIOLOGICAL OCEANOGRAPHY (3-2). Plant and animal groups in the oceans; character of the plankton, nekton, and benthos; marine biological environments; oceanographic factors influencing populations; the effect of organism on the physical-chemical properties of sea water; organisms responsible for sical-chemical properties of sea water; organisms responsible for boring, fouling, sound and light production, and sound scattering. TEXT: selected publications. PREREQUISITE: Oc 110C.

Oc 520B INTRODUCTION TO CHEMICAL OCEANOGRAPHY (3-2). Chemical composition of sea water; determination and distribution of salinity, dissolved gases and plant nutrients; sea ice; production of fresh water from sea water. TEXTS: Sverdrup, Johnson *and* Fleming, *The Oceans;* Strickland *and* Parsons, *Methods in Chemical Oceanography.* PREREQUISITES: Oc 110C, Ch 101C or equivalent is desirable but not necessary.

Oc 610B OCEAN WAVE FORECASTING (3-0). The generation and propagation of ocean wind waves; their spectral and statistical properties; wave observations and analysis of data; forecasting wind waves from meteorological data; applications to operations at sea. TEXTS: H. O. 603; departmental notes. PREREQUISITES: Oc 211A or Oc 201B.

Oc 611B OCEAN WAVE FORECASTING (3-6). Same as Oc 610B with laboratory exercises on the forecasting of wind waves and analysis of records. TEXTS: same as Oc 610B. PREREQUISITES: same as Oc 610B.

Oc 612B ARCTIC OCEANOGRAPHY (3-0). Marine geography of the Arctic; sea ice observations, formation, properties, growth, deformation and disintegration; sea ice drift due wind and currents. TEXT: *Sea Ice Manual* (unpublished). PREREQUSITES: Oc 201B and Oc 241B.

Oc 613B ARCTIC OCEANOGRAPHY (3-4). Same as Oc 612B with laboratory exercises in forecasting sea ice drift, growth and disintegration. TEXT: *Sea Ice Manual* (unpublished). PREREQUISITES: Oc 201B and Oc 241B.

Oc 615B OCEANOGRAPHIC FORECASTING I (3-4). Space/ time distributions of mixed-layer thickness; diurnal variations in the vertical temperature structure. Analysis of charts of surface temperature, mixed-layer depth, temperature gradients and currents; synoptic forecasting of these elements in the laboratory. TEXTS: Selected publications. PREREQUISITES: Ma 381C.

Oc 617B OCEANOGRAPHIC FORECASTING II (3-4). Reviews variation of ocean thermal structure and processes involved; techniques in forecasting thermal illustrated by laboratory exercises; practice in developing forecast methods from air and sea data. Applications of oceanography in ASWEPS and other Navy operations; radar propagation. TEXTS: Laevastu, *Factors Affecting the Temperature of the Surface Layer of the Sea;* selected references. PREREQUISITES: Oc 220B, Oc 260B and Oc 615B.

Oc 619B OCEANOGRAPHIC FORECASTING (3-4). Reviews variation of ocean thermal structure and processes involved; space-time distributions of mixed layer thickness; analysis of oceanographic charts of surface temperature, temperature gradients, currents; synoptic forecasting of these elements. Applications in ASWEPS and other Navy operations. TEXTS: Laevastu, *Factors Affecting the Temperature of the Surface Layer of the Sea;* selected publications. PREREQUISITES: Oc 220B, Oc 260B and Ma 381C.

Oc 700B OCEANOGRAPHIC INSTRUMENTS AND OBSERVATIONS (2-2). Theory and operation of oceanographic instruments; instructions in recording oceanographic observations, measurements and samples on log sheets. TEXTS: H. O. 607; selected references. PREREQUISITE: Oc 220B.

Oc 720B FIELD EXPERIENCE IN OCEANOGRAPHY (0-4). Field operation of instruments to accomplish a comprehensive oceanographic survey, processing and storage of the data and samples, and interpretation of the results. TEXTS: H. O. 607; selected references. PREREQUISITE: Oc 220B.

Oc 810B SEMINAR IN OCEANOGRAPHY (2-0). Students in the environmental sciences curricula conduct original research or summarize the literature in oceanography concerning a selected topic, and during their last term present their results for group discussion. TEXT: none. PREREQUISITE: none.

Oc 820A SPECIAL TOPICS IN OCEANOGRAPHY (3-0). Lectures or seminars on topics in oceanography not contained in other courses, including a review by the student of recent research papers of significance; course taken by students in the environmental sciences curricula toward the end of their program. TEXT: selected publications. PREREQUISITE: none.

Oc 830A SPECIAL TOPICS IN OCEANOGRAPHY (3-0). Lectures or seminars on specialized subjects in oceanography of particular interest to students enrolled in curricula other than those in the environmental sciences; taken toward the end of the student's program. TEXT: selected publications: PREREQUISITE: Oc 110C.

DEPARTMENT OF NAVAL WARFARE

Carl C. Schmuck, Commander, U.S. Navy; Chairman; B.S., M.F., Purdue University, 1939.

John Keith Boles, Lieutenant Commander, U.S. Navy; Instructor in Communications.

Ralph Donald Botten, Commander, U.S. Navy; Instructor in Tactics and CIC; B.S., Univ. of Maryland, 1955.

Eric Bruce Bower, Commander, U.S. Navy; Instructor in Operational Planning, B.S., USNPGS, 1963.

Kermont C. Brasted, Lieutenant Commander, U.S. Navy; Instructor in Marine Engineering.

Richard F. Campbell, Lieutenant, U.S. Navy; Instructor in Missiles and Space Operations; B.A., Ohio State University, 1960.

Richard Grant Daly, Lieutenant Commander, U.S. Navy; Instructor in Navigation; B.S., USNA, 1953.

Francis W. English, Lieutenant Commander, U.S. Navy; Intructor in Seamanship.

George William Fairbanks, Commander, U.S. Navy; Instructor in Damage Control.

John Orrell Ginn, Commander, U.S. Navy; Instructor in Leadership.

Lawrence Don Hagedorn, Commander, Supply Corps, U.S. Navy; Instructor in Naval Logistics; B.S., Linfield College, 1947.

David G. Hamilton, Lieutenant, U.S. Navy; Instructor in Marine Nuclear Propulsion; B.A., Lehigh Univ., 1951.

George H. Hedrick, Commander, U.S. Navy; Instructor, Naval Warfare Seminar.

Downing Lee Jewell, Lieutenant Commander, U.S. Navy; Instructor in Anti-Submarine Warfare; B.S., Michigan State, 1949.

James E. Law, Lieutenant, U.S. Navy; Instructor in Tactics and CIC; B.A., Washington and Lee University, 1957.

Willis Charles McClelland, Lieutenant Commander, U.S. Navy; Instructor in Mine Warfare.

Eugene Bryant Mitchell, Commander, U.S. Navy; Instructor in Marine Nuclear Propulsion; B.S., Univ. of South Carolina, 1946; Nav. Eng., MIT, 1952.

George T. Smith, Commander, U.S. Navy; Instructor in Anti-Submarine Warfare, Naval War College, 1961.

James H. Smith, Lieutenant Commander, U.S. Navy; Instructor in Amphibious Operations; B.A., Univ. of Southern California, 1960.

Leonard Alfred Snider, Lieutenant Commander, U.S. Naval Reserve; Instructor in Nuclear Weapons; B.S., George Washington University, 1948; M.S., in Mathematics, USNPGS, 1964.

William Theodore Sorensen, Commander, U.S. Navy; Instructor in Naval Intelligence, Personal Affairs.

Frank Edward Standring, Commander, U.S. Navy; Instructor in Naval Aviation.

Harold Hartley Stirling, Jr., Lieutenant Colonel, U.S. Marine Corps; Instructor in Amphibious Operations; Marine Corps Schools, Quantico, 1952; A.A., Diablo Valley College, 1961; B.A., USNPGS, 1964.

Charles C. Tidwell, Jr., Commander, U.S. Navy; Instructor in Marine Engineering.

Lester C. Wible, Lieutenant Commander, U.S. Navy; Instructor in Aviator's Aviation; B.S., USNA, 1945.

Harold James Yerly, Lieutenant Commander, U.S. Navy; Instructor in Ordnance-Weapon Systems; B.S., USNPGS, 1962.

NAVAL WARFARE

NW 101C TACTICS AND COMBAT INFORMATION CENTER (3-2). Shipboard tactical doctrine and procedures, and the functions and organization of CIC. USUAL BASIS FOR EXEMPTION: Qualified Destroyer Type OOD, or CIC School of 4 weeks or longer and qualified CIC Officer. Foreign Officers take NW 191D.

NW 102C OPERATIONAL COMMUNICATIONS (3-0). Essentials of operational communications, including doctrine, organization, radio and visual procedures, command responsibilities, Registered Publications System, Technical (Code 4) Publications and Communications Plans. USUAL BASIS FOR EXEMPTION: (a) Completion of NAVPERS 10916, 10918, and 10760, or 10403, 10996, and 10760 or (b) Appropriate formal communications course or (c) Appropriate experience in communications duties.

NW 103C ANTI-SUBMARINE WARFARE (4-0). Surface, air, and sub-surface ASW doctrine. Submarine operating characteristics, offensive and defensive tactics, and weapons. ASW search, detection and attack procedures, and weapons systems. Coordinated ASW operations are emphasized. PREREQUISITE: NW 101C (or exempt therefrom). USUAL BASIS FOR EXEMPTION: Recent completion of: Coordinated ASW Course at NORFOLK, SAN DIEGO, LONDONDERRY, or HALIFAX, or ASW Officer or CO/XO Anti-Submarine Course at Fleet Sonar School. Foreign Officers take NW 193D.

NW 104D ANTI-SUBMARINE WARFARE ORIENTATION (2-0). Fundamentals of ASW operations, submarine characteristics, search, detection, attack, planning and communications procedures, with emphasis on the effects of air-ocean environment.

NW 191D TACTICS AND COMBAT INFORMATION CENTER (3-2). Shipboard tactical doctrine and procedures, and the functions and organization of CIC. Foreign Officers course.

NW 193D ANTI-SUBMARINE WARFARE (3-0). Surface, air, sub-surface ASW doctrine. Submarine operating characteristics, offensive and defensive tactics, and weapons. ASW search, detection and attack procedures, and weapons systems. The ASW Trainer is utilized to apply attack doctrine. PREREQUISITE: NW 191D (or exempt therefrom). Foreign Officers course.

NW 201C OPERATIONAL PLANNING (3-0). Purpose and procedure for the Estimate of the Situation, the Development of the Plan, and the Preparation of the Directive (OpOrder); including the preparation of each under supervision. Staff organization. The Navy Planning System. PREREQUISITE: Facility in English Composition. USUAL BASIS FOR EXEMPTION: Naval War College Correspondence course "Strategy and Tactics (Part I)" or "Operational Planning and Staff Organization."

NW 202C AMPHIBIOUS OPERATIONS (3-0). Basic Orientation, to include doctrine, planning and fundamentals of troop organization, helicopter operations, embarkation, ship-to-shore movement, and coordination of supporting arms. USUAL BASIS FOR EXEMPTION: Completion of a Marine Corps or Amphibious Forces School and/or a tour of duty with an amphibious staff at PhibRon level or higher.

NW 203D NAVAL AVIATION SURVEY (3-0). Organizational structure and command relationship of entire naval aviation system; research and development, procurement, testing and evaluation of naval aircraft; specific discussions based on latest material available on missions, tasks, current and projected equipment, as well as present and future employment of aircraft squadrons, carriers and seaplane tenders. USUAL BASIS FOR EXEMPTION: Extensive aviation duty.

NW 204C AVIATOR'S AVIATION (3-0). A study of the present-day responsibilities and problems peculiar to senior squadron officers. Course includes (a) a review of applied aerodynamics, (b) responsibilities associated with personnel, material, doctrine, training, morale, public relations, and continuous education of pilots and mechanics, and (c) aviation safety. PREREQUISITE: Designation as Naval Aviator. USUAL BASIS FOR EXEMPTION: Served as Commanding Officer of a fleet squadron, or be a graduate of a formal Test Pilot Training Course.

NW 205C NAVAL WARFARE SEMINAR (3-0). A survey of current operations and future concepts in the various tactical and strategical fields of naval operations, including counter-insurgency. Additionally, students will participate as small groups in the research and study of selected subjects of direct naval interest, presenting their findings in seminars.

NW 206C AERO ENGINEERING AND SAFETY I (3-0). This course comprises the Aeronautical Engineering portion of the Aviation Safety Course. Material covered will be a review of basic Aero-dynamics, sub-sonic flight and super-sonic flight aerodynamics, basic strength of materials, and recognition of various types of metal fatigue.

NW 207C AERO ENGINEERING AND SAFETY II (3-0). Continuation of Aeronautical Engineering and Safety I.

NW 208C AVIATION ACCIDENT PREVENTION AND CRASH INVESTIGATION (4-0). This course consists of (a) a study of all existing Navy Department instructions covering all aspects of accident investigation and reporting procedures, (b) methods and techniques of accident investigation, and (c) implementation and use of a prevention program.

NW 301C ORDNANCE-WEAPON SYSTEMS (3-0). A survey of the fields of surface and airborne ordnance including guns, bombs, rockets, and associated delivery systems. A discussion of the elements of present fire control systems, including computers, radar, and designation systems. An analysis of the capabilities and limitations of both present fire control surface and airborne, from the standpoint of weapons systems evaluation and employment. USUAL BASIS FOR EXEMPTION: Completion of USNA, NROTC, or equivalent courses in naval ordnance and fire control and service experience in these fields. Foreign Officers take NW 391D.

NW 302C NUCLEAR WEAPONS (3-0). Characteristics, capabilities, limitations and employment of current nuclear weapons and those under development. USUAL BASIS FOR EXEMPTION: Attendance within the previous two years at a one week nuclear weapon orientation course given by DASA or Nuclear Weapons Training Center, Pacific or Atlantic; or within the previous three years at a planning or employment course given by one of the above commands.

NW 303C MISSILES AND SPACE OPERATIONS (6-0). Principles of guidance and propulsion, operational capabilities and limitations of guided missile systems. Orientation in space technology, problems and potentialities of operations in outer space. USUAL BASIS FOR EXEMPTION: Equivalent experience or educational background. Foreign officers take NW 393D.

NW 304C INTRODUCTION TO NAVAL TACTICAL DATA SYSTEM (3-0). A brief review of number systems with concentration in octal and binary operations. An introduction to Boolean algebra and logic circuitry of modern computers. Modern high-speed digital computer principles. An introduction to operational programming for NTDS. A comprehensive coverage of the Naval Tactical Data System and its associated elements, its capabilities and limitations as planned for CVA(N), CG(N) and DLG types.

NW 305C MINE WARFARE (3-0). An introduction to the principles of Mining Operations, Mine Countermeasures Operations, and the concept of Harbor Defense. Course material includes: (a) a study of the operational characteristics of selected mines, stressing capabilities and limitations; (b) an introduction to the practical application of mine laying, planning considerations, threat theory, and the area concept theory of mining; (c) an introduction to all types of minesweeping gear, and all mine countermeasures vessels, stressing operational characteristics; (d) a study of the various minesweeping procedures and tactics; (e) an introduction to harbor defense procedures and equipment; and (f) new developments. Foreign officers take NW 395D.

NW 391D ORDNANCE-WEAPON SYSTEMS (3-0). A survey of the fields of surface and airborne ordnance including guns, bombs, rockets, and associated delivery systems. An analysis of weapon system capabilities and limitations. Foreign officers course.

NW 393D MISSILES AND SPACE OPERATIONS (3-0). Principles of guidance and propulsion. Orientation in space technology, problems and potentialities of operations in outer space. Foreign officers course.

NW 395D MINE WARFARE (3-0). Fundamentals of mine laying and mining planning. Principles of mine countermeasures operations, planning, and harbor defense. Foreign officers course.

NW 401C LEADERSHIP (4-0). The improvement of Naval Leadership by broadening the line officer's knowledge and understanding of the following topics: methods and techniques of enlisted personnel administration; applications of the principles of management to the naval unit; philosophy of authority and responsibility with major emphasis on the principles of effective naval leadership. Instruction methods emphasize individual study projects and group study discussion.

NW 402C MARINE PILOTING AND RADAR NAVIGATION (2-2). Practical aspects of shipboard navigation, including marine piloting, radar and loran navigation. Included topics: charts, buoys; navigation lights; tides and currents, magnetic and gyro compasses; the navigator's records; voyage planning, electronic navigation devices. Practical work covers the use of hydrographic publications and performance of chart work. USUAL BASIS FOR EXEMPTION: Successful completion of USNA, NROTC, OCS or equivalent course; or previous assignment as navigator (assistant navigator of large ship) for one year.

NW 403C CELESTIAL NAVIGATION (3-0). The theory and practice of celestial navigation as applicable to the navigator's work at sea. Included topics: introduction to nautical astronomy; the use of the nautical almanacs and the H. O. 214; the applications of celestial navigation. Practical work covers the navigator's day's work at sea.

NW 404C LOGISTICS AND NAVAL SUPPLY (3-0). The initial phase of the course stresses the importance of military logistics to our national security. Topics covered are: the fundamental elements of the logistics process; the planning and organizational aspects of logistical administration; the budget process; and joint logistical procedures. The final phase of the course emphasizes naval logistics and its relationship to combat readiness. Topics included are: the Navy Supply System; the role of bases, mobile support, and the operating unit in naval logistics; and logistics management at the unit command level.

NW 405D PERSONAL AFFAIRS (3-0). The fundamentals of personal estate planning. Included topics: government benefits; life insurance and general insurance; budgeting and banking; borrowing; real estate; securities; wills, and related legal matters.

NW 406C COMMAND SEAMANSHIP (3-0). The fundamentals of seamanship as applicable to the responsibilities and duties assigned to the commanding officer on board ship. Included topics: shiphandling; anchoring and mooring and associated tackle; officer of the deck function at sea and in port; underway replenishment, heavy weather procedures; shipboard honors and ceremonies; marine collision laws including international and inland rules of the road with court interpretations; emergency shiphandling. Practical application of forces effecting ship by use of shiphandling model trainer. USUAL BASIS FOR EXEMPTION: Certification of qualification as Officer of the Deck (Underway) tactical steaming.

NW 407D NAVAL INTELLIGENCE (3-0). An overview of intelligence functions. Included topics: nature of intelligence; development of modern intelligence; the role of intelligence in planning national policy and military strategy; the rise of Russia and Communism as international forces; the intelligence cycle, including the line officer's role in intelligence collection; employment of intelligence by operational commanders; counterintelligence.

NW 501C MARINE ENGINEERING (4-0). Shipboard steam main propulsion plants and auxiliaries, Diesel engines, shipboard electrical distribution, miscellaneous naval auxiliary machinery, and organization and administration of shipboard engineering department. USUAL BASIS FOR EXEMPTION: Qualification as Engineering Officer of the Watch of a steam-propelled ship.

NW 502C DAMAGE CONTROL AND ATOMIC, BIOLOGICAL, CHEMICAL WARFARE DEFENSE (4-0). Fundamentals of ship construction and stability, stability calculations and analysis, damage control systems and organization, repair of damage; effects of ABC weapons, ABC detection, decontamination and personnel protection; disaster control ashore. PREREQUISITE: Course in Nucleonics Fundamentals. USUAL BASIS FOR EXEMPTION: Completion of 10 weeks "Officers' Basic Damage Control" Course, or completion of correspondence courses "Practical Damage Control" (NAVPERS 10936), "Theoretical Damage Control" (NAVPERS 10937), and "Radiological Defense" (NAVPERS 10771).

NW 503C MARINE NUCLEAR PROPULSION (2-0). An introduction to nuclear power plants of possible use in marine propulsion. Includes principles of operation, fuels and materials, limitations and economy of various reactors, and a brief description of reactor power plants currently in use. PREREQUISITES: NW 501C and a course in Nucleonics Fundamentals.

DEPARTMENT OF OPERATIONS RESEARCH

THOMAS EDMOND OBERBECK, Professor of Operations Research, Chairman, (1951)*; B.A., Washington University, 1938; M.A., University of Nebraska, 1940; Ph.D., California Institute of Technology, 1948.

ALVIN FRANCIS ANDRUS, Associate Professor of Operations Research (1963); B.A., University of Florida, 1957; M.A., 1958.

RAYMOND GLENN HEMANN, Instructor in Operations Research, (1963); B.S., Florida State University, 1957.

REX HAWKINS SHUDDE, Associate Professor of Operations Research (1962); B.S., B.A., University of California at Los Angeles, 1952; Ph.D., University of California, 1956.

RICHARD MCNEELY THATCHER, Assistant Professor of Operations Research (1960); B.A., University of California at Berkeley, 1952; M.S., USNPGS, 1963.

*The year of joining the Postgraduate School faculty is indicated in parentheses.

DEPARTMENTAL REQUIREMENTS FOR DEGREE IN OPERATIONAL RESEARCH BACHELOR OF SCIENCE

The basic requirement for the degree Bachelor of Science with major in Operations Research consists of a minimum of 64 term hours in residence at the Postgraduate School and including at least:

a. 24 term hours of Operations Research

b. 15 term hours of Probability and Statistics

c. 10 term hours of Mathematics beyond elementary Calculus

d. 10 term hours of upper division Physical Science, Engineering, or Management courses.

The degree of Bachelor of Science with major in Operations Research will be granted to a student who has successfully completed the above requirements and can demonstrate that he has met the general requirements of the Naval Postgraduate School for a Bachelor of Science degree.

MASTER OF SCIENCE IN OPERATIONS RESEARCH

In order to qualify for the degree Master of Science in Operations Research in accordance with the requirements listed below, a student must first meet the requirements for the degree Bachelor of Science with major in Operations Research. Specific course requirements include a minimum of 48 term hours of A and B level courses of which:

a. At least 18 term hours must be in A level Operations Research courses including: Linear Programming, Dynamic Programming and Queueing Theory.

b. At least 12 term hours must be in advanced physics courses.

c. At least one of the sequences of elective courses recommended by the Department of Operations Research.

In addition a student must submit a thesis on a subject approved by the Department of Operations Research and demonstrate that he has met the general requirements of the Naval Postgraduate School for a Master of Science degree.

OPERATIONS ANALYSIS

OA 001E ORIENTATION IN OPERATIONS ANALYSIS CURRICULUM (0-1). A review of objectives of the Operations Analysis Curriculum; definitions of operations analysis and operations research; origins and contemporary status of operations research; the role of operations research in the development of weapons systems. TEXTS: MCCLOSKEY *and* TREFETHEN, *Operations Research for Management*, Vols. I and II; Instructor's Notes.

OA 101C ELEMENTS OF OPERATIONS ANALYSIS (3-1). An introductory course primarily for students in the Engineering Science Curriculum. Topics covered include: review of probability theory; nature, origin, and contemporary status of operations analysis; problem formulation, measures of effectiveness; Lanchester's equations; examples of Operations Research problems using probability theory; brief introduction to linear programming and game theory if time permits. TEXTS: MCCLOSKEY *and* TREFETHEN, *Operations Research for Management*, Vols. I and II; Operations Evaluation Group, Report No. 54, *Methods of* Operations Research; TUCKER, *Submarine Firing Phase Decisions*, USNPGS Thesis; Selected Papers for Introductory Operations Analysis; Selected Applications of Lanchester's Theory of Combat; Instructor's notes. PREREQUISITE: Ma 311C.

OA 111B PRINCIPLES OF OPERATIONS ANALYSIS (4-2). An introductory course, primarily for students in the Management-Data Processing Curriculum. The definition of operations analysis and its relation to management science. Basic concepts such as formulation of an operations research problem and measures of effectiveness. Sensitivity analyses and simulation as fundamental techniques of operations analysis. Emphasis on problem formulation and the role of probability theory. TEXTS: MCCLOSKEY *and* TREFETHEN, *Operations Research for Management*, Vols. I and II; Operations Evaluation Group, Report No. 54, *Methods of Operations Research*; TUCKER, *Submarine Firing Phase Decisions*, USNPGS Thesis; Selected Papers for Introductory Operations Analysis; Selected Applications of Lanchester's Theory of Combat; Instructor's notes. PREREQUISITES: Ma 321B or equivalent, and a second course in probability theory and statistics to be taken concurrently.

OA 112A ADVANCED METHODS IN OPERATIONS ANALYSIS (4-0). A continuation of OA 111. A survey of techniques such as linear programming, dynamic programming, inventory control, the theory of games, statistical decision theory and queueing theory. TEXTS: GASS, *Linear Programming*; ACKOFF, *Progress in Operations Research*; BELLMAN, *Dynamic Programming*; TUCKER, *Introduction to Statistical Decision Functions*, USNPGS Thesis; SMITH, *Application of Statistical Methods to Naval Operational Testing*, USNPGS Thesis. PREREQUISITES: OA 111B and a second course in probability theory and statistics to be taken concurrently.

OA 121A SURVEY OF OPERATIONS ANALYSIS (4-2). The nature, origin, and contemporary status of operations analysis; fundamental concepts with special emphasis on applications; introduction to game theory, linear programming, and other advanced techniques. TEXTS: MORSE *and* KIMBALL, *Methods of Operations Research*; MCCLOSKEY *and* TREFETHEN, *Operations Research for Management*, Vols. I and II; GASS, *Linear Programming*; TUCKER, *Submarine Firing Phase Decisions*, USNPGS Thesis. PREREQUISITES: Ma 321B and Ma 322B.

OA 141B FUNDAMENTALS OF OPERATIONS ANALYSIS (4-0). The role of operations analysis in the solution of military problems. Measures of effectiveness. Special techniques such as game theory and linear programming. TEXTS: McCloskey *and* Trefethen, *Operations Research for Management*, Vols. I and II. Gass, *Linear Programming;* Tucker, *Submarine Firing Phase Decisions*, USNPGS Thesis; Williams, *The Compleat Strategyst;* Morse *and* Kimball, *Methods of Operations Research.* PREREQUISITE: Ma 321B.

OA 202A ECONOMETRICS (3-0). Mathematical economic theory. Emphasis on inter-industry analysis. Review of current theoretical investigations of relations between military programs and the national economy. TEXTS: Koopmans, *Activity Analysis of Production and Allocation;* Karlin, *Mathematical Methods and Theory of Games, Programming and Economics;* Conolly, *Interdiction Considerations in Leontieff-Type Land Logistic Networks*, USNPGS Thesis. PREREQUISITES: Ma 196A and OA 391B.

OA 211A LINEAR PROGRAMMING (4-1). Mathematical methods in logistics, with major emphasis on applications of linear programming to problems of transportation and the scheduling of inter-dependent activities. Relation of linear programming to the theory of games. Laboratory work on the computation of optimal solutions to linear programming problems, including the use of high-speed digital computers. TEXTS: Koopmans, *Activity Analysis of Production and Allocation;* Gass, *Linear Programming.* PREREQUISITES: OA 391A, OA 421B and Ma 196B. Offered Term I.

OA 212A DYNAMIC PROGRAMMING (3-1). The study of multistage decision processes using the techniques of dynamic programming with emphasis on the process structure. Techniques for machine computation and dimensionality reduction will be studied and aided by student use of the School's computation center. TEXTS: Bellman *and* Dreyfus, *Applied Dynamic Programming;* Bellman, *Dynamic Programming.* PREREQUISITES: OA 421B and Ma 304B.

OA 213A INVENTORY CONTROL (3-0). The study of deterministic and stochastic inventory-type decision processes. Optimal policies will be derived for increasingly complicated inventory models. Emphasis will be placed on the criterion functions and their sensitivity to changes in model structure. Use will be made of the IBM Inventory Management Simulator. TEXTS: Hanssmann, *Operations Research in Production and Inventory Control;* Arrow, Karlin, Scarf, *Studies in the Mathematical Theory of Inventory and Production;* Brown, *Statistical Forecasting for Inventory Control;* Bellman, *Dynamic Programming.* PREREQUISITE: OA 212A.

OA 214A GRAPH THEORY (3-0). Elements of the theory of graphs, with emphasis on applications to the study of organizations, communication systems, and transportation networks. TEXT: Berge, *The Theory of Graphs and Its Applications;* Ore, *Theory of Graphs;* Ford *and* Fulkerson, *Flows in Networks.* PREREQUISITES: Ma 196B and Ma 193C.

OA 215A GRAPH THEORY II (3-0). A continuation of OA 214A. TEXTS: Berge, *The Theory of Graphs and Its Applications;* Ore, *Theory of Graphs*, Ford *and* Fulkerson, *Flows in Networks.* PREREQUISITE: OA 214A.

OA 225A AIR WARFARE (3-0). Analyses of fleet air defense exercises. Changes in tactics and force disposition arising from the introduction of nuclear weapons and missiles. Active and passive air defense. Relationship of air defense to strike capability and ASW. TEXT: Classified official publications. PREREQUISITES: OA 292B and OA 293B.

OA 234A QUEUEING THEORY AND RELIABILITY THEORY (3-0). Basic principles of stochastic processes applied to a class of queueing models: connection between Poisson and exponential distributions, derivation of queue length and waiting time distributions for single and parallel channel models. Reliability theory and practice as applied to system maintenance, availability and safety. Reliability concepts will be developed and solutions obtained through analysis, design and testing. TEXTS: Cox *and* Smith, *Queues;* Lloyd *and* Lipow, *Reliability-Management, Methods and Mathematics.* PREREQUISITE: Ma 304B.

OA 235A DECISION CRITERIA (3-0). Survey and critique of the current literature dealing with decision criteria. Philosophy of values and allocation of effort. Applications to problems of human relations. TEXTS: Luce *and* Raiffa, *Games and Decisions.* PREREQUISITE: OA 292B.

OA 236A UTILITY THEORY (3-0). General concept of utility and its measurement. Survey and critique of the current literature dealing with the concept and measurement of utility. Applications to problems of human relations. TEXTS: Davidson, Suppes, Siegel, *Decision Making;* Churchman, *Prediction and Optimal Decision;* Hagen, *Theory of Social Change;* Thorp, *Biology and the Nature of Man.* PREREQUISITE: OA 292B.

OA 237A UTILITY THEORY II (3-0). The philosophy of measurement. The relation between the concept of utility and parallel concepts in psychophysics. The relation between utility and social philosophy. The selection and procurement of data necessary for social decisions. The first part of this course is based on a suitable text; but the main part of this course consists of student reports on the current literature. TEXT: C. W. Churchman *and* P. Ratoosh, *Measurement.* PREREQUISITE: OA 236A.

OA 291B INTRODUCTION TO OPERATIONS ANALYSIS (4-0). Development of fundamental concepts and methods of operations analysis as illustrated in the fields of submarine and anti-submarine warfare. Overall measures of effectiveness of a submarine as a weapon system. Determination of effectiveness as a product of measures of detection, attack, and kill capabilities. Lanchester's equations. TEXTS: McCloskey *and* Trefethen, *Operations Research for Management*, Vols. I and II; Tucker, *Submarine Firing Phase Decisions*, USNPGS Thesis; Morse *and* Kimball, *Methods of Operations Research.* PREREQUISITES: Ma 302B and Ma 182C. (These may be taken concurrently.)

OA 292B METHODS OF OPERATIONS RESEARCH (4-0). The methodologies and objectives of operations research. Introduction to game theory. Military applications of game theory. Analysis and critique of assumptions and results of operations research. Evaluation of weapons. TEXTS: Dresher, *Games of Strategy;* Luce *and* Raifa, *Games and Decisions; Classified and official publications.*

OA 293B SEARCH THEORY (4-0). Detection devices and their characteristics. Sweep rates and lateral range curves. Evaluation of search radars. Theories of radar detection. The design of screen and barrier patrols. Allocation of search effort. TEXTS: MORSE *and* KIMBALL, *Methods of Operations Research;* KOOPMAN, *Search and Screenings; Classified publications.* PREREQUISITE: OA 292B.

OA 296A DEVELOPMENT OF WEAPONS SYSTEMS (3-0). The areas of application of the various techniques of operations research which the student has learned are reviewed and placed in perspective relative to the procedure for evolving new weapons systems. Emphasis is placed upon the role of operations research in formulating operational requirements, developing prototype systems, and determining military specifications for selected systems and the role of operations analysis in various phases of operational testing of the system. The contributions of operations research to the coordination of the functions of those segments of the military establishment concerned with weapons systems development are analyzed. TEXTS: Classified official publications and instructor's notes. PREREQUISITE: OA 211A.

OA 297A SELECTED TOPICS IN OPERATIONS RESEARCH (3-0). Presentation of a wide selection of reports from the current literature. At the end of the term an attempt will be made to summarize the philosophy and principal methodologies of operations research. TEXT: None. PREREQUISITE: A background of advanced work in operations research.

OA 298A SELECTED TOPICS IN OPERATIONS RESEARCH II (3-0). A continuation of OA 297A. TEXT: None. PREREQUISITE: A background of advanced work in operations research.

OA 299A SELECTED TOPICS IN OPERATIONS RESEARCH III (3-0). A continuation of OA 298A. TEXT: None. PREREQUISITE: A background of advanced work in operations research.

OA 391B GAMES OF STRATEGY (3-2). Two-person zero-sum games; the minimax theorem. Methods of solving finite games. Specific games with appropriate application. Methods of solving continuous games on unit square with continuous payoff functions. Applications. TEXTS: DRESHER, *Theory and Applications of Games of Strategy;* LUCE *and* RAIFFA, *Games and Decisions;* MCKINSEY, *Introduction to the Theory of Games.* PREREQUISITES: Ma 301C or the equivalent; Ma 196B. (The latter may be taken concurrently).

OA 392A DECISION THEORY (3-0). Basic concepts. Relation of statistical decision functions to the theory of games. Applications in the planning of operational evaluation trials. TEXTS: WALD, *Statistical Decision Functions;* TUCKER, *Introduction to Statistical Decision Functions,* USNPGS Thesis; SMITH, *Application of Statistical Methods to Naval Operational Testing,* USNPGS Thesis; STAVELY, *Statistical Decision Theory,* USNPGS Thesis. PREREQUISITES: Ma 304B and OA 391B (The latter may be taken concurrently.)

OA 393B INTRODUCTION TO WAR GAMING (3-0). Historical development; simulation and monte carlo techniques with emphasis on the use of digital computers; random number generations; analysis of results of war games. TEXTS: Instructor's notes and prepared handouts. PREREQUISITES: OA 291B, Ma 303B, OA 421B or consent of instructor.

OA 394A WAR GAMING (3-0). Consideration of the problems inherent in the construction and use of large computer war games. Problems in the analysis of results of such games. Utilization of decision laboratory techniques.Construction of computer simulations. TEXT: Instructor's notes and classified official publications. PREREQUISITE: OA 393B or consent of the instructor.

OA 396A ADVANCED PROJECTS IN OPERATIONS RESEARCH I (1-4). A course in solving special problems by the use of advanced techniques of Operations Research. Emphasis is upon extending the student's ability to formulate and solve sophisticated models of problems arising in Operations Research. TEXT: None. PREREQUISITE: Consent of the instructor.

OA 397A ADVANCED PROJECTS IN OPERATIONS RESEARCH II (1-4). Continuation of OA 396A. TEXT: None. PREREQUISITE: Consent of the instructor.

OA 398A ADVANCED PROJECTS IN OPERATIONS RESEARCH III (1-4). Continuation of OA 397A. TEXT: None. PREREQUISITE: Consent of the instructor.

OA 399A ADVANCED PROJECTS IN OPERATIONS RESEARCH IV (1-4). Continuation of OA 398A. TEXT: None. PREREQUISITE: Consent of the instructor.

OA 421B INTRODUCTION TO DIGITAL COMPUTERS (5-0). Computer orientation including comparison of analog and digital devices, systems and logical design components, data systems, number systems, introduction to Boolean Algebra and its application to logical design, introductory machine language programming, and FORTRAN programming with emphasis on special mathemetical problems encountered in Operations Research. TEXTS: MCCRACKEN, *A Guide to FORTRAN Programming;* PHISTER, *Logical Design of Digital Computers;* CHAPIN, *An Introduction to Automatic Computers.*

OA 471B OPERATIONS ANALYSIS FOR NAVY MANAGEMENT (4-0). The nature, origin and contemporary status of operations analysis. Fundamental concepts with special emphasis on applications in the fields of transportation, inventory control and personnel management. Introduction to game theory. TEXTS: MCCLOSKEY *and* TREFETHEN, *Operations Research for Management,* Vols. I and II; GASS, *Linear Programming;* WILLIAMS, *Complete Strategyst;* CHERNOFF *and* MOSES, *Elementary Decision Theory.* PREREQUISITE: Ma 371C.

OA 491 METHODS FOR COMBAT DEVELOPMENT EXPERIMENTATION (4-0). Introduction to the planning, analysis and reporting aspects of tactical field experiments. Examination of criteria from the military and statistical points of view. Discriminant Analysis. TEXT: None. PREREQUISITES: OA 291B and Ma 304B.

OA 891E SEMINAR I (0-2). Review of summer assignments; selection of thesis topics; special lectures. TEXT: None.

OA 892E SEMINAR II (0-2). A continuation of OA 891E. Special lectures. TEXT: None. PREREQUISITE: None.

OA 893E SEMINAR III (0-2). Presentation of thesis developments. Special lectures. TEXT: None. PREREQUISITE: None.

OA 894E SEMINAR IV (0-2). A continuation of OA 893E. TEXT: None. PREREQUISITE: None.

OA 899E MILITARY SCIENCE SEMINAR (0-1). Review of contemporary writings on the history and developments of science in the military profession. TEXTS: Millis, *Arms and the State;* Huntington, *The Soldier and the State*. PREREQUISITE: None.

ORDNANCE

OR 241E ORDNANCE SEMINAR (Missile Systems) (0-2). Principles of Guided Missile Systems with emphasis on propulsion, guidance and tactical employment. Brief coverage of the general organization of BuWeps and its field activities. Objectives of various Advanced Weapons Systems Engineering Curricula as a basis for selection.

OR 242E ORDNANCE SEMINAR (Mine Warfare) (0-2). General concepts of Mine Warfare, including Mines, Mine Countermeasures, and the theory of tactical and strategic mining. Torpedoes and their role in missile systems.

OR 243E ORDNANCE SEMINAR (Weapons Systems) (0-2). Student presentation of principles and characteristics of modern planned Weapons Systems.

DEPARTMENT OF PHYSICS

Austin Rogers Frey, Professor of Physics, Chairman (1946)*; B.S., Harvard Univ., 1920; M.S., 1924; Ph.D., 1929.

Franz August Bumiller, Associate Professor of Physics (1962); M.S., Univ. of Zurich, 1951; Ph. D., 1955.

Fred Ramon Buskirk, Assistant Professor of Physics (1960); B.S., Western Reserve Univ., 1951; Ph.D., Case Institute of Technology, 1958.

Alfred William Madison Cooper, Assistant Professor of Physics (1957); B.A., Univ. of Dublin, 1955; M.A., 1959; Ph.D., The Queen's Univ. of Belfast, 1961.

John Niessink Cooper, Professor of Physics (1956); B.A., Kalamazoo College, 1935; Ph.D., Cornell Univ., 1940.

Eugene Casson Crittenden, Jr., Professor of Physics (1953); B.A., Cornell Univ., 1934; Ph.D., 1938.

Peter Pierce Crooker, Instructor in Physics (1960); B.S., Oregon State College, 1959.

William Peyton Cunningham, Professor of Physics (1946); B.S., Yale Univ., 1928; Ph.D., 1932.

John Norvell Dyer, Assistant Professor of Physics (1961); B.A., Univ. of California, 1956; Ph.D., 1960.

Paul Vincent Guthrie, Jr., Lieutenant Junior Grade, U.S. Navy; Instructor in Physics (1959); B.S., Univ. of Tennessee, 1955; M.S., 1959.

Mohamed Abdul Hakeem, Associate Professor of Physics (1962); B.S., Osmania Univ. (India), 1944; M.S., Univ. of Manchester (England), 1951; Ph.D., Louisiana State University, 1958.

Harry Elias Handler, Associate Professor of Physics (1958); B.A., Univ. of Calif. at Los Angeles, 1949; M.A., 1951; Ph.D., 1955.

Don Edward Harrison, Jr., Associate Professor of Physics (1961); B.S., College of William and Mary, 1949; M.S., Yale Univ., 1950; Ph. D., 1953.

Otto Heinz, Associate Professor of Physics (1962); B.A., Univ. of California, 1948; Ph.D., 1954.

William Lewis Johnson, Lieutenant Junior Grade, U.S. Naval Reserve; Instructor in Physics (1963); B.S., Univ. of Southern Mississippi, 1962.

Sydney Hobart Kalmbach, Professor of Physics (1947); B.S., Marquette Univ., 1934; M.S., 1937.

Raymond Leroy Kelly, Associate Professor of Physics (1960); B.A., Univ. of Wichita, 1947; M.S., Univ. of Wisconsin, 1949; Ph.D., 1951.

Lawrence Edward Kinsler, Professor of Physics (1946); B.S., California Institute of Technology, 1931; Ph.D., 1934.

Herman Medwin, Professor of Physics (1955); B.S., Worcester Polytechnic Institute, 1941; M.S., Univ. of Calif. at Los Angeles, 1948; Ph.D., 1953.

Paul Willby Middents, Lieutenant Junior Grade, U.S. Naval Reserve; Instructor in Physics (1963); B.S., Univ. of Dubuque, 1961; M.S., Michigan State Univ., 1963.

EDMUND ALEXANDER MILNE, Associate Professor of Physics (1954); B.A., Oregon State College, 1949; M.S., California Institute of Technology, 1950; Ph.D., 1953.

JOHN ROBERT NEIGHBORS, Associate Professor of Physics (1959); B.S., Case Institute of Technology, 1949; M.S., 1951; Ph.D., 1953.

NORMAN LEE OLESON, Professor of Physics (1948); B.S., Univ. of Michigan, 1935; M.S., 1937; Ph.D., 1940.

LEONARD OLIVER OLSEN, Professor of Physics (1960); B.A., Iowa State Teachers College, 1932; M.S., State Univ. of Iowa, 1934; Ph.D., 1937.

GERALD LEW PAYNE, Lieutenant Junior Grade, U.S. Navy; Instructor in Physics (1963); B.S., Ohio State Univ., 1961; M.S., Ohio State Univ., 1961.

WILLIAM REESE, Assistant Professor of Physics (1963); B.A., Reed College, 1958; M.S., Univ. of Illinois, 1960; Ph.D., 1962.

JOHN DEWITT RIGGIN, Professor of Physics (1946); B.S., Univ. of Mississippi, 1934; M.S., 1936.

GEORGE WAYNE RODEBACK, Associate Professor of Physics (1960); B.S., Univ. of Idaho, 1943; M.S., Univ. of Illinois, 1947; Ph.D., 1951.

JAMES VINCENT SANDERS, Assistant Professor of Physics (1961); B.S., Kent State Univ., 1954; Ph.D., Cornell Univ., 1961.

DAVID RAY SLOTBOOM, Lieutenant, U.S. Naval Reserve; Instructor in Physics (1960); B.S., Univ. of Utah, 1958; M.S., USNPGS, 1964.

ERNEST WILLIAM STEFFEN, JR., Commander, U.S. Navy; Instructor in Physics (1961); M.S., U.S. Naval Postgraduate School, 1948.

OSCAR BRYAN WILSON, JR., Professor of Physics (1957); B.S. Univ. of Texas, 1944; M.A., Univ. of Calif. at Los Angeles, 1948; Ph.D., 1951.

WILLIAM BARDWELL ZELENY, Assistant Professor of Physics (1962); B.S., Univ. of Maryland, 1956; M.S., Syracuse Univ., 1958; Ph.D., 1960.

*The year of joining the Postgraduate School Faculty is indicated in parentheses.

DEPARTMENTAL REQUIREMENTS FOR DEGREE IN PHYSICS

BACHELOR OF SCIENCE IN PHYSICS

1. It is required that any specific curriculum must be consistent with the general minimum requirements for any degree of Bachelor of Science as determined by the Academic Council.

2. A major in physics must include a minimum of 54 term hours in physics, including required courses and electives, a minimum of 38 term hours in mathematics, and the equivalent of a course in general chemistry. In addition, a minimum of 20 term hours of elective credits must be chosen in other specified areas. 108 term hours must be clearly of upper division level.

3. The following requirements must be met: (courses marked with an asterisk must include a laboratory)

Discipline	*Subject*	*Approximate Term Hours:*
Physics	General Physics*	16
	Physical Optics*	5
	Analytical Mechanics	8
	Electricity and Magnetism	8
	Atomic Physics*	7
		44
Mathematics	College Algebra and Trigonometry	8
	Analytical Geometry and Calculus	12
	Differential Equations	3
	Infinite Series	3
	Vector Algebra and Vector Analysis	6
		32
Chemistry	General Chemistry*	10

4. The remaining required hours in physics and mathematics are elective and must be of clearly upper division level. By choosing appropriate elective sequences in physics the student can begin a specialty-area on the undergraduate level. Suggested elective courses in physics are: Thermodynamics, Statistical Mechanics, Physics of the Solid State, Nuclear Physics, and Acoustics; in mathematics are: Complex Variables, Partial Differential Equations, and Probability and Statistics.

20 term hours of electives must be chosen in the areas of (a) electric circuits, (b) electronics, and (c) chemistry beyond general chemistry. At least 10 of the 20 term hours must be from one of these three areas.

5. The student must maintain grade point averages of at least 1.0 in both physics and mathematics.

MASTER OF SCIENCE IN PHYSICS

1. It is required that any specific curriculum be consistent with the general minimum requirements for any degree of Master of Science as determined by the Academic Council.

2. Each student's program of study must have a minimum of 36 term hours of physics *courses* not including thesis distributed between A and B level; of this 36 hours, a minimum of 12 hours must be A level. In lieu of the preceding requirement, students who are qualified to pursue graduate courses in physics when they arrive at the Postgraduate School may complete a minimum of 24 hours entirely of A level courses. In addition, all students must register for research and present an acceptable thesis.

3.The following specific course requirements must be successfully completed for a student to earn the degree of M.S. in Physics:

a. Thermodynamics and Statistical Mechanics—The student must take a two-term sequence (for example, PH 530 and PH 541) or present equivalent undergraduate preparation in this subject matter area.

b. Advanced Mechanics or Hydrodynamics—for example, PH 153 or PH 161.

c. Special Topics in Electromagnetism—for example, PH 367.

4. The student will be expected to specialize in one of the available options such as: (a) Acoustics, (b) Nuclear Physics, (c) Plasma Physics, (d) Solid State Physics, or (e) other recognized Physics specialization.

PHYSICS

PH 001D GENERAL PHYSICS I (4-0). Mechanics—The purpose of this course as well as the following 3 units is to provide a knowledge of the principles of physics and thus to help the student understand the scientific background of modern civilization. The first unit deals with physical quantities and the concepts of motion, force, momentum and energy. TEXT: SMITH *and* COOPER, *Elements of Physics.*

PH 002D GENERAL PHYSICS II (4-0). Harmonic Motion, Sound and Heat—This is a continuation of PH 001D and considers simple harmonic motion, oscillating systems including those producing sound, the propagation of sound and wave motion. The mechanics of gases, thermometry, transfer of heat, and thermodynamics are among other topics considered. TEXT: SMITH *and* COOPER, *Elements of Physics.* PREREQUISITE: PH 001D.

PH 003D GENERAL PHYSICS III (4-0). Electricity and Magnetism. This is a further continuation of General Physics I and II and presents the subject of electrostatics, including Coulomb's Law, potential and capacitance, electric current and electric circuits, magnetism, and induced electromotive force. TEXT: SMITH *and Cooper, Elements of Physics.* PREREQUISITES: PH 001D and PH 002D.

PH 004D GENERAL PHYSICS IV (4-0). Light and Modern Physics—This is the final unit of a four term sequence of General Physics and treats selected topics in light including the geometrical optics of mirrors and lenses, interference and diffraction and optical instruments. A brief introduction to modern physics is also given. This includes the topics of atomic structure, optical and X-ray spectra, radioactivity, and nuclear structure. TEXT: SMITH *and* COOPER, *Elements of Physics.* PREREQUISITES: PH 001D, PH 002D, and PH 003D.

PH 006D SURVEY OF PHYSICS (5-0) An introduction to the fundamental concepts and laws of statics and dynamics, including Newton's laws of motion, force, energy, momentum, and harmonic motion. Survey of gas laws, heat, wave propagations, sound and the properties of light. USUAL BASIS FOR EXEMPTION: Equivalent educational background. TEXT: WHITE, *Modern College Physics, 3rd Ed.* PREREQUISITE: Ma 010D or equivalent.

PH 011D GENERAL PHYSICS I (4-3). Mechanics—This course is designed to provide a knowledge of the principles of physics and to provide a scientific background for the study of engineering. It consists of lectures, recitations, problem sessions, and laboratory work dealing with force, motion, energy, momentum, elasticity, and hydrodynamics. TEXT: SEARS *and* ZEMANSKY, *University Physics.* PREREQUISITE: One term of calculus.

PH 012D GENERAL PHYSICS II (4-3). Heat, Sound, and Light—This is a continuation of General Physics I and deals with molecular mechanics, behavior of gases, thermal expansion, calorimetry, the laws of termodynamics, wave motion, vibrating bodies, reflection and refraction of light, dispersion, interference and diffraction, and optical instruments. TEXT: SEARS *and* ZEMANSKY, *University Physics.* PREREQUISITE: PH 011D.

PH 013D GENERAL PHYSICS III (3-3). Electricity and magnetism—This is a continuation of General Physics I and II and deals with the fundamental principals of electrostatics, electromagnetism, electrochemistry, direct and alternating currents. TEXT: SEARS *and* ZEMANSKY, *University Physics.* PREREQUISITES: PH 011D and PH 012D.

PH 014D GENERAL PHYSICS IV (4-2). Modern Physics—This is a continuation of General Physics I, II and III and deals with the fundamentals of atomic and nuclear physics. Topics include: atomic and nuclear structure, optical spectra, radioactivity, nuclear processes, and particle accelerators. TEXT: WEIDNER *and* SELLS, *Introductory Modern Physics.* PREREQUISITES: PH 011D, PH 012D and PH 013D.

PH 016D GENERAL PHYSICS MECHANICS (4-0). This course is a review in depth of that portion of General Physics dealing with Newtonian Mechanics and stressing quantitative use of such concepts as force, conservation of energy, conservation of momentum, rotational motion, elasticity and hydrodynamics. It is primarily for one year science students needing physics review at this level. TEXT: SEARS *and* ZEMANSKY, *University Physics.* PREREQUISITES: Previous exposure to college mathematics through calculus and one course in college physics.

PH 017D GENERAL PHYSICS - THERMODYNAMICS SOUND AND LIGHT (4-0). This course is a continuation of PH 016D and is a further review in depth of General Physics, stressing the concepts of temperature, heat transfer, thermal properties of solids, liquids and gases and the laws of thermodynamics. The propagation of waves in various media is considered with emphasis on sound waves. In optics, the geometrical optics of mirrors, lenses and optical instruments will be considered; and in physical optics interference and diffraction will be stressed. TEXT: SEARS *and* ZEMANSKY, *University Physics.* PREREQUISITE: PH 016D.

PH 018D GENERAL PHYSICS — ELECTRICITY AND MAGNETISM (4-0). This course is a study of the concepts of electrostatics stressing Gauss' Law and the theory of electric fields and potentials. Attention will also be given to direct the alternating current flow, electromagnetic phenomena and ferromagnetism. TEVT: SEARS *and* ZEMANSKY, *University Physics.* PREREQUISITES: Successful completion of Ph 016D and PH 017D.

PH 019C MODERN PHYSICS (4-0). This is a final course of a four term sequence and consists of a moderately rigorous study of some of the most fundamental concepts of atomic and nuclear physics. Topics included are atomic structure, radiation from atoms, nuclear structure and nuclear processes. TEXT: WEIDNER & SELLS, *Introductory Modern Physics.* PREREQUISITES: Successful completion of PH 016D, PH 017D, and PH 018D.

PH 021C MECHANICS (4-0). This course is a review and extension of the Mechanics portion of General College Physics. Emphasis is placed on a study in depth of the important concepts of physical mechanics. Representative topics are Newtons Laws of Motion, Conservation of Energy, Conservation of Momentum, Rotational Motion and Simple Harmonic Motion. TEXT: HALLIDAY *and* RESNICK, *Physics for Students of Science and Engineering;* PREREQUISITES: 8 to 10 semester hours of College Physics and 8 to 10 hours of Calculus, with acceptable grades, or demonstrated aptitude in Science and Mathematics.

PH 022C FLUID MECHANICS WAVE MOTION AND THERMODYNAMICS (4-0). This course is a continuation of PH 021C. The emphasis will be on developing a thorough understanding of the important concepts of physics which are normally catalogued under the title of this course. The relationship of Wave Motion and Acousics will be stressed as will the laws of Thermodynamics. TEXT: HALLIDAY *and* RESNICK, *Physics for Students of Science and Engineering.* PREREQUISITE: Successful completion of PH 021C.

PH 023C ELECTRICITY AND MAGNETISM (4-0). This course is a continuation of PH 021C and PH 022C. A careful study will be made of the concepts of electrostatics, Electric Fields and Gauss' Law, Electric Potential, Magnetic Effects of Currents, Electromagnetism and the Phenomena of Ferromagnetism. DC and AC electric currents will be studied. TEXT: RESNICK *and* HALLIDAY, *Physics for Students of Science and Engineering.* PREREQUISITE: Successful completion of PH 021C.

PH 024C ELECTROMAGNETIC RADIATION AND OPTICS (4-0). This course is a continuation of PH 021C, PH 022C and PH 023C and gives the student a better understanding of the electrical and magnetic character of radiation. Maxwell's Laws will be studied. In Optics, maximum attention will be given to understanding interference and diffraction. Polarization of Radiation will also be studied. TEXT: RESNICK *and* HALLIDAY, *Physics for Students of Science and Engineering.* PREREQUISITES: Successful completion of PH 021C and PH 023C.

PH 025C MODERN PHYSICS (4-0). This is the concluding course in a sequence of courses designed to provide the student with a substantial understanding of some of the most important and basic concepts of physics. Several topics classified as "modern physics" will be studied in depth. Among these are atomic structure, radiation from atomic systems, nuclear structure, nuclear processes and the tools of modern physics experimentation. TEXT: WIEDNER *and* SELLS, *Introductory Modern Physics.* PREREQUISITES: Successful completion of PH 021C, PH 022C, PH 023C, and PH 024C.

PH 031C MECHANICS II (4-0). A continuation of PH 151C for students who are not candidates for a Master's Degree. Review of elements of dynamics, motion of a system of particles, rigid body motion in a plane, motion in a central force field. TEXTS: RESNICK *and* HALLIDAY, *Physics for Students of Science and Engineering;* BECKER, *Introduction to Theoretical Mechanics.* PREREQUISITE: PH 151C.

PH 105C MECHANICS (4-0). The first term in a sequence of fundamental physics for students in Electrical Engineering and Electronics. The sequence includes PH 105C, PH 205C, and either PH 604C or PH 605B and PH 705B. The subject matter in the first term includes: kinematics, dynamics of a particle, energy, momentum, rotational motion, orbital motion, oscillations and wave motion. TEXT: RESNICK *and* HALLIDAY, *Physics for Students of Science and Engineering, Vol. I.*

PH 141B ANALYTICAL MECHANICS (4-0). Kinematics and dynamics of a particle, moving reference systems, central forces and celestial mechanics. TEXT: FOWLES, *Analytical Mechanics.* PREREQUISITES: At least 8 sem. hrs. of College Physics and 8 sem. hrs. of Calculus; Ma 182C (may be taken concurrently).

PH 142B ANALYTICAL MECHANICS (4-0). Dynamics of a system of particles, rigid bodies, Lagrange's equations and the Hamiltonian, theory of vibrations. TEXT: FOWLES, *Analytical Mechanics.* PREREQUISITES: Ma 183B (may be taken concurrently) and PH 141B.

PH 151C MECHANICS I (4-0). Fundamental concepts and laws of motion, statics and equilibrium, motion of a particle in a uniform field, oscillatory motion. TEXT: BECKER, *Introduction to Theoretical Mechanics.* PREREQUISITES: At least 8 sem. hrs. of College Physics and 8 sem. hrs. of Calculus.

PH 152B MECHANICS II (4-0). Motion of a system of particles, rigid body motion in a plane, motion in a central force field, accelerated reference frames. TEXT: BECKER, *Introduction to Theoretical Mechanics.* PREREQUISITES: PH 151C, Ma 251C and Ma 260C.

PH 153A MECHANICS III (4-0). Motion of a rigid body in three dimensions, generalized coordinates, Lagrange's and Hamilton's equations, canonical transformations, coupled systems and normal coordinates, elastic media. TEXT: BECKER, *Introduction to Theoretical Mechanics.* PREREQUISITE: PH 152B.

PH 154A CELESTIAL MECHANICS (4-0). Solar system, missile and satellite orbits, perturbation theory, mechanical problems of space flight. TEXT: Lecture Notes. PREREQUISITES: Ma 245B and PH 153A.

PH 155A ADVANCED MECHANICS I (3-0). Review of elementary principles, Lagrange formulations with applications. Hamilton's principle with applications to non-conservative and non-holomonic systems. The two body central force problem. Kinematics of rigid body motion. Orthogonal transformation. Formal properties of transformation matrix. Infinitesimal rotation. Coriolis force. Rigid body motion, the inertia tensor, Euler's equation, the symmetrical top. TEXT: GOLDSTEIN, *Classical Mechanics.* PREREQUISITES: PH 142B or PH 153A, PH 365B (may be taken concurrently).

PH 156A ADVANCED MECHANICS II (3-0). Special relativity in classical mechanics, including Lorentz transformation and Lagrange formulation. Hamilton's equations of motion. Canonical transformations. Hamilton-Jacobi equation. Small oscillations, classical perturbation theory. TEXT: GOLDSTEIN, *Classical Mechanics.* PREREQUISITE: PH 155A.

PH 161A FLUID MECHANICS (3-0). The fundamental concepts of fluid mechanics from the continuum and kinetic theory points of view; development and interpretation of the equation of continuity, the Navier-Stokes equation, the equation of state. TEXT: LANDAU *and* LIFSHITZ, *Fluid Mechanics* and instructor's notes. PREREQUISITES: PH 541B, Ma 260C and Ma 245B or equivalents.

PH 162A ADVANCED HYDRODYNAMICS (3-0). Solutions to the equations of fluid dynamics; potential flow, exact solutions of the Navier-Stokes equation, laminar and turbulent boundary layers, transitions, non-steady flow, hydrodynamic noise. TEXT: LANDAU *and* LIFSHITZ, *Fluid Mechanics,* SCHLICHTING, *Boundary Layer Theory.* PREREQUISITE: PH 161A.

PH 190D SURVEY OF PHYSICS I (3-0). Elementary concepts and laws of statics and dynamics. Introduction to the statics and dynamics of fluids. Temperature, heat, radiation, kinetic theory and the gas laws. Fundamentals of vector representation and notation. TEXT: SMITH *and* COOPER, *Elements of Physics*.

PH 191D SURVEY OF PHYSICS II (3-0). A continuation of PH 190D. A survey of wave propagation, sound, electricity and magnetism, atomic structure, the properties of light, and other electromagnetic wave phenomena. TEXT: SMITH *and* COOPER, *Elements of Physics*. PREREQUISITE: PH 190D or equivalent.

PH 192D SURVEY OF PHYSICS (3-0). A continuation of PH 191D. Survey of physical optics. Introduction to atomic structure including kinetic theory. TEXT: SMITH *and* COOPER, *Elements of Physics*. PREREQUISITE: PH 191D or equivalent.

PH 196C REVIEW OF GENERAL PHYSICS (4-2). Principle of statics and dynamics, oscillatory motion, wave motion fields, electricity and magnetism. TEXT: RESNICK *and* HALLIDAY, *Physics for Students of Engineering and Science*. PREREQUISITE: Ma 017D or equivalent.

PH 205C WAVES AND PARTICLES (4-0). Follows PH 105C. The properties of waves, propagation, Doppler effect, waves in three dimensions, reflection, refraction, interference and diffraction, polarization, wave-particle duality, photons, electron waves, phonons, indeterminancy principle, Bohr model of the atom and its defects. TEXT: HALLIDAY *and* RESNICK, *Physics for Students of Science and Engineering, Vol. II*. PREREQUISITE: PH 105C.

PH 240C OPTICS AND SPECTRA (3-3). Reflection and refraction of light, optical systems, dispersion, interference, diffraction, polarization. Basic atomic structure, photoelectric effect, radiation from atoms, molecules and solids. TEXTS: SEARS, *Optics; JENKINS and WHITE, Fundamentals of Optics*.

PH 241C RADIATION (3-3). Fundamentals of geometric and physical optics. Wave phenomena and wave propagation. Origin of the quantum theory, photoelectric effect, radiation from atoms, molecules and solids, target detection by optical and infrared devices. TEXTS: SEARS, *Optics*; JENKINS *and* WHITE, *Fundamentals of Optics*.

PH 260C PHYSICAL OPTICS (3-2). Reflection and refraction of light, optical systems, dispersion, interference, diffraction, polarization. Basic atomic structure, photoelectric effect, radiation from atoms, molecules and solids. TEXTS: SEARS, *Optics*; JENKINS *and* WHITE, *Fundamentals of Optics*.

PH 270B PHYSICAL OPTICS (4-2). Review of geometrical optics. Wave phenomena and wave propagation, interference, diffraction, polarization, double refraction, dispersion. TEXT: JENKINS *and* WHITE, *Fundamentals of Optics*.

PH 350B SPECIAL TOPICS IN ELECTROMAGNETISM (4-0). Development and applications of Maxwell's Equations for selected students. TEXTS: WHITMER, *Electromagnetics*; KRAUS, *Electromagnetics*. PREREQUISITE: Consent of Instructor.

PH 360B ELECTRICITY AND MAGNETISM (4-0). Electrostatics. Electric currents. The magnetic field, Maxwell's Equations. Plane waves, reflection radiation. TEXT: SKILLING, *Fundamentals of Electric Waves*. PREREQUISITES: PH 241C, PH 141B.

PH 365B ELECTRICITY AND MAGNETISM (4-0). Electrostatics, dielectrics, magnetostatics, induced emf, magnetic materials. TEXT: WHITMER, *Electromagnetics*. PREREQUISITE: Ma 260C.

PH 366B ELECTROMAGNETISM (4-0). A continuation of PH 365B. Maxwell's equations and applications of Maxwell's equations. TEXT: REITZ *and* MILFORD, *Foundations of Electromagnetic Theory and* WHITMER, *Electromagnetics*. PREREQUISITE: PH 365B.

PH 367A SPECIAL TOPICS IN ELECTROMAGNETISM (4-0). A continuation of PH 366B. Methods of solution to Laplace's equation and Poisson's equation. Hertz potential. Radiation, scattering and dispersion. TEXT: JACKSON, *Classical Electrodynamics*. PREREQUISITES: PH 366B, Ma 260C, and Ma 240C or Ma 241C.

PH 368A ADVANCED ELECTROMAGNETIC THEORY (3-0). Problems in electromagnetic radiation, optics and dispersion from electromagnetic point of view, retarded potentials, special theory of relativity. Lagrangian and Hamiltonian formulations of classical electrodynamics. TEXT: JACKSON, *Classical Electrodynamics and* LANDAU *and* LIFSCHITZ, *Classical Theory of Fields*. PREREQUISITES: PH 367A, and PH 155A.

PH 424B FUNDAMENTAL ACOUSTICS (4-0). This course is designed to provide a background in vibration and sound for students of operations analysis. An analytical study of the dynamics of free, forced and damped simple harmonic oscillators, string, bars and membranes. Development of, and solutions to, the acoustic wave equation. Propagation of plane waves in fluids and between different media. Acoustic filters. Beam patterns and directivity of acoustic radiation from a piston. Radiation reaction. Transducers for underwater sound. TEXT: KINSLER *and* FREY, *Fundamentals of Acoustics*. PREREQUISITES: Ma 182C and PH 141B.

PH 425B UNDERWATER ACOUSTICS (3-2). A continuation of Ph 424B for students of operations analysis. An analytical survey of the propagation of underwater acoustic waves as influenced by boundary conditions, refraction, scattering, and attenuation. Physical characteristics of sonar transducers. Sonar systems and developments. Experiments in underwater acoustics and noise analysis. TEXTS: KINSLER *and* FREY, *Fundamentals of Acoustics*; NDRC Technical Summary; *Principles of Underwater Sound;* NDRC Technical Summary, *Physics of Sound in the Sea*. PREREQUISITE: PH 424B.

PH 431B FUNDAMENTAL ACOUSTICS (4-0). This course is designed to provide a background in vibration and sound for students of electronics or ordnance. An analytical study of the dynamics of free, forced, and damped simple harmonic oscillators, strings, bars, and membranes. Development of, and solutions to, the acoustic wave equation. Propagation of plane waves in fluids and between media. Acoustic filters. Beam patterns and directivity of acoustic radiation from a piston, radiation reaction. Loudspeakers and microphones. TEXT: KINSLER *and* FREY, *Fundamentals of Acoustics*. PREREQUISITES: MA 113B and Ph 105C, PH 151C.

PH 432B UNDERWATER ACOUSTICS (4-3). A continuation of PH 431B for students of electronics or ordnance. Transmission of sound in the ocean, including problems of refraction, attenuation, scattering, reverberation, and channel propagation. Physical principles used in sonar systems. Experiments in acoustical measurements, transducer measurements and noise analysis. TEXTS: KINSLER *and* FREY, *Fundamentals of Acoustics;* NDRC, *Technical Summary—Principles of Underwater Sound;* and NDRC, *Technical Summary — Physics of Sound in the Sea.* PREREQUISITE: PH 431B.

PH 433A PROPAGATION OF WAVES IN FLUIDS (3-0). A theoretical treatment of the propagation of sound in fluids including molecular relaxation effects and both ray and wave propagation characteristics in bounded, inhomogeneous media. TEXTS: LINDSAY, *Mechanical Radiation;* OFFICER, *Introduction to the Theory of Sound Transmission;* and HERZFELD *and* LITOVITZ, *Absorption and Dispersion of Ultrasonic Waves.* PREREQUISITE: PH 432B.

PH 441B SHOCK WAVES IN FLUIDS (4-0). Hydrodynamic equations. Propagation of acoustic waves in fluids. Shock waves propagated from nuclear explositions; Rankine-Hugoniot equations for the shock front, scaling laws, experimental measurements. TEXTS: KINSLER *and* FREY, *Fundamentals of Acoustics;* COLE, *Underwater Explosions.* PREREQUISITES: Ma 183B and PH 152B.

PH 442A FINITE AMPLITUDE WAVES IN FLUIDS (3-0). Non-linear effects of intense sounds. Theory of propagation of shock waves in fluids. TEXTS: COLE, *Underwater Explosions;* LINDSAY, *Mechanical Radiation;* and LANDAU *and* LIFSHITZ, *Fluid Mechanics.* PREREQUISITE: PH 432B or equivalent.

PH 450C UNDERWATER ACOUSTICS (3-2). A survey of the fundamentals of acoustics, with particular emphasis on the radiation, transmission and detection of sound in the sea. TEXTS: KINSLER *and* FREY, *Fundamentals of Acoustics;* NDRC, *Technical Summary—Principles of Underwater Sound;* NDRC *Technical Summary—Physics of Sound in the Sea.* PREREQUISITE: Ma 073C or Ma 244C or equivalent.

PH 461A TRANSDUCER THEORY AND DESIGN (3-3). A theoretical treatment of the fundamental phenomena in the design of crystal, magneto-strictive, and ceramic sonar transducers. Characteristics and parameters of various sonar transducer systems are studied in the Laboratory. TEXTS: HUETER *and* BOLT, *Sonics;* NDRC Technical Summary, *Magnetostriction Transducers;* KINSLER *and* FREY, *Fundamentals of Acoustics.* PREREQUISITE: PH 432B or equivalent.

PH 471A ACOUSTICS RESEARCH (0-3). Advanced laboratory projects in acoustics. PREREQUISITE: PH 432B or equivalent.

PH 480E ACOUSTICS SEMINAR (0-1). Reports on current research and study of recent research literature in conjunction with the student thesis.

PH 530B THERMODYNAMICS (3-0). Fundamental theory of thermodynamics and application to physical problems. First and second laws of thermodynamics; introduction to classical phase rule. Gaseous reactions, thermodynamics of dilute solutions, specific heats of gases, the Nernst heat theorem. TEXT: MORSE, *Thermal Physics.* PREREQUISITES: PH 142B or PH 152B and Ma 183B.

PH 531A ADVANCED THERMODYNAMICS (3-0). Principles of classical thermodynamics. Extremum principles and thermodynamic stability. Applications: gases, solid state physics, electric and magnetic systems. Fluctuations and irreversible thermodynamics. TEXT: CALLEN, *Thermodynamics.* PREREQUISITES: PH 153A or PH 155A, PH 366B, PH 636B, or PH 671B, PH 530B or equivalent.

PH 541B KINETIC THEORY AND STATISTICAL MECHANICS (4-0). Maxwell-Boltzmann distribution, collision cross-sections, introduction to classical and quantum statistics, with application to radiant energy. TEXT: MORSE, *Thermal Physics.* PREREQUISITES: PH 142B or PH 153A, Ma 260C and Ma 246B.

PH 545A STATISTICAL PHYSICS I (3-0). Kinetic theory and the Boltzmann H-theorem, configuration space, phase space, the Liouville theorem, introduction to ensemble theory, grand canonical ensembles, quantum statistics. TEXTS: HUANG, *Statistical Mechanics;* ter HAAR, *Elements of Statistical Mechanics.* PREREQUISITES: PH 636B or PH 671B, PH 153A or PH 156A, PH 530B, PH 541B, and PH 366B.

PH 546A STATISTICAL PHYSICS II (3-0). A continuation of PH 545A with selected applications to molecules, Bose-Einstein gases, Fermi-Dirac liquid helium and superconductivity. TEXTS: HUANG, *Statistical Mechanics,* HAAR, *Elements of Statistical Mechanics.* PREREQUISITE: PH 545A.

PH 600D NUCLEONICS FUNDAMENTALS (3-0). A study of atomic structure, natural and artificial radioactivity, nuclear structure, nuclear fission, and chain reaction. Introduction to reactor principles, reactor components, and nuclear power plants. USUAL BASIS FOR EXEMPTION: Equivalent educational background. TEXTS: HOISINGTON, *Nucleonics Fundamentals* and NAVPERS, 10786, *Basic Nuclear Physics.*

PH 604C STRUCTURE OF ATOMS AND SOLIDS (4-0). Follows PH 205C for those students not planning to take PH 705B. Kinetic theory of gases, fundamental particles, brief treatment of nuclear physics, special relativity, the general principles of quantum mechanics, periodic chart of the elements, vector model of the atom, electrons in solids, holes, semi-conductors and semi-conducting devices. TEXTS: WEIDNER *and* SELLS, *Elementary Modern Physics;* SPROULL, *Modern Physics,* 2nd Ed.; RESNICK *and* HALLIDAY, *Physics for Students of Science and Engineering,* Vols. I and II. PREREQUISITE: PH 205C.

PH 605B ATOMIC PHYSICS (4-0). Follows PH 205C for those students planning to take PH 705B. Kinetic theory of gases, Boltzmann function, fundamental particles, introduction to nuclear physics, special relativity, quantum mechanics, free and bound particles, emission and absorption of radiation, the one-electron atom, periodic table of the elements, many-electron atoms, electron spin, x-rays, vibration-rotation spectra for molecules masers and lasers. TEXTS: SPROUL, *Modern Physics, 2nd Ed.,* WEIDNER *and* SELLS, *Elementary Modern Physics;* RESNICK *and* HALLIDAY, *Physics for Students of Science and Engineering,* Vols. I and II. PREREQUISITE: PH 205C.

PH 620B ELEMENTARY ATOMIC PHYSICS (4-0). Fundamental particles, forces on particles, kinetic theory, photons as waves and particles, electrons as particles and waves, elementary quantum physics, binding energies in atoms and nuclei. atomic structure and spectra, X-rays, molecular structure, atoms in solids. TEXT: WEIDNER *and* SELLS, *Elementary Modern Physics*. PREREQUISITE: PH 141B or equivalent.

PH 621B ELEMENTARY NUCLEAR PHYSICS (4-0). A descriptive and phenomenological course including properties of nucleons, nuclear structure, radioactivity, nuclear reactions, fission, and fusion. TEXT: KAPLAN, *Nuclear Physics*. PREREQUISITE: PH 620B or PH 630B.

PH 622B NUCLEAR PHYSICS LABORATORY (0-3). Discussions and experiments on the interactions of nuclear radiations with matter and detection techniques. PREREQUISITE: PH 621B (may be taken concurrently).

PH 630B ELEMENTARY ATOMIC PHYSICS (4-0). Elementary particles, interactions of particles, photoelectric effect, electron diffraction, the nuclear atom, Bohr model of the atom, energy levels in atoms, optical and X-ray spectra, Pauli exclusion principle. Zeeman effect, Schroedinger's equation. TEXT: WEIDNER *and* SELLS, *Elementary Modern Physics*. PREREQUISITES: PH 152B and PH 240C or equivalents.

PH 631B ATOMIS PHYSICS LABORATORY (0-3). Quantitative laboratory exercises in atomic physics. PREREQUISITE: PH 620B or PH 630B (must be taken concurrently).

PH 635B ATOMIC PHYSICS I (5-0). Special theory of relativity. Fundamental particles, interactions of particles, photoelectric effect, wave-particle duality, Rutherford scattering, elementary quantum mechanics, Schroedinger equation, quantum mechanical operators, Bohr theory of the atom, quantum mecanical solution for the hydrogen atom, vector model of the atom, quantum numbers, Pauli exclusion principle, periodic table of the elements. TEXTS: RICHTMYER, KENNARD *and* LAURITSEN, *Modern Physics*, and SPROULL, *Modern Physics*. PREREQUISITES: Ma 230D and PH 240C.

PH 636B ATOMIC PHYSICS II (4-3). Eine structure in the hydrogen atom, Zeeman effect, selection rules in atomic spectra, X-rays, binding energies in molecules, molecular structure, band theory of solids, semiconductors, electron and nuclear spin resonance. Laboratory: Quantitative experiments related to the lecture material of PH 635B and PH 636. TEXTS: RICHTMYER, KENNARD *and* LAURITSEN, *Modern Physics*; SPROUL, *Modern Physics*. PREREQUISITE: PH 635B.

PH 637B NUCLEAR PHYSICS I (3-0). Basic nuclear concepts, systematics of nuclear stability, liquid drop model, fission, interaction of charged particles and photons with matter. TEXT: BURCHAM, *Nuclear Physics*. PREREQUISITES: PH 365B, and PH 636B or PH 670B and PH 671B.

PH 638B NUCLEAR PHYSICS II (3-3). Nuclear angular momentum, electric and magnetic moments, shell and collective models, nuclear reactions with emphasis on neutrons, survey of the two-body problem, theories of radioactive decay. Laboratory: Discussions and experiments on the interactions of nuclear radiations with matter and detection techniques. TEXTS: BURCHAM, *Nuclear Physics*; VALENTE, *A Manual on Experiments in Reactor Physics*. PREREQUISITE: PH 637B.

PH 639A NUCLEAR PHYSICS II (4-3). Quantitative treatment of nuclear angular momentum and magnetic and electric moments, the shell and collective models, method of partial waves, the deuteron problem, nuclear reactions with emphasis on neutrons, semi-quantitative treatment of the theories of radioactive decay. Laboratory: Discussions and experiments on the interactions of nuclear radiations with matter and detection techniques. TEXTS: BURCHAM, *Nuclear Physics*; VALENTE, *A Manual on Experiments in Reactor Physics*; Class notes. PREREQUISITES: PH 637B and consent of instructor.

PH 646A ADVANCED NUCLEAR PHYSICS I (3-0). Partial wave analysis of scattering, the theories of nuclear reactions, nuclear forces. TEXTS: BLATT *and* WEISSKOPF, *Theoretical Nuclear Physics*; SACHS, *Nuclear Theory*; BETHE *and* MORRISON, *Elementary Theory*; the periodicals of nuclear physics. PREREQUISITES: PH 639A, PH 367A, and PH 712A.

PH 647A ADVANCED NUCLEAR PHYSICS II (3-0). Nuclear models, theory and beta-decay, theory of gamma emission, theory of alpha decay. TEXTS: BLATT *and* WEISSKOPF, *Theoretical Nuclear Physics*; SACHS, *Nuclear Theory*; BETHE *and* MORRISON, *Elementary Nuclear Theory*; the periodicals of nuclear physics. PREREQUISITE: PH 646A.

PH 648A HIGH ENERGY PHYSICS (3-0). Introduction to techniques and theories. Topics selected from scattering, relativistic particle dynamics, nuclear reactions, elementary particles, and accelerators and other experimental equipment. TEXTS: JACKSON, *Physics of Elementary Particles*; RITSON, *Techniques of High Energy Physics*. PREREQUISITES: PH 636 or 671, PH 638, PH 711.

PH 650B GASEOUS DISCHARGES (4-0). Basic phenomena in gaseous discharges and infrared spectroscopy; theory of detectors for nuclear reactions. TEXTS: VON ENGEL, *Ionized Gases*; RICHTMYER *and* KENNARD, *Introduction to Modern Physics*; Lecture notes. PREREQUISITE: PH 630B or equivalent.

PH 651A REACTOR THEORY I (3-0). Nuclear fission, the diffusion and slowing down of neutrons, homogenous thermal reactors. TEXTS: GLASSTONE *and* EDLUND, *The Elements of Nuclear Reactor Theory*; MURRAY, *Nuclear Reactor Physics*. PREREQUISITES: PH 637B, PH 638B and Ma 113B or equivalent.

PH 652A REACTOR THEORY II (3-0). A continuation of PH 651A. Time behavior, reactor control, reflected systems, multigroup theory, heterogeneous systems, perturbation theory. TEXTS: GLASSTONE *and* EDLUND, *The Elements of Nuclear Reactor Theory*; MURRAY, *Nuclear Reactor Theory*. PREREQUISITE: PH 651A.

PH 653A REACTOR PHYSICS LABORATORY (0-2). Experiments using the AGN-201 reactor including the measurement of the basic reactor parameters and the study of its transient behavior. TEXTS: AEROJECT-GENERAL, *Elementary Reactor Experimentation*; HUGHES, *Pile Neutron Researhc*; GLASSTONE *and* EDLUND, *The Elements of Nuclear Reactor Theory*. PREREQUISITES: PH 651A and PH 652A. (The latter may be taken concurrently.)

PH 654A PLASMA PHYSICS I (4-0). This is the first of a two term sequence concerned with the dynamics of plasmas to provide the basic concepts for application to such fields as controlled fusion and ion propulsion. Topics covered are collision phenomena, including atomics and surface effects, the Boltzmann equation, breakdown of a gas, diffusion both in the presence and absence of space charge. The general hydromagnetic macroscopic equation is dervied and from this the momentum transport and energy transport equations are obtained. The hydromagnetic equations for a two particle plasma are considered. TEXT: ROSE *and* CLARK, *Plasma and Controlled Fusion;* Lecture Notes. PREREQUISITES: PH 636B or PH 671B, PH 367A, and PH 541B.

PH 655A PLASMA PHYSICS II (3-0). A continuation of PH 654A. Application of hydromagnetic equations to study of macroscopic motions of a plasma, including conductivity of a magnetized Lorentzian gas. Simple shocks. Effect of coulomb interactions, including discussion of relaxation times and runaway electrons. Study of small amplitude waves occuring in a plasma. Motion of individual charges in a plasma. Types of radiation from plasmas, including bremsstrahlng and cyclotron radiation. Discussion of various types of plasma instabilities. Consideration of methods that have been used in attempts to obtain a useful thermonuclear power source. TEXT: ROSE *and* CLARK, *Plasmas and Controlled Fusion;* Lecture Notes. PREREQUISITE: PH 654A.

PH 670B ATOMIC PHYSICS I (3-0). Fundamental particles, kinetic theory, forces on particles, special theory of relativity, wave-particle duality, quantum mechanics of simple systems, quantum mechanical operators, Bohr model of the atom, quantum mechanical solution for the hydrogen atom. TEXTS: RICHMYER, KENNARD *and* LAURITSEN, *Modern Physics;* EISBERG, *Fundamentals of Modern Physics;* Lecture Notes. PREREQUISITES: PH 152B or equivalent. Ma 240C or equivalent, and PH 270B.

PH 671B ATOMIC PHYSICS II (3-3). Fine structure in the hydrogen atom, vector model of the atom, spectroscopic notation, Zeeman effect, many-electron atoms, periodic table in terms of quantum numbers, X-rays, binding in molecules. Laboratory: Quantitative experiments related to lecture material of PH 670B and PH 671B. TEXTS: RICHMYER, KENNARD *and* LAURITSEN, *Modern Physics;* EISBERG, *Fundamentals of Modern Physics;* Lecture Notes. PREREQUISITE: PH 670B.

PH 701B INTRODUCTION TO THE METHODS OF THEORETICAL PHYSICS (4-0). An introduction to the techniques used in solving problems in the classical field theories. Vector and scalar fields are studied. Solutions to the source-free equations most often encountered in physics are discussed. TEXT: To be chosen by instructor. PREREQUISITE: Consent of instructor.

PH 705B SOLID STATE PHYSICS (4-2). Follows PH 605B. Crystals and lattice properties, specific heat, thermal conductivity, phonons, properties of electrons in solids, Fermi-Dirac distribution, band theory, Brillouin zones, effective mass, negative mass, holes, electrical conductivity, Hall effect, intrinsic and impurity semi-conductors, virtual Fermi energy, photoconductivity. fluorescence, lasers, diodes, tunnel diodes, solar cells, thermo-electric power and cooling, transistors, magnetic properties of solids, masers, dielectrics and ferroelectrics, superconductivity and applications, brief treatment of plastic and mechanical properties. Laboratory experiments in selected areas of solids. TEXTS: KITTEL, *Elementary Solid State Physics,* 1962 Ed., SPROULL, *Modern Physics,* 2nd Ed.; WEIDNER *and* SELLS, *Elementary Modern Physics;* RESNICK *and* HALLIDAY, *Physics for Students of Science and Engineering,* Vols. I and II. PREREQUISITE: PH 605B.

PH 711A QUANTUM MECHANICS I (3-0). The need for quantum theory. Matrix formulation of quantum mechanics. The square well potential and the harmonic oscillator. TEXTS: DIRAC, *Quantum Mechanics;* SCHIFF, *Quantum Mechanics.* PREREQUISITES: PH 156A, PH 366B, PH 636B or PH 671B.

PH 712A QUANTUM MECHANICS II (3-0). The hydrogen atom. Time independent and time dependent perturbation theory. Identical particles and spin. TEXTS: DIRAC, *Quantum Mechanics;* SCHIFF, *Quantum Mechanics.* PREREQUISITE: PH 711A.

PH 713A QUANTUM MECHANICS III (3-0). Atoms Relativistic single particle wave equations and their solutions. TEXTS: DIRAC, *Quantum Mechanics;* SCHIFF, *Quantum Mechanics;* SCHWEBER, *Introduction to Relativistic Quantum Field Theory.* PREREQUISITE: PH 712A.

PH 714A QUANTUM FIELD THEORY I (3-0). Quantization of scalar, spinor, and vector fields. Interacting fields. TEXT: SCHWEBER, *Introduction to Relativistic Quantum Field Theory.* PREREQUISITE: PH 713A.

PH 715A QUANTUM FIELD THEORY II (3-0). The S-matrix and renormalization. Strong, electromagnetic, and weak interactions. Introduction to dispersion relations. TEXT: SCHWEBER, *Introduction to Relativistic Quantum Field Theory.* PREREQUISITE: PH 714A.

PH 719A RELATIVITY AND COSMOLOGY (3-0). Foundations of the special theory of relativity, tensor calculus, introduction to the general theory of relativity. Experimental tests of the general theory. Introduction to cosmology. TEXTS: EDDINGTON, *The Mathematical Theory of Relativity;* BOUDI, *Cosmology.* PREREQUISITES: PH 636B or PH 671B, Ma 260C.

PH 724A THEORY OF QUANTUM ELECTRONIC DEVICES (4-0). Theory of the operation of electronic devices depending on energy states and the quantum nature of radiation; topics in quantum mechanics, spin resonance, rotating coordinates, relaxation times, internal fields; application to specific electronic devices such as masers, microwave and optical pumping devices, paramagnetic amplifiers, magnetic instruments. TEXTS: HERZBERG, *Atomic Spectra Structure;* TOWNES, *Microwave Spectroscopy.* PREREQUISITE: PH 620B or equivalent.

PH 725A PHYSICS OE SOLIDS I (4-0). Theory of the structure and properties of solids; crystal symmetry and the anisotropy of physical properties, binding energy, lattice specific heat, thermal conductivity, properties of phonons. TEXTS: WANNIER, *Solid State Theory;* KITTEL, *Introduction to Solid State Physics.* PREREQUISITES: PH 635B, PH 636B.

PH 726A PHYSICS OF SOLIDS II (4-2). A continuation of PH 725A, with laboratory experiments relating to both terms. Electronic properties of solids, band theory, effective electron mass, Brillouin zones, semiconductors, and solid state electronic devices, magnetic properties, spin resonance, dielectrics, superconductivity, imperfections in solids and the related mechanical properties. TEXTS: WANNIER, *Solid State Theory*; KITTEL, *Introduction to Solid State Physics*. PREREQUISITE: PH 725A.

PH 730B PHYSICS OF THE SOLID STATE (4-2). Fundamental theory and related laboratory experiments dealing with solids, with emphasis on electronic properties; crystals, binding energy, anisotrophy, lattice oscillations, band theory of electrons, Brillouin zones, "hole" concept, effective mass, electrical conductivity, insulators and semiconductors, fluorescence, junction rectifiers, transistors, magnetism, and dielectrics. TEXTS: SPROULL, *Modern Physics*; SINOTT, *The Solid State for Engineers*; KITTEL, *Introduction to Solid State Physics*. PREREQUISITE: PH 620B.

PH 731A ADVANCED SOLID STATE PHYSICS I (3-0). Fundamental studies of selected topics in solid state physics. The material selected will be chosen from: Theory of specific heats, transport properties, one electron approximations, the cohesive energy, mechanical properties, optical properties, magnetic properties, and resonance methods. TEXTS: KITTEL, *Introduction to Solid State Physics*; SEITZ, *Modern Theory of Solids;* SEITZ, *and* TURNBULL, *Solid State Physics;* and current literature. PREREQUISITES: PH 730A and PH 711A.

PH 732A ADVANCED SOLID STATE PHYSICS II (3-0). A continuation of PH 731A with emphasis on the study of the current scientific literature. PREREQUISITE: PH 731A.

PH 750E PHYSICS SEMINAR (0-1). Discussion of special topics of current interest in the field of physics and student thesis reports.

PH 770A READING IN ADVANCED PHYSICS (3-0). Supervised reading from the periodicals in fields of advanced physics selected to meet the needs of the student.

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