Solutions of Mathematical Problems in Physics

PART II

Sound, Heat, Light and Electricity

物理算題例解

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SOLUTIONS OF MATHEMATICAL PROBLEMS IN PHYSICS

物理算題例解

SOUND 音學

I. VELOCITY OF SOUND

音之速度

1. The flash of a gun is seen 3.5 seconds before the report is heard. If the temperature is 20°C., what is the distance between the observer and the gun? 見放鎗之火光較聞其聲早三秒半，設溫度爲 20° C., 觀察者與鎗相距幾何？

解 音之速度每秒=331 m., 溫度每增 1° c 則增速 .6 m.

故其距離=(331+.6×20)×3.5 m.

=1200.5 m.

2. A locomotive whistle was sounded 3 mi. from an observer. If the temperature of the air was 10°C., how long was the sound in traversing the dis-tance? 一火車之哨距人 3 哩而鳴，設溫度爲 10° C. 音行此距離需時若干秒？

解 音之速度每秒＝1085 呎． 1 哩＝5280 呎，又溫度每增 1° C. 則加速 2呎

$$\text{故 所需之時間}=\frac{5280\times 3}{1085+2\times 10}=\frac{5280\times 3}{1105}$$

$$=14.33\text{ 秒}$$

3. The distance between the two stations is 12 mit If the interval of time between the flash and the repor. of a gun was found by experiment to be 56 seconds, what was the speed of the sound? 兩站相距 12 哩，設由試驗而知，見放鎗火光與聞鎗聲相差爲 56 秒，則音之速度若干？

解 1 哩＝5280 呎

$$\text{故音之速度每秒}=\frac{12\times 5280}{56}=1131\frac{3}{7}\text{呎}$$

4. A bullet was fired at a target 500 m. away, and in 3 seconds was heard by the gunner to strike. The temperature of the air being 20°C., what is the velocity of the bullet? 彈距靶 500 m. 放鎗者於 3 秒後聞彈着靶，空氣溫度爲 20° C. 彈之速度若干？

解 彈着靶其音傳至放鎗者所需之時間＝

$$\frac{500}{331+.6\times 20}=\frac{500}{343}\text{秒}$$

故彈着靶所需之時間＝$3-\frac{500}{343}=\frac{529}{343}$

彈之速度每秒＝$500\div\frac{529}{343}=324.2$ m.

5. When one end of an iron pipe is struck a blow with a hammer, an opserver at the other and hears two sounds, one transmitted by the iron, the other by the air. If the pipe is 1500 m. long, and the temperature 20°C., what is the interval of time between the two sounds?

以鎚擊鐵管之一端，他端立一人聞有二聲，一由鐵管傳來，一由空氣傳來，設管長 1500 m. 溫度爲 20° C. 試求二聲相隔之時間。

解 鐵傳音之速爲 5100 m. (當溫度在 20° C. 時)

故在此題其傳音所需之時間＝$\frac{1500}{5100}=\frac{5}{17}$秒

而空氣傳音所需之時間＝$\frac{1500}{331+.6\times 20}=$

$\frac{1500}{343}$秒

二音相隔之時間＝$\frac{1500}{343}-\frac{5}{17}=\frac{23785}{5831}$

$=4\frac{461}{5831}$秒

II. REFLECTION OF SOUND WAVES 音波之反射

1. A hunter fires a gun and hears the echo in seconds. How far away is the reflecting surface, the temperature being 20°C.? 一獵夫鳴鎗於五秒末聞回聲，反音地面與之相距若干，設溫度爲 20° C.

解 音之速度每秒=331 m. 又溫度每高 1° C. 則增速 .6 m

故 反音面與人相距=5(331+.6×20)÷2

=5×343÷2

=1715 ÷2=857.5 m.

2. How far is the person from the wall of a building, if on speaking a syllable, he hears the echo in 4 seconds, the temperature being 15°C.? 某人向牆發音，於四秒末聆其回聲，設溫度爲 15° C. 此人距牆若干?

解 牆距人=4(331+.6×15)÷2

=4×340÷2

=1360÷2

=680 m.

3. A gun is fired, and the echo is returned to the gunner from a clift 2,50 ft. away in 4.5 seconds. calculate the velocity of sound. 一人鳴槍，槍聲於 4.5 秒末由相距 2500 呎之山壁折回，試求音之速度。

解 音之速度每秒$=\frac{2500\times 2}{4.5}$

$=\frac{10000}{9}$

$=1111\frac{1}{9}$呎

III. VIBRATION FREQUENCY

振動數

1. Taking G as the key tone of a major scale, compute the vibration frequency of each of the tones contained in an octave. 若以 G 爲主音階中之鍵，試計依次八音之各振動數。

解 在主音階中 G=384 依次各音與之成比之率如下

$\frac{9}{8},\frac{5}{4},\frac{4}{3},\frac{3}{2},\frac{5}{3},\frac{15}{8},\frac{2}{1}$ 故 $A=384\times\frac{9}{8}=432$

$B=384\times\frac{5}{4}=480$ $C'=384\times\frac{4}{3}=512$ $D'=384\times\frac{3}{2}=576$ $E'=384\times\frac{5}{3}=640$ $F'=384\times\frac{15}{8}=720$

$G'=384\times 2=768$

2. The vibration frequency of a tone is 264. Claculate the frequencies of its third, fouth, and octave. 一音之振動數爲 264，試計其次之第三，第四，及第八音之各振動數。

解 其第三音之振動數$=264\times\frac{5}{4}=330$

其第四音之振動數$=264\times\frac{4}{3}=352$

其第八音之振動數$=264\times2=528$

3. Claculate the vibration frequency of the tone one octave below middle C. 在中C前之第八音，其振動數若干？

解 中C$=256$

在其前之第八音$C_1=256\times\frac{1}{2}$

$=128$

4. What is the wave length of a tone whose vibration frequency is 256 when the temperature is 15°C? 某音振動數，$=256$，當時溫度$=15°$ C. 其波長若干？

解 依波長公式$l=\frac{v}{n}$

可得波長$=\frac{331+.6\times15}{256}=\frac{340}{256}=1\frac{21}{64}$m.

5. If middle C were given the frequency 260, what would be the frequencies of D, A, and B? 設中C$=260$，D, A, B各音之振動數若干。

解 $D=260\times\frac{9}{8}=\frac{585}{2}=292.5$

$A=260\times\frac{5}{3}=\frac{1300}{3}=433.3$

$B=260\times\frac{15}{8}=\frac{975}{2}=487.5$

6. A tone two octaves above middle C has how many vibrations per second? 在中 C 以後相隔二音程之末音振動數若干?

解 設中 C=256

隔中 C 二音程末音之振動數=256×2×2

=1024

7. If the keyboard of a piano extends three and a half octaves in each direction from middle C, calculate the vibration number of the lowest and the highest C on the instrument. 一鋼琴之鍵盤中 C 前後各延三音程有半，試計其最低與最高 C 音之振動數.

解 設中 C=256

距中 C 三音程最低之 C 音=$\frac{256}{2\times2\times2}$=32

距中 C 三音程最高之 C 音=256×2×2×2

=2048

8. Ascertain the interval between the pitches of the tuning forks making 256 and 192 vibrations per second. 二音叉之振動數一爲每秒 256 次一爲 192 次，試考其高低之音程之比.

解 二音叉音程之比=$\frac{192}{256}$=3:4

9. The tones of three bells form a major chord. One makes 200 vibrations per second, and its pitch lies between the pitches of the others. Calculate the fre-

quency of the bells. 三鎔之音成一主弦，其一每秒振動200次，其高低適在他二鎔之間，求各鎔之振動數。

解 按主弦各音之比爲 4：5：6

今一鎔居中振動數=200

故居其前者振動數=$\frac{200}{5}\times 4=160$

居其後者振動數=$\frac{200}{5}\times 6=240$

10. A tone is produced by a siren revolving 300 times per minute. What is the name of the tone produced, if the number of holes in the row is 24? 有測音器每分轉300次，設有孔24，其發出之音應定爲何名？

解 測音器有 24 孔每分轉 300 次，則其每秒振動數=$\frac{24\times 300}{60}$=120 次，查主音程中 B 音=480 適爲此音之 4 倍，故 120 之音可定爲 B_4 即在主音程前第二音程中之 B 音也，與 ti 相當。

IV. THE VIBRATION OF STRINGS. 絃之振動

1. The bridges under a stretched wire are 4 ft. apart. Where must a third bridge be placed to raise the pitch a major third? a minor third? 弦下音橋相距長 4

呎，茲欲使其音爲主音程中第三音比首音，或爲主音程中第五音比第三音，應置第三音橋於何處？

解 欲使其成第三音與首音之比，即 5：4

(但弦長與振動成反比)

故第三音橋宜置於距後音橋$\frac{4}{9}\times 4=1\frac{7}{9}$呎之處，

又欲使其成第五音與第三音之比即 6：5

故第三音橋宜置於距後音橋$\frac{4}{11}\times 5=1\frac{9}{11}$

呎之處，

換言之即前二者其長爲 $1\frac{7}{9}$： $2\frac{2}{9}$後二者其長

爲 $1\frac{9}{11}$： $2\frac{2}{11}$也。

2. A wire 180 cm. long produces middle C. Show by a diagram where a bridge would have to be placed to cause the string to emit each tone of the major scale of C. 一弦長 180 cm. 發中 C 之音，試作圖以示主音程中各音橋應置之處。

解 主音程中各音對於中 C 之比如下 C=1

$D=\frac{9}{8}$ $E=\frac{5}{4}$ $F=\frac{4}{3}$ $G=\frac{3}{2}$ $A=\frac{5}{3}$ $B=\frac{15}{8}$

C′=2 此各數與弦成反比例，故 $D=180\times\frac{8}{9}$

=160. 由此推下 E=144. F=135, G=120,

A=108, B=96 C′=90. 本此造圖

如下。

圖 (由左向右計)

(1 mm. 代 1 cm.)

1. What is the vibration frequency of the tone three octaves above middle C? What length of the wire in Exer. 2 would be required to produce this tone? 在中 C 三音程 (1：2) 以後之末音振動數若干？若使上題中之弦發生此音，須長若干？

解 中 C=256 次，其後三音程之末音振動數=$256\times2^3=2048$ 次，第二題中之弦亦須縮短 $2^3=8$ 倍，(因絃之振動數與其長爲反比) 即 $180\div8=22.5$ cm.

4. The tension of a string is 9 kg. What tension must it have in order fo produce a tone an octave higher? an octave lower? a fifth higher? 一絃之伸力爲 9 kg. 若欲作較高之第八音，或較低之第八音，或較高之第五音，其伸力各應若干？

解 本振動數與伸力成正比之定理。

(1) 較高之第八音伸力爲 x, $1:2=9:x$,

$x=18$ kg.

(2) 較低之第八音伸力爲 y, $2:1=9:y$,

$y=4.5$ kg.

(3) 較高之第五音伸力爲 z $1:\frac{3}{2}=9:z$, $z=$

13.5 kg.

5. Write the vibration frequencies of the first four overtones of a G string. 一絃發 G 音，試列其首四加倍之音之振動數。

解 G 之振動數=384

其第一倍音之振動數=384×2=768

其第二倍音之振動數=384×3=1152

其第三倍音之振動數=384×4=1536

其第四倍音之振動數=384×5=1920

6. The density of steel is 7.8, and that of brass 8.7. What is the vibration frequency of a steel wire, if that of brass wire of equal length, diameter, and tension is 280? 鋼之密度爲 7.8，銅之密度爲 8.7，設銅絃之振動爲 280 與之同長同直徑之鋼絃振動若干？

解 絃之振動與其重之平方根成反比

設鋼絃之振動=x

$$\sqrt{7.8} : \sqrt{8.7} = 280 : x$$

$$x = \frac{280 \times 2.949}{2.792} = 295.74$$

7. The vibration frequency of two equal wires 155 cm. long is 300. How many beats per second will be heard when one of the wires has been shortened 5 cm.? 二絃各長 155 cm. 其振動數共爲 300，設一絃短 5 cm. 則一秒間可聽昇沉若干。

解 本絃振動數與絃長爲反比，設短絃之振動數爲 x 則 150 : 155=150 : x x=155 次又本昇沈之數等於單位時間內兩振動數之差。故此題之昇沈=155—150=5.

8. Two middle C forks were placed near together and the prongs of one of them weighted with bits of sealing wax; when both forks were sounded, 4 beats per second were heard. Find the frequency of the weighted fork. 二中 C 之音叉置於過近之處，惟一音叉兩股之上貼以封漆之丸，當兩音叉齊鳴時，聞每秒有四昇沈之數，試求附漆球音叉之振動數。

解 本昇沈二振動數之差，中 C＝256

附漆球音叉之振動數＝256－4＝252 次

V. VIBRATING OF AIR COLUMNS. 空气柱之振動

1. What is the wave length of the tons produced by an open pipe 2 ft. long? by a closed pipe of the same length? 一開口管長 2 呎，其音波之長若干？同長之閉口管其音波之長幾何？

解 開口管振動$=\frac{v}{2l}=\frac{1085}{2\times 2}$，故其波長$=\frac{1085}{\frac{1085}{4}}=4$，

$\left(l=\frac{v}{n}\right)$

閉口管振動$=\frac{v}{4l}=\frac{1085}{4\times 2}$，故其波長$=\frac{1085}{\frac{1085}{8}}=8$，

(同上理)

2 Compute the length of a middle C open pipe, the temperature being 20° C. 一開口中 C 音之管，當時溫度＝20°C. 求管之長。

解 中 C＝256次，以 l 代管長。

用同上開口管公式 $256=\frac{331+.6\times 20}{2l}$

故 $l=\frac{343}{2\times 256}=.669$ m.

3. A whistle may be regarded as a stopped pipe. If the cavity of a whistle is 1 in. long, find the vibration frequency of its tone when the temperature of the air with which it is blown is 25° C. 哨可視爲閉口管，哨之孔長一吋，吹時溫度爲 25°C. 求其振動數。

解 用上閉口管公式，以哨之振動爲 n,

$$n=\frac{v}{4l}=\frac{1085+2\times 25}{4\times\frac{1}{12}}=3\times 1135=3405\text{ 次}$$

4. By blowing across the end of a tube 6 in. long, closed at one end, the first overtone is emitted. Find its frequency, the temperature being 18° C. 一管長 6 吋，閉一端，吹時發第一之倍音，設吹時溫度爲 18°C. 求其振動數。

解 按閉口管公式以振動數爲 n.

$$n=\frac{v}{4l}=\frac{1085+2\times 18}{4\times\frac{6}{12}}\frac{1121}{2}=560.5\text{ 次}$$

5. Find the vibration frequencies of the first overtones of a middle C pipe, (1) when the pipe is open at both ends and (2) when it is stopped at one end. 一中C管，兩端開口時，其第一倍音之振動若干？又一端閉口時其第一倍音之振動若干？

解 中C振動=256 開口時第一倍音=2×256=512次，閉口較開口低2倍。

故其第一之倍音=$\frac{512}{2}$=256次

HEAT 熱學

VI. TEMPERATURE. 溫度

1. The boiling point of water falls 1 of a centigrade degree for a decrease of 27 cm. in the atmospheric pressure. What is the boiling point when the barometer reads 73.3 cm.? 因氣壓低減 .27 cm. 水之沸點降下 .1 攝氏度，若氣壓表爲 73.3 cm. 時，沸點應爲若干？

解 平常氣壓=76 cm 水之沸點=100°C.

本沸點與氣壓爲正比，設所求之沸點爲 x.

(76−.27) : 73.3=(100−.1) : x

75.73 : 73.3=99.9 : x

$x=\frac{73.3\times99.9}{75.73}=\frac{7322.67}{75.73}$=96°.68 c.

2. Reduce the following centigrade readings to the corresponding values on the Fahrenheit scale: 20,° 35°,

20°, 40°. 將下列各攝氏度數變爲華氏度數：—

20°, 35°, 50°, —20°, —40°.

解 公式 $F=\frac{9}{5}C.+32$

(1) $F.=\frac{9}{5}\times 20+32=36+32=68°$

(2) $F.=\frac{9}{5}\times 35+32=63+32=95°$

(3) $F.=\frac{9}{5}\times -20+32=-36+32=-4°$

(4) $F.=\frac{9}{5}\times -40+32=-72+32=-40°$

3. How many centigrade degrees lie between the Fahrenheit and centigrade zero marks? 華氏與攝氏 0 度之間，爲攝氏若干度？

解 華氏與攝氏 0 度之間=32° F.

$$\therefore\ C=\frac{(0-32)\times 5}{9}=-17\frac{7}{9}\text{度}$$

4. The following temperature measurements were taken with a Fahrenheit thermometer; 77°, 41°, 14°, -4°, 50°. What would a centigrade thermometer have indicated in each case? 下列華氏度數化爲攝氏應爲若干？；

77°, 41°, 14°, —4°, —40°

解 按$C.=\frac{5}{9}(F.-32)$ 算式

(1) $C.=\frac{5}{9}(77-32)=\frac{5}{9}\times 45=25°$

(2) $C.=\frac{5}{9}(41-32)=\frac{5}{9}\times 9 = 5°$

(3) $C.=\frac{5}{9}(14-32)=\frac{5}{9}\times -18=-10°$

(4) $C.=\frac{5}{9}(-4-32) = \frac{9}{9}\times -36=-20°$

(5) $C.=\frac{5}{9}(-40-32)=\frac{5}{9}\times -72=-40°$

5. The difference in temperature of two vessels of water is 25 centigrade degrees. Express the difference in Fahrenheit units. 水二杯其温度之差=25°C. 合華氏若干？

解 按 $F.=\frac{9}{5}C.+32$

$$F.=\frac{9}{5}\times 25+32=45+32=77°$$

6. One room is 18 Fahrenheit degresss warmer than another. What is the difference between their temperatures on the centigrade scale? 一屋温度較他度高 18° F. 若合爲 C. 應若干？

解 C：F=5：9

C：18=5：9

$$C=\frac{18\times 5}{9}=10 \text{ 度}$$

7. The boiling point of water at a certain place was found to be 98 8°C. What was the atmospheric pressure at the time? 某地水之沸點爲 98.8° c. 是時之氣壓若干？

解 按沸點與氣壓成正比之理，設是時之氣壓爲 x.

$100 : 98.8 = 76 : x$

$x = 98.8 \times 76 \div 100 = 75.088$ cm.

VII. LINEAR EXPANSION AND ITS COEFFICIENTS

線膨漲與其係數

1. How much does the length of a 90-foot steel rail vary if the extremes of temperature are -24°C. and 35°C.? 設溫度由 −24° 昇至 35° c, 鋼軌長 90 呎者應若干？

解 按系數公式 $K = \frac{L_2 - L_1}{L_1 (t_2 - t_1)}$ 故 .000011

$$= \frac{L_2 - 90}{90\ (35 + 24)}$$

軌長 $L_2 = .000011 \times 90 \times 59 + 90$

$= .05841 + 90$

$= 90.05841$ 呎 (註鋼之膨漲係數 $= .000011$)

2. At the temperature of O° C. an iron pipe is 100 ft. long. What will be its length when steam at 100°C. is passing through it? 一鐵管長 100 呎由 O° c. 時通以蒸汽，溫度 100° C. 則應長若干？

解 鐵之膨漲係數 $= .000012$ 所求之長 $= L_2$

依上引公式 $.000012 \frac{L_2 - 100}{100 \times 100}$

故 L_2 (管長) $= 100 + .12 = 100.12$ 呎

8. A metal rod is 60 cm. long and expands 1.02 mm. when the temperature is raised from O° C. to 100°C. Compute the coefficient of linear expanison of the metal. 一金屬棍長 60 cm. 當溫度由 O° c. 高至 100° c. 時此棍漲由 1.02 mm. 試求此金屬之膨漲係數。

解 K (所求系数) $= \frac{.102}{60 \times 100} = .000017$

(與銅相同)

VIII. CUBICAL EXPANSION AND ITS COEFFICIENTS

體膨漲與其係數

1. What fractional part of its volume at O° C. does a cubic meter of gas expand when warmed from that temperature to 50°C., the pressure remaining constant? What is the final volume of the gas? 設壓力不變，一立方公尺之气體由 O° c. 至 50° c. 時其體積漲若干最後之體積若干。

解 依 $K = \frac{v_1 - v_0}{v_0 t}$ $K = \frac{1}{273}$ 故 $v_1 - 1 = \frac{1}{273} \times 50$

即漲大二百七十三分之五十

最後之體積 $= 1 + \frac{50}{273}$ 或 $= 1 + 50 \times .00366$

$= 1.183$ 立方公尺

(或用 $V : V' = T : T'$ 亦可)

2. The volume of a certain gas at 20°C. is 300 cm³. What is its volume when the temperature is reduced to O°. C., the pressure being constant? 某气體當 20° C. 時其體積爲 300 立方 cm. 若壓力不變，而溫度降至 O° C. 時其體積若何？

解 按 $V_0=V_t\div(1+Kt)$ $V_0=O°$ 時之體積

$V_0=300\div(1+20\times.00366)$

$=279.53$ 立方 cm.

3. The pressure exerted by a gas confined in a reservoir is 500 g. per square centimeter when the temperature is 10°C. What is its pressure when the temperature is raised to 40°C.? 當溫度 =10° c. 時一气礮中气體之壓力 =500 g.（每平方 cm.）若溫度昇至 40° c. 其壓力若何？

解 气體壓力與容積之相乘積與絕對溫度成正比

以所求之壓力爲 x.

$500\ v : x\ v=10+273 : 40+273$

$x=500\times313\div283=553\frac{1}{283}$ g.

4. The volume of a gas collected in a chemical experiment is 30 cm³., its temperature 25°, and its pressure 750 mm. Find the volume of the same gas at O°C. and under a pressure of 760 mm. 作化學試驗時，收集一气體，其容積爲 30 立方 cm. 溫度 =25°，壓力 = 750 mm. 此气體若在 O° 壓力 750 mm. 之下，其容積若干？

解 同上理以所求之容積爲 v

$$30\times750:x\times760=25+273:273$$

$$x=\frac{30\times750\times273}{760\times298}=27.12\ cm^3$$

5. If the mass of a cubic centimeter of air at O°C. and under a pressure of 769 mm. is .001293, what will be its density in a room where the temperature is 22°C. and the barometer read 745 mm? 一立方 cm. 之空气在 O° c 壓力 760 mm. 下，其重爲 .001293 設在 22° c. 之室中，气壓爲 745 mm. 時，其密度若干。

解 在一定量下容積與密度成反比，以 d 爲所求之密度，又本上理列式如下

$$760\times\frac{1}{.001293}:745\times\frac{1}{d}=273:295$$

$$d=\frac{745\times273\times.001293}{760\times295}=.001173\ 弱$$

6. The quantity of air in a room 8×12×15 ft. will con-ract to what volume when its temperature falls from 20°C. to O° C.? 一室之容積 =8×12×15 呎，設其中空气，由 20° c. 降至 O° c. 空气之容積當縮至若干？

解 容積與絕對溫度成正比，以所求之容積爲 x.

故 $8\times12\times15:x=293:273$

$$x=\frac{8\times12\times15\times273}{293}=1341\frac{207}{293}\ 立方呎$$

7. To what temperature would the air confined in a flask at atmospheric pressure and a temperature of 10°C. have to be heated in order to exert a pressure of 3.5 at-

mospheres? 閉于瓶中之容气在氣壓下温度 =10° c. 若使其气壓爲 3.5 倍，須熱至若干度？

解 容積不變气壓與絕對温度成正比

以所求之温度爲 x.

x : 283=3.5 : 1

x=283×3.5=990.5 但須減去 273 實

=717.5° c.

8. Upon heating 300 cm³. of a gas from O° C. to 30°C., the volume was found to be 333 cm³. Ascertain the coefficient of expension of the gas. 一气體容積 =300 立方 cm. 温度由 O° c. 昇至 30° c. 其容積則變爲 333 立方 cm. 試定此气之膨漲係數

解 設所求係數爲 K.

$$K=\frac{v_1-v_0}{v_0\,t}=\frac{333-300}{300\times30}=\frac{33}{9000}=.00366$$

9. The capacity of a steel gas cylinder is 8 cu. ft. Illuminating gas is compressed in the cylinder until the pressure is 15 atmospoeres at a temperature of 10°C. What volume will the quantity of gas assume when allowed to escape into a spaee where the pressure is 1 atmosphere and the temperature of 25°C.? 一鋼气桶容積=3 立方呎，壓煤气于此桶中气壓 =15，温度 = 10° c. 倘使此气逃入一處，气壓 =1，温度 =25° c. 則其容積應若干？

解 按气體壓及容積相乘積與絕對温度成正比

以所求之容積爲 v.

1×v : 15×3=273+25 : 273+10

283 v=15×3×298

v=15×3298÷283=47.35

立方呎强

IX. CALOIMETRY AND SPECIFIC HEAT

熱單位與比熱

1. A mass of 75 g. of water is cooled from 95°C. to 32°C. How much heat is given up? 75 g. 之水由 95° c. 降至 32° c. 失熱若干?

解 依公式 H=m—t 以所失之熱爲 H.

H=75 (95—32) =75×63=4725 熱單位

2. A 100-gram mass of copper rises in temperature from 15°C. to 100°C. How much heat does it absorb? 銅一塊重 100 g. 溫度由 15° c. 昇至 100° c. 吸熱幾何?

解 銅之比熱 =.093 以所吸之熱爲 H

H=100×(100—15)×.093

=100×85×.093=771.9 熱單位

3. If 500 calories are applied to 500 g. of mercury at 10°C., to what point will the temperature of the mercury rise? 水銀 500 g. 溫度爲 10° c. 茲加以 500 熱單位, 則此水銀應昇至若干度?

解 水銀之比熱 =.033 以應昇之度爲 x

500=500(x—10)×.033

I =.033 x—.33

x =1.33÷.033=40°.3 c.

4. A mass of iron weighing 400 g. and having a temperature of 98°C. is placed in 100 g. of water at 14°C.; the temperature of the combined masses is 40°C. Compute the specific heat of the metal. 鐵一塊重 400 g. 溫度 = 98° c. 置于 14° c. 100 g. 之水中，二者混合之溫度 =40° c. 求鐵之比熱？

解 本失熱=得熱之理以 s 爲所求之比熱

$$400\ (98-40)\times s=100\ (40-14)$$

$$s=\frac{100\times 26}{400\times 58}=\frac{1}{8}=.125$$

5. Find the resulting temperature when 400 g. o water at 90°C. are mixed with 150 g. of water at 10°C. 以 90° c. 400 g. 之水混于 10° c. 150 g. 之水中，求其混合之溫度。

解 本失熱=得熱 以混合後之溫度爲 x

$$400(90-x)=150(x-10)$$

$$720-8x=3x-30$$

$$11x=750$$

$$x=68°\frac{2}{11}C$$

6. A vessel contains 250 g. of lead shot and 150 g of water. Find the amount of heat required to raise the temperature of the mixture from 15°c. to 89°C. 一器盛鉛彈 250 g. 水 150 g. 欲由 15° c. 昇至 80° c. 共須熱若干？

解 鉛之比熱=.032 以所需之熱=H

$$H=(250\times.032+150)\ (80-15)$$

$$=(8+150)65=158\times 65$$

$$=10270 \text{ 熱單位}$$

7. The temperature of a blyck of ice weighing 100 Kg. raise from -15°c. to the melting point. What quantity of heat is absorbed? 冰塊重 100 Kg. 由－15° c. 昇至融點，其吸熱若干？

解 冰之比熱 =.502 以所吸之熱爲 H

$$H=100\times1000\times(0+15)\times.502$$
$$=50200\times15$$
$$=753000$$

8. If 100 g. of aluminium at 97°C. were dropped into 50 g. of water at 10°C., what would be the temperature of the mixture? 100 g. 之鋁在 97° c. 時墜入 10° c. 50 g. 之水中，其混合溫度若干？

解 鋁之比熱 =.212 以混合溫度爲 x

$$100(97-x)\times.212=50(x-10)$$
$$97\times.424-.424x=x\ 10$$
$$1.424x=51.128$$
$$x=35.9°c.$$

X. HEAT OF FUSION 融熱

1. Find the amount of heat required to melt 50 g. of ice at O°C. and to raise the temperature of the resulting water to 15°C. O° C. 冰 50 g. 使之融化，並使其溫度爲 15° c. 須若干熱單位？

解 以 x 爲應需之熱每 1 g. 之冰融化須熱 80 熱單位並須加以冰水昇至 15° c 之熱

故 $x=50\times80+50\times15$
$=4750$ 熱單位

2. A kilogram of ice at O°C. is placed in an equal mass of water at 100°C. Find the resulting temperature. 1 Kg. 之冰在 O° C. 時，置于同量 100°C. 之水中，混合結果溫度應若干？

解 本得熱＝失熱以 x 爲所求之溫度

$$1000-80+1000\,x=1000(100-x)$$

$$80+x=100-x$$

$$2x=20$$

$$x=10^{\circ}\text{ c.}$$

3. A piece of ice weighing 100 g. and having a temperature of -16°C. is brought into a room where the temperature is 30°C. What thermal processes take place? What quantity of heat is involved in the process? 冰一塊重 100 g. 溫度 ＝－15° c. 移置室中，溫度 ＝30° c. 應有何種變化發生？每次所需之熱若干？

解 (1) 第一變化須先將 －15° c. 之冰昇至 O° c. 其所須之熱 ＝100×15×.502 (冰比熱)

＝753 熱單位

(2) 第二變化再將 O° c. 之冰化爲 O° c. 之水並與室中溫度混合其所須之熱爲

$$100\times80+100\times30=8000+3000$$

＝110000 熱單位

4. What mass of ice at O°C. will be required to reduce the temperature of a kilogram of water from 100°C. to 20°C.? 1 Kg. 之水，欲使其溫度由 100° c. 降至 20° c. 須加 O° c. 之冰若干？

解 以所求之冰爲 x

$$80x+20x=1000\times 80$$

$$x=800 \text{ g.}$$

XI. EVAPORATION AND EBULLITION. 汽化與沸騰

1. How much heat is required to raise the temperature of 30 g. of water from 0°C. to 100°C. and conyert it into steam? 30 g. 之水欲使由 0°C. 昇至 100°C. 需熱若干？化爲蒸汽需熱若干？

解 水之汽化熱=536 熱單位

故共需熱=30×100+30×536

=30×636

=19080 熱單位

2. If 50 g. of steam at 100°C. change into water at 40°C., how much heat is given out j 100°C. 之蒸汽 50 g. 欲變爲 40°C. 之水，生熱若干？

解 其所生之熱=50×536(還原)+50×60(低降)

=26800+3000

=29800 熱單位

3. If the heat delivered by 10 G. of steam in condensing at 100°C. and cooling down to 0.C. were all applied to ice at 0°C., how many grams of ice would be melted? 10 g. 之蒸汽凝爲 100°c. 之水，加于 0°c. 之冰上，降至 0°c. 所有之熱能融冰若干？

解 以 x 爲所求之冰

$$80x = 10 \times 536 + 10 \times 100$$

$$x = \frac{5360 + 1000}{80} = \frac{6360}{80} = 79.5 \text{ g.}$$

4. A vessel containing 500 g. of water at 20°C. is heated until it is one half vaporized. How many calories have been received? 一器盛 20° C. 之水 6000 g. 加熱，使半化爲蒸汽，共所得之熱幾何？

解 所得之熱 $= 600 \times 80 + 300 \times 536$

$= 48000 + 160800$

$= 208800$ 熱單位

5. The boiling point of water falls I centigrade degree for a decrease in pressure of 2.7 cm. Find the boiling point when the barometer reads 74.5 cm. 氣壓每減 2.7 cm. 則沸點降 1°c. 現氣壓爲 74.5 cm. 沸點若干？

解 沸點與氣壓爲正比，以所減之數 $= x$

故 $2.7 : (76 - 74.5) = 1 : x$

$2.7x = 1.5 \quad x = .55°c.$

沸點 $= 100 - .55 = 99.45°45°c.$

6. The boiling point of water falle I centigrade degree for an elevation of 295 m. above sea level. Find the temperature of boiling water at Denver, Colo., altitude 1600 m. above sea level. 較海平線每高 295 m. 則沸點低降 1°c. 丹威爾地方較海平線高 1600 m. 則沸點應若干？

解 以 x 爲所減之度

$$295 : 1600 = 1 : x$$

$$x = \frac{1600}{295} = 5.42$$

沸點 $= 100 - 5.42 = 94.58°c.$

7. If water boils at 85°.5 C. at the top of Mont Blanc, what is the altitude? 設在白山之頂，水之沸點爲 85.5°c. 其高若干？

解 本上題每低 1°c. 則高 295 m. 以所求之高爲 x.

$$x : 295 = 14.5 : 1$$

$$x = 295 \times 14.5$$

$$x = 4277.5 \text{ m.}$$

8. If 20 g. of steam at 100°C. are passed into 500 g. of water at 5°C. what will be the resulting temperature? 100°c. 之水蒸汽 20 g. 通入 5°c. 重 500 g. 之水中，結果溫度若何？

解 以 x 爲結果溫度

$$20 \times 536 + 20(100 - x) = 500(x - 5)$$

$$26x = 761$$

$$(x = 29.27°c.)$$

9. How much heat will be required to convert 150 g. of ice at 0.C. into steam at 100°C.? 0°c. 之冰 150 g. 欲使之變爲 100°c. 之汽，需熱若干？

解 冰變水需熱 $= 150 \times 80 = 12000$

水至百度需熱 $= 150 \times 100 = 15000$

水化汽需熱 $= 150 \times 536 = 80400$

共需 $= 107400$ 熱單位

XII. HEAT AND WORK. 熱與工

1. The heat developed by the combustion of a garm of coal of a certain grade is 5000 calories. How many kilogram-meters of work could be done if all the energy could be used for this purpose? 某種煤 1 g. 燃燒可生 5000 熱單位，設此熱能悉歸實用，可作工若干 kilogram-meters (千克米)

解 本 1 熱單位=427 克米(工)

故 5000 熱單位=5000×427 克米

=5×427 千克米

=2135 千克米(工)

2. If all the potential energy stored in 500-gilogram mass of rock at an elevation of 200 m. were converted into heat, how many calories would be produced? 設一石重 500 Kg. 在 200 m. 之高，以其勢能變爲熱力，應生若干熱單位？

解 以 H 爲所生之熱，勢能=500×200 Kg. m.

=100000000 g. m.

故生熱=100000000÷427=234193.2 熱單位

3. The energy of a falling body is transformed into heat when it strikes. Compute the number of calories of heat produced when 10-gram mass of iron falls 25 m. 落體能力若擊某物，可變爲熱，設一鐵重 10 g. 落下 25 m. 試計其所生之熱幾何？

解 生熱 =10×25÷427=.58 熱單位

4. A steam engine raises 8000 four-pound bricks to the top of a building 75 ft. high. How many calories of heat are thus expended? If the efficiency of the engine is 10%, how many calories must be developed by the combustion of the coal that is used? 一汽機舉 4 磅重之磚 8000 塊，至熱 75 呎之房頂，費熱若干？設機器之實效爲百分之十，所用之煤須生若干熱單位？

解 工$=4\times8000-75$ 呎磅

$=4\times8000\times75\times13550000$ ergs

$=\frac{4\times8000\times75\times13550000}{41990000}$ 熱單位

$=774613\frac{13}{4199}$ 熱單位

若實效 $=10\%$ 則煤須生熱較此多 10 倍

即 $7746130\frac{130}{4199}$ 熱單位

5. How high could 100 g. of ice be elevated by the amount of heat required to melt the same amount, if all the heat could be utilized for that purpose? 設熱力悉歸實用，融 100 g. 冰所需之熱，可舉同量冰高至若干？

解 以所求之高爲 h 融冰需熱 $=100\times80$

舉冰工力 $=100$ h

100 h$\div427=100\times80$

$$h=\frac{100\times80\times427}{100}=34160 \text{ m.}$$

6. Show that the energy required to vaporize 1 g of water at 100°C. is equivalent to the work done by a force of 10 Kg. in moving a body a distance of 22.89 m. in the direction of the force. 使 100° c. 之水 1 g. 化汽，等于用 10 Kg. 之力，使一物行 22.89 m. (與力同向)，試證明之。

解 汽化需熱 $=1\times536$ 熱單位又 $=536\times427$

$=228872$ g. m.

運物需工 $=10\times1000-22.89=228900$ g. m.

二者之工能大致相等

7. Show that it requires more energy to raise the temperature of 100 g. of iron from O° C. to 100°C. than to elevate a weight of 404 kg. through a hight of 1 m. 鐵 100 g. 欲使之由 O° c. 熱至 100° c. 所需之能力，較諸舉 400 kg. 之重高至 1 m. 者爲多，試證明之。

解 熱 $=100\times100\times.113$ (鐵比熱) 熱單位

$=1130\times427=482510$ g. m.

工 $=400\times1000\times1=400000$ g. m.

故前者之能力較多

8. The average pressure of the steam in the cylinder of an engine is 125 lb. to the square inch and area of the piston is 50 sq. in. Compute the work done by the steam during each 20-inch stroke of the piston. 一機器其汽缸中汽之平均壓力 =125 磅 (每方吋)，其活栓之面積 =50 方吋，試計汽當活栓每動 20 吋一次之工作

解 $工=\frac{50}{144}\times125\times\frac{20}{12}=\frac{15625}{216}$

$=72.33$ 呎磅

LIGHT 光學

XIII. SPEED OF LIGHT

光之速度

1. The circumference of the earth is about 25,000 mi. How many times could this distance be traversed by light in a second? 地球圓周約25000哩，光一秒間能繞行幾次。

解 光之速度每秒 =186000 哩

故光每秒可繞行地周 $\frac{186000}{25000}$ 次 =7.44 次

2. The distance of the north star from the earth is so great that requires about 43 yr. for its light to reach the earth. Express the distance in miles. 北斗星距地太遠，故其光欲達地面須 43 年，試以哩計之。

解 北斗星距地 =186000×43×365×24×60×60 哩

=252224928000000 哩

若按四年一閏則上數尚加其 $\frac{1}{4}$

則 =321531160000000 哩

3. How many minutes are required for light to reach the earth from the sun? 太陽之光射達地面，須若干分鐘？

解 地球距日$=\frac{186000000}{2}$哩

光每秒行$=186000$ 哩

故日光至地須$\frac{186000000}{2\times186000}=500$ 秒 $=8\frac{2}{3}$分

4. Since the sun moves (apparently) through 360° in 24 hr., over what arc will it move while a light wave is on its way from the sun to the earth? 表面上觀之，太陽似于 24 小時經行 360°，當光由太陽行達地面時，太陽所行之弧有若干度？

解 按上題太陽每秒行$\frac{360}{24\times3600}$度

日光至地須 500 秒

故太陽在此時間可行$\frac{360\times500}{24\times3600}=\frac{25°}{12}$

$=2°\frac{1}{12}$

XIV. SHADOWS 影

1. If the sun's rays make an angle of 45° with the horizontal plane, how long is the shadow cast on level ground by a vertical pole 50 ft. high? 設太陽光線與平面成 45°，有杆高 50 呎，直立平地上，其影長若干？

解 依三角正切定理 $\tan 45°=1$ 以 x 爲影

故 $\frac{50}{x}=1$ $x=50$ 呎

2. A vertical rod 10 ft. in height casts a shadow 12 ft. long on a level sidewalk. How tall is a tree whose shadow at the same time is 72 ft. in length? 一直立之杆長 10 呎，投影于路傍長 12 呎，若有樹同時投影長 72呎，則樹高若干？

解 實物與影爲正比，以樹高爲 x

$12 : 72 = 10 : x$

$x = 72 \times 10 \div 12 = 60$ 呎

XV. INTENSITY AND CANDLE POWER OF LIGHTS

光之强度與燭光單位

1. A 2-candle-power light is placed 1.5 m. from a screen. Where must an 8-candle-power light is placed to produce the same illumination on the screen? 一光爲二燭光力，距幕 1.5 m. 又有八燭光之光，欲使對此幕生相等之光輝，須置於何處？

解 本光之强度與其距離之平方爲反比，但强度不變，則成爲正比

故 $x^2 : 1.5^2 = 8 : 2$

$$x = \sqrt{\frac{1.5^2 \times 8}{2}} = 1.5 \times 2 = 3 \text{ m}$$ 即應置于距幕 3 米處

2. In measuring the candle power of an electric light it was found that a 4-candle-power light placed 2 m. from a disk produced the same illumination as the electric light at 10 m. Compute the power of the electric light. 欲測一電燈之光，發現距盤 2 m. 四支燭光，與此燈距盤10m時，光之強弱相等，此燈之燭光若干？

解 同上理以 x 爲此燈之燭光

$$x : 4 = 10^2 : 2^2$$

$$x = \frac{10^2 \times 4}{2^2} = 100 \text{ 支燭光}$$

3. If a book receive ample illumination when placed 10 ft. from a 5-candle-power lamp, how far must it be placed from a light of 5 candle-power to be equally well illuminated? 有燈爲 50 支燭光，相距 10 呎處置一書，光明頗足，今易以 5 支燭光之燈，亦欲使之與前同亮，須置之何處？

解 本光度不變則燭數與距離平方成正比，以x爲所求之距離

$$x^2 : 10^2 = 5 : 50$$

$$x = \sqrt{10} = 3.16 \text{ 呎}$$

XVI. REFLECTION OF LIGHT AND IMAGE. 光之反射與像

1. A pole is inclined at an angle 45° to the surface of water in a quiet pond. Construct the image of the pole seen in the water. 一杆與靜池中水面成 45°. 試作杆在水中之像。

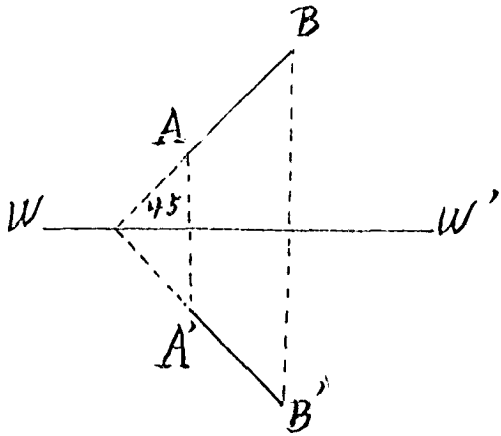


圖 解 AB 爲杆 WW' 爲水平面猶如一平鏡，AB 與 WW' 成 45° 水下成像 A'B'. A' 與 A. 距 WW' 同遠，B' 與 B 距 WW' 亦同遠，故 A'B' 卽 AB' 在水中之像，(本光以直線進行之原理)

2. A man approaches a plane mirro with a velocity of 3 m. per second. How rapidly is he approaching his image? 一人向平面鏡行，每秒 3 m. 其向影之速度若干？

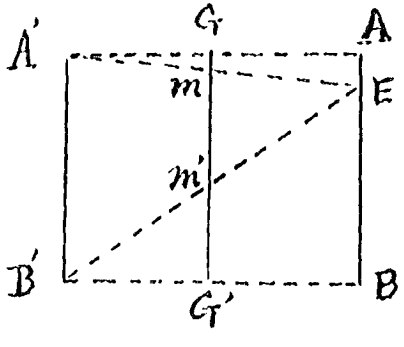
解 本人與像距鏡等遠，

故人向鏡行每秒 3 m.

像向鏡行亦每秒 3 m.

故人向像行每秒=2×3=6 m.

3. Find by construction the shortest vertical mirror in which a man six feet tall can see his entire image when standing erect. 一人高 6 呎，立於直鏡之前，鏡至短須若干方見全像，試作圖以解之。



解 設 AB 爲人之高，E 爲其目，GG′ 爲鏡，則 A′B′ 爲人像距 GG′ 與 AB 距 GG′ 同遠，今連 CA′ 及 CB′ 依平行，及三角定理，知 G, G′ 爲 AA′ BB′ 之中點，故 m m′ 亦爲 EA′ EB′ 之中點，在△ A′EB′ 中可證 mm′ 爲 A′B′ 之半，即 AB 之半，今此人既=6 呎，故鏡至少須 3 呎方見全像。

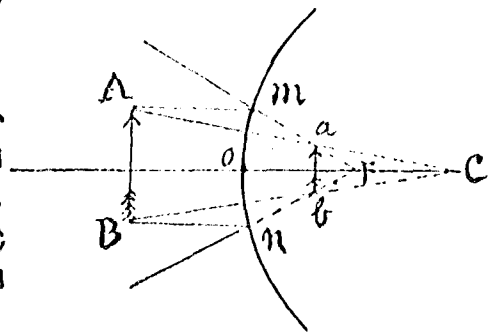
XVII. REFLECTION BY CURVED MIRRORS.

曲面鏡之反射

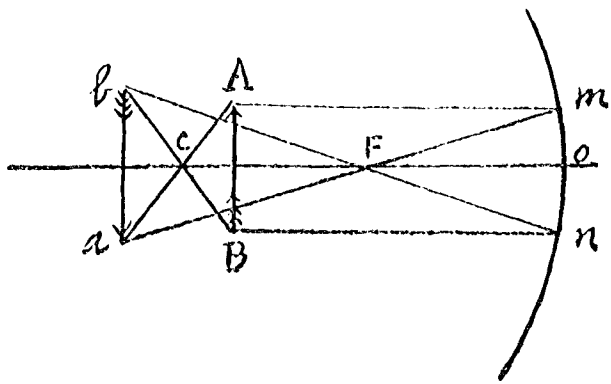
1. An object is placed 6 in. in front of a convex mirror whose radius of curvature is 12 in. Find by construction the position of the image. 一物置於凸面鏡前 6 吋，鏡之半徑=12 吋，試作圖以現其像。

解 本凹面鏡前物像作法·

以AB代物，C為曲鏡中心，MON為曲鏡，OC=12. OF=6. F為焦點，ab即所求之像·

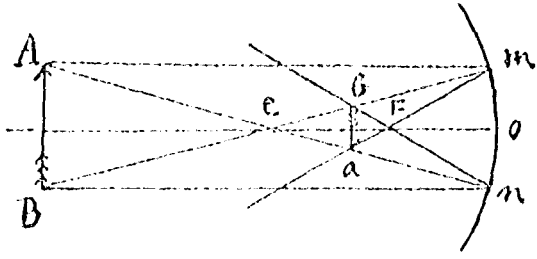


2. An object is placed 44 cm. from a concave mirror whose radius of curvature is 50 cm. Find by construction the location of the image. 一物置于凹面鏡前 44 cm. 鏡之半徑=50 cm. 試作圖以現其像·



解 本凹面鏡前物中心與焦點間作法，C為鏡心，F為焦點，MON為鏡，CO=50 cm, FO=25 cm. AB為物，ba即所求之倒像也·

3. An object 8 in. in height is placed 30 in. in front of a concave mirror whose redius of curvature is 15 in. Find the distance from the mirror to the image. 一物高八吋，置于凹面鏡前 30 in. 鏡之半徑＝15 in. 試求像距鏡若干？



物在心外作法，AB 爲物，C 爲鏡，F 爲焦點 CO＝15 吋，FO＝7.5 吋，AB 距鏡 30 吋，依圖求得 ba 倒像，以比例推之，知其距鏡爲 10 吋。

XVIII. REFRACTION OF LIGHT.

1. What is the speed of light in water, the index of refraction being 4/3? The speed of light in air is 186,000 mi. per second. 折率光＝$\frac{4}{3}$，光在空氣中每秒速度＝186000 mi. 求光在水中之速度。

解 本折光率公式，光在空氣中之速度 ÷ 光在水中之速度＝$\frac{4}{3}$故光在水中之速度＝$18600 \times \frac{3}{4}$

＝13900 mi.

2. Compute the speed of light in crown glass, assuming that the index of refaretion is 3/2. 設折光率=$\frac{3}{2}$，求在王冠牌玻璃中之速度。

解 同上理

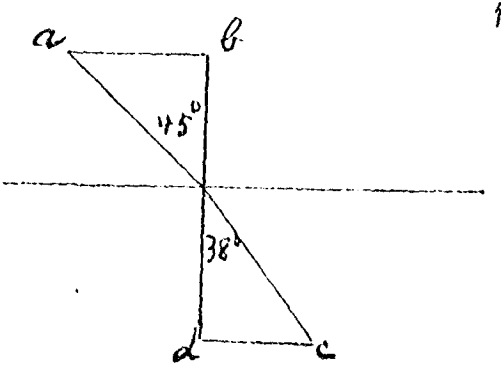
光在玻璃中之速度$=186000\times\frac{2}{3}=124000$ mi.

3. Compare the speed of light in water with that in crown glass. 試比較光在水中之速度與在玻璃中之速度。

解 就前二題之結果可得二者之比

$$\frac{13900}{124000}=\frac{139}{1240}=.112$$

4. The angle of incidence at which a ray of light enters a medium from air is 45°, and the angle of refraction 38°. Find by construction the index of refraction of the medium. 一光線由空氣中入一光媒，其射入角=45°，其曲折角=38°，試作圖以求此光媒之折光率。



解 折光率之比

$=\frac{\text{Sin } 45°}{\text{Sin } 38°}$

$=\frac{ab}{cd}$

$=\frac{.7071068}{.6156615}$

$=1.14$

XIX. IMAGES FORMED BY LENSES. 凹凸透鏡所成之像

1. By the help of equaion $1/f=1/p+1/q$. compute the focal length of a lens when the image of a candle flame 120 cm. away is focused at a distance of 60 cm. 用公式$\frac{1}{t}=\frac{1}{p}+\frac{1}{q}$計算透鏡焦點距，此鏡映一燭，相距 120 cm. 而其像則距 60 cm.

解 本上公式求 t 即焦點距

$$故\frac{1}{t}=\frac{1}{120}+\frac{1}{60}=\frac{3}{120}=\frac{1}{40}\quad t=40\text{ cm.}$$

2. The focal length of a lens is 50 cm. if an object is situated at a distance of 75 cm. from the lens, how far from the lens will its image be focused? 透鏡焦點距 =50 cm. 物與鏡相距 75 cm. 像應在何距離？

解 同用上式以 q 爲像距，

$$故\frac{1}{50}=\frac{1}{75}+\frac{1}{q}，\frac{1}{q}=\frac{1}{150}，q=150\text{ cm.}$$

3. An object is placed 30 cm. from a lens whose focal length is 45 cm. Locate the image by employing the equation in Exer. 1. 有透鏡其焦點距=45 cm. 一物距鏡 30 cm. 用第一題公式，以定像之距離。

解 同上理以 q 爲像距

$$故\frac{1}{45}=\frac{1}{30}+\frac{1}{q}，\frac{1}{q}=\frac{-1}{90}，=-90.$$

得負號，像爲虛像。

4. What is the height of a tree 350 ft. away when its image on a screen 10 in. from a convex lens is 2 in. in height? 有物距鏡 350 呎，其像映于幕上，幕距凸透鏡 10 吋，像高 2 吋，物高若干？

解 本物與像之比等于二者距鏡之比，以物高＝x

$$\text{故}\ \frac{x}{12}=\frac{350}{10}\quad x=\frac{350\times 12}{10}\times\frac{2}{12}=70\ \text{呎}$$

ELECTRICITY 電學

XX. POTENTIAL DIFFERENCE. 正負電力之差

1. Three Leyden jars are charged with -4, -7, and 10 units respectively. How many units will remain in the jars after the knobs have been connected? 有玻電瓶三，各具電力如下 −4, −7, 10 電球相連之後，尚餘電力若干？

解 10−4−−7＝−1 尚餘負電 1 分佈 3 瓶。

XXI. ELECTRICAL ENERGY AND POWER. 電之能力

1. Compute the number of joules transmitted by a current of 10 amperes maintained for 20 minutes at a potential difference of 110 volts. 一電流具 10 amperes 繼續 20 分，其電力差爲 110 volts. 試求其 joules 之數。

解 公式 volts × amperes × seconds = joules

依此題 = 110 × 10 × 20 × 60

= 1520000 joules

2. Compute the heat loss per hour in an electric line of 3 ohms resistance when the current is 5 amperes. What is the result if the current is 10 amperes? 一電線抵抗爲 3 ohms. 電流爲 5 amperes. 每小時失熱若干？設電流爲 10 amperes, 則其結果如何？

解 依公式失熱 = C^2Rt

(1) 失熱 = $5^2 \times 3 \times 3600$

= 270000 watts (若變爲熱單位可

= 64800 calories 以 .24 乘之)

(2) 失熱 = $10^2 \times 3 \times 3600$

= 1080000 watts

= 259200 calories

3. If the power required far an incandescent lamp is 60 watt, what is the consumption of 50 lamps measured in terms of the horse power? 設一白熱燈須 50 watts, 則五十盞須若干，以馬力計之。

解 $60 \times 50 = 3000$ watts

746 watts = 1 馬力

3000 watts = $\frac{1}{746} \times 3000$

$= 4\frac{8}{373}$ 馬力

4. A piece of platinum wire is heated by a current of 2 amperes, and the potential difference between its

ends is 8 volts. Compute the heat developed per minute. 一白金線爲 2 amperes 電流所熱，兩端電位差=8 volts，試計其每分所生之熱

解 volts × amperes × seconds = joules

joules = 8 × 2 × 60 = 960

1 joule = .24 calorie

960 joules = .24 × 960

= 230.4 熱單位

XXII. COMPUTATION AND MEASUREMENT OF RESISTANCE 抵抗之計算

1. A current of 4 amperes divides and passes hrough two parallel coils of wire, one of 5 ohms and the other of 8 ohms. What is the current that goes through each branch? 4 amperes 之電流分流于二平行電綫，一爲 5 ohms 一爲 8 sohms 每綫所通之電流若干？

解 依平行連法其電流與抵抗爲反比之理

故 5 ohms 之支含電流 $= \frac{4}{13} \times 8 = \frac{32}{13}$

$= 2\frac{6}{13}$ amperes

8 ohms 之支含電流 $= \frac{4}{13} \times 5 = \frac{20}{13}$

$= 1\frac{7}{13}$ amperes

2. Find the combined resistance offered by the two parallel conductors in Exer. 1. 試將第一題平行導體所有之抵抗合計之·

解 依 $R=\frac{r_1\times r_2}{r_1+r_2}$ 公式 合抵抗爲 R

$$R=\frac{5\times 8}{5+8}=\frac{40}{13}=3\ \frac{1}{13}\ \text{ohms}$$

3. How much current will a dry cell of 2 ohms resistance and 1.43 volts send through a wire of 25 ohms resistance? 一乾電池抵抗爲 2 ohms, 有電位 1.43 volts, 若用一線, 有抵抗 25 ohms 通之, 能發電流若干?

解 依公式 $C=\frac{E}{R+r}$

$$\text{電流}=\frac{1.43}{25+2}=\frac{1.43}{27}=.053\ \text{ampere}$$

4. How much current would five cells similar to the one in Exer. 3 send through the same wire (1) when joined in series and (2) in parallel? 有同上電池五個, 通以同上之線 (1) 按正負互連法 (2) 按正負平行法各發電流若干·

解 (1) 正負互連法, 依公式 $C=\frac{n\,E}{R+5r}$

$$=\frac{5\times 1.43}{25+5\times 2}=\frac{7.15}{35}$$

(電流) = .204 ampere

(2) 正負平行法, 依公式 $C=\frac{E}{R+\frac{r}{n}}$

$$=\frac{1.43}{25+\frac{2}{5}}=\frac{7.15}{127}=.0563$$

5. What current would 8 Daniel cells of which the E. M. F. is 1.08 volts and the resistance 8 ohms each send through an ammeter of .4 ohm, when joined in seriesd What would be the current from one cell alone? 8 Daniel 電池各具 1.08 電位 (volts), 抵抗 3 ohms, 經由一電表其抵抗爲 .4 ohm, 用互連法，應發生電流若干？由一個電池發生電流若干？

解 (a) 電流 $= \frac{n\,E}{R+n\,r} = \frac{8\times 1.1}{.4\times 8\times 3} = \frac{8.8}{24.4}$

$= .36$ ampere

(b) 電流 $= \frac{1.1}{.4+3} = \frac{1.1}{3.4} = .323$ ampere

6. What would be the current produced from the same 8 celle connected in parallel and using the same ammetor? 用同上之電表及電池八個，若用平行連法則生電流若干？

解 電流 $= \frac{1.1}{.4+\frac{3}{8}} = \frac{8.8}{3.2+3} = \frac{8.8}{6.2} = 1.42$ amperes

7. Which is the better arrangement of 4 Danil cells (M. M. F. 1.1 volts and r = 2.5 ohms each) when the external reistance is 6 ohms? 4 Daniel 電位 1.1 volts, 抵抗 2.5 ohms, 外抵抗 = 6 ohms, 用如何連法較爲有利·

解 (1) 用相互連法，電法$=\frac{4\times1.1}{6+4\times2.5}=\frac{4.4}{16}$

$=.275$ ampere

(2) 用平行連法，電法$=\frac{1.1}{6+\frac{2.5}{4}}=\frac{4.4}{26.5}$

$=.166$ ampere

故相互連法較爲有利

8. Show that a small Daniel cell will give practically as much current as a large one through 1000 ohms of resistance, the resistance of the small one being 30 ohms while that of the large one is 4 ohms. 一小 Daniel 電池，抵抗爲 30 ohms；一大 Daniel 電池，抵抗爲 4 ohms；外抵抗各爲 1000 ohms，則小者與大者所生之電流殆相等

解 小者電流$=\frac{1.1}{1000+30}=\frac{1.1}{1030}=.001068$

ampere

大者電流$=\frac{1.1}{1000+4}=\frac{1.1}{1004}=.001085$

ampere

二者相差爲百萬分之十七故殆相等

9. A dry cell whose E. M. F. is 1.5 volts produces a current of .2 ampere through an instrument whose resistance is 7 ohms. Find the resistance in the cell. 一乾電池電位 = 1.5 volts，生電流 .2 ampere，所通過之器抵抗力 =7 ohms，試求此電池之抵抗力。

解 依公式 $C=\frac{It}{R+r}$ 以 r 爲電池之抵抗

$$\text{故 } .2\ (7+r)=1.5 \quad r=\frac{2.9}{.2}=14.5$$

10. Which will produce the greater effect in an external circuit of 5 ohms, a dry cell whose resistance is 3 ohms or a copper-oxide cell (E. M. F. = .8 volt) having a resistance of .2 ohm? 一乾電池抗抵爲 3 ohms 又一養化銅電池其電位=.8 volt, 抵抗爲 .2 ohm, 皆經過外抵抗 5 ohms 之輪道二者所生之電流孰大·

解 (1) 乾電池之電流 $=\frac{1.5}{5+3}=\frac{1.5}{8}=.1875$

ampere

(2) 養化銅電池之電流 $=\frac{.8}{5+.2}=\frac{.8}{5.2}$

$=.1538$ ampere

乾電池所生之電流較大

11. What current will be derived from a Daniel cell whose resistance is 3 ohms and a dry cell with a resistance of 2 ohms when they are joined in series and the external resistance is 2.74 ohms? 外抵抗=2.74 ohms —Daniel 電池，抵抗爲 3 ohms, 又一乾電池抵抗爲 2 ohms, 二者用正負相互連法，能生電流若干？

解 依公式 $C=\frac{1.1+1.5}{2.74+3+2}=\frac{2.6}{7.74}=.3359$

ampere

12. A circuit contains 4 dry cells (E. M. F. of each 1.5 volts) joined in series. Three of them are known to have resistance of .5 ohm each, and the external resistance is 10 ohms. If the current is .15 ampere, what is the resistance offered by the four cell? 一輸道計有乾電池四，各具電位 1.5 volts. 接相互連法，有三個抵抗 = .5 ohm. 外抵抗爲 10 ohms. 設電流爲 .15 ampere, 第四電池之抵抗若干?

解 依公式 $C=\frac{nE}{R+nr}$ 以第四電之抵抗爲 r.

$$\text{故 } .15=\frac{4\times 1.5}{10+3\times .5+r}=\frac{6}{11.5+r}$$

$$.15\times 11.5+.15r=6 \quad .15r=4.275$$

$$r=28.5 \text{ ohms.}$$

13. Two instruments of 3 and 4 ohms respectively are connected parallel between the poles of a dry cell (E. M. F. 1.5 volte) whose resistance is 1 ohm. Find (1) the external resistance of the circuit, (2) the current flowing through each branch. 有一乾電池電位=1.5 volts. 抵抗=1 ohm 有二器一爲 3 ohms 一爲 4 ohms 平行連其兩極，(1)求此輸道之外抵抗，(2)求此電池之電流，(3)求每支所通之電流，

解(1)依公式 $R=\frac{r_1\times r_2}{r+r_2}=\frac{12}{7}=1.714$ ohms (外抵抗)

(2)依公式 $C=\frac{E}{R+r}=\frac{1.5}{\frac{12}{7}+1}=.553$ ampere (電流)

(3) a. 3 ohms 之支 $=\frac{.553}{7}\times 4=.316$ ampere

b. 4 ohms 之支 $=\frac{.553}{7}\times 3=.237$ ampere

14. Two electro-magnets of 4 and 12 ohms respectively are connected in parallel to each other and then placed in a circuit containing a coil of 3 ohms and a battery of 10 ohms. Find (1) the total resistance of the circuit, and (2) the strength of the current in each part of the circuit, the E. M. F. being 4.8 volts. 二電磁石一爲 4 ohms. 一爲 12 ohms. 平行相連置於輸道內，有電綿，具有 3 ohms. 及一濕電池，具有 10 ohm. (1) 求其總抵抗，(2) 求各部之電流，(電位爲 4.8 volts)

解(一)總抵抗 $=\frac{4\times 12}{4+12}+3+10=3+3+10=16$ ohms.

(二)因電流共 $=\frac{4.8}{16}=.3$ ampere

故 4 ohms 之部分電流 $=\frac{.3}{16}\times 12=.225$ ampere

12 ohms 之部分電流 $=\frac{.3}{16}\times 4=.075$ ampere

15. A galvanometer of 30 ohms has a shunt of 30 ohms. When connected in an electric circuit, what part of the whole current will pass through the instrument? By that number must the current measured by the galvanometer be multiplied to give the entire current? 一測電器具 30 ohms 連一平行導器有 30 ohms. 連成輸道時總電流幾分之幾通過此器，若欲發生全數電流，則須增多幾倍。

解 按 $C=\frac{E}{R+r}$ 以 E=1 volt

$C=\frac{1}{30+30}=\frac{1}{60}$ 即電流僅爲原電位六十分之 1 若使與原電位相等則須增 60 倍

16. If the resistance of the shunt in Exer. 15 is reduced to 20 ohms, what part of the total current will the galvanometer carry, and what will be the multiplier? 上題平行導體之抵抗設降爲 20 ohms. 則測電器含總電流幾分之幾，且應增若干倍，始得全體電流？

解 設 E=1 測電器所含之電流 $=\frac{1}{30+20}\times 20=$

$\frac{2}{5}$ 應增之倍數 $=\frac{5}{2}=2.5.$

17. If the galvanometer has 300 ohms of resistance, what must be the resistance of a shunt so that only one tenth of the entire current will pass through the wire of the instrument? 設測電器具有 300 ohms 之抵抗，若欲此器僅通全電流十分之一，則所用之平行導體抵抗若干，

解 以 r 爲平行導體之抵抗

則 $\frac{1}{300+r}\times r$ $\frac{1}{10}$ $10r=300+r$

$9r=300$

$r=33\frac{1}{3}$ ohms.

XXIII. TRANSFORMER AND INCANDESCENT LAMP

轉電器與白熱電燈

1. A transformer carries a current of 10 amperes in its primary coil, under a potential difference at its terminal of 2000 volts. If it delivers a current of 194 amperes with a potential difference of 100 volts, how much delivered, and how much wasted? 一轉電器其原電綫具有電流 10 amperes. 其極端電位差＝2000 volts, 設以 100 volts 之電位差，能轉 194 amperes 之電流，每小時所變之能力若干？所轉者若干？所消耗者若干？

解 每小時所變之能力＝$10 \times 2000 \times 3600 =$
72000000 watts

每小時所轉之能力＝$194 \times 100 \times 3600 =$
69800000 watts

每小時所消失之能力＝2160000 watts

較原有者爲 3 %

2. If a building contained fifty 110-volt incandescent lamps, what voltage would have to be supplied to operate them if they were all joined in in series? Show

that this would be impracticable. 設一房中有 110-volt 白熱電燈 50 盞，若均用相互連法須電位若干，試說明其爲不合實用。

解 50 盞 110-volt 之電燈須電位 $50\times110=5500$ volts 電位過高故不合實用。

8. Forten 16-candle-power 110-volt incandescent lamps in parallel, what would have to be the voltage and how much current would be required? 十六支燭 110-volt 白熱電燈 10 盞，平行連法，須電位若干？電流若干？

解 所需電位 $=10\times110=1100$ volts

所需電流 $=.5\times10=5$ amperes

4. Compute the monthly cost of operating five 16 candle-power incandescent lamps when current costs 10 ct. per kilowatt-hour, allowing an average use of 2 hr. per day and 3.5 watts per candle power. 有 16 支燭白熱燈 5 盞，每日用 3 小時，每支需 3.5 watts. 每 1 Kilowatt. hour 電流費爲 10 分，問每月需費若干？

解 每月需費 $=5\times16\times3.5\times3\times30\times\frac{10}{1000}$

$=25.2$ 分

5. Compute the monthly cost of current for an open arc lamp requiring 8 amperes at 50 volts, allowing 8 hr. per day and 10 ct. per kilowatt-hour.

XXIV. TELEGRAPH 电報

1. Compute the resistance of an iron telegraph line 150 mi long, the size of the wire being .1 in., the line containing also 10 relays of 150 ohms each. Allow nothing for the earth connectionsr 鐵線電報長 150 mi. 線，切面直徑=.1 in. 此線並有助電器 10 具，各有 150 ohms 之抵抗，計此線之總抵抗，與地連接者不在此內，

解 鐵綫之抵抗 $=61.5\times150\times5280\times\frac{1}{10000}$

$=5485.8$ ohms.

助電器之抵抗$=10\times150=1500$ ohms

合計之 $=6985.8$ ohms

2. A telegraph wire offers a resistance of 35 ohms per mile. If the line contains five 150-ohm instruments, what current will be produced by 30 Daniel cells of 2 ohms each in a line 80 mi long! 一電線每哩抵抗=35 ohms. 設此線有 152 ohms. 之器 5 具，則 30 Daniel 電池各有 2 ohms. 之抵抗，線長 80 哩能生電流若干？

解 本 $C=\frac{E}{R}$

$$\text{電流}=\frac{30\times1.1}{35\times80+5\times150+2\times30}=\frac{33}{3610}$$

$=.00914$ ampere

APPENDIX

Laws and Equations

Sound

I. VELOCITY OF SOUND.

1. The velocity of sound in air is 1085 ft., or 331 m., per second at the temperature of freezing water. It increases 2 ft., or .6 m., per second for each degree centigrade.

2. The velocity of sound in iron is about 5100 m. per second at 20°C. The average velocity of sound in wood is approximately 4000 m. per second.

3. The average velocity of sound through water is 1400 m. per second.

II. VELOCITY, WAVE LENGTH, AND VIBRATION FREQUENCY.

1. Vibration frequency is generally put as 256 per second. Hence, the length of each wave is 4.4 ft. (1120 ÷256). Letting n be the frequency, v the velocity of sound, and l the wave length, we have

$$l = v \div n$$

III. INTENSITY OF SOUND.

1. The intensity of sound is inversely proportional to the square of the distance measured from the source of the sound.

2. The intensity of sound depends upon the density of the medium in which the sound is produced.

VI. PITCH OF TONES.

1. The pitch of a tone depends upon the number of wave pulses per second sent from a sounding body to the ear.

V. THE MAJOR SCALE.

1. The major scale is a series of tones whose vibration frequencies have the same relation as the numbers 24, 27, 30, 32, 36, 40 45, and 48. To these tones we give the names do, re, mi, fa, sol, la, ti, do, denoted by C, D, E, F, G, A, B, C' respectively. The first tone of such a series is the key tone. Physicists assign to the tone called middle C, 256 vibrations per second. The vibration ratios with reference to the first tone are :—1, 9/8, 5/4, 4/3, 3/2. 5/3, 15/8, and 2. These ratios are the same for all major scales, no matter what the key tone may be. The perfect scale of middle C is :—C=256, D =288, E=320, F=341.3, G=384, A=426.6, B=480, C'=512.

IV. INTERVALS.

1. A musical interval refers to the relation between the pitches of two tones. The interval between C' & C, that is, 2: 1, is an octave.

V. LAW OF BEATS.

1. The number of beats produced per second is equal to the difference between the vibration frequencies of the two sounding bodies.

VI. THE VIBRATION OF STRINGS.

1. The vibration frequencies of strings or wires are inversely proportional to their lengths.

2. The vibration frequencies of strings or wires are directly proportional to the square roots of their tensions.

VII. LAW OF MASSES.

1. The vibration frequencies of strings or wires are inversely proportional to the square roots of their masses per unit length.

VIII. OPEN AND STOPPED PIPES.

1. The pitch of a closed pipe is an octave lower than that of an open one of the same length.

2. Hence, the equations are :—

Open Pipe $n = v \div 2l$

Closed Pipe $n = v \div 4l$

Heat

IX. GRADUATION OF THERMOMETER SCALES;

1. According to the centigrade scale, the freezing point of water is marked 0°, and the boiling point 100°.

2. On the scale of Fahrenheit, the freezing point is marked 32°, and the boiling point 212°.

3. Letting F represent a Fahrenheit reading and C the corresponding reading on the centigrade scale, we have: $F - 32 = 9/5\ C$

X. COEFFICIENT OF LINEAR EXPANSION.

1. The ratio of the increase in length of a metal bar for an increase of one degree in temperature to its length at 0°C. is called the coefficient of linear expansion of the metal.

2. The coefficient of linear expansion of a substance is expressed by the equation :—

$$k=(l_2-l_1)\div l_1(t_2-t_1)$$

Here l_1 and l_2 are the lengths before and after heating, and t_1 and t_2 are the initial and final temperature.

XI. COEFFICIENT OF CUBICAL EXPANSION.

1. The coefficient of cubical expansion of a substance is the ratio of the increase in volume for a change of one degree in temperature, to the volume at 0°C.

2. The cubical expansion of a substance may be expressed by the equation :—

$$k=(v_1-v_0)\div v_0t,$$

where v_1 and v_0 are the volumes at the temperature t°C. and 0°C. respectively.

XII. CUBICAL EXPANSION OF GASES.

1. Under a constant pressure, all gases have the same coefficient of cubical expansion (Law of Charles). This number has been found experimentally to be 1/273, or .00366.

XIII. LAWS OF GASEOUS BODIES.

1. The volume of a given mass of gas under constant pressure is proportional to its absolute temperature. (The temperature measured from 273 below 0°C. as the zero of the scale is called absolute temperature.)

2. The pressure of a given mass of gas whose volume remains constant is proportional to the absolute temperature.

3. Laws of Charles and Boyle combined :—

The produce of the pressure and volume of a given mass of gas is proportional to the absolute temperature.

XIV. CALORIMETRY.

1. The calorie is the quantity of heat required to raise the temperature of a gram of water one centigrade degree.

2. To change the temperature of a mass of m grams of water t centigrade degrees, we may write for the required quantity of heat,

$$H = m \times t.$$

XV. SPECIFIC HEAT.

1. The specific heat of a substance is the ratio of the quantity of heat required to raise the temperature of a certain mass of it one degree to the quantity of heat required to raise the temperature of an equal mass of water one degree.

XVI. SPECIFIC HEAT DETERMINED.

1. The quantity of heat gained by the cold body equals to that lost by the warm body.

XVII. LAWS OF FUSION.

1. A crystalline substance under a constant pressure has a definite fusing point which is also the temperature at which solidification takes place.

2. When a crystalline substance begins to melt, its temperature remains constant until all of it is liquefied.

3. A substance that contracts while melting has its fusing point slightly lowered by increased pressure, but a substance that expands while melting has its fusing point slightly raised by an increase of pressure.

4. In the presence of a dissolved substance, the solid forms by crystallization at a temperature below the freezing point of the pure solvent.

XVIII. HEAT OF FUSION.

1. The number of calories per gram required to liquefy a substance without producing any change in its temperature is called the heat of fusion of that substance.

2. Careful investigation has shown that the heat of fusion of ice is 80 calories.

3. When a gram of water freezes, 80 calories are given out to its surroundings.

XIX. LAWS OF EVAPORATION.

1. The rate of evaporation becomes greater as the exposed or free surface of liquid is increased.

2. The rate of evaporation becomes greater as the temperature of the liquid and vapor is increased.

3. The rate of evaporation is increased by the removal of the vapor from the space above the liquid.

XX. LAWS OF EBULLITION.

1. Every liquid has its own boiling point, which is invariable under the same conditions.

2. The boiling point of a liquid rises or falls as the pressure upon the liquid increases or decreases.

XXI. HEAT OF VAPORATION.

1. The amount of heat required to change a gram of any liquid at its boiling point into vapor at the same temperature is called the heat of vaporation of that liquid.

2. The heat of vaporation of water accepted by physicists is 536 calories.

XXII. THE MECHANICAL EQUIVALENT OF HEAT.

1 calorie=427 gram-meters, or 41,900,000 ergs.

Light

XXIII. THE SPEED OF LIGHT

1. The speed of light is 186,000 miles per second or 300,000 kilometers per second.

XXIV. RECTININEAR PROPAGATION OF LIGHT.

1. We always assume that the object sending the light to us is located in the straight line which marks the direction of the light as it enters the eye.

XXV. INTENSITY OF LIGHT.

1. The intensity of illumination is inversely proportional to the square of the distance from the sourse of light.

XXVI. CANDLE POWER

1. A candle power is approximately the power of a sperm candle of the size known as "sixes" (meaning six to the pound), burning 120 grains per hour.

XXVII. THE LAW OF REFLECTION.

1. The angle of reflection equals the angle of incidence.

XXVIII. IMAGE IN A PLANE MIRROR.

1. The image of a point is as far behind a plane mirror as the point itself is in front.

XXIX. INDEX OF REFRACTION.

1. The number which expresses the ratio of the speed of light in air to its speed in another medium is called the index of refraction of that medium.

2. Index of refraction=speed in air:speed in other medium=dd':aa'.

3. dd'÷aa'=ex÷e'x' index of refraction.

XXX. IMAGES FORMED BY CONVEX LENSES.

1. When the object is situated at more than twice the focal length from a convex lens, the image is at less than twice and more than once the focal length from the lens on the opposite side, inverted, and smaller than the object.

2. When the object is situated at more than once and less than twice the focal length from a convex lens, the image is at more than twice the focal length on the other side, is real, inverted, and larger than the object.

3. When the object is situated at a point between a convex lens and its principal focus, the image is apparently behind the lens, is virtual, erect, and larger than the object.

4. When an object is at a great distance from a convex lens, its image is at the focal distance from the lens, is real, inverted, and smaller than the object.

XXXI. IMAGES FORMED BY CONCAVE LENSES.

1. The image produced by a concave lens is always apparently on the same side of the lens as the object, is virtual, erect, and smaller than the object.

XXXII. THE LENS EQUATION.

1. Experiments have shown that the position of an image formed by a lens is determined by the focal length of the lens and the distance from the lens to the object. If p represents the distance from the lens to the object, q the distance from the lens to the image, and f the focal length, then the following relation between these distances will be found to exist:

$$1/f = 1/p + 1/q$$

XXXIII. RELATIVE SIZE AND IMAGE.

1. The ratio of the size of the object to the size of the image is equal to the ratio of their respective distances from the lens.

XXXIV. THE ELECTROSTATIC UNIT OF QUANTITY.

1. Unit charges of electricity are such equal quantities as exert upon each other a force of one dyne when separated by one centimeter of air.

XXXV. MIXING POSITIVE AND NEGATIVE CHARGES.

1. Not only does electricity tend of flow from a positively to a negatively charged body, but a mixture of unlike charges tends to produce a cancellation of both. If, however, one of the charges exceeds the other in amount, the excess remains distributed over both surfaces. In the final condition both bodies are of the same potential.

XXXVI. CURRENT.

1. A continuous discharge, or movement, of electricity is called an electric current.

XXXVII. VOLTAIC CELL.

1. The terminals of a voltaic cell and the wires leading from them are electrically charged,—a positive charge being borne by the carbon (or copper) and a negative charge by the zinc.

XXXVIII. ELECTROMOTIVE FORCE.

1. The difference of potential that the cell maintains between these two charges when the plates are not connected by a conductor is the electromotive force (abbreviated E. M. F.) of the cell.

XXXIX. AN ELECTRIC CIRCUIT.

1. The entire conducting path along which a current of electricity flows is called an electrical circuit.

XL. ACTION OF A VOLTAIC CELL.

1. The greater the disparity in the chemical actions at the two plates, the greater difference of potential maintained by the cell.

XLI. CURRENT STRENGTH—THE AMPERE.

1. The ampere is that current which will deposit in an electrolytic cell .001118 grams of silver or .0003287 grams of copper per second.

XLII. ELECTRICAL RESISTANCE.

1. The opposition that a conductor offers tending to retard the transmission of electricty is called electrical resistance.

XLIII. LAWS OF RESISTANCE.

1. The resistance of a conductor of uniform size and composition is directly proportional to its length.

2. The resistance of a conductor is inversely proportional to its cross-sectional area; or, if circular in form, to the square of its diameter.

3. The resistance of a conductor depends upon the nature of the substance of which it is composed.

XLIV. POTENTIAL DIFFERENCE—THE VOLT.

1. The volt is that difference of potential between the ends of a wire having a resistance of one ohm which will produce a current of one ampere.

XLV. OHM'S LAW.

1. This law states that the strength of an electric current is directly proportional to the E. M. F. furnished by the voltaic cell or combination of cells, and inversely proportional to the total resistance of the circuit. The equation is:

$$C = E \div R$$

XLVI. CELLS CONNECTED IN SERIES.

1. The equation is:

$$C = nE \div (R + nr) \quad \text{or} \quad C = (E_1 \times E_2 \times E_3) \div (R_1 + r_2 + r_3)$$

XLVII. CELLS CONNECTED IN PARALLEL.

1. The equation is:

$$C = E \div (R + r \div n)$$

XLVIII. ENERGY OF AN ELECTRIC CURRENT.

volts × amperes × seconds = joules

XLIX. POWER OF AN ELECTRIC CURRENT.

power = volts × amperes

L. WATT.

1. A power of one joule per second is called a watt.
2. One horse power is equal to 746 watts.

LI. CALORIE AND JOULE.

1. A calorie is equivalent to 4.2 joules.

LII. JOULE'S LAW.

1. The heat developed in a conductor by an electric current is proportional to the square of the current, to the resistance of the conductor, and to the time the current is flowing.

$$\text{Heat} = .24\ C^2 R\ t \text{ calories.}$$

LIII. CURRENT IN BRANCHES.

1. The currents from the cell in a two-branched circuit are inversely proportional to the corresponding resistance.

$$R = r_1 \times r_2 \div (r_1 + r_2)$$

APPENDIX

Laws and Equations

1. Equation of Uniform Motion.

$$d = vt.$$

2. Equation of Uniformly Accelerated Motion.

$$v = at.$$

$$d = \tfrac{1}{2} at^2$$

3. Equations of Force.

f (in dynes) = m (in grams) × v(in cm./sec.) ÷ t (in seconds)

f (in dynes) = m (in grams) × a(in cm./sec.^{2})

The dyne is that force which, acting uniformly for one second, imparts one C. G. S. unit of momentum.

A force of one poundal is equivalent to 13,825 dynes.

If a mass is free to move, gravity will produce an acceleration of 980 cm./sec.^{2}

A gram-weight is equivalent to 980 dynes.

Gravity in F. P. S. system is 32.16 ft./sec.^{2}

4. The Laws of Parallel Forces:—

1. The resultant of two parallel forces acting in the same direction at different points on a body is equal to their sum, and has the same direction as the components.

2. The moment of one of the components about the point of application of the other is equal and opposite to the moment of the supported weight about the same point.

5. Resolution of Forces:—

A given force may be resolved into the components whose directions are given by making the line of force the diagonal of a parallelogram whose sides are drawn from the point of application of the force in the directions required for the components.

6. The Centripetal Acceleration:—

$$a = v^2 \div r$$

7. Equation of Centripetal Force:—

$$\text{Centripetal force} = m \times v^2 \div r$$

8. (a) Work:—

$$\text{Work} = f\ d$$

(b) Unit of Work:—

The erg is the work done when a force of one dyne acts through a distance of one centimeter.

1 dyne-centimeter equals 1 erg.

1 kilogram-meter equals 98,000,000 ergs.

1 foot-pound equals 13,550,000 ergs.

1 foot-poundal equals 421,390 ergs.

9. Activity or Power:—

Activity is the rate of doing work, and is found by dividing the work performed by the time consumed in the process.

10. Unit of Activity:—

The unit of activity or power commonly used is the horse power, which is the rate of doing work equal to 550 foot-pounds per second.

The unit of power in C. G. S. system is the watt, which is equivalent to the work done at the rate of 10^7 ergs per second.

One horse power equals 746 watts, or 746×10^7 ergs per second.

11. Potential Energy:—

The potential energy of a body is measured by the work that was done upon it to bring it into the condition by virtue of which it possesses that energy.

12. Kinetic Energy:—

Kinetic energy $= \frac{1}{2} m v^2$ ergs.

Kinetic energy $= \frac{1}{2} m v^2$ foot-poundals.

13. Law of Weight:—

The weight of a body above the earth's surface is inversely proportional to the square of its distances from the center of the earth.

14. Equations of Freely Falling Bodies:—

$$v = g t$$

$$d = \frac{1}{2} g t^2$$

$$d = v^2 \div 2g$$

$$v = \sqrt{2gd}$$

15. The Pendulium Equation:—

$$t = \pi \sqrt{l \div g}$$

16. Machanical Advantage of a Machine:—

The mechanical advantage of a machine is the ratio of the distance through which the effort moves to the distaince through which the resistance is moved by the Machine.

17. Equation of the Pulley System:—

$$W = n\,F.$$

18. Law of the Lever:—

The moment of the effort is equal to the moment of the resistance.

The equation of the lever is:—

$$F \times l = W \times l'.$$

19. Equation of the Wheel and Axle:—

$$F \times R = W \times r$$

20. Equation of the Inclined Plane:—

$$F \times l = W \times h.$$

21. Equation of the Screw.—

$$F \times 2\pi \times r = W \times s.$$

2. Efficiency of a Machine:—

The ratio of the useful work done by a machine to the work done upon it is the efficiency of the machine.

23. Equation of Liquid Pressure:—

$$\text{Force} = ahd.$$

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