SCIENCE RELATED TO LIFE

BOOK FOUR

LIGHT, FORCES AND MACHINES

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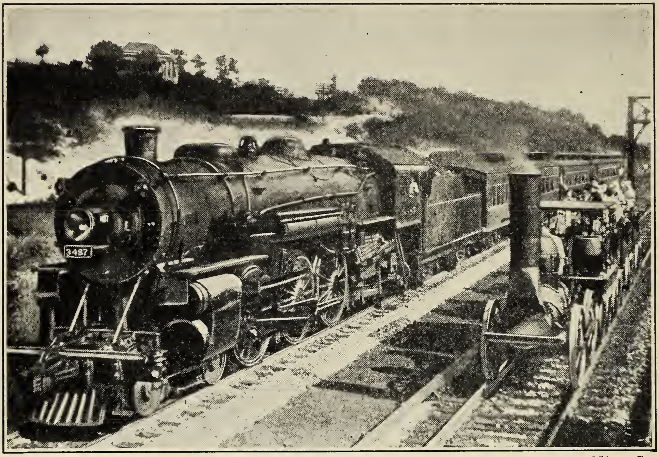
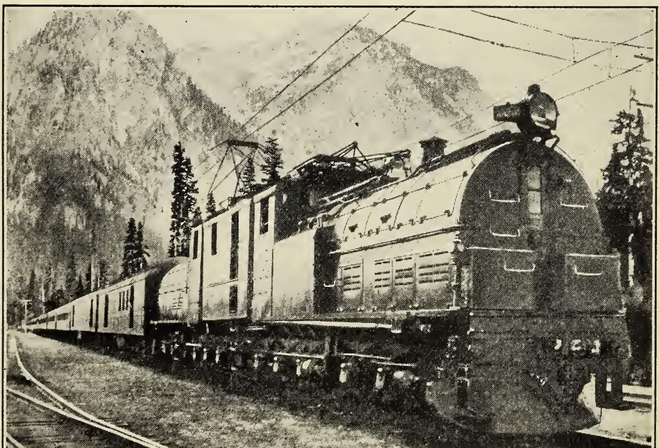


Keystone View Co.

. An old and a modern steam locomotive.



A modern electric train.

SCIENCE RELATED TO LIFE

BOOK FOUR

LIGHT, FORCES AND MACHINES

By

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PREFACE

"Science Related to Life" is a series of four books written to supply the need of elementary science teachers for textbooks that can be used independently by pupils. Throughout the series the author has kept in mind the aims of elementary science, as recognized by modern courses of study, namely:

1. To develop in pupils an interest in the natural phenomena about them, and knowledge and appreciation of the practical applications of science.
2. To give pupils training in the scientific method.
3. To lead pupils to appreciate the order and beauty which pervade the realm of nature.
4. To show that science is a potent factor in human betterment, since it affords mankind leisure in which to enjoy greater comforts and cultural advantages, by giving him more comforts and greater leisure for their enjoyment, and for cultural development.

Following are outstanding features:

1. Each book is divided into *problems,* or "units."
2. In almost every case, the problem begins with an interesting approach, often in story form. This arouses the curiosity of the pupil and makes him eager to solve the problem.

3. Each scientific term is printed in italics, indicating that it is defined in the glossary. The glossary may also serve as a basis for a special list of spelling words in science.

4. Every scientific term is clearly explained in the text and is defined at least twice; first in the text or in the form of a footnote on the page where it appears, and then in the glossary.

5. The demonstrations are so simple that any pupil can perform them either at home or in the classroom with a minimum amount of apparatus.

6. Each problem ends with a simple summary, a set of questions, and suggestions for additional demonstrations and projects.

7. At the end of each book are simple, interesting biographical sketches of scientists mentioned in the text.

8. A list of reference books and suggestions for additional reading is appended.

TABLE OF CONTENTS

THE SCIENCE NOTEBOOK

People who live in great cities usually change their residences many times. Each time it is necessary to take inventory of belongings and to get rid of things that have piled up because of the collecting habit to which most people are slaves. Often, parting with these things is not easy, for the owners grow unreasonably fond of them.

One of the "treasure-boxes" that always comes in for an overhauling on such occasions is likely to contain notebooks written during school days, perhaps many years past. How lovingly one turns the musty pages! What work had been put into the science books! What pleasant recollections are aroused by those elaborate diagrams and the carefully shaded or colored sketches! They seem crude now, as does the faulty language in which the notes are written; yet one loves them because they represent sincere effort: an attempt to do the best of which one was capable. Although one may be cramped for space and determined to part with them, these notebooks still remain.

What practical suggestions can be given you in regard to *your* science notebook? In the first place, choose a book that appeals to you — one in which you will like to write. It need not be expensive, but let it be attractive. The loose-leaf form is superior to the bound form because one can add, subtract, or substitute pages without spoiling the appearance of the book in any way.

Write up your science notes at home. Every real student will think enough of science to wish to make his notes as complete and attractive as possible. In the classroom the time is extremely limited. A sheet of paper for rough notes, and a simple sketch that can be redrawn with more care at home, are all that the time generally permits. At home, one can not only improve the penmanship and draftsmanship, but there is an opportunity to add original notes and ideas and information gathered from magazines and library books. The true student of science will find this sort of homework a pleasure.

Throughout the textbook you will find demonstrations which you are required to do either alone or with the help of your teacher. After the demonstration has been performed you should write an account of it in your notebook.

The form in which the report of the demonstration is written is not of great importance. For the most part, it should be in composition form, telling in your own language what you saw in the classroom and what conclusions you reached as a result of such observation. It is a good idea, occasionally, to arrange the report in a more scientific form, carefully tabulating your observations in an orderly manner. This will help you to cultivate the scientific habit of orderliness that should be one of the purposes of studying this subject.

If you should decide to write your report in scientific form, the following arrangement is suggested:

Problem. Under this heading write the question that is to be answered by the demonstration.

Apparatus. Give a list of the materials needed in performing the demonstration.

Procedure. Under this heading tell in your own way, and as briefly as possible, how the demonstration is performed. Be sure to include every important step in the work. If you are performing the demonstration yourself, be sure to carry out all the steps with great care and to repeat the demonstration several times, if necessary, to get an average that is reliable. Make diagrams whenever you feel they will be helpful.

Observation. During the demonstration you should watch closely and you should note, under this heading, anything in connection with the demonstration that you consider important, especially if you think it will help to solve the problem.

Inference. The inference is what you learn from the demonstration. If the inference is correct, it is the solution of the problem which the demonstration is intended to settle. Usually it may be written in the form of a simple statement.

Do not be sparing in your efforts. Become a member of the S. S. N. C. ("the Superior Science Notebook Club"); not only will you get real pleasure out of your work, but you will, in time, have a treasure box of notes that will prove a delight to you in after years: a product of your own hands, that you will love and cherish.

THE MACHINE AGE

One night in the early eighteen hundreds the watchman at the gate of a little town in England was dozing as usual. Suddenly he was aroused by an unfamiliar rumbling in the distance. Nearer and nearer it came and, peering into the darkness, he was able to see the outline of a strange object. It appeared to be a wagon and yet it had a peculiar looking funnel which belched forth clouds of black smoke. It moved, and yet there were no horses to pull it. Behind the smoke stack the watchman could see two men, their faces red from the reflection of the flames that burned inside the monster. "Demons," muttered the frightened watchman, as with trembling hands he undid the bolts to let the clattering thing pass. He was in such haste that he forgot to collect the usual toll; anything to get the horrible monster out of his sight.

However, this was no invention of the imagination created by the sleep-dulled senses of the gate keeper. It was Richard Trevethick and a friend riding in the first steam-drawn vehicle.

Trevethick's steam wagon was an application of the steam-engine constructed in 1769 by James Watt, the Scottish inventor. Perhaps the greatest credit is due to Watt because he was the first to realize that steam had the power to do work.

It is a long jump from Trevethick's peculiar looking steam wagon to the huge engines that pull our luxurious trains across the continent. It is a long and fascinating story and many of you will want to read more about it.

In this book you will study about the forces of nature; the simple machines; how the combination of these has resulted in our great factories where one man by a simple shifting of levers can do the work of a dozen or more.

Underwood & Underwood

Sunlight makes bathing healthful.

PROBLEM I

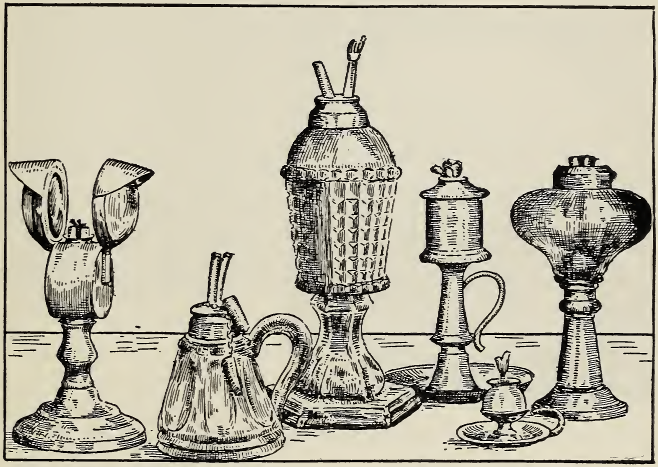
WHAT ARE THE CHIEF SOURCES OF LIGHT?

With the exception of the faint light that comes from the distant stars and an occasional flare from a volcano in eruption, practically all the natural light that we enjoy comes from the sun. So accustomed have we become to the existence of sunlight that we seldom consider what life might be without it. If we were deprived of the sun we should be plunged into darkness and the earth would become extremely cold. We should be obliged to work and play, if, indeed, we could live at all, by artificial light, for even the moon and the planets would cease to give light, since they shine only by reflecting the light of the sun.

Man cannot hope to manufacture light that compares with that of the sun. He builds immense power houses to produce electric light; he burns, yearly, great quantities of coal to make illuminating gases; he invents lamps that, in time, consume vast amounts of oil; he makes use of the taper, the match, and the wax candle. All these result in light that is pitifully feeble when compared to the glorious light of the sun.

When one considers how absolutely helpless we would be if deprived of the sun, it is not difficult to understand why so many peoples in the past set up temples and shrines to worship it. They were in constant fear that the sun would leave them forever and plunge the world into darkness. Each night when it set in the west they had no assurance that it would return in the morning.

Sources of artificial light. Man felt the need of artificial light early in his existence. He built fires at night to supply whatever light was needed. If he wished to find his way in the dark, a blazing stick, taken from the fire, served as a torch. Then, during the early history of man, someone discovered that animal fat would burn brightly. This discovery led to the making of torches from substances soaked in animal fats and, perhaps, to lamps made by burning animal fat in a hollow stone vessel. When man learned to make metal vessels improved lamps, still employing animal fats as fuel, were fashioned. Metal lamps of this type were used for centuries by the Greeks and the Romans. Some of these lamps had wicks made of thin twigs soaked in fat. The next advance was the invention of the tallow candle, con-



Some interesting lamps.

sisting of a stick of solidified tallow with a wick embedded within it. Candles like these are still used except that paraffin wax is usually employed in place of the tallow.

When petroleum was discovered, oil lamps came into general use for lighting. Then illuminating gas was made from coal, and mantles were used to improve the quality of the light. A mantle is a fine network of metal, usually thorium, which glows when heated in the gas flame. In a gas light employing a mantle, therefore, it is the glowing mantle, and not the burning gas, that gives off light.

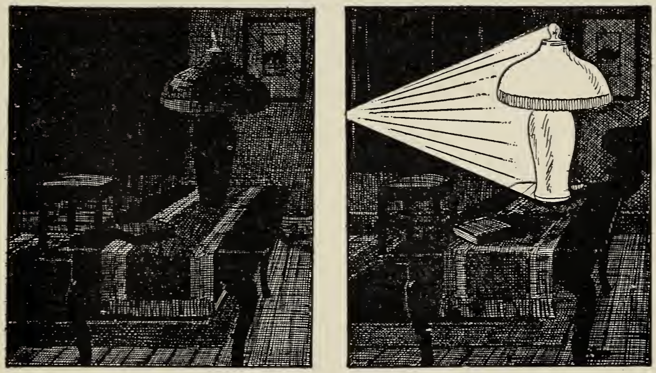
After the gas light came the invention of the electric light, about which you have already learned. The electric light has practically replaced every other device for lighting the modern home.

Ewing Galloway

Is the moon luminous or non-luminous?

The moon gives light by reflection. You have learned that when an object is sufficiently heated it becomes incandescent, that is, it glows with light. Such objects are known as *luminous* objects, from the Latin, *lumen*, "light." The sun and the stars are luminous objects. So are the candle light, gas light, and electric light. Luminous objects give off light. The moon is not a luminous object. We see it only because it is in the path of the sun's light, just as we see objects on the earth during the day time merely because they are made visible by the light of the sun. Objects like the moon, which are not incandescent, that is, which do not glow, are known as non-luminous objects.

Demonstration. To show the differences between luminous and non-luminous bodies. Enter a room that has been darkened by dark shades and heavy hangings over the windows. What can you see in the room? Turn on a flash-



How does this illustrate the difference between luminous and non-luminous bodies?

light and aim it at various parts of the room. What is the result? Light a match and then extinguish it. Notice the effect of the light of the match on objects in the room. Draw back the hangings and roll up the shades, permitting daylight to enter. What is the effect on objects in the room?

Most objects are non-luminous and are visible only because they are *illuminated*, that is, lighted up, by luminous objects. The moon, then, gives light when it is illuminated by the sun. That the moon is non-luminous is shown during an eclipse of the sun. At such a time the moon gets between the earth and the sun and plunges the earth into darkness for a few seconds. If the moon were luminous the earth would be lighted by moonlight during the eclipse.

Natural and artificial light. On page 8 you read the brief story of the development of artificial lighting devices, from the open fire of primitive man to the incandescent electric light of today. A source of light, then, may be artificial or natural. You have already learned about some natural sources of light, for example, the sun, the stars, and the moon. There are other natural sources of light, such as comets, meteors, planets, lightning, and volcanic eruptions.

Question. Can you add to this list?

You will notice that some of these sources of light are luminous and others are non-luminous. Sources of light, then, may be natural, artificial, luminous, or non-luminous.

The speed of light. You may recall, when you learned about radio waves, that these waves travel with a speed of 186,000 miles a second. This is fast enough to encircle the earth, at the equator, seven times in one second. Light travels at the same speed as radio waves. A ray of light coming from the moon, a little more than a quarter of a million miles away, reaches the earth in little more than a second. To come from the sun, a distance of 93,000,000 miles, light requires only eight minutes!

93,000,000 miles is a great distance, yet the stars are much farther off than this. The star nearest to us is so distant that light, traveling at the rate of 186,000 miles a second, would take more than four years to reach the earth. This star is named *Alpha Centauri*, which means "star A in the *constellation*[1] of the Centaur."

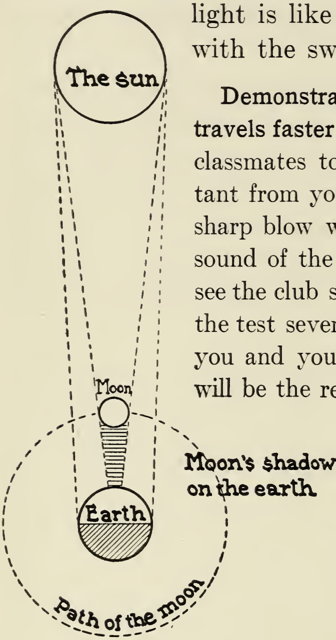
The distance that light travels in one year is known as a *light year*. Alpha Centauri is, therefore, more than four light years away; in other words, about twenty-six millions of million miles! If it were possible for some one, today, to flash a beam of light from Alpha Centauri to the earth, this beam, traveling 186,000 miles every second, would take over four years to reach its destination.

Yet Alpha Centauri is our nearest star-neighbor. There are many stars that are hundreds, thousands, and even hundreds of thousands of light years away. Imagine, then, how vast these stars must be to be visible at so great a distance. Imagine, too, how transparent the space must be through which the light from the stars travels to the eye of an observer.

Light and sound do not travel with the same speed. Have you ever measured the time between a flash of lightning and the corresponding peal of thunder? Frequently the difference is four or five seconds, and sometimes it is even more, for sound is a slow traveler, as speeds in nature go. It travels at the rate of about 1100 feet per second. Perhaps you will say that this is very swift. Indeed it is much swifter than the flight of

[1] A constellation is a group of stars. The group known as the Centaur was so named by the ancients because it seemed to resemble a mythical figure having the head of a man and the body of a horse, known as a Centaur.

an arrow, and even faster than the speed of a bullet, but comparing the speed of sound with the speed of light is like comparing the slow snail with the swift-footed deer.



An eclipse of the sun.

Demonstration. To show that light travels faster than sound. Get one of your classmates to go off to a point quite distant from you and strike the pavement a sharp blow with a heavy club. Does the sound of the blow reach you just as you see the club strike the pavement? Repeat the test several times. The farther apart you and your companion are, the better will be the results.

Light travels readily from the sun to the earth because space, through which it travels, is *transparent*. Transparent means easy to see through, from the Latin *trans*, "across," and *parere*, to "appear." Glass, air, and clear water, are transparent because light passes through them readily. The transparency of glass makes it useful for many purposes.

Some substances allow part of the light to pass through. Thin paper, colored glass, mica, thin linen, cotton, or silk cloth, are substances of this kind. We call these substances *translucent*, from the Latin, *translucere*, "to shine through."

Substances that allow no light to pass through are said to be *opaque* from the Latin, *opacus*, "dark." When light falls upon an opaque object, the object will cast a shadow. You will see your own shadow

How do these figures illustrate the meaning of *transparent*, *translucent*, and *opaque*?

cast upon a wall when you get between a light and the wall. When the moon gets between the sun and the earth, the moon, because it is opaque, casts a shadow on the surface of the earth. In a similar way, when the earth gets between the sun and the moon, the earth casts a shadow on the moon and the moon is eclipsed.

Demonstration. To show that opaque objects cast shadows. Hold a ball between a lighted lamp and the wall. Look for the shadow on the wall. Move the ball, first nearer to the lamp, and then farther off. What changes do you notice in the shadows? How does the distance of the object from the light affect the size of the shadow? Hold other opaque objects between the light and the wall. Look for the shadow in each case. What may you conclude from this demonstration?

If you are clever, making shadows on a wall may be made an interesting source of entertainment. Perhaps you have seen shadow pictures resembling animals, made by holding the hands in various positions between a lamp and the wall. Try this game yourself.

Why does the hand cast a shadow?

Summary

The sun is the chief source of light.

Man also obtains light from fires, torches, candles, and lamps.

The moon gives light by reflection.

Light travels as fast as radio waves, 186,000 miles a second.

Substances that do not allow light to pass through them are opaque.

Questions

1. What is the difference between natural light and artificial light?
2. Name three sources of natural light.
3. Name five sources of artificial light.
4. Explain the purpose of the mantle of a gas burner.
5. Is moonlight a natural or an artificial source of light? In what way does it differ from sunlight?
6. Tell which of the following are natural and which are artificial sources of light: the light of the firefly, light from

an erupting volcano, burning oil, *phosphorescent* jelly fish, starlight, wood fire, arc light, lightning.

7. Who invented the incandescent electric lamp?

8. What is meant by "luminous" bodies? "Non-luminous" bodies?

9. What is the cause of night and day? Illustrate your answer by means of a diagram or a model.

10. How is an eclipse of the sun caused? Illustrate your answer by means of a diagram or a model.

11. What is the speed of light? What is the speed of sound?

12. The sun is 93,000,000 miles away; how long would it take for sound to travel that distance?

13. How long does it take light to travel from the sun to the earth? Explain how you get your answer.

14. Name three transparent and three translucent substances.

15. What is the meaning of "opaque"?

16. Make a diagram to show how the distance of an opaque body from a source of light affects the size of the shadow cast by the opaque body.

Can You Also Answer These?

17. Why is window glass a very important article?

18. If you were out in mid-ocean, in a darkened boat on a moonless but clear night, you would still be able to see to some extent. How do you account for this?

19. Which comes first, the flash of lightning or the peal of thunder?

20. How far off is the source of thunder if the time between the flash of lightning and the sound of the thunder is $3\frac{1}{2}$ seconds?

Supplementary Demonstrations And Projects

1. Observe the sun through smoked glass to show how translucent substances allow some, but not all, light to pass through.

2. Find out the distance from the earth to each of the planets and calculate the length of time it takes light to travel from each of the *planets* to the earth.

3. List five to ten bodies or substances which belong under each of the following headings:

Opaque, Translucent, Luminous, Non-Luminous

4. Read about stars and planets.

5. Find out how Michelson measured the speed of light.

How do we receive light from the stars?

PROBLEM II

HOW IS LIGHT REFLECTED?

On a warm evening, late in September, a group of boys were gathered around a man in an open field a good distance away from the lights of the road. They were all gazing up at the twinkling stars and the man was pointing toward one particularly bright star almost directly overhead. The man was Mr. Hackett, teacher of science, and the boys were members of class 8B.

" The name of that star," Mr. Hackett was saying, " is *Vega*."

" And how many light years away is Vega? " asked one of the boys.

" Vega is 26 light years away," said Mr. Hackett, " you can imagine what a huge star it must be to appear so bright to us in spite of the great distance through which its light has traveled. And here I should like to call your attention to an important characteristic of light: it always enters the eye in straight lines."

" Does that mean," asked another of the group, " that there is a straight line many millions of miles long between Vega and my eye?

" That is exactly what it means," answered the teacher. " Sound may travel around corners, over high fences, and through crooked passageways because, as you have learned, sound waves travel in ever-widening spheres from the source of sound. So do radio waves, and heat waves. But light travels in a straight line. A beam of light that hits a wall will not leap over or bend around it. The beam is stopped short. If you want to illuminate an object in a dark room with a flashlight you must point the flashlight directly at the object; to view a distant star with a telescope, you must aim the telescope directly at the star."

Next day, in the science room, Mr. Hackett performed the following demonstration. Try it at home or in the classroom:

Demonstration. To show that light enters the eye in straight lines. Make a small hole in the center of each of a number of cardboards, equal in size. Arrange the cardboards so that the holes are in a straight line. Place a lighted candle behind the last cardboard and look through the holes toward the candle. What do you see? Move one of the cards out of line and look again. What difference has moving the card made? Why?

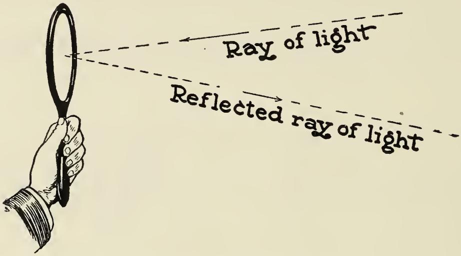
Take a piece of rubber hose and lay it on the table so that

Why is it impossible to see the apple through the bent hose?

it is perfectly straight. Place an object opposite the far end of the hose and look through it. The object is, of course, visible. Now, keeping the far end of the hose in exactly the same position, bend the rest of the hose into a curve as shown in the figure. What difference does this make? Why?

Light is reflected from smooth surfaces. Primitive man must have discovered early that hills, trees, and other objects form images in the quiet waters of lakes on whose shores these objects are located. It was probably very long ago when he learned to polish metal surfaces into mirrors for reflecting his own image. Excavations of very ancient centers of civilization bring to light small hand mirrors, apparently for the use of women.

Today mirrors have many uses. They are indispensible aids in dressing. If all the mirrors in your home were removed you would probably feel greatly inconvenienced. Mirrors are frequently used for decorative effect, particularly where an impression of great size is desired. No doubt you have seen res-



Mirrors reflect rays of light.

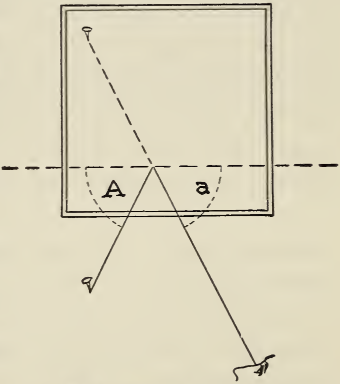
taurants and, perhaps, hotel ballrooms in which mirrors are used to obtain such an effect.

More important than using mirrors as ornaments is their use in mechanical devices and scientific instruments, such as automobile headlights, searchlights, telescopes, microscopes and periscopes.

To understand the principle of a mirror, it is first necessary to know what happens to rays of light when they strike a mirror. You have learned that light, from objects, comes to the eye in straight lines. However, when light strikes a smooth surface it is *reflected*, that is, bent back, from the Latin *re*, " back," and *flecto*, " bend."

Demonstration. To show that smooth surfaces reflect light. Hold a piece of cardboard before you. Can you see your face in it? Do the same with a polished piece of wood. Do you see yourself dimly reflected in the surface? Try again with a piece of window-glass, with a number of bright metal pans, the polished gold surface of a new watch-case, and, finally, with a mirror of *silvered glass*. Which of these objects reflects the image of your face best?

A ray of light that strikes a smooth surface such as a mirror, may be bent by holding the mirror at an angle to the rays of light. You have, perhaps, done this by holding a small mirror so that it catches a beam of sunlight and then turning the mirror in such a way as to reflect the light to the wall or ceiling of the room. Some of you may have considered it fun to reflect the sunbeam into the eyes of a person near by, but this should never be done because it is likely to injure the sight of the person. When a mirror is turned in such a way as to bend a ray of light at an angle, the angle at which the ray of light leaves the mirror, is known as the *angle of reflection*, and the angle at which the ray of light strikes the mirror, is known as the *angle of incidence*. The angle of reflection is equal to the angle of incidence.



Are the angles A and a equal?

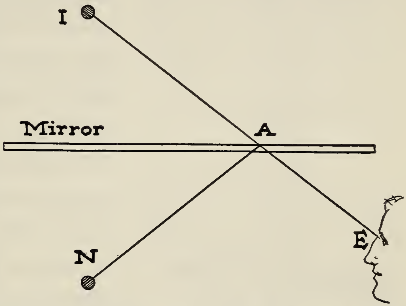
Demonstration. To show that the angle of reflection is equal to the angle of incidence. Place a small mirror upright on a sheet of paper as shown in the illustration. Stick a tack into the paper in front of the mirror and a little to one side. Move the eye until the image of the tack is clearly seen in the mirror. Draw a line from the eye toward the image until it strikes the mirror. Draw another line from this point to the tack. Do you notice that the angles *A* and *a* are equal? Move the eye to the left or right and repeat the test. How about the angles *A* and *a* at the mirror? Are they again equal?

In plane mirrors *A*, the angle of incidence, and *a*, the angle of reflection are equal to each other. This is known as *the law of reflection.*

A peculiar effect, which you must have noticed, in connection with mirrors, is that an image reflected in a mirror seems to be behind the mirror and in front of the observer. This is due to the fact that no matter how rays of light from an object may be bent, we see the object in a straight line. If the rays of light from the object are bent by a mirror, that is, reflected at an angle, the object appears to be as far behind the mirror as it actually is in front of the mirror.

Demonstration. To show how far behind a mirror an image appears to be. Place an object, such as a nickel, on the paper in front of the mirror as shown in the illustration, and a little to the left of the center of the mirror. Move the eye to a position, as shown, from which the image of the nickel can be seen in the mirror. Note how far behind the mirror the image seems to be. Now move the nickel, first nearer, and then farther from the mirror. How does the image seem to move? How does the distance of the nickel in front of the mirror, in each case, compare with the apparent distance of the image behind the mirror? Repeat the test in various ways until you feel certain of the results.

The total length of the ray of light from the nickel to the eye, in the illustration, is the bent line, $NA + AE$, and the total distance, IE, from the image to the eye, is the same; therefore $NA = AI$, which proves that the image is as far behind the mirror as the nickel is in front.

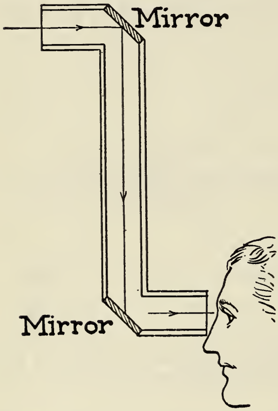


How far behind the mirror does the image of the nickel appear to be?

Test the truth of this fact by standing before a mirror and noting the apparent distance of the image behind the mirror. Move, first toward, and then away from the mirror to see whether or not the rule holds.

In a similar manner, the image of an object formed in the surface of a quiet lake or pond seems to be as far beneath the surface as the object actually is above the surface. You may recall the story, probably read by you years ago, of the dog who was about to cross a bridge with a bone in his mouth. Looking into the clear, mirror-like surface of the pond, he saw what he thought was another dog, carrying a bone. The selfish dog snapped at his image and lost the bone. Had the animal known that what he beheld in the surface of the pond was an image, instead of another dog, he would not have gone hungry.

Making a periscope. A reflecting instrument that you will all delight to make is a *periscope*. The illustration shows how this works. It consists, chiefly, of a tube which contains two mirrors set at an angle. Rays of light from an object enter an opening at the upper end of the tube and are reflected downward to a lower mirror. From this second mirror the rays are again reflected into the eye of the observer. Periscopes are important parts of a submarine boat equipment and have been used by troops in trenches. The trench periscope permits the observer to remain sheltered in the trench, unobserved by the enemy, while he looks out through the periscope and over the top of the trench.

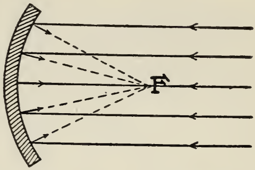


Explain the use of the periscope.

Make a simple periscope and use it, during a parade, to look over the heads of those who may be standing before you.

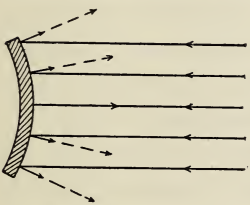
Images in curved mirrors. If you have ever looked into the large, curved mirrors provided by many amusement places, you will remember how one mirror made you look short and fat, another, tall and thin, and others, still, reflected images of you that were so strange in shape as to be unrecognizable. Mirrors that produce these effects are curved mirrors.

Curved mirrors may be either *concave*, that is, shaped like the inside of the polished bowl of a spoon, or *convex*, that is, shaped like the outside of the bowl of a spoon.



Concave mirrors collect rays of light.

Concave mirrors collect rays of light at a single point, known as the *focus*, and represented in the illustration by the letter, F.



Convex mirrors scatter rays of light.

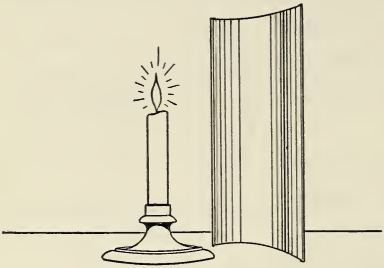
Convex mirrors scatter rays of light. Curved mirrors are used in telescopes, microscopes, automobile headlights and pocket flashlights.

Question. Why is the mirror used in an automobile headlight a concave mirror?

Demonstration. To show images in curved mirrors. Obtain a thin sheet of polished metal from a tinsmith. Light a candle and hold it before the sheet of metal. Bend the sheet of metal so that it is, first concave, and then convex. View the image of the light in the surface of the metal and note the results.

Obtain, if possible, the concave mirror of an automobile headlight and repeat the experiment with the candle. Try to locate the focus.

You may recall having learned, last year, about solar engines which obtain heat for boiling water to operate small steam engines by collecting rays of sunlight with the aid of large mirrors. What is the shape of the mirrors employed in this device? Can you tell why?


Concave mirrors collect rays of light.

Objects having light colored surfaces reflect more light than those with dark surfaces. You have learned that most objects are non-luminous and that they are visible only because they reflect light. To convince yourself of this perform, once more, the demonstration on page 11. When the room is absolutely dark, no object can be seen. As soon as sunlight is let in objects become visible.

In a dimly-lighted room you will notice that some objects are more easily seen than others. Close observation will show that the objects most easily seen are those which have light colored surfaces. This is due to the fact that light colors reflect more light than dark colors. This is a very useful fact to know in connection with decorating rooms. If the room is naturally dim, the walls should be light in color in order to brighten the effect. Bright rooms, on the other hand may be made more comfortable by painting the walls a color instead of white. White walls in a bright room reflect so much light that they cause a glare which may become injurious to the eyes.

You probably know that looking directly at a bright light, either natural, or artificial, causes eye strain. You can convince yourself of this by looking directly at an electric light for a few minutes. When reading, always be careful to sit in such a position that the light shines, not into your eyes, but on the book or paper which you are reading. The best way is to have the light fall on the book or paper, over your left shoulder. Notice, in the classroom, that no light ever comes from the front of the room, but usually from the left side. At home, reading lamps are provided with shades that keep the glare of light from the eye. If a "drop light," such as we find in business offices, is used, it may hang in front of the person using it so long as the shade is low enough to protect the eye from the direct glare of the incandescent bulb.

Correct conditions for reading by lamplight.

A drop light

Examine the reading lamps at home to see if they are properly placed for the purpose for which they are intended.

Summary

Light enters our eyes in straight lines.

Light is reflected in straight lines from smooth surfaces.

The angle of reflection is equal to the angle of incidence.

Convex mirrors scatter light.

Concave mirrors collect light.

How Much Have You Learned?

Which of the following statements are true and which are false?

T. F. 1. Light travels only from smooth surfaces.

T. F. 2. The moon is a smooth surface because it reflects light.

T. F. 3. Concave mirrors are used in searchlights.

T. F. 4. Mirrors were used in ancient times.

T. F. 5. Mirrors may be used as decorations.

T. F. 6. Mirror walls make a room look smaller than it really is.

T. F. 7. Reflected means "thrown back."

T. F. 8. Light rays may be bent.

T. F. 9. The angle of reflection and the angle of incidence are equal.

T. F. 10. The image of an object always seems to be in front of the mirror.

T. F. 11. The length of a line from the eye to the image is equal to the length of the bent ray from the object to the eye.

T. F. 12. The closer we get to a mirror, the further behind the mirror the image seems to be.

T. F. 13. Calm water of lakes reflects objects on the shore but not out near the middle.

T. F. 14. Periscopes always have curved mirrors.

T. F. 15. Concave mirrors are used in flashlights.

T. F. 16. Light from a candle may be scattered by convex mirrors.

T. F. 17. The lighter the wall, the less light it reflects.

T. F. 18. Always face the light when you are reading.

T. F. 19. If the eyes are exposed to the glare of bright lights they become tired.

T. F. 20. Objects that are non-luminous can be seen only by reflected light.

Questions

1. A glass mirror has two surfaces because it has thickness; in which of these surfaces are the images formed?
2. Which do you think is better, a mirror made of highly polished metal or a glass mirror? Why?
3. A ballroom containing walls covered with mirrors looks larger than it is. Why?
4. Name two uses for mirrors, either plane or curved, which have not been mentioned in this Problem.
5. For use as a reflector in an oil lamp, would you use a convex or a concave mirror? Explain your answer.
6. Of what value is the " sight " of a rifle?

Supplementary Demonstrations and Projects

1. Construct a cardboard periscope.
2. Study the patterns made in a Kaleidoscope and explain how these patterns are formed.
3. Read about indirect lighting.
4. Find out more about solar engines.
5. Read about the 200-inch reflecting telescope at Mt. Wilson Observatory, California.

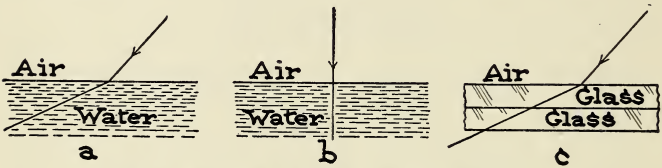
Mount Wilson Observatory

PROBLEM III

HOW ARE LIGHT RAYS REFRACTED?

Harold was strolling along the grassy shore of a pond, enjoying the sunshine of a warm July morning, and taking in deep breaths of the clean, sweet-smelling air. He whistled a gay tune as he walked, and occasionally lunged at an imaginary foe with a long, thin, lance-like stick which he carried in his right hand. Harold loved to lunge at objects with his stick. So skilled was he in this that he could spear a leaf on the ground, several feet in front of him, at the very first try. A bright, shining object resting on the bottom of the pond and very near the shore, attracted him. This should be a good target for his marksmanship. Taking careful aim he plunged the stick into the pond. To his amazement, the stick which, he was sure, was more than sufficiently long for the purpose, barely reached the bottom of the pond. Furthermore, as he held the stick, partly in and partly out of the water, the stick seemed bent at the point where it entered the water. But what annoyed Harold most of all was the fact that something was wrong with his aim. Usually so accurate at spearing objects he found that, in this particular case, his stick touched the bottom of the pond almost a foot from the mark!

What Harold did not know was that when rays of light pass from one transparent medium, such as air,



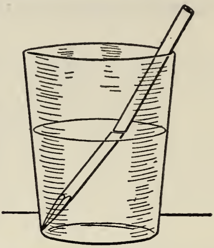
Explain what happens to the ray of light in each case.

to another, such as water, the rays of light are bent. This bending is known as *refraction*. Rays of light are refracted only when they enter the second medium at an angle, and when the second medium is either more dense or less dense than the first.

Every one of us has noticed that a spoon, partly immersed in water, or a straw thrust into a glass of

[1] From the Latin *re*, "back," and *frango*, "break."

soda, seems bent at the surface of the liquid. Certainly no real change has been made in the shape of the spoon or the straw, for we have only to remove it from the liquid to convince ourselves that all is well. The rays of light, however, are bent so that they cause this strange appearance.

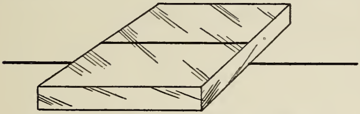


What causes the pencil to appear bent?

Demonstration. Draw a long, straight line on a piece of paper and place a small piece of thick window glass on the paper so that it covers only part of the line. Does the line now appear to be broken? What has caused this?

Stick a pencil into a glass half full of water. Does the pencil seem bent? At what point does the bending take place? What causes this?

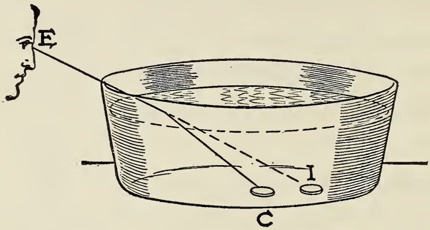
Place a coin in the bottom of an empty basin so that it is just out of the line of sight, hidden by the edge of the basin. Keeping the eye perfectly still in this position, let some one fill the basin with water. Does the coin come into view? Has the coin actually moved from its original place? What has caused the coin to come into view?



Why does the line appear to be broken?

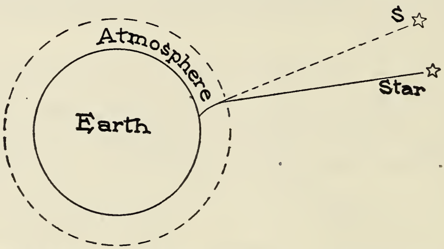
Light passing obliquely from one transparent medium through another, is bent or refracted.

To explain just why the coin appears to rise in the basin, remember that we see objects in straight lines. This was explained in connection with images formed in mirrors. (Read, again, page 24). Therefore, although the rays of light from the coin are actually bent when they leave the surface of the water



Why is the coin not where it appears to be?

and enter the eye, the eye sees the coin as though it were at the end of a straight line. When light from a star enters the atmosphere, the rays are refracted, as



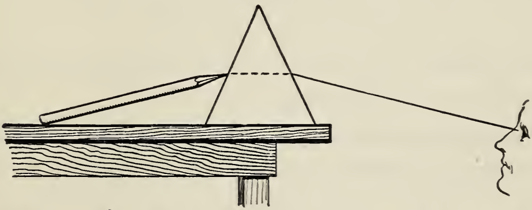
Stars are not where they seem to be. Explain why.

shown. The eye of an observer, however, sees the star as if it were at S.

You can see, by glancing at the diagram of the coin in the basin, that the coin seems further away and higher up than it actually is. The effect is to make the water in the basin appear less deep than it really is. That explains why Harold was surprised to find the pond deeper than it appeared, and it also explains why, when he aimed the stick at the object at the bottom of the pond, he missed the mark by a number of inches.

Demonstration. To show that light going through a glass prism is bent toward the base. Your science teacher has a number of glass *prisms* which you may examine and use.

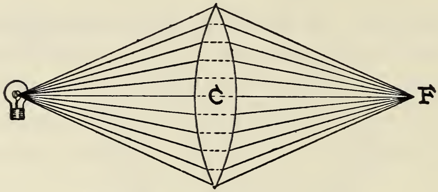
Stand a prism on its base, near the edge of a table, as shown in the illustration. Use as large a prism as you can obtain



Explain what happens to the rays of light that travel from the pencil to the eye.

for this demonstration. Rest a pencil against the face of the prism as indicated. Bend down and place the eye in such a position that the pencil appears to be in your line of sight. Get one of your classmates to make a diagram to illustrate the position of the pencil, the prism, and your eye. It will appear as shown in the illustration. Note how the rays of light from the pencil were refracted as they entered the first surface of the prism and, again, as they left the second surface of the prism. Note, also, that the rays are bent toward the base of the prism.

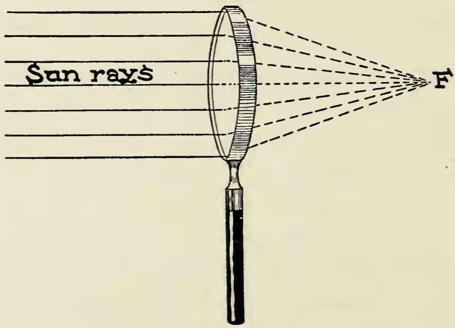
Scientists have made use of the principle of refraction of light in *lenses*. A lens is a piece of clear glass whose surfaces are curved. Just as there are convex and concave mirrors, so there are convex and concave lenses. By means of lenses of various shapes we are able to bend light rays to suit our purposes. If we wish to collect light at a single point, or focus, we use



Convex lenses collect rays of light.

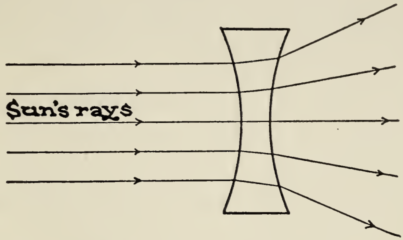
a convex lens. If our purpose is to scatter rays of light, we employ a concave lens.

When both surfaces of a lens are convex, the lens is said to be a double-convex lens. Such a lens bends



What kind of lens is here shown?

light in somewhat the same way as two prisms would when placed base to base. The rays of light are gathered at the focus, F. The distance from the center of the lens, C, to the focus, is known as the focal distance. A lens of this type, with which most of you are, no doubt, familiar, is the *burning glass.* Rays of light from the sun, which are parallel, are focused by the double-convex lens of the burning glass and a con-



Concave lenses scatter rays of light.

siderable amount of heat may be developed at the focus. It is possible, in this way, to light a match or to set fire to a piece of thin paper.

When both surfaces of a lens are concave the lens is said to be a double-concave lens. Such a lens bends light in somewhat the same way as two prisms would when placed tip to tip. Double-concave lenses scatter rays of light.

Demonstration. To show that an enlarged upright image is seen when the eye views an object through a convex lens that is less than its focal distance from the object. Look through a double convex lens, such as a reading glass, at the printed matter on this page. Place the lens near enough to the page to be sure that the lens is *less* than its focal distance from the page. How does the size of the printed letters as seen through the lens compare with their actual size? Instead of examining the printed page, look through the lens at various objects, such as a pencil, a finger, or the dial of a watch. What do you observe?

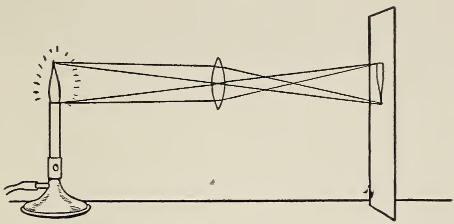
The microscope is based on this principle. By selecting lenses of certain curvature and arranging them in the proper way, objects may be magnified in a microscope to several hundred times their actual size.

Lenses are also used in field glasses, ordinary eye glasses, *telescopes*, projection lanterns and cameras. A lens for a huge telescope weighs hundreds of pounds and requires many months of painstaking work on the part of experts to perfect. The largest lens of this type thus far made is 40 inches in diameter. It is the lens of the great refracting telescope in the Yerkes Observatory at Williams Bay, Wisconsin.

Man's genius, however, has yet to make a lens that can compare with the tiny lens in the human eye. This remarkable device has the power to change its shape so as to adjust itself to varying conditions. It is thus able to gather light rays from objects at any distance and to bring them to a focus on the sensitive surface at the back of the eyeball, known as the retina.

The image made by the convex lens of the eye is inverted, that is, upside down.

Demonstration. To show that light from a distant object may be refracted by a convex lens to form a small inverted image on a screen. Light a Bunsen burner. Turn the tube of the burner until a bright flame results. Set upright a white cardboard screen about three feet from the flame. Begin by placing a double convex lens at the screen and then



slowly move it toward the flame until a small image of the flame is formed on the screen. What do you notice about the image? Can you explain it by means of a diagram?

A camera lens forms small inverted images in this way. This device will be explained more fully a little later.

Summary

Rays of light are bent when they pass obliquely from one transparent medium through another.

Light going through a glass prism is bent toward the base.

The double-convex lens bends rays of light somewhat as do two prisms placed base to base.

Objects seen through a convex lens that is less than its focal distance from the object appear enlarged and upright.

Light from a distant object may be refracted by a convex lens to form a small inverted image on a screen.

Questions

1. Under what conditions will a ray of light be bent?
2. At what point does a spoon, partly immersed in water, appear to be bent?

3. Why do pools of clear water appear less deep than they are?

4. Why are stars really not where they appear to be? Do they appear to be higher or lower than they really are? Explain your answer with the help of a diagram.

5. Make diagrams of a double-convex and a double-concave lens.

6. What is meant by the "focal length" of a lens?

7. What kind of a lens is used for magnifying objects?

8. Name five devices that make use of lenses.

9. State one way in which the lens of the human eye is superior to all artificial lenses.

10. In what way are the lens of the eye and the lens of a camera similar?

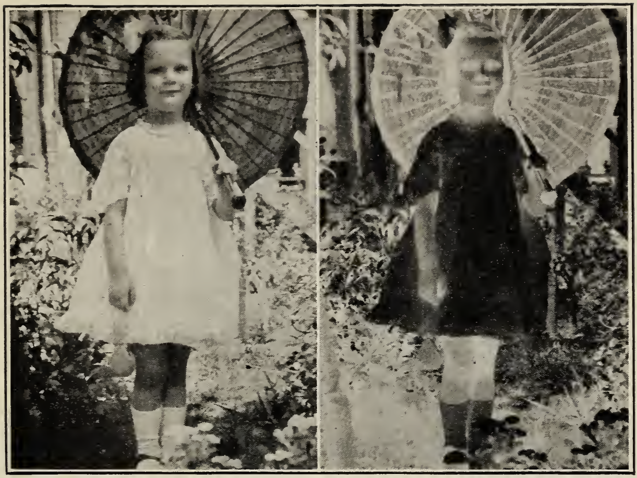
Supplementary Demonstrations And Projects

1. Make a simple telescope.

2. Read about great telescopes in the United States.

3. Find out the differences between reflecting telescopes and refracting telescopes.

4. Set fire to a piece of thin paper by collecting rays of sunlight in a double-convex lens.



A positive and a negative.

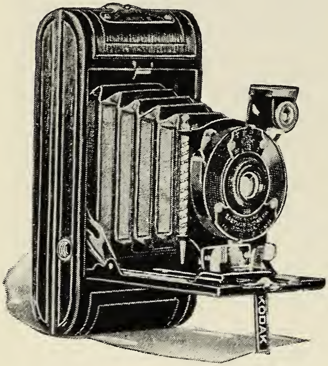
PROBLEM IV

HOW ARE PHOTOGRAPHS MADE?

The Camera Club of Jefferson Junior High School was in session. Each member had brought six photographs and these were being examined and discussed. Pictures that were satisfactory in every way were set aside for further consideration; pictures that were poor in composition or not clear, were cast out. Finally the best five pictures were marked for exhibition and the owners of these pictures were complimented by the director of the club for good work in photography.

"Let us now," suggested one of the members, "make a study of the important parts of the camera in order to learn their use."

The suggestion was favorably received and the members of the club asked Mr. Pelton, their science teacher and director of the club, to explain the camera. Mr. Pelton readily consented and the members of the club gathered around his table on which rested a splendid camera.



Eastman Kodak Co.

A folding camera.

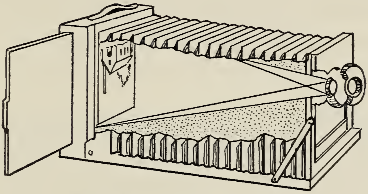
"The word camera has the same origin as the word chamber, a room. The camera is a box in which images are formed by lenses in front and projected to a photographic surface in back.

Cameras are either fixed in length, as in the box camera, or extensible, as in the folding camera. The extension is made possible by what is known as the bellows of the camera."

As Mr. Pelton spoke he pointed to the lenses and the bellows. He then removed the lens and exhibited it to the members.

"The lens, as you see, is a double-convex lens and therefore, as you have learned, the image formed on the screen at the back of the camera is an inverted image."

To show that this was so, Mr. Pelton held the lens so as to form an inverted image of a Bunsen burner flame, using a sheet of paper as the screen in place of the photographic surface that is actually employed in cameras.



Why is the image inverted?

" Large, professional photographs are generally taken on sensitized glass plates which fit into light-proof plate holders that may be inserted in a compartment at the rear of the cameras. Smaller cameras, such as are used by amateurs, are generally provided with flexible celluloid films. These may be either the type known as the film pack, which fits into a magazine at the back of the camera, or the roll film, which is wound on a spool and mounted, like a small shade-roller, in the magazine of the camera."

At this point Mr. Pelton exhibited plates, plate-holders, a film pack and a roll film, all of which he took from a supply closet filled with photographic supplies and science apparatus.

" The rolls are usually made in two lengths: long enough to allow for six or for twelve pictures. After a picture is taken, the exposed section of the film is wound on a second roller, thus bringing the next portion of the sensitized film into position to take a picture. When all six, or all twelve pictures, as the case may be, have been taken, the magazine is opened and the spool that holds the film is removed and is ready for developing and printing.

"The camera permits no light to enter, except through the lens at the front. The lens is protected by a shutter which opens to admit light only when released by a small lever called the shutter release. The size of the opening, and the length of time during which it remains open, are regulated by delicate timing devices. If the light in which the picture is taken is bright, as at noon on a sunny day, the adjustments are made for a smaller opening and a shorter exposure than when the light is less bright. In most cameras, the length of exposure for ordinary pictures varies from $\frac{1}{25}$ to $\frac{1}{100}$ of a second. Pictures taken with such short exposure are called "snapshots." Longer, or "time" exposures can be made by other adjustments. Time exposures are necessary when the light is very faint, as late in the day or indoors."

"But how are pictures made?" asked one of the boys. "I know how to snap a picture and I have often given a roll of film to the druggist to be developed and printed. Are we going to learn how to make our own pictures?"

"Next week," replied Mr. Pelton, "I shall explain how pictures are made. I shall also tell you something about the history of photography — that is, if you would like to have me do so."

The suggestion was met with applause and when the club met the following week, Mr. Pelton was there. While the minutes of the last meeting were being read, he was busy arranging, on the table, bottles containing chemicals, glass and porcelain basins, and glass and rubber tubes of various sizes and shapes. Later, as he spoke, he made use of these materials to explain the processes in photography.

A daguerreotype. For whom is it named?

Before the 19th century, little was known about the art of photography. In 1802, Wedgewood and Davy produced transient pictures, that is, pictures that fade in a very short time, by a process based on the discovery that certain compounds of salt are sensitive to light. Hours of exposure were needed to make a picture by the methods known in those early days of photography.

The first important step in the direction of modern photography was made in 1839, when Daguerre, in France, and Talbot, in England, perfected a way to take pictures, with an exposure of only a few minutes, on metal plates that were coated with silver salts. This type of photograph is known as the daguerreotype, in honor of the inventor. Soon after this event, a considerable advance was made by the invention of a transparent glass plate: an invention that made it possible to print a number of pictures from a single original plate.

For almost 50 years, glass and metal were the only substances on which negatives could be made. Then, in 1888,[1] George Eastman, of Rochester, invented the flexible celluloid *film*.[2] To make this film, a mixture of guncotton and camphor, in the form of a thick paste, is poured on a polished surface and allowed to harden. The celluloid is then cut into strips to be used in cameras.

In rooms especially equipped to prevent daylight from coming into contact with the chemicals, these celluloid strips are coated with gelatin containing bromide of silver, a chemical that is very sensitive to light. As the light from the object that is being photo-

[1] Some give credit to Hannibal Goodwin for the invention of the celluloid film. Goodwin's invention came in 1885, three years before Eastman's but Eastman seemed unaware of Goodwin's work.

[2] film, from the Anglo Saxon word, *fylmen*, skin. A thin skin.

graphed falls on this sensitive surface, the chemical action is such that the silver compound is broken up, the bromide becoming separated from the silver, or "loosened." Small particles of silver then become deposited on the part of the film that was exposed to light. Certain lights affect this silver compound more than others. The more intense the light, the greater the effect on the silver bromide.

You have learned that photographic films are exposed to light for only very short periods. This short exposure is not enough to permit a sufficient deposit of silver particles to take place. The process is completed in a dark room by immersing the film in a bath of pyrogallic acid, or "pyro" known as *developer*. The bath is continued just long enough to complete the process of depositing silver particles where the film had been exposed. This is what happens when we "develop" pictures.

When the film has been sufficiently developed, it is plunged into another bath containing a solution of clean water and certain salts. This mixture is known as a *fixing solution*. Its purpose is to stop the action of the silver and to make permanent the effect thus far obtained.

The film is now taken out of the bath and dried. Because the silver deposit is black, the parts that had been exposed to bright light in the camera appear dark on the film and the parts that were exposed to less light in the camera appear light on the film. This is the reverse of the light and dark shades of the object photographed. The film is therefore said to be a *negative.*

From this negative, any number of prints can be made. The paper on which photographs are printed is coated with a compound containing silver chloride, instead of silver bromide. Like silver bromide, silver chloride is sensitive to light. The negative plate is placed on the printing paper, and the whole is exposed to light for a short time. Where the negative is dark, that is, where the silver deposit is heavy, the light does not penetrate; where the negative is transparent, that is, where there is little or no silver deposit, the light penetrates, and affects the silver salts. The effect of light and shade on the negative is thus reversed, making the result the same as that of the object photographed. At the proper moment, which is determined by experience, the paper is bathed in a developing solution and then plunged into the fixing solution. After several minutes this *positive,* now known as a photograph, may be dried and the picture is ready for mounting in your photograph album.

Summary

In a camera, an inverted image is formed on a sensitive film by a double-convex lens.

The image affects the silver salt on the film.

After exposure, the film is developed; the result is a negative.

Photographs are printed from negatives and are known as positives.

How Much Have You Learned?

In each of the following statements three possible words or phrases are printed in parentheses. Only one of these words or phrases is correct. Select the correct one in each case.

1. The word, camera, has the same origin as the word, (comrade, chamber, came).
2. Cameras that have bellows are (extensible, extreme, fixed).
3. The lens of a camera is (double-concave, plane, double-convex).
4. The image formed by the lens is (inverted, large, upright).
5. The camera lens (refracts, reflects, rejects) light.
6. The amount of light admitted into the camera is controlled by the (film pack, shutter, bellows).
7. Snapshots are taken with (long exposure, no exposure, short exposure).
8. A scientist who did much to develop photography was (Ampere, Volta, Daguerre).
9. The celluloid film was invented by (Eastman, Edison, Bell).
10. The first photographs were made on (metal, glass, celluloid).
11. (Gold salts, silver salts, mercury salts) are used on photographic films.
12. Celluloid contains (chalk, camphor, mica).
13. The film, when developed, is known as a (positive, negative, neutral).
14. When the sensitive film has been exposed to very bright light it becomes (dark, light, clouded).

15. From one negative (one, two, many) positives may be made.

16. Positives are usually printed on (paper, metal, celluloid).

17. Fixing means (making the picture permanent, correcting mistakes in the picture, repairing the torn picture).

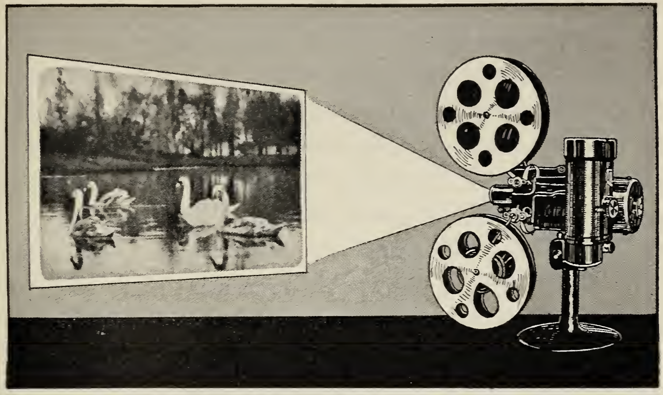
18. Developers contain (hydrochloric acid, pyrogallic acid, muriatic acid).

19. A negative is (entirely transparent, entirely opaque, partly transparent).

20. Films are developed in a room that is (entirely dark, dimly lighted, bright).

Supplementary Demonstrations And Projects

1. Make a series of drawings showing how the camera resembles the human eye.
2. Snap a picture, develop, and print it.
3. Make a pinhole camera.
4. Expose a new roll of film to a bright light and note what color it becomes.
5. Read about color photography.
6. Find out how photographs are sent by wire or radio.



An amateur projection machine.

PROBLEM V

HOW ARE MOTION PICTURES MADE AND PROJECTED?

Each scientific invention is usually the result of the combined effort of many minds. It was so, as you have learned, with the electric generator and with the radio, and it is so with the motion picture machine. As we sit, comfortably, in a motion picture theatre, enjoying the performance that is artistically pictured on the screen, we are not likely to give a thought to those who made this marvelous thing possible.

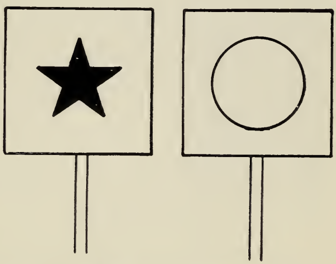
In 1878, Muybridge, a Californian, photographed a race-horse in motion by means of a row of twenty-four cameras, the shutters of which were released by strings placed in the path of the horse, and broken by the animal in its progress along the race track. The horse thus photographed itself twenty-four times, each position differing but slightly from the next. The idea of taking pictures of a moving object with a single camera sprang from this test. To realize this idea, however, several handicaps of a practical nature had to be overcome: a more sensitive photographic surface than those in use had to be discovered; a shutter that would open and close in the twinkling of an eye had to be invented; and, above all, a flexible plate that could be rolled on a reel was needed to replace the rigid glass plate. The first two of these needs were soon supplied. Goodwin and Eastman overcame the third obstacle by the invention of the flexible celluloid film you learned about in Problem IV. Such films are used for both still and motion picture photography. In 1888 the celluloid film was used in a camera, for the first time, by Eastman.

Edison, always quick to improve upon promising devices, made use of the flexible film combined with Muybridge's idea of photographs shown in rapid succession, in a device which he called the kinetoscope. This is a machine in which pictures on a flexible film are made to pass before the eye in rapid succession to create the effect of motion. These pictures were inclosed in a box, lighted from within by means of an electric light. The pictures were viewed through an opening in the top. Edison's kinetoscope was exhibited, for the first time, at the Chicago World's Fair, in 1893 and at once became popular.

A disadvantage of Edison's kinetoscope is that only one person can view the pictures at a time. It was not long, however, before some one, in England, thought of the idea of projecting these pictures on a screen so that they might be seen by a number of people at the same time.

The rest of the story of motion picture development is merely an account of how photographing and projecting devices were improved. To-day, the art is so highly developed that the effect of reality produced by motion pictures is truly marvelous.

The principle of the motion picture. The human eye retains (holds) the image of an object for a small fraction of a second after the object itself is gone. By means of numerous experiments scientists have discovered that an image is thus retained for about $\frac{1}{16}$ of a second.



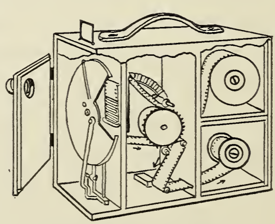
Try this trick at home.

Demonstration. To show that the eye retains an image for an instant after the object is gone. On one side of a card draw a star. Turn the card over and directly opposite the star, draw a circle. Attach the card firmly to a stick. Hold the stick between the palms of both hands and twirl the stick. What do you seem to see on the card? What makes this effect possible?

In Edison's kinetoscope, a series of pictures is shown in rapid succession. If the series of pictures represents a boy running, each successive picture shows the boy just a little advanced in his progress

beyond the last picture. If these pictures are moved rapidly enough, at the rate of at least 16 a second, an effect of continuous motion will result. The change from one picture to another is not noticed because the eye retains the image of the first picture during the short fraction of a second that the change is made to the second picture.

Demonstration. To show how a continuous effect is produced by rapidly moving pictures. Obtain a small pad of blank white paper, about 3″ by 4″. Draw a series of sketches, showing the progress of a person doing an arm-stretching-and-knee-bending exercise. (A series of pictures representing stages in any other continuous motion will do). Turn the pages rapidly by means of the thumb and observe the pictures carefully. What effect is produced?



A motion picture camera.

Motion Picture Cameras. Motion pictures are taken by special cameras in which flexible celluloid films are used. The film used for professional motion pictures is $1\frac{1}{4}$ inches wide and usually

200 feet long. Ordinarily, pictures are taken at the rate of 16 to 20 a second. This film, when developed and printed, is made up into reels, usually 1,000 feet long, and is then ready to be projected on the screen.

Flexible celluloid film.

Projecting pictures. Each picture, as it is projected on the screen, is really stationary for a moment, but as it passes rapidly to make room for the next picture, the eye still retains the image of the first and blends it with the second. Each picture differs so little from the next that, as the pictures move before the eye at the rate of 16 to 20 pictures per second, really in slight jerks, the effect on the eye is that of continuous motion. While the shift from one picture to the next is being made, an opaque pin-wheel shutter passes in front of the lens and momentarily blocks the beam of light.

The film is moved by means of a motor and can be speeded up or slowed down at the will of the operator. If the film moves too slowly, that is, less than 16 pictures a second, the effect of continuous motion is spoiled. So-called "slow motion" pictures are obtained by photographing at the rate of several hundred pictures a second, and then showing the film at the normal rate of speed. Slow-motion pictures of athletes in action are employed by trainers to demonstrate good form to young athletes who are eager to improve.

Films may be *inflammable*[1] or non-inflammable and may vary in width. In the standard professional projection machine the film used is 35 millimeters, that is, $1\frac{1}{4}$ inches in width. Professional films are highly inflammable and must be kept in metal containers when not in use. Licensed operators, only, are permitted to operate such films. 35 millimeter non-inflammable films are manufactured but at present these are not quite as transparent as the inflammable film.

For small portable projectors (projectors that may be carried from place to place) such as are suitable for classroom or home use, non-inflammable films $\frac{5}{8}$ inch or $\frac{3}{8}$ inch in width are available.

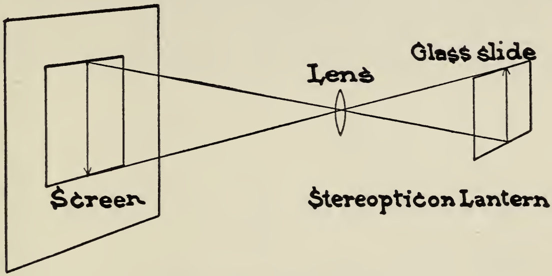
Demonstration. To show that the projector lens forms an inverted, enlarged image on the screen. In the slide holder of a *stereopticon*[2] lantern, place a lantern slide in an upright position. For a screen, use a large sheet of white, or light-colored paper, or a sheet of white muslin. Darken the room and then turn on the electric light in the lantern. Move the bellows of the lantern in and out until the image of the slide is focused on the screen. Note the size of the image on the screen. Why is the image inverted?

Move the lantern, first nearer, and then farther from the

[1] Inflammable means easily set on fire.
[2] A stereopticon lantern is a machine for projecting lantern slides.

screen. How does the distance of the slide from the screen affect the size of the image on the screen?

It will never do, of course, to project an image that is upside-down on the screen. To correct this, the



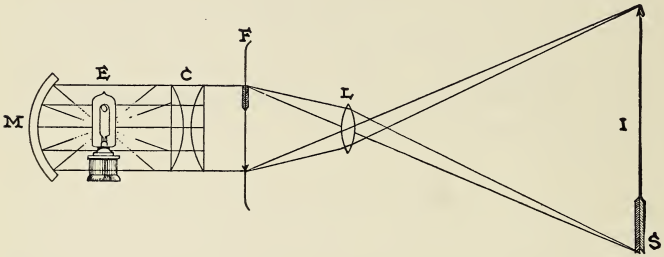
Why is the image inverted?

lantern slide must be placed upside-down in the slide holder. Repeat the demonstration, this time inverting the slide, to convince yourself that the image will then be upright.

In a motion picture projector, the film is inverted in the machine in order to make an upright image on the screen. The size of the image, as in the case of a stereopticon lantern, depends upon the distance between the lens and the screen; the greater this distance, the larger the image. A large picture is, of course, desirable.

The more light on the object, or the nearer the lens to the screen, the brighter will be the image. In projecting pictures, it is desirable not only to have the image large, but also as bright as possible. In order to understand how this may be done, let us first learn how the image of a film is projected.

Light from an electric lamp, E, shines through two lenses, known as condensing lenses, C. These serve to concentrate the light and to spread it evenly over the inverted film, F, which is located between the condensing lenses and the double-convex lens, L.



This, as you know, causes an upright image, I, to be formed on the screen, S. A concave mirror, M, is placed behind the lamp. This reflects to the condensing lenses and, finally, to the screen, some of the light which would otherwise be wasted.

Demonstration. To show how the image may be made brighter. Using a 100-watt lamp in a stereopticon lantern, project the image of a lantern slide. When the image is as clear as it can be made, note its brightness. Replace the lamp with a 250-watt lamp. Note the brightness of the image. Use a 400-watt or a 500-watt lamp, if you can get one. What effect has the wattage of the lamp on the brightness of the image? Carefully remove the mirror and note what effect this has on the brightness of the image. Replace the mirror and move the projection lantern, first nearer to and then farther from the screen. How does the distance of the lens from the screen affect the brightness of the image?

Powerful lamps generate a considerable amount of heat. If glass lantern slides are used, these may become cracked by the heat if exposed too long. In motion picture projectors employing inflammable films there is danger of fire. That is why such films may be projected only by machines housed in fire-proof booths. Some projection machines have cooling devices which prevent overheating. Non-inflammable films are being used more and more and it is very likely that, in the near future, the use of inflammable film will be abandoned.

Summary

The eye retains the image of an object, or a picture, for a short time after the object or the picture has disappeared.

If pictures in a series in which the action progresses from picture to picture, are shown in rapid succession, the effect is that of continuous motion.

Motion picture projectors project series of pictures photographed on films.

The projector lens forms an inverted, enlarged image on the screen.

The more light on the object, or the nearer the lens to the screen, the brighter will be the image.

Questions

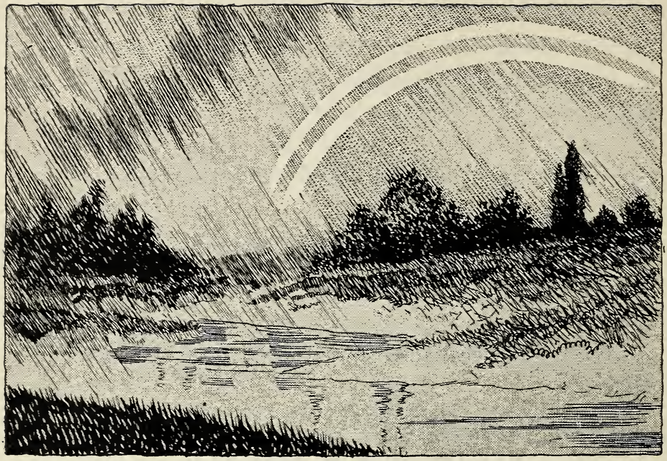
1. How did Muybridge photograph a race-horse in motion?

2. Name the two men who are credited with the invention of the flexible film.
3. Of what material is a flexible film made?
4. Who invented the kinetoscope?
5. Explain, briefly, the principle of the kinetoscope.
6. Mention one disadvantage of the kinetoscope as a motion picture machine.
7. Why does a motion picture give the effect of continuous motion?
8. In a motion picture projector, what is the purpose of the pin-wheel shutter?
9. At what rate of speed is the film of a motion picture projector usually shown?
10. How wide is a standard width film?
11. In what other widths are films manufactured?
12. Explain "slow motion" pictures.
13. Now that non-inflammable films can be manufactured, why are inflammable films still used?
14. State two precautions that must be taken with inflammable films.
15. What is a "portable" projector and for what is it used?
16. Why is the film placed upside-down in the projector?
17. Upon what does the size of the image on the screen depend?
18. What is the purpose of the concave mirror in a projection machine?
19. Of what use are the condenser lenses?
20. How does the wattage of the projection lamp affect the brightness of the image?
21. State one disadvantage of powerful lamps when used in projection machines.

22. Make a diagram showing how rays of light from the lamp are reflected by the concave mirror and pass through the condensing lenses, film, and double-convex lens, and finally reach the screen.

Supplementary Demonstrations And Projects

1. Mount a concave mirror, an electric lamp, a lantern slide, and a double-convex lens on a base in such a way as to make a simple projection lantern.
2. Find out how talking pictures are made.
3. Write a composition on the progress of the motion picture industry.
4. If possible arrange, with the help of your teacher, an excursion to a motion picture studio.



The rainbow.

PROBLEM VI

WHAT IS COLOR?

One of nature's most delightful surprises is the rainbow. Rainbows are most frequently formed after sudden showers. At the end of the storm, while the raindrops are still falling, the sun breaks through the clouds and the rainbow appears. In the twinkling of an eye nature spreads all her colors across the heavens as if to dispel from our thoughts the gloomy landscape of the rainy day. To many it comes as a symbol of hope; a message of promise.

How dull and uninteresting the things of this world would be if there were no such thing as color! In a dull, gray world, not only would our eyes look with displeasure on the objects about us, but we, ourselves, would reflect the gloomy surroundings. Yet few of us appreciate, fully, the charm that color brings to our lives, probably because we are so used to having color with us. The possession of anything usually dulls the enjoyment of it. It is only the blind man, deprived of the power to see, who longs for the beautiful colors that once met his gaze: the restful green of the wide meadows and the wooded hillside, the beautiful blue

Keystone-Underwood

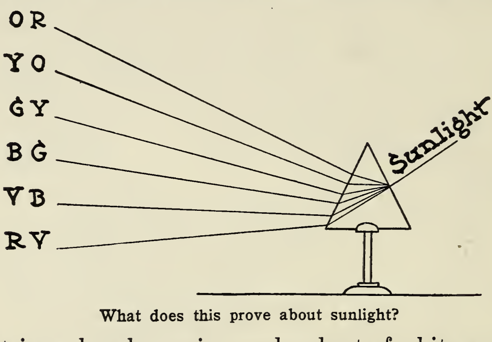
A motion-picture in the making

of river and lake, the scarlet and gold of the autumn forest, the rainbow hues of the wild flowers in the glen. How he would appreciate these colors of nature if his sight could be restored!

The scientist, not only knows the cause of the rainbow but he can actually make tiny ones of his own by means of glass prisms. In the clever device known as the *spectroscope*,[1] he uses the principle of the rainbow to tell us marvelous things about the secrets of the most distant stars.

The secret of the artificial rainbow, or the *spectrum*, as it is scientifically known, was discovered by the great scientist, Sir Isaac Newton, about whom you may read at the end of this book.

Demonstration. To show that light from the sun consists of, and may be broken up into, the colors of the spectrum.



What does this prove about sunlight?

Hold a triangular glass prism and a sheet of white paper near the window on a bright day so that the sun shines through the prism and on the paper. What do you see on the paper? Move the paper back and forth until the effect is as clear as you can make it. Is this really a rainbow?

You can hardly be expected to guess what has happened. Scientists have proved that sunlight is really a mixture of all

[1] A spectroscope (spĕc′ trō scōpe) is an instrument which employs glass prisms to form spectra of luminous bodies or gases.

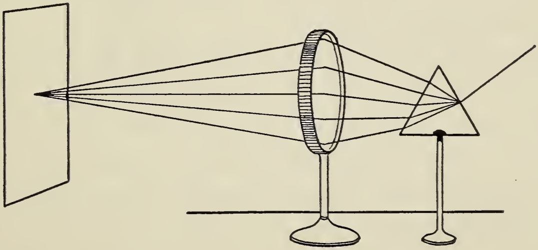
the colors found in the rainbow. When this mixture is allowed to pass through a triangular glass prism, each color is bent (refracted) at an angle different from every other color. In this way they become separated so that we see them on the paper screen as a band of different colors, the spectrum.

Note that the color which is bent least is red. This appears at the top of our screen. The color that is bent most is violet and appears at the bottom of the screen.

To obtain a better spectrum, cover the windows with some opaque material and allow the sunlight to come in through a small hole in the window screen.

The effect on the eye of all these spectrum colors combined, is to produce white. If sunlight, which is white, can be broken up into the various colors of which it is composed, it should be possible to reverse the process: to combine all the colors of the spectrum to produce white.

Demonstration. To produce white by combining the colors of the spectrum. With a prism, form a spectrum as before.



Explain what happens to the ray of sunlight that strikes the prism.

Hold a double convex lens in the path of the spectrum so as to focus the light from the spectrum on a screen. It may be necessary to move the screen back and forth until the light from the lens is concentrated in a single bright spot, the focus. What is the color of the spot of light? How do you account for this?

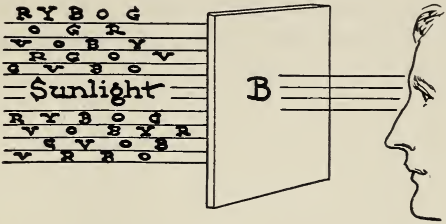
On a circular disk of cardboard paste sectors (triangular sections) of all the important rainbow colors, using the purest colors you can obtain. Rotate the disk very rapidly by revolving it on a double string. What color does the disk now appear to be? Do you see the separate colors or are they all combined into one?

If the colors are absolutely pure and if the disk could be rotated much more rapidly, the effect would be almost pure white.

When all the colors of sunlight are reflected from an object to the eye, the eye sees the object as white. The tiny crystals of snow reflect all the colors of sunlight to the eye; snow, therefore, appears white. When snow melts it loses its crystal form and becomes water. Some of the colors of sunlight are absorbed by the water so that, unlike snow, water does not appear white.

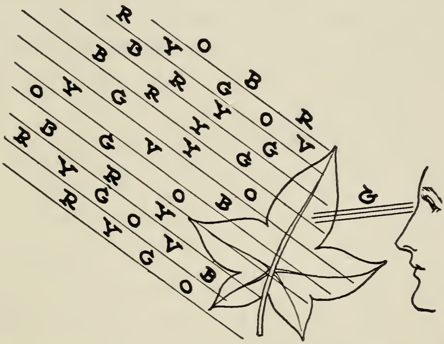
The question naturally arises: Why do objects vary in color? When sunlight passes through a colored transparent medium, such as stained glass, all the colors of white light are absorbed except the color of the medium itself. You can easily prove this to your own satisfaction.

Demonstration. To show that a colored transparent medium absorbs all the colors of sunlight except the color of the medium itself. Obtain pieces of red, green, brown, and yellow glass. Colored cellophane will do as well. Look at some object, through each of these colored glasses in turn. What color does the object appear to be in each case?



When sunlight passes through blue glass, only the blue rays reach the eye. Why?

If our eyes were covered with a blue transparent film, all the world would look blue to us; if the film were red, all objects would appear red. Sun glasses produce this effect. Usually sun glasses are made

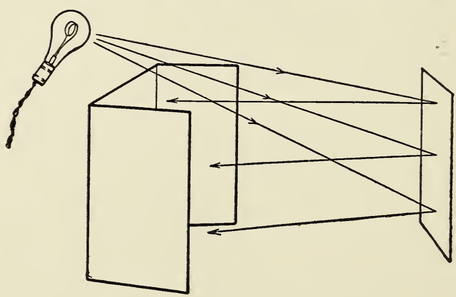


When sunlight is reflected from the surface of a green leaf, only the green rays reach the eye. Why?

brown and therefore they absorb all the colors of sunlight except those which, when combined, produce brown.

When white light falls upon a colored opaque body, all colors are absorbed, except the color of the object, which is reflected to the eye. Some objects reflect only certain rays of white light. The others are absorbed and converted into other forms of energy, usually heat. Thus, a leaf is green because it absorbs all the colors of white light except green. The green light is reflected to the eye. If all the colors of white light are reflected from the surface of an object to the eye, the object appears white. If all the colors of white light are absorbed by an object, no color remains to be reflected and the object appears black. White thus indicates the presence of all colors in an object; black, the absence of all color.

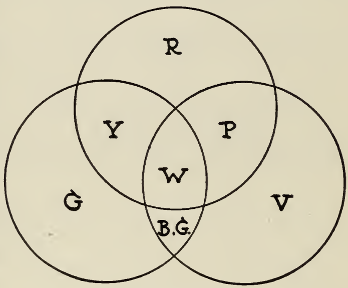
Demonstration. To show that colored surfaces affect the degree of brightness of a room. Make a triple screen by folding a large piece of gray-colored cardboard. Fold



the screen in such a way as to represent the walls of a room. Obtain papers of various colors, such as poster papers. Hold an electric lamp behind the screen and a little above it so that the front of the screen is in shadow. Hold each of the colored papers in turn toward the light in such a way that the surface of the paper will reflect light into the screen. Which colors seem to brighten the screen? Which colors darken the screen? How may the results of this demonstration be applied to the selection of color for the walls of rooms?

The interior decorator selects his wall coverings, furniture, rugs, and fabrics, in accordance with the amount of light a room receives. If the room is naturally dark, he obtains an effect of brightness by using light-colored walls and fabrics. For the brilliant, sunny room, cool and dull tones are more desirable.

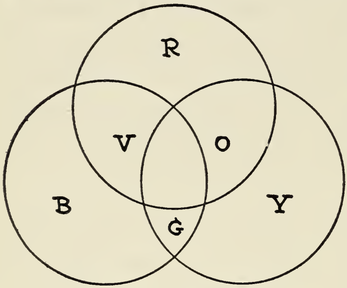
Combining colors to produce other colors. The colors seen in a rainbow are said to be "pure" colors and are known as "primary" colors. According to Newton, the primary colors of the rainbow are red, orange, yellow, green, blue, indigo and violet. Young and Helmholtz, two other scientists, selected three of these colors, red, green, and violet, as the basic colors from which all other colors may be made. Thus, red and green light produce yellow; red and violet light produce purple; green and violet light produce blue-green; and all colors combined produce white.



Explain the diagram.

While this may be true with rays of light, paints cannot produce the same results. Paints, or pigments as colored paints are called, are, however, frequently mixed to produce other colors.

Demonstration. To show how certain colors may be produced by mixing colored pigments. On a sheet of white paper, draw three overlapping circles as shown in the figure. With water colors, paint one circle red, a second yellow, and the third, blue. Be sure, in each case, that one color is dry before you paint another color over it. Examine the result of your work. Where the red and the blue overlap, what color results? What color is produced where the red and the yellow overlap? What is the result of mixing blue and yellow pigments?



Explain the diagram.

Summary

Light from the sun consists of, and may be broken up into, the colors of the spectrum.

The effect on the eye of all these spectrum colors combined is to produce white.

A colored transparent medium absorbs all the colors of sunlight except the color of the medium itself.

A colored opaque body absorbs all the colors of sunlight except the color of the object, which is reflected to the eye.

When a body absorbs all the colors of sunlight, it reflects none to the eye and the body appears black.

By properly combining colors, other colors may be produced.

Questions

1. Who discovered that sunlight is composed of many colors?

2. What causes the white light of sunlight to form a spectrum when the light passes through a glass prism?

3. Which color of the spectrum appears at the top. Why?

4. How may the colors produced by refraction of sunlight passing through a prism be combined, again, to produce white light?

5. What happens to rays of sunlight that are allowed to pass through a piece of red glass?

6. How do scientists explain the fact that objects vary in color?

7. A gloomy room may be made more cheerful by painting the walls a light color. Why?

8. Why is white a good color for summer clothing?

9. Dark clothing for winter is warmer than light-colored clothing. Why?

10. What color results when each of the following pairs of colors is mixed: red and yellow? yellow and blue? red and blue?

Supplementary Demonstrations And Projects

1. Make soap bubbles and observe the colors in the bubbles.

2. Find out how a rainbow is formed.

3. Read about the method employed in printing colored pictures.

4. Read about color photography.

5. Read the story of Newton at the end of this book.

Wide World

The horse is overcoming gravity for a moment.

PROBLEM VII

WHAT CAUSES OBJECTS TO FALL?

Did you ever stop to think about all the different kinds of motion we have about us; the drifting clouds, the trees swaying in the breeze, the rushing brooks, the restless motion of the ocean waves?

Even where things appear to be still we find continual motion. Scientific instruments tell us that the houses we live in, and the ground under our feet are always trembling. The very book you are reading is made up of tiny particles in continual motion. Mighty continents are slowly shifting from place to place. And, if you could stand off in space and have a look at the world you would wonder how anything can stick to its surface, so great is the speed with which it rotates.

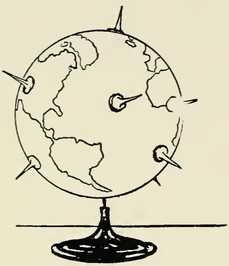
All this motion is due to the various forces of Nature. The most powerful of these is the force that causes things to fall down instead of up; that enables us to live on the surface of the earth instead of hurtling off into space; the force which attracts all bodies toward the earth's center — the force of gravity.

A plumb line. For what is it used?

Demonstration. To show how gravity works. Drop various objects to the desk or to the floor. Do they fall vertically downward? So accustomed are we to seeing things behave in this way that we seldom stop to think about the phenomenon. Why do the objects not go upward, or off at an angle, when released by the hand? Is some *force* at work on these objects to cause them to move? Yes, for without some force, there can be no motion. What should happen to an object released by the hand if there were no force working on it? This force that always works in a downward direction, we call *gravity.*

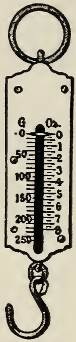
Gravity acts on all objects, from the smallest grain of dust to the largest mountain. If the mass of the object is small, the pull of gravity is slight; if the mass of the object is great, the pull of gravity is great.

If gravity were free to act on bodies without being checked, all bodies would continue to fall until they reached the center of the earth. An object, held in the hand and then released, falls toward the center of the earth, but it gets no farther than the floor. If the mass of the object were large enough, the pull of gravity might be great enough to overcome the resistance of the floor. A ship, floating on the water, is acted upon by gravity and would sink, were it not for the opposing force of the buoyancy of water. A snowflake flies about in various directions before it falls because the force of wind and the buoyancy of air oppose the pull of gravity on the tiny mass of snow and, for a time, overcome this pull.



Demonstration. To illustrate how objects are pulled toward the center of the earth. Place a strong electromagnet within a small geography globe. Place small carpet tacks on various parts of the surface of the globe. Why do they remain on the surface? Disconnect the electromagnet. What happens to the tacks? What force is represented by the electromagnet? What would happen to objects on the surface of the earth if there were no force of gravity?

The weight of a body is a measure of the force of gravity acting on it. Lester accompanied his mother to the butcher shop and stood by while the butcher helped Lester's mother select a roast for the Sunday dinner. "This roast," said the butcher, taking the meat off the scales, "weighs $3\frac{1}{2}$ pounds; is that large enough?" Lester's mother finally selected a roast that weighed 4 pounds. Lester carried the meat home for his mother and secretly wished that it had not weighed so much, for his arms were quite tired when he finally deposited the bundle on the kitchen table.



A spring balance.

Every one has, of course, observed that objects vary in weight. Many objects are so light that we can pick them up and move them about with ease; other objects are so heavy that we cannot lift them at all. The weight of an object is the force of attraction of the earth on the object. The pull of gravity on a pebble is very small, therefore the pebble weighs very little; the pull of gravity on a large rock is great, therefore the rock weighs a great deal. When the butcher placed a roast upon the scales to be weighed, he was measuring the force of gravity acting on the meat.

The effects of gravity are observable in many common phenomena. In *Science Related to Life*, Book One, you learned how the water from a tiny brook in the Catskill Mountains finds its way into a larger stream and then, finally, into a huge reservoir many miles distant. This illustrates the effect of gravity. All rivers are made to flow downward by this force. Gravity also causes dust to settle, leaves, rain and snow to fall and weak or poorly supported structures to topple to the ground. When you throw a ball or your hat into the air you may be sure that gravity

Why does rain fall?

will cause it to return to the ground. Gravity is the force which permits the earth to hold its atmosphere and which prevents our oceans from being hurled off into space. It would be too great a task to list all the common phenomena about us which are due to the force of gravity.

Gravity may aid man. Man makes use of the force of gravity to help him perform many tasks. Some of these uses of gravity have already been mentioned. Water from rapidly flowing streams and waterfalls is made to turn wheels or turbines that provide power to be used for operating machines.

In many industries, chutes are used for transferring materials from one part of a building to another. You have often seen such chutes attached to coal trucks. The coal slides down the chute from the coal truck and is caught in bags or is led directly into the coal bin in the cellar. Mail chutes provide an easy means of sending letters from various floors of a building to a large mail box on the lowest floor, whence it is collected by the mail carrier.

When a building is being torn down to make room for a new structure, gravity helps in the process and, again, chutes are used, this time to carry the debris to the street level.

A mail chute.

Gravity also helps us enjoy some of our outdoor sports. Whenever we coast down a hill, it is gravity that pulls us downward. Whenever we leap or dive into water, it is gravity that helps us perform the act.

Gravity may hinder man. In the affections of Ralph, science shared first place with athletics. Even the very night before the interclass games in which Ralph hoped to win the broad jump for his class, he sat under his reading lamp in the hot dormitory room, poring over an old account of Newton's discovery of the laws of gravity.

" Gravity is no friend of broad jumpers," he mused. " If it were not for gravity, I suppose the broad jump record would fall every day. By Jove," he suddenly exclaimed, " wouldn't it be fun! If there were no gravity we could walk in the air right over peoples' heads; shelves and hooks would become unnecessary, for with no force of gravity to pull them down, objects would remain suspended in the air wherever they were left. And what weights one could lift!" Ralph smiled as he pictured himself juggling a piano on the tip of his little finger.

The next morning he confided his "discovery" to the science instructor.

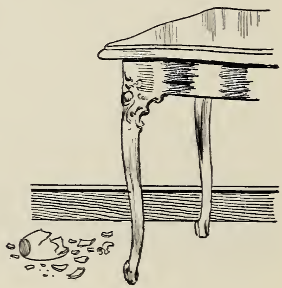
"You would not have as much fun as you think, if there were no gravity," said his science teacher. "In fact, conditions would be quite serious. Anything you tossed into the air would fail to return. Then, too, without gravity there would be no more rain, but what would be the use of rain when we could not even remain on the surface of the earth? Spinning around at the rate of about a thousand miles an hour, the earth would hurl us out into space were it not prevented from doing this by the friendly force of gravity. You will find, Ralph," concluded the instructor, "that all the laws of nature are helpful to man, and it is worth our while to understand them thoroughly so that we may put them to the best use."

"Well," agreed Ralph, very soberly, "I guess you are right. Gravity is not altogether undesirable."

And when Ralph won the broad jump that afternoon, he was thankful for the mysterious force that kept tugging at the contestants, forcing them to drop back to earth. "After all," he mused, "if there were no force of gravity, there would be no broad jump contests."

The force of gravity is a great hindrance, as well as a great help to man. Weights that have to be lifted and weary legs that have to be dragged up flights of stairs against the pull of gravity make us realize that gravity is not always helpful. If there were no force of gravity, climbing mountains would be no exertion at all.

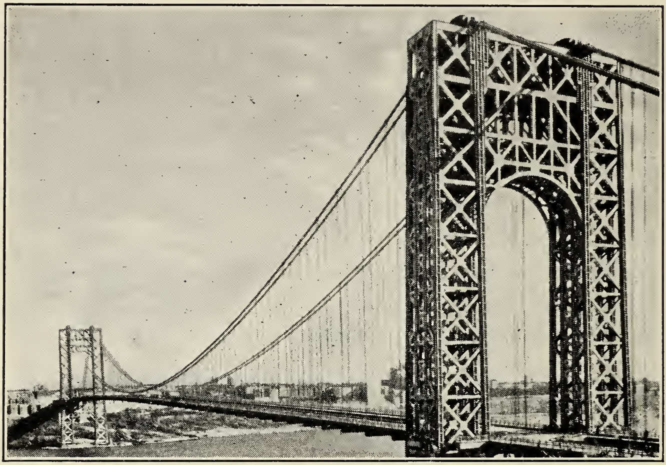
We are frequently annoyed by phenomena due to gravity. Small objects that fall from the hand often roll off into corners where they remain out of sight. Precious objects fall and break when gravity is permitted to exert its force on them. Falls due to loss of balance when we trip over an obstacle are caused by the pull of gravity.



The broken vase.

Engineers are constantly being called upon to use their knowledge to overcome gravity. When it is desired to build a great auditorium in which the view will not be obstructed by posts that are usually necessary to hold up the ceiling, a great deal of engineering skill is required. A similar problem faces the engineer when he is called upon to construct a bridge that will support hundreds of thousands of tons. The pull of gravity on so tremendous a mass is very great, and the piers, cables, and girders that support the load must be made strong enough to overcome the force of gravity, otherwise the bridge would soon collapse.

If you will read, again, the story of the struggle of the Wright brothers to solve the problem of keeping a heavier-than-air airplane afloat, you will realize,



The strong cables of a great suspension bridge overcome the tremendous pull of gravity caused by the load on the bridge.

now, that the chief problem in the development of aviation was to overcome the force of gravity. It took many years before man learned how to fly safely and, even today, a slight fault in the engine of an airplane may result in loss of control, and the airplane, pulled by the force of gravity, will be hurled to the earth, a worthless wreck.

Summary

Gravity pulls all bodies toward the center of the earth.

The weight of a body is a measure of the force of gravity acting on it.

The effects of gravity are observable in many common phenomena.

Gravity may aid man.

Gravity may hinder man.

How Much Have You Learned?

Which of the following statements are true and which are false?

T. F. 1. Gravity and magnetism are the same force.
T. F. 2. All motion is due to force.
T. F. 3. Gravity acts only on objects that are heavier than air.
T. F. 4. Gravity does not act on objects resting on a table.
T. F. 5. A ship floats because the buoyancy of water overcomes the pull of gravity on the ship.
T. F. 6. The smaller the mass the greater the pull of gravity.
T. F. 7. Weight is a measure of gravity.
T. F. 8. Gravity causes brooks to flow.
T. F. 9. The pressure of air is due to gravity.
T. F. 10. An ascending balloon proves that the force of gravity does not operate on bodies that float in air.
T. F. 11. Muscular force can sometimes counteract the force of gravity.
T. F. 12. If there were no force of gravity all objects would remain on the surface of the earth.
T. F. 13. The tired feeling that results from climbing is chiefly due to gravity.
T. F. 14. Gravity tends to make aerial travel unsafe.
T. F. 15. The laws of gravity were discovered by Newton.

Supplementary Demonstrations And Projects

1. Find out by means of a test conducted from the top of a tall structure in a safe place, whether a heavier stone falls faster than a light stone.
2. Find the center of gravity of an irregularly shaped object.
3. Find the relationship between the length of a pendulum and its rate of vibration.
4. Construct a toy that will always remain upright.
5. Demonstrate to your classmates that two vertical lines are not parallel.
6. If there were no force of gravity, tell how each of the following would be affected. (Do not forget that the other forces would still be at work). (*a*) Power derived from waterfalls. (*b*) Natural drainage of land. (*c*) Rain and snow. (*d*) Walking. (*e*) High jumping. (*f*) Weight lifting. (*g*) Mountain climbing. (*h*) Use of coat hooks and shelves.
7. Read the biography of Newton, at the end of this book.
8. Read about gravitation in the *solar system.*

Underwood–Underwood

Music from the violin is due to friction

PROBLEM VIII

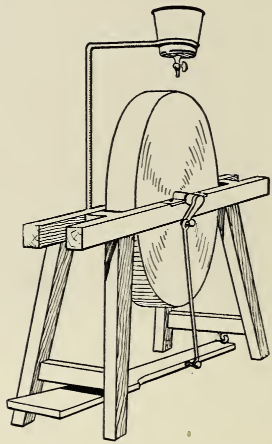
HOW DOES MAN USE OR CONTROL FRICTION?

Peter was hard at work on his arithmetic homework when his attention was attracted by the sound of a gong coming from somewhere on the street. As he ran to the window he saw a strange-looking truck coming slowly down the street toward his house. From within the truck there came the sound of a gong.

" Here comes the knife grinder, mother," he called. " You said you wanted your steak knife sharpened."

"Yes, Peter," replied his mother from the kitchen, "come and get the knife and take it out to the man."

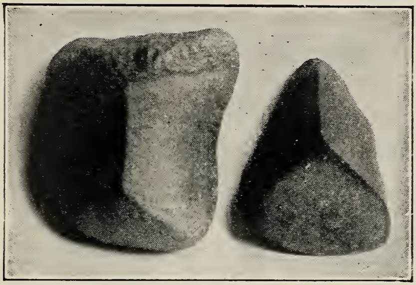
Peter was glad to get away from his arithmetic for a while and, also, he loved to watch the knife grinder at work. He took the knife, promised to heed his mother's caution to go carefully down the stairs, and went out to hail the grinder. The man took the knife from Peter, examined the edge for a moment or two, and then turned on an electric switch within the truck. Immediately there was a hum from the motor and the big sandstone wheel began to turn. Peter watched as the grinder applied the knife blade to the wheel. Sparks began to fly and there was a harsh, grating sound as the wheel rubbed against the surface of the steel. Water from a small bucket fell upon the wheel in a thin, steady stream. Peter knew that this helped to prevent overheating of the knife blade. Occasionally the mechanic tested the keenness of the blade and, when quite satisfied, he handed the sharpened knife back to Peter.



Of what use is the water bucket above the wheel?

Friction is the resistance caused by rubbing one surface against another.

Friction, the waster. The knife grinder's sandstone rubbed against the steel surface of the knife blade, causing *friction* between the two surfaces. Whenever two surfaces are rubbed together, both are, to some extent, worn away. Every one has had to suffer some of the inconveniences due to friction. Even the strongest leather shoe sole will, in time, be worn thin by constant rubbing against the pavement.

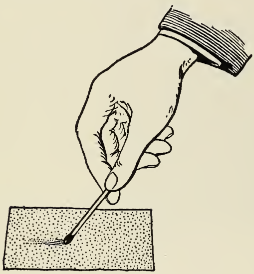


What force has worn these rocks?

Were it not for friction the clothes we wear would never wear out and we could in this way, save a considerable sum of money. A wheel, rubbing against the axle, makes it necessary to replace the worn parts in time. Automobile tires are constantly being worn by rubbing against the pavement. Floors, carpets, lead pencil erasers, books, and tools — all are being steadily worn by friction. Friction is, indeed, a great waster, and causes so much loss and expense that we are constantly seeking ways to overcome its ravages.

Friction, the friend. But can we afford to do away with friction entirely? Is there no way that we can use it that would be to our advantage? There are, indeed, many ways in which friction is useful. Without it how could we light a match? By what means could we start a fire? What way would there be to slacken the speed of a vehicle that is racing down grade? The *brake* that depends upon friction is, without doubt, a necessary device.

All polishing is the result of friction. Without polish, how dull would be the sparkling gems that so delight us? How crude would be our walls, our marbles, our furniture! No more would the sport-loving boy enjoy winter sliding on the pond. The music of the violin and the cello would be impossible, for without friction the bow would glide noiselessly over the smooth strings. It is friction that holds the nail firmly in the wood, and it is because of friction that wheels of vehicles are able to make progress along roads.



Making use of friction.

Friction, then, has its uses as well as its drawbacks. It is for the scientist to develop the one, and to find ways of overcoming the other.

Friction produces heat. When Peter took the sharpened knife from the knife grinder, he noted that, in spite of the water-cooling device that had been used, the blade was warm. He recalled, also, the sparks that flew from the grindstone while the blade was being sharpened. You have only to rub your hands together to realize that friction produces heat. Some time ago you learned how the American Indian made use of friction in the fire-drill to produce enough heat to start a fire, and how matches are lighted by means of friction. After a long trip the tires of an automobile or of a bicycle are hot; so, too, are the bearings where the wheels rub against the axles. Friction, then, produces heat.

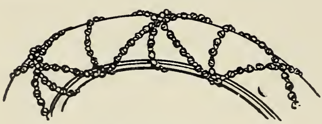
Demonstration. To show that friction depends upon the roughness of the rubbing surfaces. Prepare inclines of rough wood, varnished wood, wood covered with sand or sandpaper, and one of glass. These inclines should be equal in length and all should incline at the same angle. By means of a spring balance pull a heavy block of wood up each of the inclined planes in turn. Make a record of the scale readings. Which surface requires the least force? Which requires the most? To what are the differences due?

Knowing that smooth surfaces produce less friction than rough ones, it becomes possible to reduce friction in many cases. A good mechanic will see that the bearings of the machine he uses are well oiled. If you have ever watched a train pull into a depot after a long trip, you will know that a mechanic immediately begins to oil the bearings which have been heated by friction during the journey.

Demonstration. To show that lubrication (oiling) reduces friction. Obtain a well-used wheel toy such as a kiddie-car or a heavy iron toy automobile. By means of a spring balance attached to it, pull the toy for a distance over the floor. Read the scale. Oil the axles thoroughly and repeat the test. Is the force required now less? What caused the change?

Did the wheels "squeak" in the first test? Did the squeaking cease after the oil was applied? What caused the squeaking?

Sometimes, as already explained, friction is useful. In such cases smooth surfaces are not desirable. Automobile tires are made rough so as to "grip" the surface of the road. If the tires are smooth, there is danger of slipping or "skidding." In icy weather the road itself becomes smooth and at such times automobile traffic becomes dangerous. To overcome this danger, friction between the tire and the road is increased by the use of skid chains on the tires. In dry weather locomotives run along the smooth rails with a minimum of friction. In wet or icy weather, however, the rails become so smooth that it becomes difficult to stop at stations or to slow up at will. This is particularly true when the train is running down grade, that is, downhill. At such times, sand is applied to the track to increase the friction.

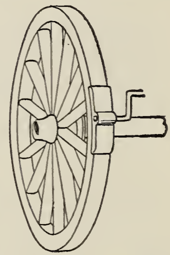


Why are skid chains useful?

Demonstration. To show that friction depends upon the pressure between the rubbing surfaces. Attach a spring balance to a board and drag the board across a table. Add various weights to the board and note the reading of the balance, in each case, just before the board begins to move. How does the pressure (due to the increased weight) affect the friction between the board and the table?

A heavy body rubbing against a surface creates more friction than a light body. The harder two surfaces are rubbed together, the greater the friction produced.

When an automobile driver wishes to stop the car, he applies the foot brakes. This presses a band, known as a brake band, against a drum connected with each of the wheels. Because of the pressure applied, the rough surface of the brake bands creates friction against the surfaces of the drums, and causes the wheels to stop. To stop more suddenly, the brakes are applied with greater pressure. Railroad cars are also supplied with brakes. The greater the pressure applied to the brakes, the greater the friction produced and the sooner the motion of the cars can be stopped.



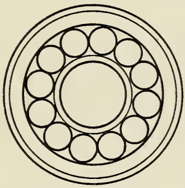
A wagon-wheel brake.

Rolling friction is less than sliding friction. Edward had been promised a pair of roller skates for his birthday and when he arose on the morning of that important day, there were the skates, next to his bed. Edward was delighted. He picked up a skate and, with the index finger of his right hand, he made one of the wheels spin around rapidly. "Hurrah, ball bearing wheels!" he cried, "This is just what I was hoping for." Edward knew that ball bearings meant swift skating. Then, running in to his mother, who was already busy preparing breakfast, he thanked her for the gift.

"How did you know I wanted ball bearing skates?" he asked.

"Well, to tell you the truth," replied his mother, "I didn't know; the salesman told me to be sure to buy ball bearing skates and I let him have his way."

"I'm glad you did, mother, because ball bearing wheels run much more easily than others and do not wear out nearly as quickly."



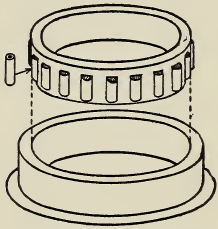
Why do ball bearings reduce friction?

Demonstrations. To show that friction is less with rolling bodies than with sliding bodies. 1. Remove the balls from the bearings of one wheel of a roller skate. Spin the wheels around rapidly, applying the same turning force to each. Which wheel is the first to stop rotating? To what is this due?

2. Load a toy truck with weights, attach a spring balance to the truck and drag the truck across the floor. Note the reading of the scale just before the truck begins to move. Now remove the wheels and repeat the test. Again read the scales just before the truck begins to move. These readings indicate, in each case, the force that is required to overcome friction. In which case is the force less? To what is this due?

Inasmuch as friction is the resistance caused by the rubbing together of two surfaces, friction is reduced when the rubbing surfaces are reduced. This is accomplished by ball bearings and by wheels.

Some scientists believe that the wheel is the greatest of man's inventions. Just when the first wheel was used, no one really knows but it must have been thousands of years ago for scientists have found evidences of the use of wheels in the carved inscriptions of very primitive peoples. The invention was probably made 4,000 or 5,000 years ago by primitive people known as Indo-Europeans, for we find the word "wagon," in modified form, in all the various tongues which grew out of the language of the ancient Indo-Europeans.



Of what use are roller bearings?

Ball bearings are recent inventions. When a wheel turns on an axle there is a certain amount of friction between the rubbing surfaces. This can be reduced by oiling but, after a time, the rubbing surfaces will become worn sufficiently to make it necessary to replace the worn parts. Ball bearings reduce the area of the rubbing surfaces and thus prolong the life of the bearing.

Recently, in place of ball bearings, roller bearings have been introduced into machinery. These bearings consist of small cylinders of steel which fit into grooves in the inner bearing surface and act like a series of wheels on which the outer bearing surface rotates.

SUMMARY

Friction is the resistance caused by the rubbing of one surface against another.

Friction produces heat.

Friction depends upon the roughness of the rubbing surfaces.

Friction depends upon the pressure between the rubbing surfaces.

Rolling friction is less than sliding friction.

Questions

1. Give a definition of friction.
2. State two results of rubbing rough surfaces together.
3. Many things are worn away by friction; list five instances of this fact.
4. What makes it difficult to withdraw a nail from a piece of wood?
5. Why does a saw become hot while it is cutting through wood?
6. Why is sand strewn on a car track in snowy weather?
7. What kind of material should be used for the wheel of a tool grinder? Why is water applied to the wheel during the grinding?
8. What causes automobiles to skid in wet weather? How can this be overcome?
9. Explain the use of rubber strips on steps.
10. Why is wax applied to the floor of a dance hall?
11. Why does a violinist apply resin to his bow?
12. Why is axle grease necessary?
13. When we strike a match on a piece of sandpaper, what causes the heat that is necessary to light the match?
14. On what principle does the wagon brake work?
15. Why is it harder to pull a load in a sled over a surface than to pull the same load over the same surface in a wheel cart?
16. Explain the principle of the ball bearing.
17. What is the difference between ball bearings and roller bearings?

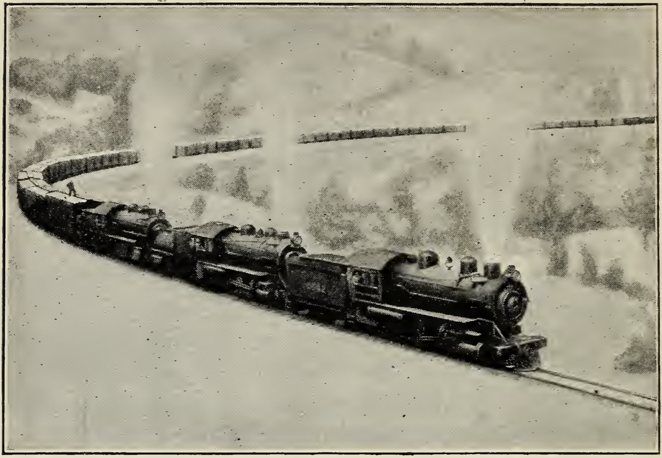
Can You Also Answer These?

18. Why is concrete better than asphalt for paving state highways?

19. What makes it possible for leather belting to turn the smooth steel pulleys attached to shafting?

Supplementary Demonstrations and Projects

1. Make a match scratch of sandpaper mounted on wood.
2. Make a friction gas lighter.
3. Read about Walker's invention of the friction match.
4. Read about the automobile tire industry.
5. Examine the ball bearings of a skate wheel.
6. Examine the lubrication chart of an automobile.



Will the train stop as soon as the brakes are applied?

PROBLEM IX

WHY DOES AN AUTOMOBILE CONTINUE TO ROLL AFTER THE POWER HAS BEEN SHUT OFF?

Delayed by light fog, almost a half hour late, train Number 261 was making up for lost time on a long, straight stretch of road. At each crossing the engineer pulled a cord and the whistle shrieked a warning. Small by-stations were swiftly passed and everything seemed going well when suddenly the fireman shouted a warning. Straight ahead, looming rapidly larger as the train rolled on, was a freight train! Somebody had made a mistake; the freight train was not scheduled to be on that track. With a quick motion the engineer shut off the throttle and applied the brakes. There was a harsh, grinding sound and the passengers suddenly lurched forward as the train slowed down and then came to a stop, just a few yards behind the rear car of the freight train.

Why did the train continue to move after the engineer had shut off the power and, for a time, even after the brakes had been applied?

Demonstration. To show that bodies in motion tend to remain in motion. Get a classmate to roll a heavy iron ball along the floor toward you. Stop the ball with your hands. You will note that some force is needed to stop the ball. The rolling ball resists an attempt to stop it; it tends to keep rolling.

All bodies in motion have this tendency to keep moving and to resist attempts to stop them. When you are running you find it quite difficult to stop suddenly. Runners in a race continue a considerable distance past the finish line before they stop. To attempt to stop suddenly would probably mean a fall.

The tendency of bodies in motion to continue in motion explains why the train failed to stop suddenly when the power was shut off. Moving automobiles also illustrate this tendency. In order to stop a moving automobile it is not sufficient to shut off the supply of gas. The brakes must be applied because the automobile continues in motion after the power is shut off. If it were not for this tendency to continue in motion, brakes would not be needed.

If you have ever coasted along level ground on a bicycle, roller skates, or ice skates, you know that, once you get a good start, you can coast along for a considerable distance until stopped by friction.

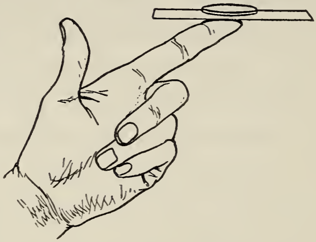
A batted ball speeds toward a fielder with considerable force. Once set into motion the ball keeps moving until a fielder gets in the way or until the ball, rolling along the ground, is gradually slowed up and finally stopped by the combined effects of friction and gravity.

What causes the arrow to speed through the air?

When an archer draws back a bow string and then releases the string, the forward motion of the string is imparted (communicated, passed on) to the arrow. The string cannot continue to move forward because it is held fast by the bow, but the arrow speeds on until stopped by other forces.

When the engineer suddenly applies the brakes to the wheels of the locomotive, the smooth, forward motion of the train is suddenly checked. The passengers in the train, who have, of course, been moving forward with the train, tend to continue this forward motion and, as a result, they lurch forward in their seats.

A body at rest tends to remain at rest. Just as bodies in motion tend to continue in motion and resist efforts to stop them, so bodies at rest tend to remain at rest and resist efforts to move them. It requires force to stop a body in motion and it requires force to start a body moving.



Why does the coin remain on the finger when the card is sharply flicked forward?

Demonstration. Balance a card on the tip of the index finger of the left hand. Place a coin on the card, directly over the tip of the finger. With a sharp blow of the fingers of the right hand, flick the card forward. The coin will remain at rest on the tip of the finger. You may have to try this several times before you succeed.

On the stage, a favorite trick is to snatch a table cloth, by a sudden jerk, from under dishes on a table. The dishes remain at rest on the table. This trick requires considerable skill, however, and you had better not try it as the results may be disastrous.

The tendency of a body at rest to remain at rest is evident when a driver attempts to start an automobile. It takes considerable power to get the car started, but once it is in motion, less power is needed to keep it moving.

The tendency of bodies, when at rest, to remain so, and when in motion, to continue in motion, is known as *inertia*. The tendency of a body at rest to resist attempts to move it is referred to as *inertia of rest;* the tendency of a body in motion to resist attempts to stop it is referred to as the *inertia of motion.*

Inertia of rest and inertia of motion are observable in many common phenomena. After the freight train, which had almost caused a serious accident, was switched off to a side track, the passengers returned to their seats and the engineer once more took his place in the locomotive. Still somewhat upset by the incident, the engineer opened the throttle rather suddenly, and the train leaped forward with a jerk. Immediately the passengers lurched backward for, having been at rest, they resisted the forward motion of the train and tended to remain where they were for an instant, while the train moved forward beneath them. After this false start the train moved on smoothly and the passengers became adjusted to the motion.

What will cause the ball to stop?

Newton stated that if no force acted on a body in motion, it would remain in motion forever. A batted ball is set in motion by the muscular force of the batter. Immediately, other forces are at work on the ball. The force of gravity pulls it downward, and the friction created by the passage of the ball through the air reduces its motion. When the ball finally falls to the ground it continues to roll for a time until stopped by the combined effects of gravity and friction. Were it not for the opposing force of gravity and the effect of friction, the ball would continue to move forever, without any reduction in speed. In a similar manner, a ball at rest would remain at rest forever, if not acted upon by some force.

Newton's statements about motion are usually referred to as the "laws of motion."

Summary

A body at rest tends to remain at rest.

A body in motion tends to remain in motion.

The inertia of rest and the inertia of motion are observable in many common phenomena.

How Much Have You Learned?

In each of the following statements three possible words or phrases are printed in parentheses. Only one of these words or phrases is correct. Select the correct one in each case.

1. When a train stops suddenly, the passengers (lurch forward, lurch backward, remain still).
2. Runners find it difficult to stop suddenly because of (gravity, inertia, friction).
3. A body in motion tends (to stop, to move in the opposite direction, to move in the same direction).
4. Brakes are necessary because of (inertia, friction, gravity).
5. Inertia of rest is the tendency of a body to (continue in motion, to come to rest, to remain at rest).

On a sheet of paper write the word that is needed to complete each of the following statements. Number the word to correspond to the number of the statement which it completes.

1. The laws of motion were discovered by ——.
2. To start a car moving, a considerable amount of —— must be overcome.
3. Passengers lurch —— when a train starts suddenly.
4. A boy coasting down hill on skates illustrates inertia of ——.
5. —— is needed to overcome inertia.

Can You Answer These Questions?

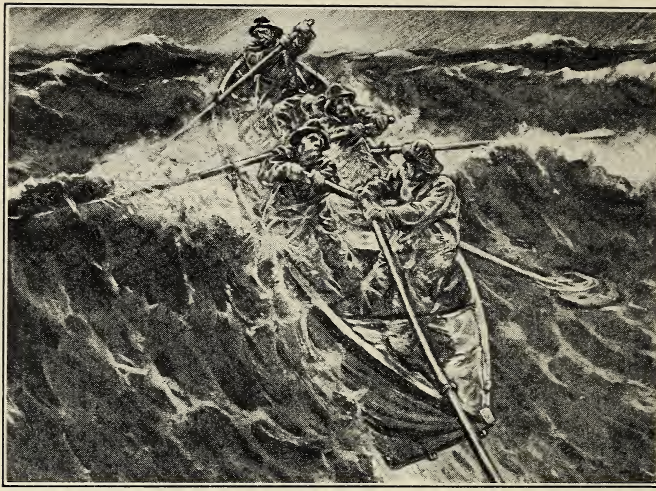
1. Name five forces.
2. A batter bats a pitched ball into the waiting hands of a fielder. What forces are at work on the ball from the moment it leaves the hand of the pitcher until it is caught by the fielder?
3. Who was Newton, and in what century did he live?
4. Why does a jumper on skis sail horizontally through the air for a while instead of coming down vertically when he leaps from the snow embankment?
5. What force do you connect with each of the following quotations?
   (*a*) "The smith, a mighty man is he."
   (*b*) "He holds him with his skinny hand."
   (*c*) "The rocking pines of the forest roared."
   (*d*) "The breaking waves dashed high."

Supplementary Demonstrations and Projects

1. Demonstrate the action of a gyroscope.

2. Read about *gravitation* and *centrifugal force* as applied to the motion of the planets in their orbits.

3. Read the biography of Newton, at the end of this book.



What class of levers is shown here?

PROBLEM X

HOW IS THE LEVER USED?

Although it was midsummer, the morning was brilliant and even a bit cool. It was one of those crisp mornings that occur only once or twice during the summer months in New York State. Tom had just ended a delightful vacation in the Catskill Mountains, and was returning to the city by train. The trees, dripping with the morning dew, glistened in the bright sunshine. The train entered Stony Clove, and as the rocky hills, rising precipitously on both sides of the road, closed in, the train seemed to increase its speed on the down grade as though to avoid being crushed in the trap. The train rounded a sharp curve and suddenly, without warning of any kind, the brakes grated harshly and every one was hurled violently from his seat. The train came to an abrupt stop.

Tom soon learned that a huge tree trunk lay across the tracks not more than a hundred feet ahead! While the passengers buzzed with excitement, the train crew rushed out to grapple with the log. Each was armed with a long iron bar, and in an incredibly short time, under the able leadership of the engineer, the obstacle was pried off the road and hurled into the ditch at the side.

Never before had the worth of a *lever* [1] been so thoroughly demonstrated to Tom. Without this simple, almost primitive device, the huge log would have held its own against the train crew for a much longer time.

The lever is, indeed, one of man's best friends. Far back in ancient history we read that it was used for all sorts of heavy lifting. The Egyptians worked marvels with it in connection with the construction of the Pyramids. To-day it is just as much needed as ever. The lumberman who breaks the log-jam, the road builder who, single-handed, pries the huge boulder from its ancient resting place, the switchman who with but a slight motion of the hand on a lever throws the ponderous railroad switch, the oars-

[1] Lever (lē′ ver). A device, usually bar-shaped, for moving heavy objects by reducing the amount of force necessary for the task.

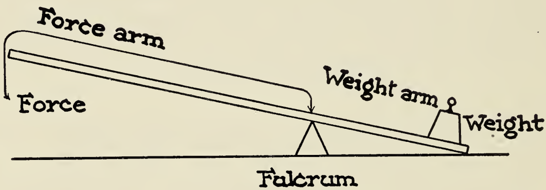
man who with a tug on the oar forces the boat through the water, the tailor who with an ordinary pressure of the fingers on his shears cuts through several thicknesses of heavy cloth: all prove the value of the lever.

The lever is a simple machine designed to overcome a resistance, by an applied force. The essential parts of a lever are:

(1) The *fulcrum,* which is the point at which the lever is supported.

(2) The *force arm,* which is the part of the lever between the fulcrum and the point at which the force, or effort, is applied.

(3) The *weight arm,* which is the part of the lever



Explain each of the terms used in this diagram.

between the fulcrum and the point at which the weight, or resistance is applied.

Levers of the First Class

Demonstration. To show why crowbars are used to pry up heavy rocks. Near the edge of a table, arrange the apparatus shown in the illustration above. Use a support with a thin edge as the fulcrum. Tie a heavy weight to the top of a three-foot ruler at the extreme end, as shown. At the other extreme end attach a spring balance to measure the force, needed to lift the weight. Pull down gently on the bal-

Why is this a lever of the first class?

ance until the weight is lifted. Read the scale. Is the force less than the weight? How much less? Perform the test several times, each time changing the position of the fulcrum. What position of the fulcrum requires the least force? Can you establish any relation between the weight, the force needed, and the distances of the weight and the force from the fulcrum? See if your deduction is the same as that which you will find at the end of this lesson.

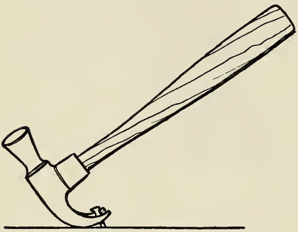
Examine the illustration of the man lifting a heavy rock by means of a crowbar. Do you see why a crowbar is used?

When the fulcrum is somewhere between the force and the weight, the lever is said to be a lever of the *first class*.

The distance from the fulcrum to the weight will, in our discussions, be known as the weight arm. The distance from the fulcrum to the point where the force is applied will be known as the force arm.

In general, the greater the force arm in proportion to the weight arm, the less force will be needed to lift a given weight.

Note: Whenever we save force in lifting a weight, we make up for it by working through a greater distance. In other words, *a small force working through a great distance can do the same amount of work as a greater force working through a shorter distance.*



To what class does this lever belong?

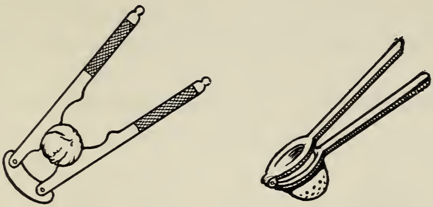
It must be understood at the very start that machines do not save work. In fact we must put more work into the machine than we get out of it, for there is always some friction to overcome.

Levers of the Second Class

Demonstration. To show why a long handle on a wheelbarrow is desirable. Fasten a weight to the top of a three-foot ruler a short distance from one end. Attach the spring balance to the other end and pull upward. When the weight is lifted, read the scale. Is the force less than the weight? Where is the fulcrum? How long is the force arm? How long is the weight arm? Is the ratio of the force to the weight about equal to the ratio of the weight arm to the force arm?

A wheelbarrow.

Repeat the test, changing the weight arm. In each case note the reading of the scale. As the weight arm grows less, does the force needed to lift the weight grow greater or less?



Why are these second class levers?

Note once more that the less the force, the greater the distance through which it moves. What we save in force we lose in distance.

Apply the results of your observation to the wheelbarrow in the illustration. Can you now explain why a long handle is desirable?

Levers in which the weight is somewhere between the fulcrum and the point at which the force is applied, are known as levers of the second class.

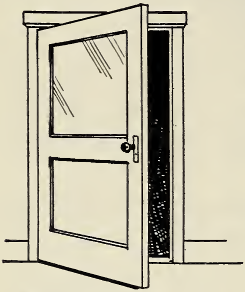
Is this a third class lever?

Levers of the Third Class

Demonstration. To show how levers of the third class work. Arrange the lever as shown in the figure. Is the force needed now greater than the weight to be lifted? Of what advantage can it be to use such levers?

Such levers have the advantage of being able to move weights quickly from place to place. This is sometimes so desirable that it is worth while using the necessary amount of force. Examine the photograph of a derrick and show how it is similar to the arrangement just described. Note again that the ratio of the weight to the force is about equal to the ratio of the force arm to the weight arm.

The law of levers. In the case of all levers you will find that the following law or formula may be applied. *Force multiplied by force arm is equal to weight multiplied by weight arm.* If any three of these quantities are known, the fourth can be found by solving the equation.



What class of lever is this?

It must be understood that this formula does not take into consideration the force needed to overcome friction.

SUMMARY

The lever is a simple machine designed to overcome a resistance, by an applied force.

The essential parts of a lever are the fulcrum, the weight arm, and the force arm.

Depending on the relative location of these essential parts, levers are of three classes.

First and second class levers enable man to overcome a great resistance with a smaller force.

In third class levers the force applied is greater than the resistance.

The law of levers is: Force multiplied by force arm equals weight multiplied by weight arm.

Questions

1. Why are the handles of the tinsmith's shears made very long?

2. In drawing a nail out of a board why should you hold the hammer-handle as near the end as possible?

3. Explain the advantage of using a third class lever in spite of the fact that the force needed is greater than the weight lifted.

4. How much force will be needed to lift a weight of 60 lb. if the weight arm is 3 in. and the force arm is 30 in.? (A diagram may help you.)

5. Explain why it is difficult to cut thick cardboard with the tips of a pair of scissors.

6. Make diagrams illustrating the three classes of levers.

7. Show how the beam scales are really levers of the first class.

8. Write the formula for the law of levers and tell the meaning of each symbol in the formula.

9. Name two examples of each of the three classes of levers.

Can You Also Answer These?

10. Who was the famous Greek scholar who boasted that if he could get a lever long enough, and a fulcrum on which to rest it, he would be able, single-handed, to move the world?

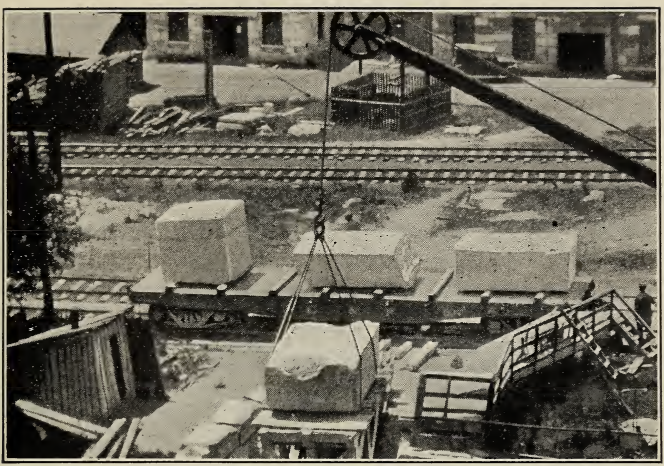
11. Why is one's finger more likely to be crushed in a door if caught at the hinges than if caught at the latch?

12. To what class of levers does each of the following belong: scissors, derrick, beam scales, wheelbarrow?

13. In using a crowbar, why should the fulcrum be placed near weight to be lifted?

Supplementary Demonstrations And Projects

1. Make a beam scale.
2. Demonstrate the principle of the see-saw.
3. Make and operate a toy derrick.
4. Read the biography of Archimedes. You will find it at the end of "Science For Young Folks," Book I.



Pulleys play an important part in man's work.

PROBLEM XI

WHAT ARE OTHER SIMPLE MACHINES?

Pulleys

The Arrowbell Toy and Novelty Company occupied the entire top floor of the five-story loft building. The loft was a great open storage space extending clear through from one street to the next. The long-expected shipment for the Christmas season business had arrived and was being unloaded from the trucks that followed one another in rapid succession. The chief of the shipping department ordered one half of the load deposited on the sidewalk of one street, and the other half on the sidewalk of the other street. In this he had a double purpose: first, to avoid blocking either street with the entire load and, second, to enable him to have the load hoisted up to the loft from both streets at once, in order to save time. His next act was to assign a man to take charge of the load on each of the streets. Each of these men was permitted a porter to assist in the hoisting, and each was provided with a *single pulley* and a long, stout rope.

Each of the men, unseen by the other because of the intervening building, set to work with a will. Jenkins attached his pulley to the cornice of the building, and took up his position in the loft to handle the cases, while his porter remained below to attach the cases and to haul them up with vigorous pulls. Palmer, on the other hand, used the pulley as a movable pulley, attaching the cases to the pulley itself, while his porter pulled the load up into the window of the loft.

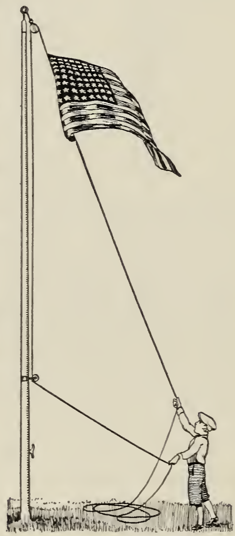
Jenkins, perspiring and tired, was little more than half through when Palmer and his assistant appeared and good-humoredly offered to help him complete his job, for Palmer knew what Jenkins did not even suspect; that a *single movable* pulley requires only half as much force to lift a load as does a *single fixed* pulley.

It is needless to add that in due time Palmer, who was constantly applying scientific methods to his work, was advanced to a responsible position with the firm, while Jenkins never earned more than an ordinary wage.

By means of a single fixed pulley, a force may be conveniently applied. When a pulley is firmly attached so that it cannot move, it is known as a fixed pulley. Pulleys may contain one or more grooved wheels rotating on a common axle. A pulley that contains one wheel is known as a single pulley. Pulleys that contain two wheels are known as double pulleys. Pulleys that contain three or more wheels are known as multiple pulleys.

Single fixed pulleys change the direction in which a force is applied and, often, this makes work more convenient.

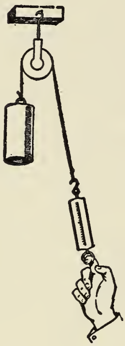
Hoisting a flag is an example of the use of a single fixed pulley. A pulley is attached to the top of the flagpole. The flag is tied to a long cord which passes over the wheel of the pulley. By pulling downward on one side of the cord the flag is made to go up.



Hoisting a flag.

Demonstration. To show the advantage of using a single fixed pulley. Suspend a single pulley (a pulley with one wheel) from a nail. Pass a piece of cord over the wheel of the pulley. To one end of the cord attach a weight, and to the other end attach a spring balance as shown in the figure. Pull the weight up by means of the balance and read the scale.

Is the force needed about equal to the weight it lifts? There is, then, no saving of force in this arrangement of the pulley. Why, then, should such pulleys be used?



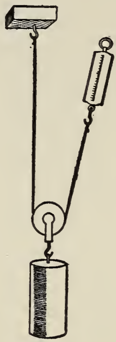
Pulleys used for wash lines serve a similar purpose. There is no saving in force but the pulley changes the direction of the force so that, by pulling the upper cord of the wash line we can make the wash on the lower cord move away.

By means of a fixed pulley attached to a beam above a well, we may, by pulling downward, lift the bucket from the bottom of the well shaft. Pulling downward is more convenient than pulling upward.

By means of a single movable pulley, a resistance may be overcome with a less force. In the story about Palmer and Jenkins of the Arrowbell Toy and Novelty Company, Palmer used a single pulley as a movable pulley. To do this, the weight to be lifted is attached directly to the pulley and the pulley moves up or down with the weight.

Demonstration. To show the advantage of using a single movable pulley. Arrange the pulley, cord, weight, and balance as shown in the figure on page 117. Lift the weight by pulling upward on the balance. Read the scale. Is the force required now less than the weight it lifts? How much less is it? If it were not for the friction that must be overcome, the force in this case would be just half the weight.

How many cords are now supporting the weight? Do you think that this may have something to do with the saving of force? Perhaps the two cords divide the load between them.



Note that the force moves through a distance twice as great as the weight. As in the case of a lever, then, what we save in force we lose in distance and in speed.

This arrangement also has the disadvantage that we must pull upward, always an awkward thing to do. This may be overcome by adding a single fixed pulley. The single fixed pulley that is added does not save any more force, but it changes the pull to the more convenient downward direction.

Demonstration. To show how much force is needed to lift a weight with different arrangements of pulleys. Arrange weights and pulleys as shown in the accompanying illustration. Lift the weight by pulling on the spring balance, and read the scale. Count the number of supporting cords in the arrangement and see what relation there is between this and the force needed. *The force required is about equal to the weight divided by the number of supporting cords.* Why is it not *exactly* equal to this fraction?

Note that the more cords we use, the slower the weight moves. Again we see that whatever we save in force we lose in speed.

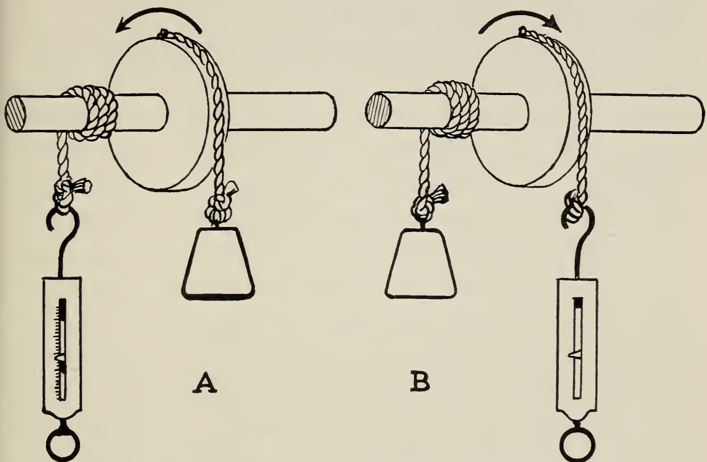
Questions

1. Explain why it is possible for one or two men to hoist a piano.
2. List as many uses of the pulley as you can.
3. A man who is able to lift a load of 150 lb. is required to hoist a box weighing 200 lb. to a top-floor window. He is alone, and is given a single pulley and a rope. How shall he proceed?
4. If a single fixed pulley does not result in a saving of force, why is it used at all?
5. What is the difference between a fixed and a movable pulley?
6. Give four different uses of single fixed pulleys.
7. There is a simple rule that tells how to find the force needed to lift a weight with *any* system of pulleys; what is this rule?
8. How does friction affect the answer we get when we apply the rule mentioned above to a pulley problem?
9. What relation is there between the speed with which a weight may be lifted and the number of cords that support the weight?

The Wheel and Axle

By means of a wheel and axle, force can overcome a greater resistance or produce rapid motion. So far you have learned about two kinds of simple machines: the lever, and the pulley. You will now learn about another simple machine. When a wheel is attached to an axle in such a way that both turn as one, the device is known as a *wheel and axle.*

Demonstration. To show how a wheel and axle works. Make or obtain a simple wheel and axle consisting of a wheel 8 inches in diameter, and an axle 2 inches in diameter. Mount



How the wheel and axle works. In which case is the force greater?

it on a pivot and arrange a weight and a spring balance as shown in figure A. Pull downward on the balance, turning the wheel and axle in the direction indicated by the arrow. Read the scale. Is the force needed more than the weight to be lifted? How much more? Now arrange the same apparatus as shown in B. Again hoist the weight by pulling downward on the balance. Read the scale. Is the force now *less* than the weight? Is it better to attach the weight to the wheel or to the axle?

Repeat the test, this time noting how fast the weight moves in each case. To do this, remove the scale and pull the loose end of the cord with the hand. What do you observe?

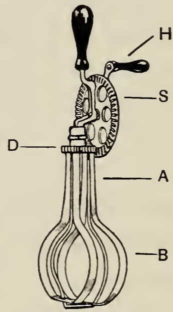
The demonstration shows that a small force applied to the wheel may overcome a greater resistance on the axle and that a force applied at the axle can produce rapid motion of the wheel.

Many common devices make use of the principle of the wheel and axle. In the automobile steering wheel a small force applied to the wheel overcomes the resistance of the front wheels of the automobile, which are attached to the axle of the steering wheel. In order to remove a nut, that is tightly held in place, a wrench is needed. The wrench, acting in an arc of a circle, operates like the wheel of a wheel and axle. Sailors hoist heavy anchors by means of a winch, which is a form of wheel and axle. The carpenter's brace and bit also operates like a wheel and axle. The force is applied to the handle of the brace, which acts like a wheel, and overcomes the resistance of the bit as it bores its way through the wood.

The bicycle makes use of the principle of the wheel and axle to produce rapid motion of a wheel by application of force at the axle. The force is applied to the pedals which are connected to the sprocket wheel. By means of a chain this motion is communicated to the axle of the rear wheel. If the axle is one fifth the size of the sprocket wheel, the axle will make five turns to one of the sprocket wheel. But the rear wheel is firmly attached to the rear axle and turns with it. Therefore, for every complete turn of the pedals, the rear wheel will make five complete turns. Bear in mind, however, that the greater the ratio between the size of the sprocket wheel and the size of the rear axle, the greater will be the force required to drive the rear wheels of the bicycle.

Thus, again, with a simple machine, a gain in speed means an increase in the force that must be applied.

An application of this same principle which is found in almost every home is the egg-beater. In this device a sprocket wheel, S, is turned by a crank handle, H. The teeth of the wheel fit into the cogs of a smaller wheel, D, which is attached to the axle, A, of the beater, B. If the sprocket wheel has four times as many teeth as the small wheel attached to the axle, the axle, and the beater attached to it, will make four turns for every complete turn of the sprocket wheel. The beater thus rotates rapidly.



An egg-beater.

Look about you in your home, in the shops, on the streets, and at the water front. Amuse yourself by noting on a piece of paper all the forms of wheel and axle you can identify. You will be surprised at the length of the list, and yet, I have no doubt, you will have missed many in your search.

The Inclined Plane

By means of inclined planes weights may be lifted with less force. History singles out for fame the hero who leads in battle, the patriot who incites to arms or who cleverly adjusts a dispute, the poet who sings the national epic, and the discoverer of new territory. Too frequently it overlooks the man or woman who, without any hope of reward, devotes hours, days, and often years of thought to make life more comfortable for his fellow men.

Can history tell, for example, who invented the *inclined plane,*[1] that simple device which to the end of time will be an aid to workers? Far back in the days of the early Egyptian Pharaohs, the energy-saving inclined plane was known. Instead of attempting to lift the huge blocks of stone of which the great pyramids were built, the ancient craftsmen constructed smooth, sloping inclines up which the massive stones were dragged with the aid of rollers.

The Assyrians who built lofty palaces, the walls of which rose high above the plains, supplied gentle sloping ramps that wound up and up so that it was possible to reach the uppermost terraces with very little effort.

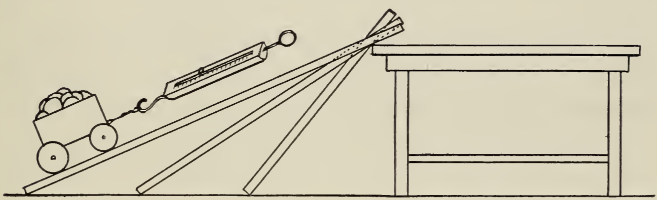
In our own day, the ancient forms of inclined plane are replaced by others more familiar and just as useful, although not a bit improved. We see it in the gang plank which makes it possible for passengers to climb aboard a ship with their baggage. We use it every day when we ascend steps which make access to upper floors much easier than it would be by ladder. The truckman employs it to drag heavy cases from the street to the floor of his truck. The engineer acknowl-

[1] An inclined plane is a sloping surface.

edges its value when he builds a road that winds its long spiral way up the hill instead of attempting a direct path to the top, and again when he plans a long inclined bridge approach instead of trying to make a short, steep one.

By what means does the inclined plane save energy? What governs the angle that the slope should assume? What, if any, are the disadvantages of this device? These, and other questions about the inclined plane, the young scientist may decide for himself, and he can best do so by means of experiment.

Demonstration. To show how inclined planes are used. Make several inclined planes of boards of various lengths



Compare the results of hauling the load up these three inclines.

reaching from the floor to the table-top, as shown in the figure. Obtain a toy wagon and fill it with weights. Weigh the loaded wagon and note the result in your notebook. Attach a cord to the wagon and haul it up each of the inclined planes. In each case note the reading of the scale. How does the reading compare with the weight of the loaded wagon? What does this prove? Compare the results of hauling the load up the various inclines. What do you observe? What rules regarding the use of inclined planes may you state as a result of this demonstration?

Questions

1. Explain why the approach to a great bridge is so very long when money might be saved in its construction if it were made shorter.

2. Why do truckmen haul heavy boxes into a truck by means of inclines instead of lifting them straight up by hand?

3. How would it be easiest to ascend to an upper floor: by a ladder, a steep stair, or a stair with a gradual rise? Explain your answer.

4. Why does a truckman lead his team up a steep street by following a zig-zag path when a heavy load is being hauled?

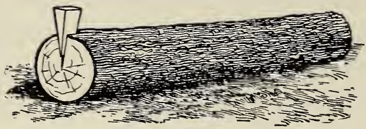
5. A man is required to haul a safe from the sidewalk into a truck. He has two inclined planes: one 6 ft. long and the other 8 ft. long. Which should he choose? Why?

6. If you were making a new trail up a steep mountain, what would you do to make it easy to climb? Illustrate by means of a diagram.

7. What is the disadvantage of making an inclined path up a hill too long and gentle?

The Wedge

The wedge is a simple machine whose action resembles that of the inclined plane. A farmer was busy at a large woodpile. He selected a heavy section of tree trunk, set it firmly on end and, with a lusty swing of the long-handled ax, brought the keen edge down with all the force of his brawny arms. The ax cut a deep gash in the wood but stuck there, failing to split the block. It seemed hopeless, but apparently the farmer was not dismayed. In fact he seemed prepared for just what had happened and, inserting into the cut a thick iron *wedge* [1] which he kept at hand, he released the ax from its prison.



Using a wedge to split a log.

The wedge prevented the fibres of wood from closing again and, using the ax now as a hammer, the farmer drove the wedge deeper and deeper into the wood until finally the stubborn block was split in two.

The most powerful of men could not have torn that log in two by inserting his fingers into the cut and tugging away with all his might. The tiny wedge was able to accomplish what a strong man could not hope to do.

The wedge is another application of the principle of the inclined plane. And, just as a long incline conserves more energy than a short one, so too, the longer the wedge the less will be the force required to overcome the resistance.

The ax is itself a wedge. So, too, are the chisel, the knife, and practically all of the carpenter's cutting tools.

[1] A wedge is a piece of wood or metal tapering to a thin edge and used for splitting wood or for raising heavy objects.

The Screw

The screw is a simple machine whose action resembles that of an inclined plane. It is not difficult to see the resemblance between a wedge and an inclined plane. But to recognize a *screw* as an inclined plane seems to call for a slight stretch of the imagination. Nevertheless the identity is a true one. To drive a heavy nail about two inches long and about an eighth of an inch in thickness requires many lusty blows of a heavy hammer. Replace the nail by a screw of the same dimensions and very little force will be needed to drive it into a board with ordinary finger pressure applied to a screw driver.

A little reflection will reveal that the long, easy, spiral path of the screw has taken the place of the short, direct, two-inch path of the nail. A long, winding uphill road requires less energy to climb than does a steep, but more direct path to the top. So, too, the long path traversed by the spiral thread of the screw requires less force to drive than does the more direct path of the nail.

The principle of the screw is used in the carpenter's vise, in the lifting jack, in the bookbinder's press, and in many other useful mechanical devices.

Summary

Single fixed pulleys change the direction in which a force is applied.

By means of a single movable pulley, a resistance may be overcome with a less force.

By means of a wheel and axle, force can overcome a greater resistance or produce rapid motion.

By means of inclined planes weights may be lifted with less force.

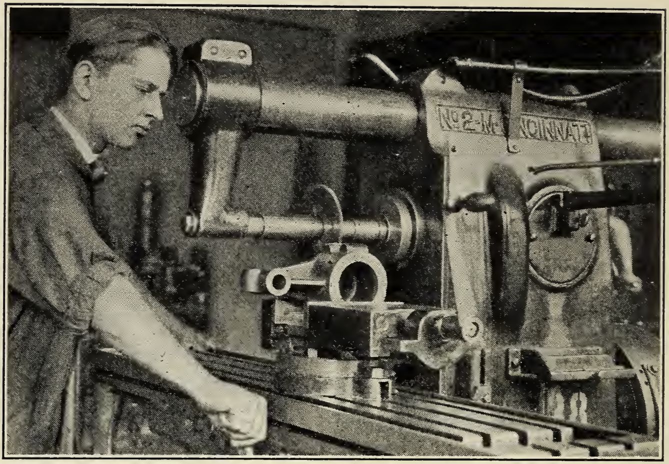
The wedge and the screw are simple machines whose action resembles that of the inclined plane.

Questions

1. What two simple machines are combined in the carpenter's vise?
2. What simple machine is illustrated in each of the following: a chisel? the prow of a ship? a hatchet? a gimlet? a bolt and nut? a meat grinder?

Supplementary Demonstrations And Projects

1. Explain the principle of a tourniquet.
2. Make a model of a screw water pump.
3. Read about automobile gears.
4. Make an inclined railroad with a car that is pulled up the incline by means of a weight and pulley.



Many machines are operated by steam.

PROBLEM XII

HOW DOES THE STEAM ENGINE OPERATE?

Machines that do man's work. If you have ever visited a large factory and watched the long rows of machines at work, you will remember how thrilling, yet how mysterious it all seemed. Throbbing creations of steel, giants of shining metal, are fed raw material and turn out finished products. Huge wheels spin around at a dizzy speed. Long rods dart into mysterious *cylinders* and reappear only to repeat the process over again. Serpent-like belts of leather glide smoothly over *shafts* and pulleys.

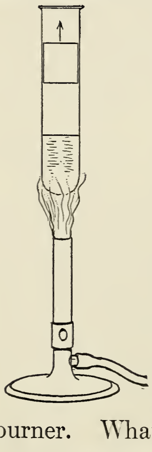
It all seems beyond our power to understand. But, examine the machinery more closely, look at it piece by piece, instead of as a whole, and gradually you realize that this complexity consists merely of a great many familiar parts cleverly put together to make these giants of metal. These parts are old friends. Here is the lever, there the screw; this piece is an inclined plane, that, a wedge! Now we recognize the wheel and axle; and is not that member a pulley? Gradually we feel more and more at home. The mystery fades. We begin to understand.

Indeed, this is so. All machinery, no matter how complex, is made up of the *simple machines*, that we have just studied. In fact, the simple machine is seldom found by itself. A carpenter's brace and bit is a combination of the wheel and axle and the screw. A paper-cutting machine is a combination of the lever and the wedge. A pencil sharpener is a combination of the wheel and axle and the screw. And so, all machines, no matter how complex, may be analyzed into these simpler parts.

How to study machines. It is hardly likely that you will be able to study many machines in the classroom. In order to learn much about machines or engines you should study them "first hand." If there are any, visit the factories near you and get permission to watch the machines in action. If you are lucky, you may come across an obliging machinist, who will be willing to explain how his machine works, and who will answer a few questions for you. After getting this first-hand experience, go to the library and make a further study of the machine which you are studying. You will find the story of the invention and the development of each machine extremely interesting. The diagrams which you will find in reference books should also help greatly to explain to you how the machine works.

Write the results of your investigation and study in your notebook, illustrating, whenever possible, either by means of a labeled diagram or by photographs cut out of catalogs and magazines. Then bring these notes to the classroom and be prepared to report to your classmates and to your teacher.

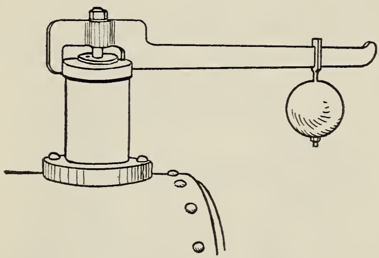
Confined steam exerts pressure upon the surrounding surfaces. In *Science Related to Life*, Book Two, you learned that when water is heated to the boiling point, 212° F., it is changed to *steam*, which expands to 1600 times the volume of the water from which it is made. This steam exerts pressure and thus can be made to do work.



Demonstration. To show that steam exerts pressure. Cut a cork so that it fits snugly, but not tightly, inside a test tube. Put a little water in the test tube. Push the cork about half way into the test tube and boil the water in the flame of a Bunsen burner. What happens to the cork? What causes this?

Pressure gauges and safety valves. In a steam engine, the expansion of steam is made to do work.

Water is boiled in large metal boilers which must be made very strong to resist the pressure of the steam. Sometimes, however, the pressure of the steam becomes so great that boilers have been known to explode. To avoid such explosions, boilers are provided with two safety devices. One is the pressure gauge,

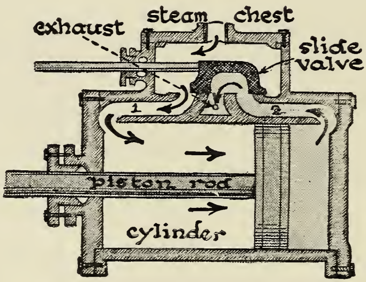


A safety valve. Explain how it works.

which indicates how many pounds of pressure per square inch is being exerted on the boiler at any moment. When the pressure becomes dangerously high the engineer or fireman cools the fire a bit and the pressure falls. The other device is the safety valve. When the pressure of steam becomes dangerously high it forces the valve to open and thus some of the steam is permitted to escape. This reduces the pressure and overcomes the danger of an explosion.

In the steam engine the pressure of steam is used to push a piston back and forth in a closed cylinder. The cork, which was made to move in the test tube by expanding steam, resembles the *piston* of a steam engine; the test tube resembles the cylinder.

Demonstration. To show how the piston of a steam engine operates. When the slide valve is in the position shown in the diagram, steam from the boiler passes through the intake, into the left end of the steam cylinder. Pressure is thus exerted against the left side of the piston, and the piston moves toward the right. In the meantime the



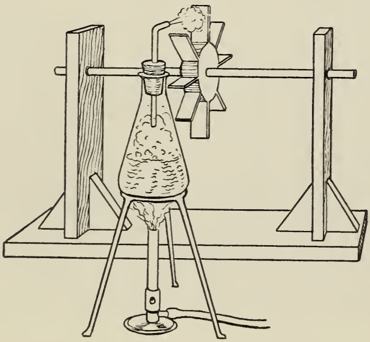
valve moves to the left, shutting off the supply of steam in the left end of the cylinder and permitting steam to enter the right end of the cylinder. Pressure is thus exerted against the right side of the piston, forcing the piston to move toward the left. The process is then repeated and in this way the piston is made to move constantly back and forth in the cylinder. The expanded steam escapes through the exhaust at each stroke.

The motion of the piston is communicated, by means of the *piston rod,* to a *crank* attached to the main shaft of the engine. Pulleys and belts attached to the rotating shaft transmit the motion of the shaft to machines and devices which are thus operated by the steam engine (see page 134).

Demonstration. To show that in a steam turbine, the pressure of the steam against the blades causes the wheel to

turn. Make a wheel similar to the one shown in the figure. Boil water in a Florence flask arranged as shown. Place the wheel in a position such that a jet of steam from the bent glass tube inserted in the one-hole stopper of the flask will strike against the paddles of the wheel. What happens? What causes this?

In a steam turbine the wheel is enclosed in a metal case to prevent the escape of steam. The wheel con-



Pressure of steam can be made to turn a wheel.

tains many paddles which are specially shaped in order to obtain the best possible results. The steam is supplied under great pressure and the wheel is made to rotate rapidly. Power obtained in this way is often used in power houses to drive the armatures of electric generators.

The steam engine is used to do many kinds of work. Since the steam engine was perfected by James Watt, in 1769, it has been used to operate so many kinds of machines that it would take many pages to list them.

At first the steam engine was used to operate pumps and it was found that one steam engine, even as crude as the earliest one made by Watt, was able to perform the work of a number of men.

Not long after the first steam engine was built, Robert Fulton made use of the device to turn a paddle

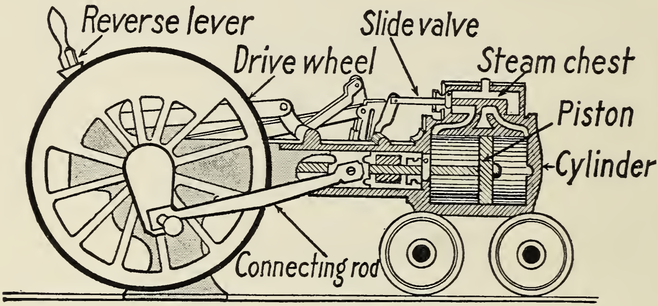


Diagram of a steam engine. Explain how it works.

wheel in such a way as to propel a boat. He spent several years improving his idea and, finally, in August 1807, he made a trip from New York to Albany, in the first successful steamboat, the *Clermont*. The trip took 32 hours but it was an important event in history. From that time progress in building steamships was very rapid. When screw propellers replaced paddle wheels it became possible to increase the size of the ships. Later, still, the steam turbine replaced the steam engine for propelling ships. The greater power possible with the steam turbine gave a new impulse to shipbuilding and today great liners driven by steam make travel on the ocean safe, swift, and comfortable.

The history of the steam-driven locomotive is as interesting as the development of the steamship. A crude steam locomotive was built as early as 1804,[1] but the man who is given credit for constructing the first successful steam locomotive is George Stephenson. In 1815 he built and patented a steam locomotive.

Great liners are operated by steam.

Several mining companies built small railroads and purchased Stephenson's locomotives to haul coal cars. In 1829 Stephenson built the *Rocket*, a locomotive that was capable of hauling coal cars and passenger cars at the rate of 20 miles per hour on level stretches. After that, progress in building locomotives was steady and today steam locomotives are used to carry millions of passengers from place to place on railroads that are built in almost every part of the world. The ease

[1] Richard Trevethick built a steam carriage in England in 1804. Special tracks for a railroad engine had not yet been thought of.

with which transportation on land has been made possible by the rapid development of railroads is one of the most important reasons for man's rapid progress in commerce and industry. It has also done much to create a bond of understanding among inhabitants of countries which, like our own, cover vast areas of territory.

Summary

Confined steam exerts pressure upon the surrounding surfaces.

In the steam engine, the pressure of steam is used to push a piston back and forth in a closed cylinder.

In a steam turbine, the pressure of the steam against the blades causes the wheel to turn.

The steam engine is used to do many kinds of work.

How Much Have You Learned?

Which of the following statements are true and which are false?

T. F. 1. Many modern machines are operated by the pressure of expanding steam.

T. F. 2. When water reaches a temperature of 212° F. it becomes steam.

T. F. 3. Steam occupies much more space than the water from which it is made.

T. F. 4. A pressure gauge allows steam to escape from a boiler.

T. F. 5. Steam pressure may burst a boiler.

T. F. 6. The safety valve is operated by steam pressure.

T. F. 7. All pistons are made of cork.

T. F. 8. Pistons are made to move by means of pulleys.

T. F. 9. The motion of the piston in the cylinder of a steam engine is controlled by a sliding valve.

T. F. 10. The piston always moves in one direction, that is, to the right.

T. F. 11. Machines are operated by means of belts which communicate the motion of the main shaft of the steam engine to the machines.

T. F. 12. Steam turbines are steam engines in which a wheel replaces the piston.

T. F. 13. Steam turbines may operate electric generators.

T. F. 14. James Watt invented the steam locomotive in 1769.

T. F. 15. Robert Fulton demonstrated his steamboat in 1807.

T. F. 16. Screw propellers took the place of steam engines for propelling ships.

T. F. 17. The first steam locomotive ever built was Stephenson's, *Rocket,* in 1829.

T. F. 18. The steam locomotive has made transportation on land easy.

T. F. 19. Steam engines are used only in steamships and in locomotives.

T. F. 20. All ships are now propelled by steam.

Supplementary Demonstrations And Projects

1. Make a wooden model to demonstrate the essential features of the steam engine.

2. Explain, by means of a diagram or a model, how the safety valve works.

3. Write a composition about any of the following topics:

(*a*) James Watt and the steam engine.
(*b*) Robert Fulton and the steamboat.
(*c*) George Stephenson and the steam locomotive.
(*d*) The effect of the steamboat and the steam locomotive on the progress of commerce and industry.

Wide World

What kind of engines supply the power for these boats?

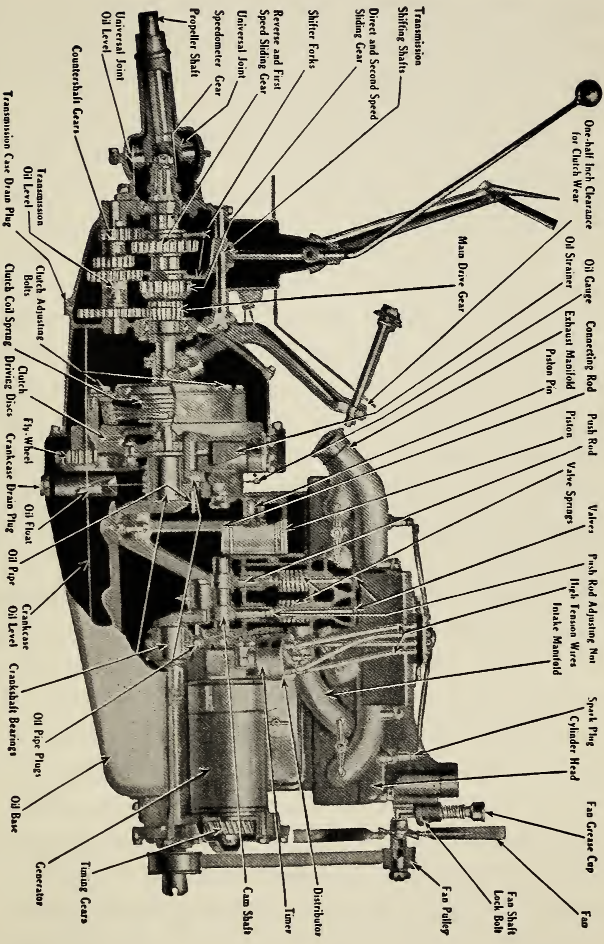
PROBLEM XIII

HOW DOES THE GASOLINE ENGINE WORK?

The question, " who invented the gasoline engine? " is not an easy one to answer. Like the dynamo, the radio, the steam engine, and other important inventions, the gasoline engine (or gas engine) is the result of the work of many inventors, each one contributing a little toward the final result. In 1680 Huyghens, a famous Dutch scientist, caused a piston to move in a closed cylinder by exploding gunpowder in the cylinder. A number of scientists improved upon the work of Huyghens and produced " explosion " engines that were capable of performing work. In 1791, John Barber, an Englishman, made use of the explosion of illuminating gas to operate a turbine. Three years later, Robert Street invented an engine which made use of explosions of turpentine *vapor* to move a piston. After this, little progress was made until about 1850, when a method of obtaining gasoline from petroleum was discovered. At first this fuel was considered too dangerous to use but there are always scientists willing to experiment. In 1860, Lenoir, a Frenchman, made what may be considered the first successful gasoline engine.

But the man who is usually credited with the invention of the gas engine such as we know it, is Dr. Nicholas A. Otto, a German scientist. In 1878, he perfected the first " four stroke cycle " engine which is still used. We shall presently learn what is meant by a " four stroke cycle " engine. Let us now try to understand the principle on which the gasoline engine works.

Gasoline vaporizes rapidly at normal temperatures. It has been found that liquid fuels burn more rapidly and completely when the liquid is broken up into a fine spray or vaporized. Any liquid fuel such as kerosene, alcohol, crude oil, or gasoline, may be employed as a fuel in a gas engine provided it is changed to a vapor before it is burned. In order to change liquids to vapors heat, as you know, must be applied. Some liquids, however, change to vapor at ordinary temperatures and, if inflammable, should make excellent fuels for gas engines. Some time ago you learned that gasoline behaves in this way.



The gasoline engine of an automobile.

Demonstrations. To show that gasoline vaporizes at normal temperatures. 1. Dip a very small sponge into gasoline and with it wet part of the blackboard. Do the same on another board, using water. Which blackboard dries more quickly? What may you conclude?

2. Fill one saucer with gasoline and another with water. Place both saucers in a safe place. Observe the liquid in the saucers on the following day. What has happened? How can you account for it? What may you conclude?

In a gasoline engine, gasoline is stored in a large tank and is conveyed, either by gravity or by means of a pump, through a thin feed pipe into a device known as the *carburetor*. The carburetor is sometimes spoken of as the "lungs" of the gasoline engine and will be described more fully later. In the carburetor the gasoline, in the form of a fine spray, is mixed with air, in proper proportions, and the fuel is thus made ready for burning.

A suitable mixture of gasoline vapor and air is readily exploded by an electric spark. It has been found that a mixture of 16 parts of air to one part of gasoline vapor makes a good explosive mixture. The air furnishes the oxygen without which combustion is not possible. After this mixture is supplied to the cylinder of the gas engine, some means must be provided for igniting it. This problem is solved by the *spark plug*. The spark plug is a device that contains two wires the ends of which are separated by a small fraction of an inch. The spark plug fits tightly into the upper end of the cylinder of the gas engine.

The wires are connected to an induction coil through which a current from a storage battery is passed. When the current is on, an electric spark jumps across the gap between the ends of the wires in the spark plug. This spark sets fire to the highly explosive mixture supplied to the cylinder by the carburetor.

The rapid burning of gasoline vapor produces a pressure within the cylinder that drives the piston. When the gasoline vapor in the cylinder explodes, the sudden combustion results in the formation of gases which occupy much more room than the gasoline vapor did. These gases need room and, in order to get it, they force the piston to move in the cylinder, just as the expanding steam in the cylinder of a steam engine causes a piston to move. The rest of the story is the same as that of the steam engine. The motion of the piston is communicated, by means of a piston rod, to a crank attached to the main shaft of the engine. Pulleys and belts attached to the rotating shaft transmit the motion of the shaft to machines and devices to be operated by the engine.

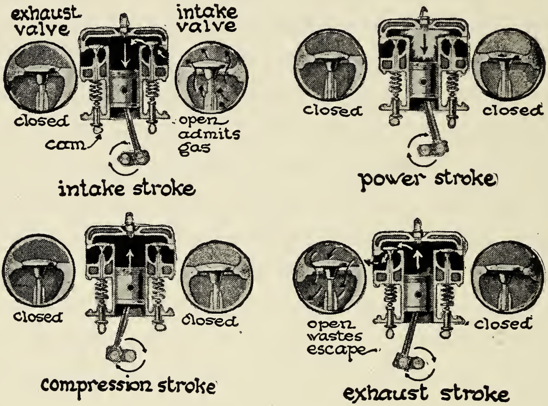
A heavy wheel, known as a *flywheel* is also connected to the crankshaft of the engine. Once set into motion, the flywheel, because of inertia, continues to rotate and helps to keep the piston in motion.

What goes on in the cylinder? Let us now make a more detailed study of what goes on in the cylinder, the better to understand how a gasoline engine operates.

1. Observe, in the first figure, that, in addition to the

spark plug, there are two valves at the top (head) of the cylinder. One is called the *intake valve* because the gasoline enters the cylinder through this valve; the other is called the *exhaust valve* because the exploded gases pass out of the cylinder through this valve.

As the engine is started, the flywheel begins to rotate and the piston rod, connected to the flywheel, is pulled downward, as shown in the first figure. This



reduces the pressure of air in the cylinder by creating a partial vacuum just as does the piston of a suction pump, about which you learned some time ago. The pressure of the air outside, which is now greater than that in the cylinder, forces the inlet valve to open and the mixture of gasoline vapor and air from the carburetor rushes in. This is known as the *intake* stroke of the cycle.

As the flywheel continues to rotate, the piston rod moves the piston upward in the cylinder, as shown in the second figure. This motion compresses the mixture in the cylinder and closes the inlet valve. This stage in the operation of the gasoline engine is known as the *compression* stroke of the cycle.

Just as the gas is highly compressed, a device in the engine causes an electric spark to jump across the gap in the spark plug, as shown in the third figure. This spark ignites the compressed gas, causing an explosion. The expanding gases force the piston downward in the cylinder. This stage is known as the *ignition* stroke of the cycle, sometimes referred to as the *power* stroke.

As the piston returns toward the head of the cylinder, the exhaust valve is opened and the gases formed by the explosion escape through it, as shown in the fourth figure. This is the fourth, or *exhaust* stroke of the cycle of the engine.

At the end of the fourth stroke the exhaust valve is closed and the engine is ready to repeat the four strokes of the cycle.

Bear in mind that the figures all represent the same cylinder. Note, also, that only in the ignition stroke is the piston moved by expanding gases. In the other strokes the piston is moved by the rotating flywheel. The motion of the piston is not even. It moves fastest during the ignition stroke because of the explosion. This tends to communicate a jerky movement to the crankshaft and flywheel. The inertia of the flywheel overcomes this tendency to some extent but smoother motion is usually obtained by adding more cylinders to the engine. The pistons of these cylinders are all connected to the same shaft and to the same flywheel but the explosions do not all take place at the same time. A two-cylinder engine would communicate one jerk to the flywheel for each rotation of the wheel; a four-cylinder engine communicates two jerks to the flywheel for each rotation of the wheel, and so on. Modern gas engines have four, six, eight, twelve, or sixteen cylinders, ensuring smooth operation.

Summary

Gasoline vaporizes rapidly at normal temperatures.

A suitable mixture of gasoline vapor and air is readily exploded by an electric spark.

The action within the cylinder takes place in four strokes, or cycles.

The rapid burning of this mixture produces a pressure within the cylinder that moves the piston. This takes place in the third, or ignition, stroke.

The more cylinders an engine has, the more rapid are the explosions and the more evenly is the power applied to the crankshaft and the flywheel.

How Good is Your Judgment?

In each of the following statements select the one word of the three in parentheses that correctly completes the statement.

1. Huyghens made a piston move in a cylinder by means of (kerosene, explosions, steam).

2. Barber operated a turbine using (turpentine, alcohol, illuminating gas) as a fuel.

3. Street's explosion engine was operated by vapor of (gasoline, turpentine, kerosene).

4. Gasoline is obtained from (petroleum, coal, illuminating gas).

5. Among those who constructed engines that were operated by explosions of gasoline vapor, the earliest was (Lenoir, Huyghens, Otto).

6. The first "four-cycle" gas engine was invented by (Lenoir, Huyghens, Otto).

7. Liquid fuels burn more completely when they are (condensed, vaporized, liquified).

8. Air is mixed with gasoline vapor to supply the (fuel, kindling temperature, oxygen) that is necessary for combustion.

9. Gasoline vaporizes at (low, normal, freezing) temperatures.

10. Air and gasoline vapor are mixed in the (cylinder, spark plug, carburetor) of the gas engine.

11. The spark plug has to do with (ignition, compression, exhaust) in the gas engine.

12. The motion of the piston after ignition of the mixture in the cylinder is caused by the (heating, compression, expansion) of gases.

13. During the intake, compression, and exhaust strokes, the piston is kept moving by the (flywheel, spark plug, exhaust valve).

14. The mixture of gasoline vapor and air enters the cylinder through the (spark plug, intake valve, exhaust valve).

15. The four strokes take place in gas engines having (one, four, any number of) cylinders.

16. The more cylinders a gas engine has, the more (rapidly, evenly, noisily) the engine works.

Supplementary Demonstrations And Projects

1. Make a wooden model of the cylinder of a gas engine and demonstrate the operation of a four-cycle engine.

2. Find out what an internal combustion engine is and explain the principle of this type of engine to your classmates.

3. Obtain and operate a toy gas engine.

4. Write a composition about the development of the gasoline engine.

Scientific

Water keeps the engine cool.

PROBLEM XIV

HOW ARE THE PRINCIPLES OF WATER, AIR, SOUND, AND HEAT APPLIED IN THE AUTOMOBILE?

As we stand on the corner of a busy street and see the hundreds of automobiles that pass rapidly, it is hard to believe that in 1896 there were only four automobiles in the United States, and one of these was imported from Europe. Now more than 4,000,000 automobiles are manufactured yearly in this country.

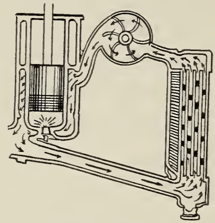
All of this has been made possible by Otto's four-cycle gasoline engine. A number of scientists attempted to apply Otto's engine to the operation of a car and several claimed to be successful at an early date but the one who is generally credited with having built the first successful gasoline-driven car is Daimler, a German. Daimler's first four-wheel car was built in 1884 and, although crude in appearance, it contained many of the features found in automobiles today.

The first car built in the United States was the work of Duryea, in 1892. A year later, Haynes built the second American-made car, and shortly after that Ford built the third. These three, and a Benz car imported from Germany, were the four gasoline cars in this country in 1896.

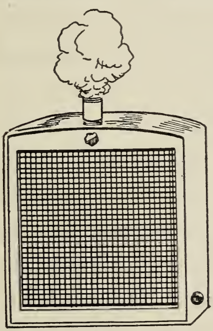
After that, progress in automobile building was very rapid and today the automobile industry is one of the greatest in this country, giving employment to hundreds of thousands of people.

You are now completing your study of the fourth book of *Science Related to Life*. In the first book you learned about water, air, and sound. The second book dealt with the principles of heat and health. In the third book the principles of magnetism and electricity were discussed and explained. In this, the fourth book, you were told about the principles of light and were introduced to the study of simple machines. In the automobile, practically all of these principles are applied, as a further study of the automobile will reveal.

Water principles are applied in the automobile. The constant explosions that take place in the cylinders of an automobile engine generate a considerable amount of heat. In order to prevent overheating, a water-cooling system is supplied. A small pump causes water to circulate in the water jacket, a hollow metal casing that surrounds the parts of the engine. Water enters this jacket through a pipe which leads in from the top of the radiator. The opening is protected by a radiator cap which can be opened or closed at will. The water circulates through the jacket and absorbs heat from the engine. A fan located behind the radiator helps, somewhat, to keep the water cool. However, if the engine is running for a considerable length of time the water may become quite hot. This causes it to evaporate. Whenever you see steam issuing from the radiator cap you may be sure that the water in the jacket is vaporizing rapidly and needs to be replenished in order to keep the engine cool.



The water-jacket.



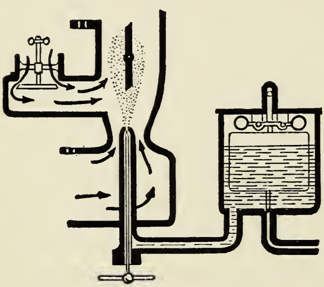
What causes the radiator to steam?

If water in the radiator is permitted to freeze, as it will when the temperature falls below 32° F., the radiator is likely to burst because, as you know, freezing water expands. This may be prevented in one of two ways:

1. If the car is idle, drain off all the water in the radiator. Fill the radiator again when the car is to be used.

2. Add to the water in the radiator, a certain amount of alcohol. Alcohol freezes at a very low temperature (200° below zero, F.) and adding alcohol to water results in reducing the freezing point of the mixture. The correct proportion of alcohol to use is given in automobile handbooks and, of course, varies with the temperature of the weather. Other anti-freezing mixtures, usually containing compounds of glycerine, can be purchased for use in radiators.

Distilled water is used in the storage batteries of automobiles. Because water evaporates, it is necessary, occasionally, to replenish it. Distilled water may be prepared at home or it may be purchased at druggists or at automobile supply shops and public garages.



A carberator. Can you explain how it works?

Air principles are applied in the automobile. You have learned that air must be mixed with gasoline vapor to produce an explosive mixture for combustion in the gasoline engine. The mixing is done in the carburetor.

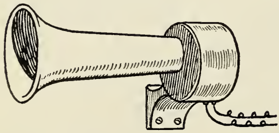
Study the diagram carefully. Gasoline, in liquid form, is supplied by a feed pipe leading from the gasoline storage tank. A float in the gasoline chamber of the carburetor regulates the flow of gasoline into the chamber by a needle valve attached to the bottom of the float. When the valve is open, the suction caused by the motion of the pistons in the cylinders of the engine reduces the pressure of air in the mixing chamber, at the right. This causes air from outside to rush into the mixing chamber, carrying gasoline from the spray nozzle with it. As the opening in the nozzle is very small, the gasoline is broken up into a fine spray, just as it would be in an atomizer. The proportion of air to gas (about 16 to 1) is regulated by special devices. Thus mixed, the gasoline vapor and air are admitted to the cylinder through the inlet valves, as explained earlier.

Air is used for cooling the radiator. This cooling process is hastened by a fan, operated by a small motor. Some automobile engines are cooled entirely by air. This system has advantages over water-cooling systems. In the first place the possibility of freezing water in a radiator is eliminated. Secondly, it reduces the weight of the engine considerably. Radiators of average sized water-cooled motors contain 15 to 20 quarts of water. Radiators of large cars contain more. A pint of water weighs about a pound so that the water, even in a small car, weighs about 30 pounds. Because of this, air-cooled motors are preferred to water-cooled motors for airplanes.

Another use of air is for inflating automobile tires. For this, compressed air is supplied by most gas stations and public garages. The pressure of air in tires is usually 35 to 40 pounds.

Air serves to dilute poisonous and objectionable gases that result from combustion and issue from the exhaust pipe under the car. One of these gases, carbon monoxide, is a deadly poison. Automobile drivers are cautioned never to keep the engine running, for any length of time, within a closed garage. Failure to heed this caution has resulted in numerous deaths. What makes carbon monoxide more deadly is the fact that it is odorless and therefore gives no warning of its presence. Carbon monoxide and other gases from thousands of automobiles make the air of a great city impure. No doubt, in the near future, some way of eliminating this nuisance will be discovered.

Principles of sound are applied in the automobile. Every automobile is provided with a horn to warn pedestrians and drivers of other cars of the near approach of the automobile. The horn contains a disk which is made to vibrate by an electric current. The current is supplied when the circuit is closed by means of a push button usually located in the center of the steering wheel. The driver can thus sound the horn without losing control of the steering wheel.



When expanding gases that result from an explosion are made to pass through a narrow pipe, they escape from the pipe with considerable noise. In order to reduce this noise the gases must be allowed to expand. This is done, in the automobile, by a device known as the muffler, which is merely an enlargement in the exhaust pipe. The larger the muffler the quieter the sound made by escaping gases.

Heat principles are applied in the automobile. Some time ago you learned that air and other gases expand when they absorb heat. In the gasoline engine, a mixture of air and gasoline vapor is heated and, as a result, the gases expand with such force as to move pistons in the cylinders where the combustion takes place. The motion of the pistons is communicated to the crankshaft of the motor which, in turn is connected to the rear wheels of the automobile by means of the drive shaft. Thus expanding gases are made to move the wheels of the automobile.

Summary

Principles of water, air, sound, and heat are applied in the automobile.

How Much Have You Learned?

Which of the following statements are true and which are false?

T. F. 1. There were only four automobiles in the United States in 1896.

T. F. 2. Otto built the first successful automobile.

T. F. 3. A water-cooling system keeps the engine of an automobile from overheating.

T. F. 4. All automobile engines are cooled by water.

T. F. 5. A pump causes the water to circulate in the water jacket of the motor.

T. F. 6. A fan helps to keep the radiator cool.

T. F. 7. Air-cooled engines are lighter than water-cooled engines.

T. F. 8. Water in the radiator is mixed, in cold weather, with some substance that freezes only at very low temperatures.

T. F. 9. To prevent freezing, water may be drained off from the radiator.

T. F. 10. Any kind of water may be used in the storage battery.

T. F. 11. Air is used in the carburetor of the automobile.

T. F. 12. The proportion of air to gasoline vapor in the carburetor should be about 1 part of air to 16 parts of gasoline vapor.

T. F. 13. Air at normal pressure is used to inflate automobile tires.

T. F. 14. Carbon monoxide has a strong, unpleasant odor.

T. F. 15. The automobile horn is operated by compressed air.

T. F. 16. Exploding gases produce noise.

T. F. 17. A muffler is a piece of soft material wrapped around the exhaust pipe to reduce noise.

T. F. 18. Heated gases expand.

Supplementary Demonstrations And Projects

1. Make an antifreeze mixture.
2. Inflate an automobile tire and test the pressure.
3. Find out and explain the use of the air gauge.
4. Write about the development of the automobile.

Keystone — Underwood

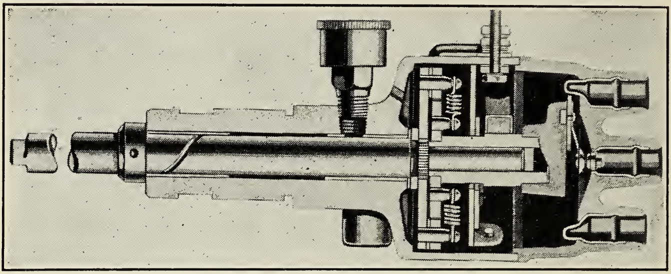
Automobile headlights are operated by electricity.

PROBLEM XV

HOW ARE THE PRINCIPLES OF ELECTRICITY, LIGHT, AND GRAVITY APPLIED IN THE AUTOMOBILE?

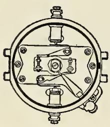
It had been raining heavily for several hours and heavy clouds still hung in the sky. Here and there, through spaces in the clouds, an occasional sunbeam shone through and it was quite apparent that the storm was over. John's father had left his car out in front of the house and, all through the storm, he had been hoping that no damage would be done to the engine, for this was his day off and he had promised to take John for a ride. Now he stepped into the car and attempted to start it. But the engine did not respond.

"Wet wires again," John heard his father mutter. After several unsuccessful attempts, he went back



A distributor

into the house and soon reappeared with a bottle of kerosene and a piece of cloth. He opened the radiator hood and, wetting the cloth with kerosene, he applied it to the wires that lead from the spark plugs to a device known as the *distributor*.[1]



A timer. For what is it used?

"But, Dad, you are making the wires wetter, aren't you?"

"No, John," answered his father, "kerosene evaporates rapidly and this rapid evaporation helps to dry the moisture on the wires. Wet wires interfere with the flow of electricity."

After a few minutes, John's father again attempted to start the engine and, this time, much to John's surprise, he was successful.

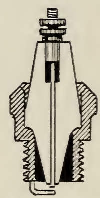
Principles of electricity are applied in the automo-

[1] A device for distributing the electric current so that it enters first one spark plug and then another in a definite order.

bile. Every automobile contains an electrical system, current for which is supplied by a storage battery. This battery is usually located under the footboard, just in front of the driver's seat.

The motor is started by electricity. The driver turns an electric switch and then steps on a conveniently placed push button, sometimes called the starter, which closes a circuit. Current from the battery begins to flow and causes a motor to turn. This motor is connected to the crankshaft of the engine and the pistons are connected to the crankshaft by means of piston rods, as explained before. Thus the pistons in the cylinders are made to move by a flow of current from the storage batteries.

It is not enough, however, to move the pistons. The gas compressed by the pistons must be ignited and exploded. You learned, some time ago, that very high voltage is needed in order to make a spark jump across a gap. How is this high voltage current obtained from a low voltage (usually 6 volts) storage battery? An induction coil solves the problem.


A spark plug

Not only must the sparks be made in the spark plugs, but they must be made in a certain order so that the explosions do not all occur at the same time. You recall that the pistons are so mounted on the crankshaft that when one is compressing gas, another is exhausting the gas from the cylinder, a third is performing the power stroke, and so on. The spark must be ignited just when the gas is compressed to the utmost, that is, at the top of the compression stroke. This is taken care of by the distributor, already explained, and by an adjustment known as the *timer*.[1]

The storage battery supplies current to start the car, but once the car is in motion the engine turns the shaft of an electric generator which then operates the car. If there were no generator the storage battery would soon become used up. This would mean frequent recharging of the battery, a condition which would make operation of automobiles very inconvenient and impracticable.

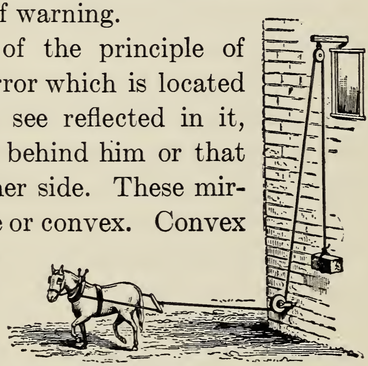
The lighting system of an automobile is also electrical. Every car is supplied with headlights which may be made dim or bright, a tail light to warn drivers who may be coming up behind the car, smaller lights, sometimes called " parking lights " for use at night when the car is standing at the curb, a dome light to light the interior of the car, and a light or several lights on the " dashboard " where are located indicators of various kinds.

Principles of light are applied in the automobile. Headlights, particularly for use on dark, country roads, must be bright and must be so adjusted as to light up a considerable stretch of road ahead. Concave mirrors in the headlights reflect the light from the electric lamps and help to provide a powerful beam. Most headlights are provided with lenses of special design, usually of ribbed glass, which refract light

[1] A device connected with the distributor. It regulates the intervals between spark plug ignitions.

and diffuse it. This not only serves to light as much of the road as possible, but prevents the glare which would result if a plane glass instead of a special lens were used. Glaring lights are dangerous as they may confuse the driver of a car approaching in the opposite direction. Many accidents have occurred in this way. The use of red glass for tail lights has already been mentioned. Red is an attractive color and is accepted everywhere as a signal of warning.

Another application of the principle of light is found in the mirror which is located so that the driver can see reflected in it, cars that are coming up behind him or that are about to pass on either side. These mirrors may be either plane or convex. Convex mirrors give a wider range of vision. Can you explain why?


The old way of measuring horsepower.

Principles of gravity are applied in the automobile. If all roads were perfectly level, once a car is started it would take very little power to keep it in motion. Unfortunately roads are not level; sometimes, in fact, they are quite steep. When going uphill, considerable power is needed to overcome gravity. Automobiles are therefore supplied with powerful engines.

The power of an engine is measured in units known as *horse power*. Originally one horsepower was probably the amount of work that an average horse could do. Such a measure, however, is not scientific, since some horses are stronger than others. Scientists therefore agreed that one horsepower should be the power that is needed to lift a weight of 550 pounds through a vertical distance of one foot in one second. A 60-horsepower engine, for example, is one that can do 60 times this work in one second. The greater the horsepower, the greater the load a car can carry with ease and the greater the ease with which it can climb hills.

The effect of gravity is observable, also, when a car is going downhill. Here gravity aids the motion of the car and little or no power is needed to run the car. When a car is moving downhill without power it is said to be coasting.

In most cars the gasoline is fed to the carburetor by means of air pressure. There are some cars, however, in which the gasoline storage tank is higher than the carburetor. In such cars the gasoline flows downward from the tank to the carburetor by means of gravity. Such a system is known, therefore, as a "gravity feed" system.

Summary

Principles of electricity, light, and gravity are applied in the automobile.

Questions

1. Name five devices in the automobile that depend upon an electric current for their operation.

2. Where is the storage battery usually located?

3. About how many volts does the average storage battery generate?

4. How is the crankshaft made to rotate?

5. How is the high voltage, needed to produce a spark in the spark plug, obtained?

6. At what stage in the four strokes of a piston is the gas ignited?

7. What is the purpose of the distributor?

8. For what purposes are lights usually provided in an automobile?

9. Mention two uses for mirrors in an automobile.

10. What is the color usually used for the glass of a tail light? What is the purpose of the tail light?

11. State two ways in which the glare of a powerful headlight may be reduced.

12. Tell how gravity sometimes aids and sometimes hinders the running of a car.

13. What is meant by one " horsepower "?

14. What is meant by a " gravity feed " system?

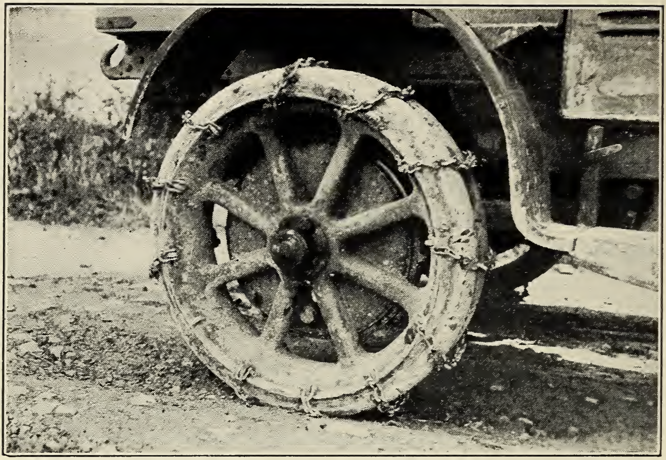
Supplementary Demonstrations And Projects

1. Study the dials found on the dashboard of an automobile and explain for what each one is used.

2. Use a storage battery to run a small motor, to light electric bulbs, and to blow a horn.

3. Test the specific gravity of the acid in a storage battery.

4. Make a diagram of the electrical system of an automobile.



Brown Bros.

Skid chains increase friction and prevent slipping.

PROBLEM XVI

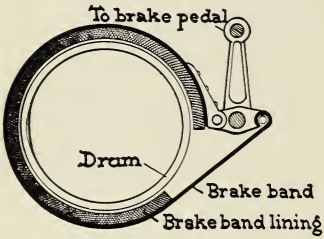
HOW ARE THE PRINCIPLES OF FRICTION, INERTIA, AND THE SIMPLE MACHINES APPLIED IN THE AUTOMOBILE?

Two automobiles were approaching a street crossing. Both were going at a fairly high rate of speed and it was apparent that if they continued the result would be a collision. The driver whose car was traveling along the avenue felt that he had the right of way and continued without slackening speed. The other driver applied pressure to his brakes with all the strength he could command. The brakes, however, were defective, and, the next moment he struck the first car squarely in the middle. Both cars were badly damaged and both drivers were injured. Fortunately, their injuries were slight.

Many accidents of this kind happen and they illustrate how important a part friction plays in the operation of an automobile, for brakes depend upon friction.

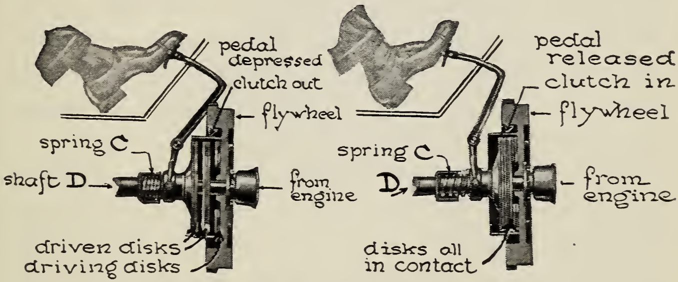
Friction helps and hinders the running of an automobile. If both the road and the tires of an automobile were perfectly smooth the most powerful engine could not make the car go. The wheels must grip the ground securely; in other words, there must be friction between the wheels and the road. This is secured by specially designed tires with rough, instead of smooth surfaces and by attaching skid chains to the rear wheels when the road is wet or icy. Occasionally a car fails to start when it is on an icy, muddy or slimy section of a road. At such times gravel and sand may be strewn in the path of the wheels or, if the spot is very soft, rough planks or stones may be placed under the wheels to increase the friction. Heavy tractors such as are used by farmers are frequently driven over soft soil. To increase the friction the tractor wheels are provided with spikes or cleats which grip the soil.

The importance of the brakes has already been mentioned a number of times. Attached to each of the wheels is a steel band known as a drum, because it resembles that instrument. Another steel band containing a gap which may be closed or made smaller, is known as the brake band and fits somewhat loosely over the drum. This band is lined with some rough material, known as the brake band lining. When the brake pedal is pressed downward by the foot of the driver, the brake bands are tightened and the rough brake band lining grips the drum. The friction causes the wheel to stop. As all four brakes are applied when the driver presses the pedal, very little pressure is needed to overcome the inertia of the car. The same friction that helps to stop the car, however, serves to wear out the brake band linings. These must therefore be replaced from time to time and the brake bands must occasionally be adjusted. In addition to the brakes that are operated by the foot pedal there is an emergency brake operated by hand. The emergency brake lever is conveniently located so that in case of emergency the driver can pull the lever without losing control of the car.



Pressure on the brake bands causes the brake band lining to grip the drum.

Another very important device that depends upon friction is the *clutch*. The car does not move, even when the engine is operating, unless the engine is connected to the driving shaft. The clutch is the device that performs this work. A pedal in the front of the car, just to the left of the brake pedal, controls the clutch. The clutch consists of a number of metal disks pressed against the flywheel of the engine by a powerful spring. In this position the clutch moves with the flywheel. As the clutch is also connected to the drive shaft, the wheels of the automobile are made to move. If the driver wishes to stop the car without stopping the engine, he steps on the clutch pedal. This forces back the spring that presses the clutch disks against the flywheel and therefore releases the clutch from the flywheel. In this position the



Explain how the clutch works.

flywheel turns without causing any motion in the drive shaft or wheels.

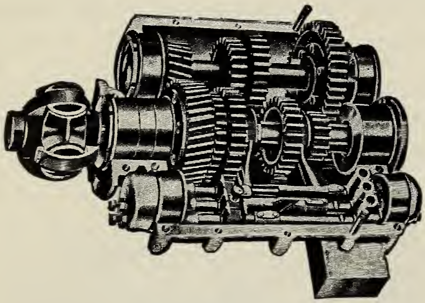
Friction in the numerous movable parts and bearings of an automobile causes constant wear on these parts. This, as you have learned, is overcome to some extent by lubrication. Oils and greases must be applied regularly by experts. Some automobiles have special lubricating devices by means of which oil is pumped into the bearings. Ball bearings and roller bearings are used when possible to reduce the rubbing surfaces but in spite of all precautions, parts will wear out.

Principles of inertia are applied in an automobile. You probably recall the laws of inertia: a body at rest tends to remain at rest and resists attempts to move it; a body in motion tends to continue in motion and resists attempts to stop it. These laws apply, of course, to automobiles. A light car, even when empty, weighs over 2,000 pounds and most cars weigh considerably more. It therefore requires considerable power to start a car in motion. The more powerful the motor, the sooner this inertia is overcome. Once the car is in motion it tends to keep going, even after the engine is stopped, until stopped by friction. The faster the automobile moves the greater is its inertia and, therefore, the more force is needed to stop it.

When the forward motion of an automobile is suddenly checked, passengers in the automobile lurch forward. This is the result of inertia of motion in the passengers. In a similar manner inertia causes passengers in a car to lurch backwards when the car is started suddenly. Bumping up and down on a rough road is also caused by inertia. Can you explain how?

Inertia of the flywheel was explained some time ago. Once the heavy wheel is set in motion it helps to overcome the tendency on the part of the pistons to communicate an undesirable jerky motion to the crankshaft. The flywheel thus insures smooth motion of the motor.

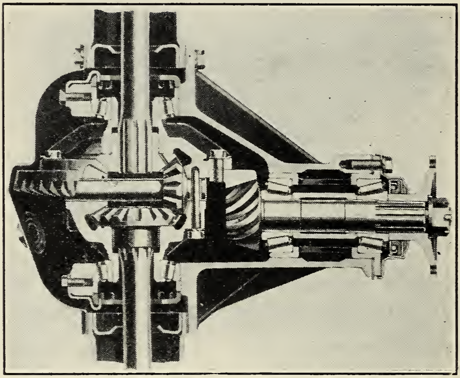
Gears. Cars are usually constructed to run in three speeds. These are known as "first speed" or "low," "second speed," and "third speed" or "high." When the car is about to start, a great deal of inertia must be overcome, as explained before. It is advisable to utilize the full power of the engine. To do this, a small gear wheel engages a large gear wheel that is connected to the drive shaft. This results in great power but slow motion. After the car is started, the clutch is disengaged, and then two gear wheels of intermediate size are engaged. This results in less



Transmission gears.

power but a greater speed. After the car has run in this second speed for a few yards, the clutch is again disengaged and a large gear wheel is made to engage a small gear wheel. Just as in the case of the bicycle sprocket wheel, this results in rapid motion of the small gear which, in turn, communicates rapid motion to the drive shaft. The car then runs in high speed, but the power is considerably reduced. The shift from one set of gears to another is accomplished by a gear shift lever, near the driver's right hand. There is a neutral position of the lever, in which position no gears are engaged.

The differential. In order to transmit the motion of the drive shaft to the axle of the rear wheels, which is at right angles to the drive shaft, an ingenious device called the differential is used. This consists of a number of gears which not only change the direction of the motion from that of the drive shaft to that of the rear axle, but also permit one rear wheel to go faster than the other when the car is making a turn. The differential is contained in a disk-shaped metal box which may be seen at the middle of the rear axle.



The differential

The rear wheels of the car, which are attached to the rear axle, are, then, the wheels which make the car go. A recent development is the automobile with the front-wheel drive. In this type the power is transmitted to the axle of the front wheels instead of to the rear wheels.

Many automobile parts are adaptations of simple machines. The principle of the lever is illustrated in the gear shift lever, the hand brake lever, and in the brake and clutch pedals. The steering wheel and the brakes are good examples of the wheel and axle. So, too, are the transmission gears. Jacks used for lifting cars are usually combinations of levers and screws, and tools used for tightening nuts and bolts are either levers, as in the case of the monkey-wrench, or modified wheel and axles.

Summary

Friction may help or hinder the running of an automobile.
Principles of inertia are applied in the automobile.
Many automobile parts are adaptations of simple machines.

How Good Is Your Judgment?

In each of the following statements select the one word (or words) of the three in parentheses that correctly completes (or complete) the statement.

1. An automobile will not move unless there is (inertia, friction, gravity) between the wheels and the road.
2. Tires should be (rough, smooth, thick).
3. Icy pavements reduce the (power, speed, friction) of the wheels.
4. The brake drums are attached to the (wheels, drive shaft, flywheel) of the automobile.
5. Brake bands are made of (asbestos, rubber, steel).
6. Brake bands fit (over, under, alongside of) the drums.
7. Brake linings should be (smooth, rough, hard).
8. Most automobiles have (one-wheel, two-wheel, four-wheel) brakes.
9. The emergency brake is applied (by hand, by foot, automatically).
10. The clutch is connected to the (steering wheel, flywheel, rear wheel) of the car.

11. The drive shaft is connected to the (front, rear, steering) wheel of the car.

12. Friction in a car may be reduced by (evaporation, condensation, lubrication).

13. If the engine is shut off while the car is still in motion on a level stretch the car will continue to go because of (friction, gravity, inertia).

14. The greatest power is needed to (start the car, stop the car, continue the car in motion).

15. Lurching forward when the car stops suddenly is due to (gravity, defective brakes, inertia).

16. The steering wheel is an adaptation of the (lever, wheel and axle, screw).

17. The greatest speed is attained when (a large gear drives a small gear, a medium-sized gear drives one of equal size, a small gear drives a large gear).

18. The device that transmits motion of the drive shaft to the axle of the rear wheels is the (differential, clutch, drum).

Supplementary Demonstrations And Projects

1. Bring to school a labeled drawing of an automobile and explain the purpose of each part.

2. Have some one teach you how to run a car.

THE AUTOMOBILE TRIP

Fred was just thirteen and a graduate of grammar school. In fact he had just been graduated that very day and was still wearing his smart blue serge "graduation suit," with a small white carnation gaily pinned to the left lapel, when his father came home with the good news. In honor of Fred's graduation and, at the same time, to enjoy a well-earned rest, Fred's father had arranged with his employer for a two-weeks vacation. There was to be a trip to the mountains in their automobile, for Fred's father was a thrifty man and had saved enough money to buy a small car the year before.

Fred felt that he was indeed a lucky boy. An automobile trip with his father and mother; and to his beloved mountains! He scarcely slept that night, his head was so full of schemes. He had been very fond of science and, gradually, out of all the ideas that rushed through his mind, he decided upon a plan. He would use this trip as a means of testing his knowledge of science. Yes, he would combine this great pleasure trip with a practical application of his favorite study. How well Fred succeeded, you may judge for yourself.

The happy family had not been out long before Fred realized that there was plenty of opportunity to study the atmosphere and what it means to man. As they sped out of the city with its smoke and dust-filled air, and reached the country with its clean atmosphere and clear sky, he felt how good it was to breathe pure air. The first night they stopped at a small country boarding house. Here Fred was at once confronted with the problem of ventilation. He remembered to open one bedroom window at the top and the other at the bottom. This, he knew, was the best way to obtain a good circulation of air in the room. How soundly he slept that night!

The next morning there was a fresh breeze blowing. He had taken along a thermometer and an aneroid barometer. The barometer showed a slight drop in pressure. Was it going to storm? A look at the weather map in the Post Office of the village showed him that a storm was approaching but that it was not due until that night.

They rode on all through the day. The barometer continued to fall and, sure enough, rain came at nightfall. A strong wind blew. Fred was able to observe the destructive work of the wind, for there was much damage to young trees and to the flowers.

The next day one of the tires was punctured and Fred made use of the air pump to inflate the tube. His father showed him how to test the pressure with a pressure gauge and he was surprised to learn that there were forty pounds of pressure in the tube when the job was done.

The travelers stopped for lunch at a small wayside inn and Fred went in to " wash up." Hearing the throb of an engine near-by, he discovered that the water was being pumped into a reserve tank high up on a steel frame. This resembled the roof tank of his home in the city. The next day they picnicked on a grassy spot near a merry little brook. How good the water looked! Fred was about to stoop down to quench his thirst when a farmer called to him to stop. The water was polluted by a cesspool that drained into it a little farther up, the farmer explained, but there was an artesian well near the farmer's house, and there Fred could drink with safety. Fred recalled, then, that it was dangerous to drink water from unknown sources. He was grateful to the farmer for the warning, and resolved to be careful in the future.

During the day they crossed a great concrete dam that made a large reservoir for a near-by community. Fred insisted on stopping to see the method used in filtering the water. Below the dam the stream fell in cataracts, and situated near one of these was a quaint old mill. Fred caught a glimpse of the clumsy old water wheel with its large, wooden paddles. He recognized it at once as an undershot wheel. He was able, too, to see the results of erosion by water, for the rapidly flowing stream had cut a deep bed in the rock through which it flowed, and great, round boulders lay at the bottom of the stream, washed smooth by the action of the water.

Soon they came upon a lake. There was a boathouse with splendid boats for hire, and it was so tempting that they all got into a boat for a row on the blue water. There seemed to be "high water marks" on the rocky shore, but Fred knew there could be no tide in a lake. The low water must have been caused by evaporation. The hot summer sun was doing this, he concluded. And his attention was drawn to the boat itself. There were three of them in it and yet it did not sink! This, surely, was a fine illustration of the buoyancy of water.

Fred was enjoying his study of science immensely. He felt, now, that he understood more about the properties of air and of water than he had by just reading his textbooks and performing experiments in the science room. But he had only begun his studies.

The sun was beginning to set. Now that it threatened to leave the earth in darkness, Fred realized what a wonderful source of light the sun is. Looking down into the water, he noticed that the oar seemed bent where it pierced the surface of the lake. This was due to refraction. The water was glassy, now, and as they approached the shore, Fred marveled at the perfect reflection of the trees and of the grassy bank. The sun, very low, was darting its fierce rays on the mirror-like water, and they shone unmercifully into Fred's eyes. "The angle of reflection is equal to the angle of incidence," he repeated to himself, proud of his memory.

The next day, the party "camped" in the open. Fred and his father started a fire. Luckily there were matches in the car so that it was not necessary to resort to the Indian drill or to the ancient flint and steel. But fuel had to be gathered and the small flame fanned to increase the supply of oxygen so much needed to kindle a fire. The coffee pot with the wooden handle gave Fred plenty of opportunity to recall his knowledge of heating by convection, and of good and poor conductors of heat. The hot sun kept reminding him constantly about heat by radiation. After the meal, Fred carefully extinguished the fire by removing what was left of the fuel, and by smothering the embers under a heap of earth. He felt like a fire-fighter in the forest. The remainder of the hot coffee was poured into the thermos bottle and Fred admired the device that kept things hot or cold by means of a non-conducting vacuum.

That night, under the bright stars, Fred was able to review his knowledge of sound. The sweet, high-pitched soprano voice of his mother floated pleasantly on the balmy mountain air, while his father strummed a soft accompaniment on his mandolin. Pitch, quality, intensity: all had a new meaning for Fred as he enjoyed the harmonies of his parents. From the far shore of the lake the echoes came back, sweeter and softer, even, than the voices that made them.

A day or so later, having by that time become quite familiar with the mysteries of automobile mechanics, Fred was permitted to "tune up" the engine. He got first-hand knowledge of electromagnets, batteries, spark plugs, electric lighting, cylinders, water jacket, and lubrication.

They stopped for lunch in an inviting town and, directly opposite the restaurant in which they ate, a small brick house was being erected. Fred was fortunate enough to see masons using the plumb line and level, instruments that depend upon the principle of gravity. The lever, the pulley, the wheel and axle, the wedge, and the inclined plane: all were in use here.

Once, when the car was stopped rather suddenly to avoid a bad rut in the road, Fred pitched forward in the car and realized that this was due to inertia of motion.

And so his studies continued. At almost every turn there was occasion for use of his knowledge of science. Indeed, when the wonderful two weeks had come to an end, Fred felt that science was a live, useful thing, and not merely something that one reads about in books but never meets in real, every-day life.

GALILEO

(1564–1642)

Galileo lived during a dangerous age for scientists. Pisa, charming, dreamy little town where he was born, was then the center of debate over the theory of the Polish astronomer, Copernicus. This man had dared to say, and to insist, that the sun, not the earth, was the center of the solar system. He declared that the universe did *not* revolve about the earth as Ptolemy and the ancient Greeks had taught, and as the Church of Rome had decreed. The few thinking men of the time who agreed with Copernicus were obliged, at the peril of persecution, to keep their opinions to themselves. Bruno, the philosopher, who had been bold enough to declare that Copernicus was right, was condemned and executed because he refused to repent. Nor was he the only victim of the narrow-mindedness of the period.

Imagine then, the fate in store for Galileo who, even as a boy, showed the forbidden courage of the experimentalist. In those days, a boy had little to say about the choice of a career. This youth, so his father planned, was to become a cloth merchant. Joy must have known no bounds, however, when his parent later gave up this idea and sent Galileo to the university to study medicine.

Yet medicine was not to be his field either. One day, during services in the beautiful Cathedral of Pisa, Galileo's gaze became arrested by the great sanctuary lamp that hung from the ceiling. Something had started it in motion, and as he watched the huge lantern he noticed that it swung to and fro with perfect rhythm. Even as the oscillations died down, the time of vibration remained the same. From that moment, instead of attending to the study of medicine, Galileo spent his time experimenting with pendulums. His studies resulted in the discovery of the principles of the pendulum. Briefly stated, these are:

1. The same pendulum will always vibrate in the same period of time.

2. The time of vibration of a pendulum depends entirely upon the length of the pendulum; the shorter it is, the more rapidly it vibrates.

As Galileo was absolutely ignorant of mathematics at this time, he determined to follow up this science of numbers at once. He developed a longing to try things, to experiment. He was treading on dangerous ground, experimentation was taboo! But Galileo went ahead, regardless of dangers.

Aristotle had taught, among other things, that a heavy body will fall more rapidly than a light body. This, Galileo declared, was not so! What is more, he proclaimed publicly that he would prove his statement to any who might care to come to witness a demonstration of its truth. The epoch-making experiment was performed at the Leaning Tower of Pisa. While great numbers of scholars, philosophers, and curious citizens waited below, Galileo stood on the uppermost gallery of that famous tower and, at a given signal, let fall, simultaneously, a great and a small weight. There was a hush, a moment when hearts stood still, and then a single thud. The two weights struck the ground at exactly the same instant!

It would appear to us that the teachings of Aristotle should have crashed to earth with the falling of Galileo's weights. But in those days, people were so bound by tradition and the word of the Church, that they would not believe what even their own senses should have convinced them was so, and they looked upon Galileo as a trickster, a master of the "dark arts," a dangerous enemy, rather than the founder of truth in science. From that day his foes increased and he was carefully watched. He was soon brought into a controversy with those in authority and, as a result, was forced to resign his position as professor at Pisa.

He accepted a position at the University of Padua in the Republic of Venice, where people were more tolerant of new ideas. At Padua he was a brilliant success. Science was now making itself felt among the masses; great numbers thronged to hear Galileo talk. His classrooms were far too small to accommodate the crowds; he had to deliver his lectures in the open air.

It was at this stage of his career that Galileo invented what was probably the first thermometer, and the first real telescope. Through the telescope, he discovered new truths, and dealt a final death-blow to ancient ideas; he pointed his invention at Jupiter, and found four moons revolving around the planet. Even to Galileo these were unbelievable marvels.

By this time Galileo was easily the most famous man in Padua and his reputation had spread over all Italy. He was invited to take the position of Mathematician to the Grand Duke of Florence and in 1610, after twenty-eight years of noble work in Padua, he accepted. At Florence he furthered his celestial research, discovering the rings of Saturn.

Forgetting that he was once more in a land opposed to Copernican teaching, he wrote in support of the theories of that great Polish astronomer. His old enemies once more became active and he was summoned to explain his views. Old and broken by this trial, and with the fate of the martyr, Bruno, still fresh in his memory, he committed the one regrettable act of his life: to escape death, he weakly renounced all his writings and swore that he would never again bring suspicion upon himself. His statement saved his life, but he was imprisoned and later exiled to Siena. Here disheartened, blind and deaf as a result of his persecution, he was seized with a fever, and in his seventy-eighth year, came to a miserable end.

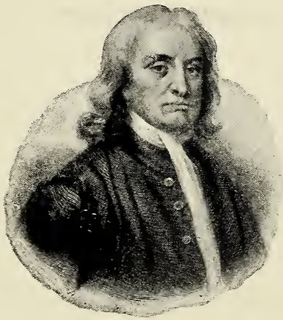
But Galileo did not die in vain. Soon the story of the harrowing circumstances under which the shameful retraction had been wrung from him, proved to be a clarion horn that helped to rouse the great masses from their long, deep sleep. Everywhere there arose champions of the new theory of the construction of the universe. From every side, the idea was advanced that actual observation should take the place of slavish belief in laws laid down by the ancients and Galileo was proclaimed by all to be the father of experimental science.

SIR ISAAC NEWTON

1642–1727

It was the year 1642. Christmas festivities in the little snow-clad town of Woolsthorpe, in Lincolnshire, England, were at their height. Sleighbells tinkled merrily and ruddy faces reflected the joy that comes with gay greetings, family reunions, steaming brown goose stuffed with chestnuts, golden gravy, and hot plum pudding. To the anxious household of the Newtons, came a welcome Christmas gift, a tiny human mite, later to be knighted as Sir Isaac.

As a boy, little Isaac Newton was not at all unusual. Neither in games nor at school did he shine above his playmates. He was, in fact, considered rather a poor student at the grammar school, and often had difficulty keeping up with his fellow students. Until he was nineteen years old, when he entered Trinity College, Cambridge, he showed hardly any interest in his work. But once he did apply himself, he proved to be a brilliant student. After four years, in 1661, he received his degree and



was declared the most proficient mathematician who had ever passed through the Gothic portals of that famous English school.

Just when he discovered the universal laws of gravitation that gave him undying fame, is not known. Whether or not the story of how the great truth of science came to him as he lay under an apple tree is true, it is also hard to tell. We are certain it was soon after his graduation that he began to add to the science of mathematics those important principles now accepted as general truths, but unheard of before his day. It is probable, too, that about this time he pondered much over the sun and the planets. How the tremendous, unseen power controlling the majestic motion of these bodies must have gripped his imagination!

All through his life, Newton was a noble figure, working ceaselessly for the good of his country and for mankind. In 1705, during his term as president of the Royal Society, Queen Anne knighted him. When, after eighty-five years of usefulness, he was put to rest with England's great in Westminster Abbey the foundation of the modern science of physics had been firmly established.

BOOKS OF GENERAL INFORMATION

Title	Publisher
Book of Popular Science	Grolier Society
Compton's Pictured Encyclopedia	F. E. Compton and Company
Encyclopedia Britannica	The Encyclopedia Britannica Inc.
The Book of Knowledge	Grolier Society
The Story Book of Science	The Century Company
The Wonder Book of Knowledge	John C. Winston Company
The World Book	W. F. Quarrie Publishing Company

OTHER BOOKS

Author	Title	Publisher
Abbot, Charles G.	*The Sun.*	D. Appleton and Company
Amid, John.	*With the Movie Makers.*	Lothrop, Lee and Shepard Company
Collins, A. Frederick.	*Amateur Photographer's Handbook.*	Thomas Y. Crowell Company
Darrow, Floyd L.	*Masters of Science and Invention.*	Harcourt, Brace and Company
Davis, William S.	*Practical Amateur Photography.*	Little, Brown and Company
Eastman Kodak Company.	*How to Make Good Pictures.*	Eastman Kodak Company
Fabre, Jean-Henri.	*The Secret of Everyday Things.*	The Century Company
Fournier, d'Albe E. E.	*Wonders of Physical Science.*	The MacMillan Company
Fryer, Mrs. Jane.	*Stories of Everyday Wonders.*	John C. Winston Company
Gibson, Charles R.	*Great Inventions and How They were Invented*	J. B. Lippincott Company
Gibson, Charles R.	*The Motor Car and Its Story.*	J. B. Lippincott Company
Hall, A. Neely.	*Home Handicraft for Boys.*	Doubleday Doran and Company
Hiscox, Gardner D.	*Mechanical Appliances.*	The Norman W. Henley Publishing Company
Houston, E. J.	*The Wonderbook of Light.*	Frederick A. Stokes Company

Author	Title	Publisher
Houston, Robert A.	*Light and Color.*	Longmans, Green and Company
Pagé, Victor W.	*The Modern Gasoline Automobile.*	The Norman W. Henley Publishing Company
Parkman, Mary R.	*Conquests of Invention.*	The Century Company
Usher, Abbott Paysen.	*A History of Mechanical Inventions.*	McGraw-Hill Book Company
Williams, Archibald.	*Things to Make.*	Thomas Nelson and Sons

DEFINITIONS OF IMPORTANT WORDS

Al′pha Cen tau′ri: A star of the first magnitude in the constellation of the Centaur. It is the nearest star to the earth, about four and a half light years away.

angle of in′ci dence: In light, the angle which a ray of light makes with the surface it strikes.

angle of re flec′tion: The angle which a ray of light makes with the surface from which it is reflected. When a ray of light strikes a reflecting surface, the angle of incidence is equal to the angle of reflection.

brake: Any device for retarding or stopping motion, especially that of a wheel, by friction.

burning-glass: A double convex lens which, by concentrating the rays of the sun at a focus, is capable of setting fire to paper and other inflammable substances.

car′bu ret′or: The device in gasoline engines which combines air with the gasoline vapor to make an explosive mixture.

cen trif′u gal force: (From the Latin, *centrum*, center, and *fugere*, flee.) Force directed away from the center, as in the case of rotating bodies.

clutch: Any device for coupling or connecting two working parts of a machine, arranged in such a way that the parts may be connected or separated at will.

com pressed′: Condensed into a smaller space by pressure.

com pres′sion: The act of being compressed.

con′cave: Hollow and curved. The opposite of convex.

con′stel la′tion: (From the Latin, *con*, together, and *stella*, star.) A group of stars which really have no physical connection, but which appeared to the ancients to form figures in the sky. Most constellations are named for characters of ancient mythology.

con′vex: Bulging outward, like the surface of a globe. Convex lenses have bulging surfaces. The opposite of concave.

crank: A small handle usually attached to an axle and used to turn a wheel.

cyl′in der: A closed chamber in an engine, in which a piston is made to move by some force such as pressure of air or water, or the expansion of gases.

de vel′op ing: Chemically treating a sensitized surface, such as a photographic plate, in order to bring to view the invisible image produced by the action of light on the sensitized surface.

dis trib′u tor: A device for distributing the electric current of the ignition system of a gasoline engine so that it enters first one spark plug and then another, in a definite order.

ex haust′: To draw off. To drain the contents. In gas engines, the stage or cycle in which the used gas (after combustion) leaves the cylinder.

exhaust valve: The valve in the cylinder of a gasoline engine through which the exhaust gases, produced by explosion, are allowed to escape from the cylinder.

film: A flexible sheet of celluloid on which a layer of gelatine, containing sensitized salts used in photography, is spread.

fixing solution: A chemical solution that "fixes" or makes permanent a photographic image.

flywheel: A heavy wheel in an engine which revolves rapidly with the crankshaft and insures smooth operation of the engine by carrying the piston of the engine past the "dead centers."

fo′cus: The point at which rays of light, passing through a lens, are concentrated.

force: Any cause that tends to produce, stop, or change motion. Sometimes the term is used when we mean energy.

fric′tion: The rubbing together of two objects. This has the effect of hindering motion and of producing heat.

ful′crum: (From the Latin, *fulcre,* to prop up.) The support on or against which a lever rests or is operated.

grav′i ta′tion: The force of attraction between all bodies.

grav′i ty: The force with which all bodies are attracted toward the center of the earth.

horsepower: A unit of power equal to 33,000 foot pounds per minute; that is, the energy required to lift a weight of 33,000 pounds through a height of one foot in a minute.

ig ni′tion stroke: The stage in the cycle of a gasoline engine during which the spark from the spark plug ignites the explosive gas mixture in the cylinder, causing the gas to expand suddenly.

il lu′mi na′ted: (From the Latin, *luminare,* to enlighten.) Lighted up. Thus, the moon is illuminated by the sun.

in clined′ plane: A sloping plane. One of the so-called simple machines. It requires less force to haul a load to any height up an incline than directly up in a vertical line.

in er′ti a: Not having the power to move. The property of matter which causes it to remain in its state of rest or of motion unless acted upon by some force.

in flam′ma ble: (From the Latin, *flammare,* to flame.) Capable of being easily set on fire.

in′let valve: The valve in the cylinder of a gasoline engine through which the explosive gas enters the cylinder.

in′take: The stage, or cycle, in the action of a gas engine, during which the mixture of gas and air enters the cylinder.

lens: A piece of glass ground in such a way as to refract rays of light.

le′ver: A device, usually bar-shaped, for lifting heavy objects by reducing the amount of force necessary for the task. One of the so-called simple machines.

light year: The distance that a ray of light travels through a vacuum in one year. Light travels in a vacuum at the rate of 186,000 miles per second.

lu′mi nous: Glowing; giving light. The sun is a luminous body.

o paque′: (From the Latin, *opacus*, dark.) Not permitting rays of light to pass through.

per′i scope: An instrument used for seeing objects otherwise hidden by obstructions in the line of vision. A mirror in the telescope tube is held in a position higher than the obstruction and reflects an image of the object viewed, downward to another mirror. From this lower mirror the image is reflected into the eye of the observer.

phos′pho res′cent: (From the Greek, *phos*, and *phero*, to bear light.) Any substance that gives out (emits) light without much heat is said to be phosphorescent. Phosphorus is a good example.

pis′ton: A sliding piece, usually cylindrical in shape, that is moved back and forth in a closed cylinder by means of pressure.

plan′ets: Heavenly bodies that revolve around the sun. The word planet means wanderer.

plumb line: (From the Latin, *plumbum*, lead.) A cord from which a weight, formerly of lead, is suspended, to test verticality. Builders use it in construction of walls.

pow′er stroke: The stage in the cycle of an engine during which the explosion of gas in the cylinder causes the piston to move. It is so named because this is the stroke during which the real work of the engine is performed.

prism: A solid whose bases are equal, regular polygons, and whose faces are plane figures. Glass prisms are used for refracting light.

pul′ley: One of the so-called simple machines. A device consisting of a small wheel, or several wheels, rotating on an axle. The pulley is used for hoisting loads.

single pulley: A pulley with but one wheel.

double pulley: A pulley with two wheels on the same axle.

multiple pulley: A pulley with more than two wheels.

fixed pulley: A pulley suspended from a fixed point, such as a beam. It does not travel up and down with the load.

movable pulley: One so used that it travels up and down with the load, carrying the load with it.

re flect′: (From the Latin, *reflectere,* to bend back.) Generally used in connection with rays of light that are bent back.

re fract′: (From the Latin, *refrangere,* to break.) To break back. Rays of light that pass from one medium of light to another are bent if the density of the second medium is different from that of the first.

screw: One of the so-called simple machines. It is really an application of the principle of the inclined plane.

shaft: A long axle on which wheels or pulleys revolve, and to which belts are sometimes attached for running machinery.

sil′vered glass: Glass made into mirrors by the application of mercury (quicksilver) to the back to make a reflecting surface.

simple machines: The six labor-saving devices, namely: the lever, pulley, wheel and axle, inclined plane, wedge, and screw.

so′lar system: (From the Latin, *sol,* sun.) The sun and all the heavenly bodies that are subject to the sun's gravitational attraction. This includes planets, planetoids, satellites, and certain comets.

spark plug: The device in a gasoline engine which makes an electric spark to ignite the combustible gas mixture in the cylinder of the engine.

spec′tro scope′: An instrument which employs glass prisms to produce spectra of luminous bodies or gases (see spectrum).

spec′trum (plural, spectra): An image formed by rays of light that have been refracted by a glass prism. The rays appear in colors arranged according to the amount which each ray is refracted, therefore resembling a rainbow.

stars: Heavenly bodies of great size, extremely hot, and luminous. The sun is a star, brighter than the others only because it is much nearer.

steam: The result of heating water to its boiling point, 212 degrees Fahrenheit.

ste′re op′ti con: A device for projecting lantern slide photographs on a screen. The image is enlarged and inverted.

tel′e scope: (From the Greek, *tele*, far, and *skopeo*, see.) An instrument consisting of lenses in a tube, so arranged as to make distant objects more clearly visible than they would be to the naked eye. Astronomers use it to observe the heavens.

tim′er: A device connected with the distributor. It regulates the intervals between spark plug ignitions.

trans lu′cent: (From the Latin, *trans*, through, and *lucere*, to shine.) Permitting light to shine through without permitting objects to be seen clearly.

trans par′ent: (From the Latin, *trans*, through, and *parere*, to appear.) Permitting light to shine through so that objects may be seen clearly; opposite of opaque.

valve (see inlet and exhaust valve)**:** A device that opens or closes a passage, as in a pipe, to permit or to stop the flow of a liquid or a gas.

va′por: The gaseous form of a substance that is ordinarily a liquid or a solid. Thus, we speak of water vapor.

Ve′ga: A first magnitude star in the constellation, Lyra.

wedge: One of the so-called simple machines. The chisel and the ax are applications of the principle of the wedge.

wheel and axle: One of the so-called simple machines. The power is applied to the wheel and the resistance is overcome at the axle.

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