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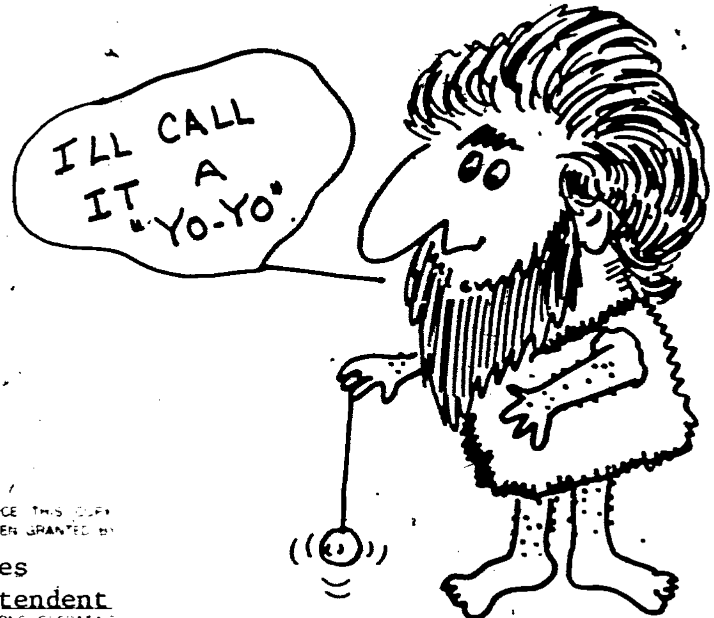
ABSTRACT

This minicourse was prepared for use with secondary physics students in the Dallas Independent School District and is one option in a physics program which provides for the selection of topics on the basis of student career needs and interests. This minicourse was aimed at providing students with an understanding of some basic physics principles by playing with toys that have been classified into five different groups on the basis of the principle that each demonstrates. The minicourse was designed for independent student use with close teacher supervision and was developed as an ESEA Title III project. A rationale, behavioral objectives, student activities, and resource packages are included. Student activities and resource packages involve experimenting with toys that demonstrate force and motion, heat and thermodynamics, wave motion and sound, the principles of light, and electricity and magnetism. (GS)

CAREER ORIENTED PRE-TECHNICAL PHYSICS

Physics of Toys

Minicourse



PRELIMINARY EDITION

1974

dallas independent school district

CAREER-ORIENTED PRE-TECHNICAL PHYSICS

Toys

Minicourse

ESEA Title III Project

1974

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This Mini Course is a result of hard work, dedication, and a comprehensive program of testing and improvement by members of the staff, college professors, teachers, and others.

The Mini Course contains classroom activities designed for use in the regular teaching program in the Dallas Independent School District. Through Mini Course activities, students work independently with close teacher supervision and aid. This work is a fine example of the excellent efforts for which the Dallas Independent School District is known. May I commend all of those who had a part in designing, testing, and improving this Mini Course.

I commend it to your use.

Sincerely yours,

Nolan Estes

Nolan Estes
General Superintendent

mfs

CAREER ORIENTED PRE-TECHNICAL PHYSICS TITLE III ESEA PROJECT

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CAREER ORIENTED PRE-TECHNICAL PHYSICS

PHYSICS OF TOYS

RATIONALE (what the minicourse is about)

You may be wondering how a knowledge of physics can help you in a career, or perhaps how physics can help you become a more responsible citizen. Three reasons for learning physics come immediately to mind:

First, physics is the most basic of all the physical sciences. Physics is the study of energy (that which makes real things "go," or which makes physical things "happen") and of matter (the real stuff of which the universe is made). The entire physical universe consists of nothing but energy and matter! And since only 20% of all high school graduates have studied physics, you can learn more about the universal nature (the basic "workings") of things than at least 80 out of every 100 citizens you might meet on the street.

Second, all technology is based upon the laws and principles of physics. Such fields as electronics technology, computer technology, business machine technology, automotive technology, construction technology, space technology; household sciences technology, medical technology, and the many other areas of engineering and industrial technology are built upon a solid foundation of physics principles. A person will certainly have a better prospect of success in any of these fields if she/he is equipped with a background in physics.

Third, the responsible citizen in a technocracy (machine-oriented society) such as ours is called upon regularly to vote upon physics-related issues. This is difficult to do without some knowledge of physics. Such issues concern the energy crisis (Should we build more nuclear reactors?), the national defense budget (Should we spend billions on anti-missile development?), public transportation (Should we build fleets of supersonic transports?), etc.

In this minicourse you will learn some technical physics principles by having fun playing with toys! These toys have been classified into the following five (5) groups:

1) Group-1 toys to demonstrate principles of force and motion (friction forces, gravity forces, distance, displacement, speed, velocity, and acceleration).
2) Group-2 toys to demonstrate principles of "disorderly motion" (heat and thermodynamics).
3) Group-3 toys to demonstrate principles of wave-related phenomena (longitudinal waves, sound, music, and related effects).

4) Group-4 toys to demonstrate principles of light (transverse waves, reflection, refraction, diffraction, color, and related effects).
5) Group-5 toys to demonstrate principles of electricity and magnetism (forces, fields, and related effects).

In addition to RATIONALE, this minicourse contains the following sections:

1) TERMINAL BEHAVIORAL OBJECTIVES (Specific things you are expected to learn)
2) ENABLING BEHAVIORAL OBJECTIVES (Learning "steps" which enable you to reach the terminal behavioral objectives)
3) ACTIVITIES (Specific <u>things to do</u> to help you learn)
4) RESOURCE PACKAGES (Instructions for carrying out the <u>Activities</u>, such as procedures, references, laboratory materials, etc.)
5) EVALUATION (Tests to help you learn and to determine whether or not you satisfactorily reach the terminal behavioral objectives.) These tests include:
   a) Self-test(s) with answers, to help you learn more.
   b) Final test, to measure your overall achievement.

TERMINAL BEHAVIORAL OBJECTIVES

Upon completion of this minicourse, you will demonstrate your level of knowledge and skill by:
1) using at least sixteen (16) toys to demonstrate principles of force, orderly motion, disorderly motion, wave motion, sound, light, electricity, and magnetism. (An explanation will accompany each demonstration.)
2) constructing a few toys to demonstrate some technical physics principles.

ENABLING BEHAVIORAL OBJECTIVE #1:

Use at least four (4) of the seven (7) toys studied in group-1 and explain how each toy demonstrates a principle of force or motion.

ACTIVITY 1-1

Read Resource Package 1-1 and pick out four (4) toys to play with. Answer all questions and do the <u>Investigations</u> related to them.

For greater understanding, examine material from Resource Package 1-2; do the same for the films and filmstrips in Resource Package 1-3.

RESOURCE PACKAGE 1-1

"Toys that Demonstrate Force and Motion"

Enabling Behavioral Objective	Activity	Resource Package
ENABLING BEHAVIORAL OBJECTIVE #1: (See page 2 for a statement of this objective)		RESOURCE PACKAGE 1-2 "Readings-Force and Motion" RESOURCE PACKAGE 1-3 "Films and Filmstrips"
ENABLING BEHAVIORAL OBJECTIVE #2: Use the steam engine and "Dunking Duck" to demonstrate a principle of physics related to heat, work, and/or disorderly motion.	ACTIVITY 2-1 Study Resource Package 2-1. Also study the material listed in Resource Package 2-2.	RESOURCE PACKAGE 2-1 "Toys That Demonstrate Principles of Heat and Thermodynamics" RESOURCE PACKAGE 2-2 "Readings - Heat and Thermodynamics"
ENABLING BEHAVIORAL OBJECTIVE #3: Use at least three (3) of the four (4) toys listed in group-3 to explain how each demonstrates a principle of physics involving wave motion and sound.	ACTIVITY 3-1 Read Resource Package 3-1 and pick out three (3) toys to play with. Follow the Resource Package instructions. For greater understanding, read from Resource Package 3-2 and study the filmstrips in Resource Package 3-3.	RESOURCE PACKAGE 3-1 "Toys That Demonstrate Wave Motion and Sound"
	ACTIVITY 3-2 Read Resource Package 3-4.	RESOURCE PACKAGE 3-2 "Readings - Wave Motion and Sound" RESOURCE PACKAGE 3-3 "Films and Filmstrips"

<u>ENABLING BEHAVIORAL OBJECTIVE #3:</u>		<u>RESOURCE PACKAGE 3-4</u>
(See page 3 for a statement of this objective)		"Noise"
<u>ENABLING BEHAVIORAL OBJECTIVE #4:</u>	<u>ACTIVITY 4-1</u>	<u>RESOURCE PACKAGE 4-1.1</u>
Use at least four (4) of the six (6) toys listed ~~in~~ group-4 to explain how each demonstrates a principle of physics involving light (include transverse waves, reflection, refraction, and color.)	Read Resource Package 4-1 and pick out four (4) toys to play with. Follow instructions carefully. For greater understanding, read from Resource Package 4-2 and view items from Resource Package 4-3.	"Toys That Demonstrate Principles of Light" <u>RESOURCE PACKAGE 4-2</u> "Readings - Principles of Light" <u>RESOURCE PACKAGE 4-3</u> "Films and Filmstrips"
<u>ENABLING BEHAVIORAL OBJECTIVE #5:</u>	<u>ACTIVITY 5-1</u>	<u>RESOURCE PACKAGE 5-1</u>
Use at least two (2) group-5 toys of the three (3) listed (at least one toy must be made by you), to explain how each demonstrates a principle of the physics of electricity or magnetism.	Read Resource Package 5-1 and pick out two (2) toys to play with. Follow instructions carefully. For greater understanding, read from Resource Package 5-2 and view the materials in Resource Package 5-3.	"Electricity and Magnetism" <u>RESOURCE PACKAGE 5-2</u> "Readings - Electricity and Magnetism" <u>RESOURCE PACKAGE 5-3</u> "Films and Filmstrips"
<u>EVALUATION</u>	<u>ACTIVITY 6-1</u>	<u>RESOURCE PACKAGE 6-1</u>
	If you feel you understand adequately the physics of the toys studied ask your instructor for Resource Package 6-1.	"Terminal Evaluation"

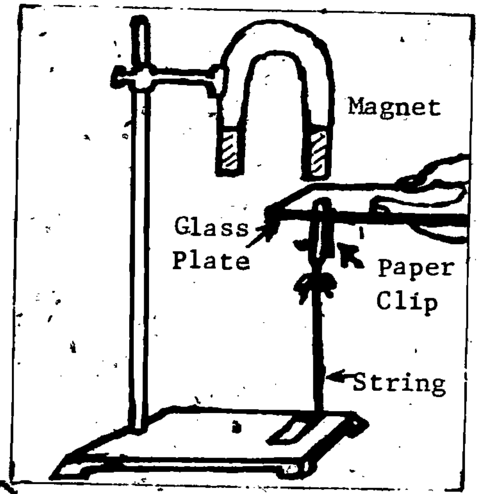
RESOURCE PACKAGE 1-1

TOYS THAT DEMONSTRATE FORCE AND MOTION

An understanding of a few principles of physics is necessary for an understanding of the operation of toys. You will be given a short summary of these principles in the Resource Packages. For more information and greater understanding of these, refer to the appropriate readings, films, and filmstrips presented in the last section of each Resource Package.

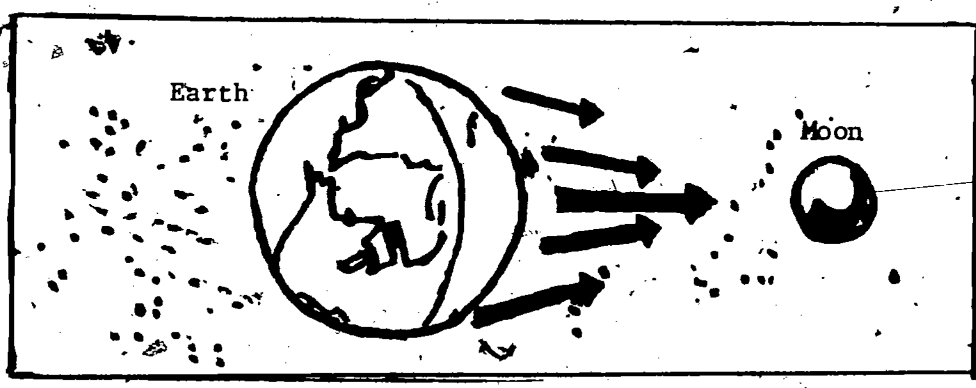
Force. To move an object which is at rest, to stop an object which is moving, or to change the speed or direction of an object which is moving requires the use of force. Force is defined as a push or a pull. Pushes and pulls have the two important properties of size and direction. (And whenever a force acts to change the motional state of an object, we say the force has accelerated the object.)

A force does not always "touch" (contact) the object it acts upon. Some forces can act at a distance. Examples of these are gravity forces, electric forces, and magnetic forces. See Figures 1 and 2.



Magnetic force acts at a distance and through the glass plate.

A MAGNETIC FORCE
Fig. 1



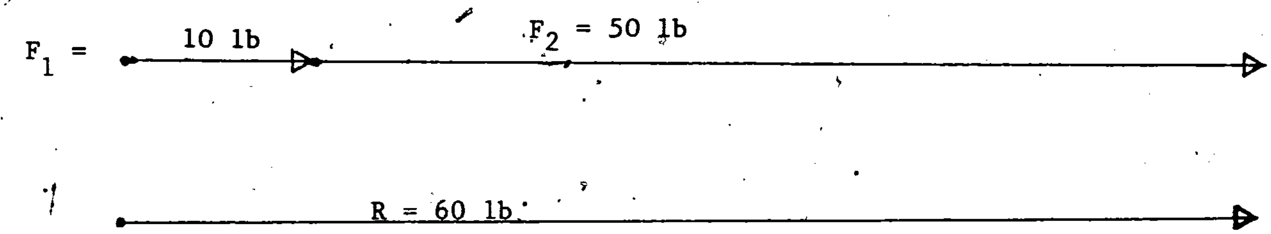
GRAVITY FORCE OF MOON ON EARTH
Fig. 2

__Gravity__ is the name given to a force which acts at any distance and which causes all objects in the universe to be mutually attracted to one other. For example, the earth gravity force pulls the moon toward the earth and thus holds it in an orbit around the earth. Of course, the gravity force of the moon pulls mutually upon the earth (See Fig. 2). This pull upon our ocean waters by the moon is a principal cause of tides. Did you know that the earth causes tides in the moon's crust? And earth tides, caused in the earth's crust by the moon, result in a change of several feet in the Washington Monument's elevation.

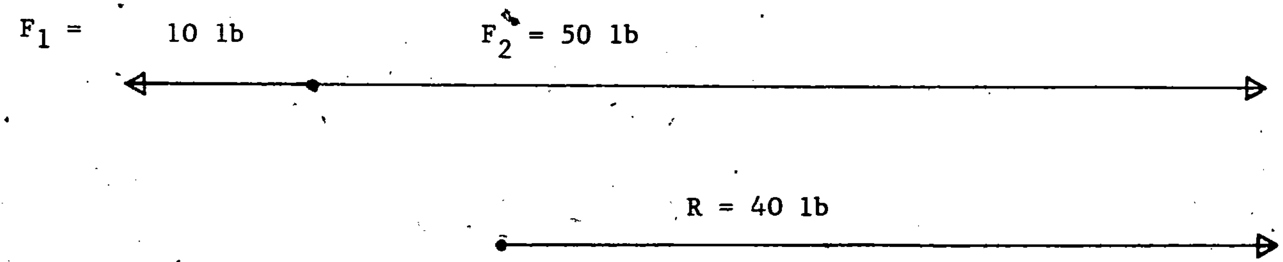
An understanding of forces and their effects will help you to better understand many devices (machines) in common use, as well as the operation of toys.

__Graphic (Picture) Representation of Force.__ Forces are often represented by __directed__ segments of a straight line. These dotted line segments are called __vector__ __representations__. Any physical measure which has __both__ a size and a direction qualifies as a __vector__ __quantity__ and can be represented by a line segment whose length is scaled to represent __size__ and whose __direction__ is specified by an arrowhead ($\rightarrow$).

__Some Ways To Combine Vectors Graphically.__ We can use pictures (vector arrows) to represent the effects of combining vector quantities. In the case of forces, when two forces act along a straight line the __resultant__ (effective) __force__ is equal to their __vector__ __sum__. See Figs. 3 and 4.

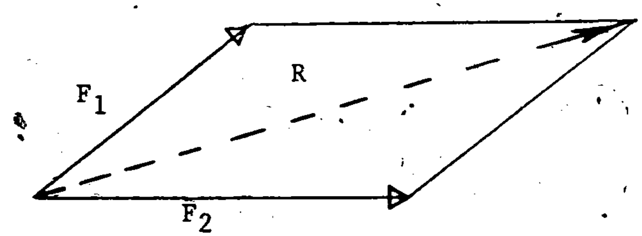


FORCES ACTING ALONG LINE (SAME DIRECTION)
Fig. 3



SAME FORCES ACTING ALONG LINE (OPPOSITE DIRECTIONS)
Fig. 4

When two forces act at an angle, the resultant vector force can be found from the diagonal of the parallelogram formed by the two force vectors. Your reference readings and/or your teacher can explain how the resultant can be found graphically, trignometrically, or algebraically.



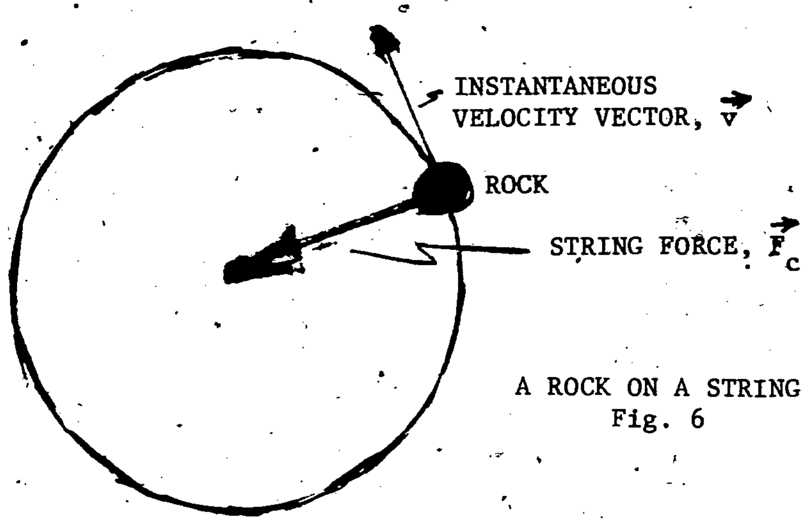
RESULTANT (DIAGONAL OF PARALLELOGRAM)
Fig. 5

Friction. Friction forces always oppose the motion of an object in contact with another object.

States of motion. To describe something's motional state (motional condition), we can say it is: (1) at rest, (2) moving linearly (along a line), (3) moving angularly (spinning), or (4) moving linearly while spinning. Further, we say whether or not the object is accelerating. To accelerate is to change linear speed, change angular speed, change direction of translation (linear motion), or change direction of spin axis. Spin is always around an axis, and to tilt or to tip this axis is to change the spin direction.

How States of Motion Change. To change the motional condition of an object requires a force (push or pull) or a moment (twist). For example, if a car is parked in your yard on a level surface it does not suddenly "take off" by itself. The car will move if the engine is started and the gears are engaged so as to move the wheels. It will move, also, if a wrecker tows it, some people push it, etc. But the car will stand still forever unless it is moved by some force.

Centripetal Force. Whenever something moves in a circular path you can rest assured than an accelerating force is acting upon it. Non-accelerated objects are in both linear and rotational equilibrium and so must move in straight lines at constant speeds if they are translating. The force which "bends" the path of an object in a circle is called the centripetal force. Centripetal derives from "center seeking" and reminds us that this force is always directed toward the center of the curved path. See Fig. 6 below:



A ROCK ON A STRING
Fig. 6

Even though the rock whirls around the center at a constant rate (constant angular speed), the rock is always accelerated by the "center seeking" force F_c acting along the string.

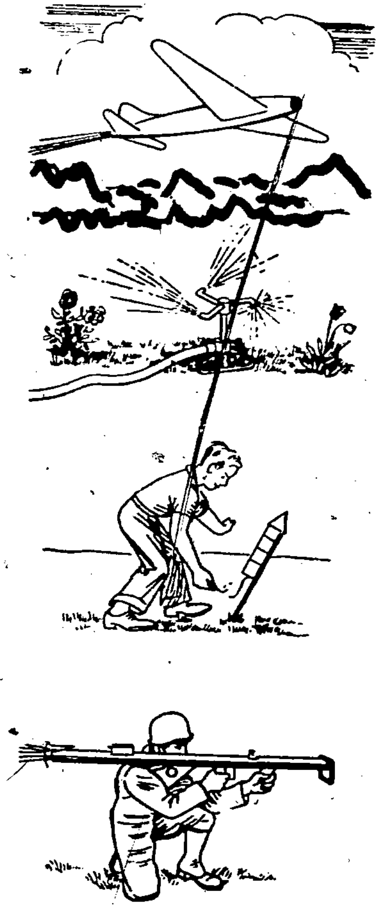
Laws of Motion. Sir Isaac Newton, a genius to rival even Einstein, discovered some great laws of physics over 300 years ago. His descriptions of force and motion are commonly called his Laws of Motion and are frequently expressed as follows:

a) Newton's First Law of Motion (Equilibrium Law). Bodies at rest remain at rest forever, unless disturbed by an outside force. Bodies in steady motion* remain in steady motion forever, unless disturbed by an outside force.
b) Newton's Second Law of Motion (Acceleration Law). When an unbalanced force or moment** acts upon a body, it accelerates that body in the direction of the force or moment. The acceleration produced is directly proportional to the force.
c) Newton's Third Law of Motion (Action-Reaction Law). Whenever one body exerts a contact force upon a second body, the second exerts an equal and opposite force upon the first. For every contact action there is an equal and opposite reaction. (See Fig. 7)

There are some precise terms used in the technology and science of motion. Some of these are vector terms because they imply both a size and a direction. Others are scalar terms because they imply only a size. Study the following terms:

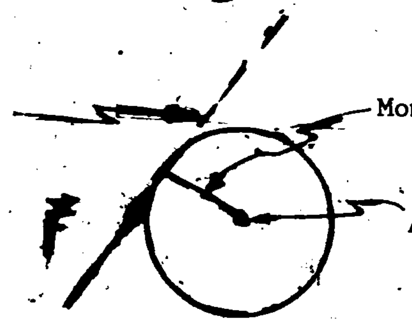
a) Distance. Length of path from one position to another (scalar).
b) Displacement. Length and direction of path from one point to another (vector).
c) Speed. Rate of change of position; rate of distance traversed (scalar).
d) Velocity. Rate of change of displacement; rate of change of direction and/or speed (vector).
e) Acceleration. Rate of change of velocity, rate of change of magnitude or velocity direction (vector). For example, you can accelerate a car by speeding up, by slowing down, or by changing direction. Also, you accelerate a rock tied to a string when you whirl it around your head at constant speed because you are continually changing the rock's direction.

* Steady motion means non-accelerated linear and/or rotational motion.
** A moment is a torque or twist; this concept will be discussed in later sections.



EXAMPLES OF ACTION-REACTION
Fig. 7

More On Rotary Motion. In the real world, things rotate as well as translate (move linearly). So an understanding of rotary (circular) motion is just as important as an understanding of linear motion. When a force acts on an object which is free to move about an axis, the force results NOT in a linear effect but rather in a twisting-about-the axis effect called a moment or torque. A push (force) on a wheel rim can produce a moment (torque) which can cause a rotation of the wheel (See Fig. 8 below).



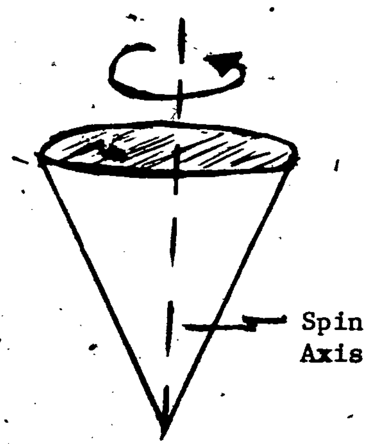
VECTOR MOMENT (TORQUE)
Fig.8

To calculate the size of the twist (moment), the length of the perpendicular distance from the force's line of action to the rotational axis is multiplied by the force size.

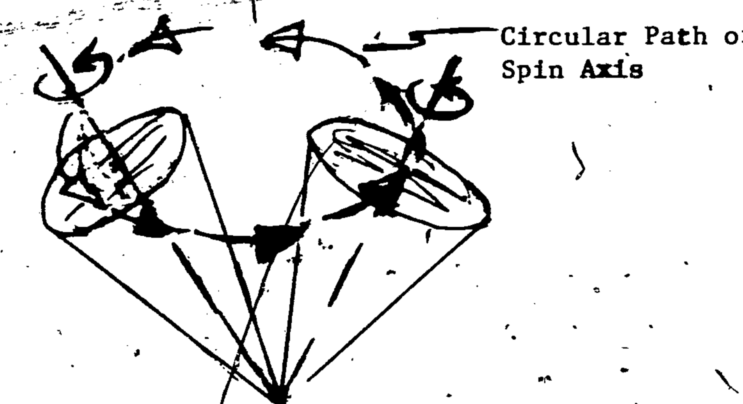
In this case the perpendicular distance is the wheel radius.

$$\underset{\text{(Moment)}}{M} = \underset{\text{(Perpendicular Distance)}}{r} \times \underset{\text{(Force Size)}}{F}$$

The direction is obviously clockwise. A moment (like a force) is a vector quantity; this moment has a size (rF) and a direction* (clockwise; as viewed from above). Consider Figs. 9 (a) and 9(b); diagrams of a spinning top. Study the terminology (labels) carefully.



TOP SPINNING RAPIDLY
Fig. 9 (a)



TOP SLOWING DOWN
Fig. 9(b)

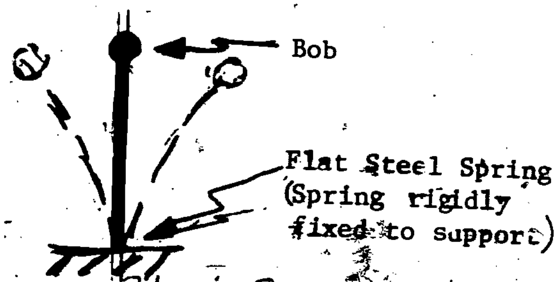
* For a more precise statement of vector moment direction see Section II of minicourse Basic Machines - The "Nuts and Bolts" of Physics.

The Greek letter <u>omega</u> (ω) is used to represent angular speed, or angular velocity when the orientation of spin is indicated.

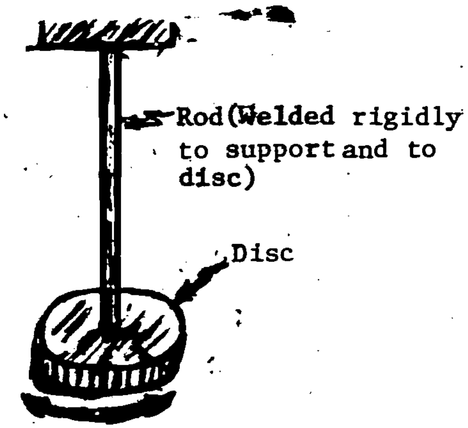
In Fig. 9 (a), the rapidly spinning top's axis is stabilized (fixed) in space.

In Fig. 9 (b) the spin axis of the slower spinning top is "circling in space," this rotation (circling) of the spin axis is called <u>precession</u>.

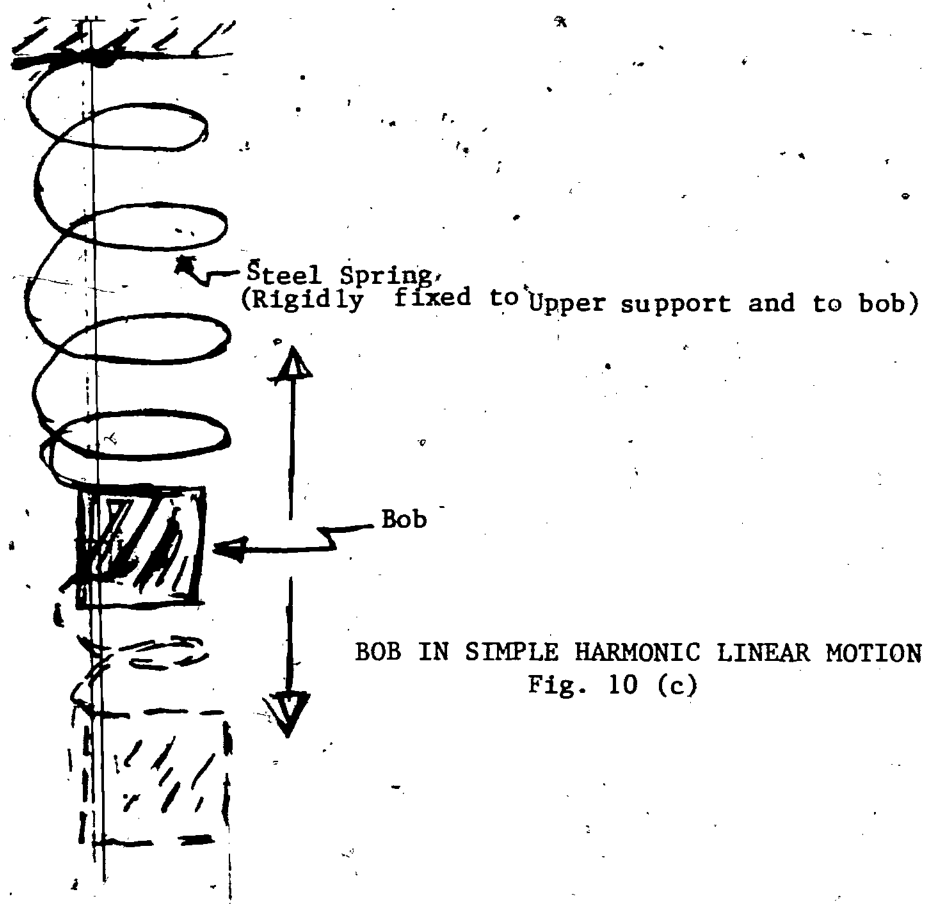
<u>Simple Harmonic Motion</u>. This is a very special, yet common type of motion which occurs in nature. In simple harmonic motion, an object continually moves back and forth over a definite path in equal intervals of time. The path of a pendulum bob of a grandfather clock <u>approximates</u> simple harmonic motion. Figs. 10 (a), (b), and (c), below illustrate some types of harmonic motion.



BOB IN SIMPLE HARMONIC LINEAR MOTION
Fig. 10 (a)



DISC IN SIMPLE HARMONIC ANGULAR MOTION
Fig. 10 (b)



BOB IN SIMPLE HARMONIC LINEAR MOTION
Fig. 10 (c)

Conservation of Momenta. A basic principle of physics is that of momentum conservation. This principle tells us that when the bodies within an isolated system (collection of bodies) interact (collide, or otherwise act upon one another), then the momenta properties of the system must ~~be~~ conserved. In other words, the system's total momenta before the interaction occurs must equal the system's total momenta after the interaction. Mathematically, it is possible to represent two kinds of momentum properties of objects; both are treated as vector quantities:

1) linear momentum, $\vec{P}$. Mathematically $\vec{P}=m\vec{v}$, where m is the inertial mass property of a body and $\vec{v}$ is its linear velocity. Inertial mass may be thought of as the measure of that property of all objects which causes them to resist linear acceleration.

2) angular momentum, $\vec{L}$. Mathematically $\vec{L}=I\vec{\omega}$, where I is the inertial moment property of a body and $\vec{\omega}$ is its angular velocity. Inertial moment may be thought of as the measure of that property of all objects which causes them to resist angular acceleration.

Energy and Work. Mechanical energy is often classified as potential (static) or kinetic (motional). An un-fired rifle cartridge is associated with potential energy (chemical potential energy); after firing, this potential energy of the cartridge is converted to the mechanical kinetic energy of the moving bullet. This exemplifies the Conservation of Energy Principle.

The mechanical linear kinetic energy of the moving bullet is expressed mathematically as $\frac{1}{2} mv^2$*; the rotational kinetic energy is expressed mathematically as $\frac{1}{2} I \omega^2$*. The work done on the bullet by the released chemical energy of the gun powder shows up as the linear kinetic energy of the speeding bullet and the rotational kinetic energy of the spinning bullet.**

This exemplifies the Work-Energy Principle: work done on a system results in an energy change of that system equal to the amount of work done.

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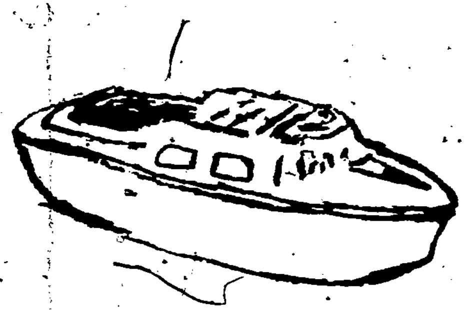
* The equations are discussed in your textbooks; consult your instructor if these equations are of further interest to you.

** Rifles are rifled. This means that their barrels have grooves inside them to impart spin to bullets because spinning bullets are more stable in flight; see your textbook, The Physics of Sports minicourse and the Ballistics Bullets and Blood minicourse for further explanations.

THE WATER-JET BOAT

The water-jet boat is a toy which demonstrates an application of Newton's Third Law of Motion (Action-Reaction Law). It also demonstrates the principle of conservation of linear momentum. See Fig. 11.

The hull of the water-jet boat contains a small heat chamber (boiler). Connected to the underside of this chamber are two metal tubes which have their open ends at the stern (one on the starboard and one on the port). Between the open ends of the tubes is a rudder. Underneath the heat chamber is a small metal cup to accomodate a small candle.



WATER-JET BOAT
Fig. 11

Investigation I. Take a medicine dropper and squirt some water into one of the tubes until the boiler chamber is filled. The boiler is filled when water comes out of the other tube. Now place the boat in the water and prepare to light the candle. (To fix the candle to the cup, light it and let some wax drip off into the cup. Place the candle base into the melted wax, which anchors the candle as it cools.) Place the candle underneath the boiler, light the candle, and very soon the boat will begin to move.

Heat energy from the candle brings the water in the boiler nearly to the boiling point. The heated water expands in the boiler chamber and this pressure drives a bit of water out of <u>one</u> of the tube ends. The bit of water leaving the tube causes a momentary decrease in pressure in the boiler and in the other tube end. Atmospheric pressure on the other tube end drives a bit of cool water into the boiler. The cycle then repeats itself; therefore, a series of pulses of ejected bits of water drives the boat. Since the tubes are on both sides of the rudder, the boat goes either clockwise or counter-counterwise depending on which tube is taking in or letting out bits of water. Of course, changing the position of the rudder affects the direction of boat movement.

Why The Boat Moves. An explanation of the boat's motion can be found in the Conservation of Linear Momentum Principle. This Principle implies that if you were standing in a boat near a shoreline and suddenly jumped shoreward, the boat must move away from the shore. It implies that if you are motionless on a skateboard and jump off it in one direction, the skateboard will move off in an opposite direction. If we release an inflated balloon, it speeds off in one direction as it deflates and spews air in the opposite direction. This Principle is also known as action-reaction.

In the case of our boat, it is quite free to move over the water in a direction opposite to the "spitting" of the bits of water backward out of the tube. The backward momentum of many bits of water is compensated for by the forward momentum of the boat, as it must be to conserve the linear momentum of the system.*

*Precisely speaking, this system of boat-and-bits-of-ejected-water is not completely isolated, principally because of the "outside" force of friction between the hull and water, which tends to slow the boat down (so total linear momentum is not conserved).

Impulse. Related to momentum is the concept of impulse. An impulse is defined as that which produces a change in the momentum of a body. Linear impulse can be expressed mathematically as the product $\vec{F}$ (Δt), where $\vec{F}$ is the vector force and Δt is the time interval over which this impulse force acts. Angular impulse can be expressed as $\vec{M}\,(\Delta t)$, where $\vec{M}$ is the vector moment (torque) and Δt is the time interval that the impulse moment acts.

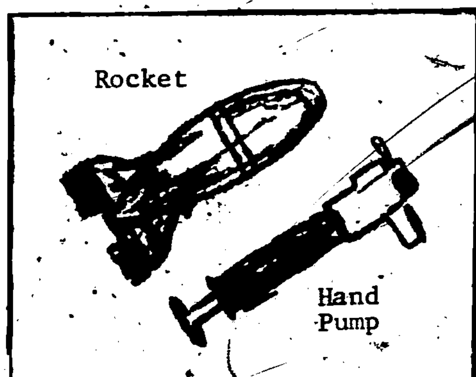
In terms of linear impulse, a bit of water ejected backward by the boiler pressure (force) has its linear momentum changed in accordance with $\vec{F}\Delta t = m\,\Delta\vec{v}$. The $\Delta\vec{v}$ tells us that the "boiler force" results in a change in the speed of the boat such that $m\,\Delta\vec{V}_{(water)} = M\,\Delta\vec{V}_{(boat)}$ In other words, conservation of linear momentum tells us that the change in water momentum in a backward direction must equal the change in boat momentum in the forward direction.

Evaluation. When you have finished investigating the boat and studying the resource material, write out responses to the following. Turn them in for evaluation.

1) In your own words, why does the boat move?
2) What factors govern the speed of the boat?
3) Does a jet plane propel itself by "pushing backward" against the atmosphere? Why or why not?
4) Assume you are marooned on a flat, frictionless surface and have no tools. Devise a means of moving across that surface.

THE WATER ROCKET

The water rocket is a toy which can be used to illustrate some physics of rocket propulsion. This toy is truly a rocket-propelled missle. Its hull is made of plastic; it is about 8 inches long and about 2 inches in diameter at the midsection; and the tail section has a ¼-inch exhaust opening. A hand pump fits over the exhaust opening. See Fig. 12. A funnel is provided to facilitate fueling the rocket with water.



WATER ROCKET
Fig. 12

You are to play with this toy and to investigate some related physics. To operate the rocket, first fill about one-third of the rocket fuel chamber with water. Then lock the hand pump onto the orifice (opening for the exhaust) and pressurize the fuel chamber by pumping 15 to 20 times.

Point the rocket skyward, free the pump-locking mechanism, and pull the launch trigger. The pressurized water will rush out the nozzle and the rocket will be driven some 300 feet or more into the air. If fired horizontally from shoulder height, the rocket's range is 100 feet or more. The quantity of water (fuel) ejected is governed by the pressure built up in the fuel chamber by the hand pump, as is the speed of the ejected water. Also, the greater the load of water the lower the speed of the rocket, since the rocket has the additional weight of any unexpelled water to carry upward with it.

You will find that in flight the rocket is aerodynamically stable because it is <u>spin stabilized</u>. Its direction of spin is governed by adjustment of the tail fins and the spin velocity is governed by the pitch of these adjustable tail fins. The rocket trajectory is parabolic, and the rocket falls nose first. You can vary the rocket's range and altitude by varying its angle of firing.

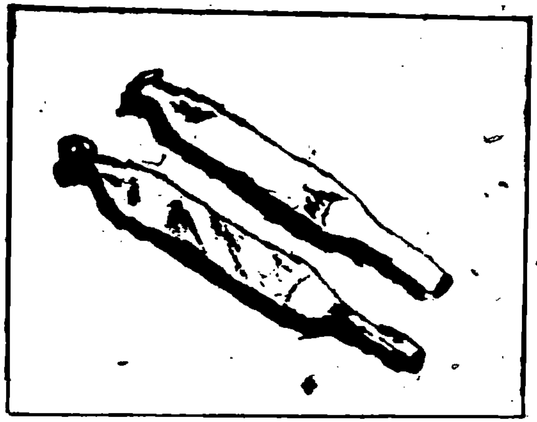
The rocket thrust can be accounted for in terms of linear momentum conservation and energy conservation. Mechanical energy is stored in the fuel chamber as the air is compressed by the hand pump (pressure energy). Once the trigger mechanism is fired, this energy is converted to motional energy of the rocket. Further, at the instant of launch the system of the rocket and its load can be considered as isolated. In terms of momentum conservation, as the water rushes out the exhaust the rocket must acquire an equal and opposite momentum such that the momentum of the rocket forward exactly equals the momentum of the water backward. Can you see that if the linear momentum <u>before</u> launch is zero (no $\vec{v}$ in the momentum product, $\vec{P} = m\vec{v}$), then for linear momentum to be conserved the momentum product <u>$m\vec{v}$ of the rocket</u> forward must at all times be <u>precisely</u> equal to the momentum product <u>$m\vec{v}$ of the water</u> backward?

Write out responses to the following and turn them in to your teacher (unless directed otherwise).

1) Does the rocket need the atmosphere to push against? That is, does the <u>effluxing</u> (out-going) fuel need the air to push against?
2) Consider the statement: This toy works <u>best</u> where there is no air (in a vacuum). Explain your reasons why this statement is valid or invalid.
3) At what approximate firing angle does the rocket:
   a) reach the highest altitude?
   b) have its farthest range?
4) Can a rocket go faster than its exhaust? Hint: Consider the equation $\vec{P} = m\vec{v}$.
5) You have read and have seen that the rocket is spin-stabilized.
   a) Relate this stability to Newton's First Law. Hint: Consider <u>inertial</u> <u>moment</u>.
   b) In question 2, did you consider the rocket's stability as a part of "works best"?
   c) Would this rocket be spin-stabilized if fired in a vacuum?
   d) How might one launch a space craft and then spin stabilize it if it were in a vacuum after launch? Note: Many space vehicles <u>are</u> spin-stabilized, and manned space vehicles are sometimes spun to produce an artifical gravity effect!

THE AIR BALLOON ROCKET

The air balloon rocket is a device which can also be used to illustrate Newton's Third Law of Motion and conservation of momentum. The rocket balloon is an elongated rubber balloon with a flattened mouthpiece at its open end. See Fig. 13. The balloon is inflated by mouth or by pump.



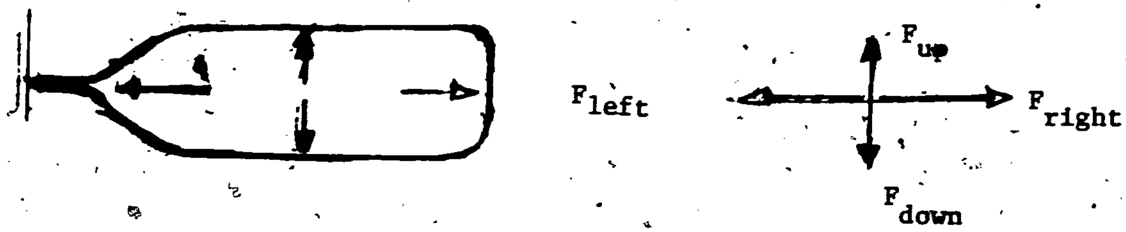
ROCKET AIR BALLOONS
Fig. 13

Inflate the balloon. Hold the mouthpiece closed until ready to launch. When you release the mouthpiece, the pressurized air will rush out (backward) and the reaction effect will cause the balloon to be driven forward. The flight trajectory will be erratic and the sound of the escaping gas will vary in pitch (frequency) and in intensity (loudness).

Mechanical energy is stored in the balloon's compressed air (pressure energy) and in the balloon's stretched wall material (elastic potential energy). When you release the balloon, this potential energy is converted to the kinetic energy of the ejected air and to the kinetic energy of the balloon as it drives opposite the direction of the expelled air.

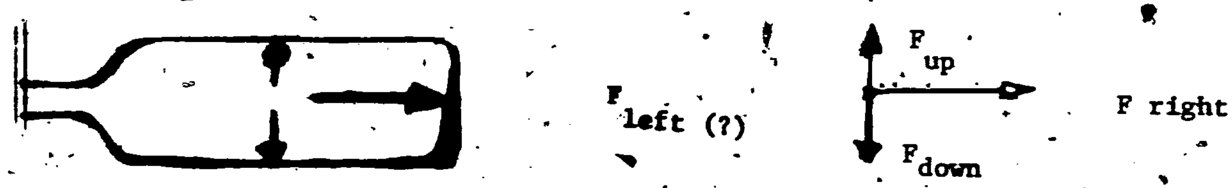
The compressed air molecules within the balloon exert a pressure on the inside wall of the balloon. This pressure is <u>equal at all points</u> on that inside surface. This pressure is also exerted at the <u>orifice</u>

(mouthpiece opening). Consequently, as the air rushes out of the balloon the force exerted by the air molecules on the <u>front</u> inside wall is NOT the same as is exerted on the back inside wall because the mouthpiece opening is essentially no wall at all! This results in an <u>unbalanced</u> force on the balloon, acting in the forward direction. So the balloon must be driven forward in accordance with Newton's Second Law of Motion. See Fig. 13 (a) below.



INFLATED BALLOON, EXHAUST END CLOSED
Fig. 13(a)

Air pressure inside is the same in all directions*; therefore; all forces up = all forces down, and, all forces left = all forces right. There is no unbalanced force to produce an acceleration. The balloon is at rest.



INFLATED BALLOON, EXHAUST END OPEN
Fig. 13 (b)

* You will read about gas pressures and Pascal's Law in the reference material for Activity 2.

Examine Fig. 13(b). Air pressure inside is the same in all directions; therefore, all forces up equal all forces down. BUT the forces right inside of the balloon must be greater than the forces <u>left</u> inside of the balloon <u>because</u> <u>no</u> <u>wall exists</u> at the orifice (opening) on the left side.

Can you see that an <u>unbalanced</u> <u>inside</u> force exists to the right, and that from Newton's Second Law ($\vec{F} = m\vec{a}$) the rocket must experience an acceleration in the direction of the force $\vec{F}$?

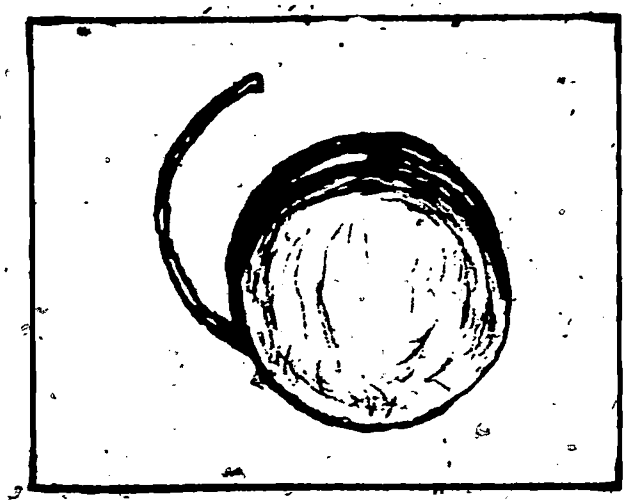
If you recall that $\vec{F}\Delta t = m\Delta\vec{v}$ (the impulse-momentum relation), then you can see that the unbalanced impulse force ($\vec{F}$) acts on the right wall during the time (Δt) that the air is expelled. This impulse produces a <u>change</u> in the balloon's momentum. So the balloon speeds away from the exhaust gases, and both linear momentum and mechanical energy are conserved for the balloon-compressed air system.

Answer at least four (4) of these questions and turn them in to your teacher:

1) How does the rocket balloon propulsion relate to that of the water-jet boat and the water rocket?
2) What are some factors which govern the time of flight of the balloon? (For example, if you double the volume of the balloon during inflation, do you double the flight time?)
3) Do you think the pressure in the balloon increases as the balloon gets larger during inflation?
4) Where do you suppose the sound of the balloon rocket comes from?
5) Is the balloon rocket aerodynamically stable?
6) List three (3) devices or techniques used to obtain stability in flight.

THE YO-YO

The Yo-Yo is a toy that can be used to demonstrate the inertial properties of matter, conservation of energy, and the effect of friction forces. The Yo-Yo is essentially a spool with a very short, small diameter waist around which a string is wound. (See Fig. 14). The string then behaves quite like an inclined plane on which the spool rolls. An inclined plane is one of the simple machines of technical physics (See the minicourse Basic Machines - The "Nuts and Bolts" of Technical Physics).



THE YO-YO
Fig. 14

To operate the Yo-Yo wind the string around the spool; hold the free end, and let the spool fall so that the string unwinds. At the opportune moment, you can apply a gentle upward jerk and the Yo-Yo will rewind itself (climb up the string). With skill this process can be repeated over and over again, in a cyclic fashion.

Observe that as the spool is released a torque (moment) is applied on the spool by the string. As the Yo-Yo falls, it is losing potential energy of position in the earth's gravity field and this loss is resulting in a gain of motional kinetic energy. Because of the moment produced by the string, part of this kinetic energy is rotational; and the rest is linear kinetic energy. So the Yo-Yo does not fall as fast as a body in free-fall; a Yo-Yo which is dropped will reach the ground sooner than one which must unwind as it falls.

When the lower end of the path is reached, the Yo-Yo has a large amount of rotational kinetic energy. The Yo-Yo will then start to climb the string. But it cannot reach the same height from which it fell unless it is helped (jerked). This is principally because of energy losses to friction effects. A jerk at the right moment gives the needed energy for the Yo-Yo to climb to the top of the string.

When you have finished playing with this toy and reading the resource material, write out responses to the following:

1) In your own words, define inertial moment.
2) Describe the Yo-Yo cycle in terms of conservation of energy. Assume no friction and don't forget that both linear and angular kinetic energy are relevant here.

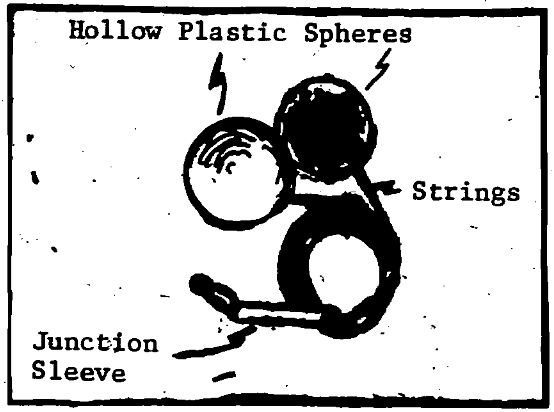
*Optional Exercise. Obtain a large spool with a large axle. Wrap a cord about the axle and pull on the cord at different angles and with different magnitudes, to produce different kinds of motion:

1) Can you produce rotation clockwise?
2) Can you produce rotation counterclockwise?
3) Can you produce translation backward?
4) Can you produce translation forward?

Try to account for your observations.

THE DOUBLE BANSHEE

The Double Banshee is a toy useful for illustrating centripetal force.



DOUBLE BANSHEE
Fig.15

The Double Banshee consist of two identical thin-walled hollow plastic spheres which are fixed to two strings about 2 feet long. See Fig. 15. An acoustical (sound) hole is drilled through the thin wall of each ball. The ends of the strings are joined in such a way as to allow shortening or lengthening either string by slipping the junction sleeve.

Hold the junction of the string in your right hand (for a right-handed person). With your left hand hold one ball at arm's length, while the other ball hangs vertically on its string. Your right hand now sets its ball moving in a vertical circle, counter-clockwise. After this ball has completed a few orbits and its motion has been stabilized, your left hand will project its ball into a vertical, circular path which is clockwise. You now have both balls moving in circular paths in opposite directions. This takes a little practice and is easier to accomplish if you observe that the right hand (which holds the string juction sleeve) must execute an up-and-down harmonic motion of small amplitude. Some operators put the spheres in motion by laying them on the floor, separated from each other, and then suddenly pulling up on the junction sleeve. Try it, you might like it!

Because these balls are hollow and have a hole on one side, when they are in motion the air inside is set into vibration and a "howling" sound results. The Banshee is so named because of this wailing sound.

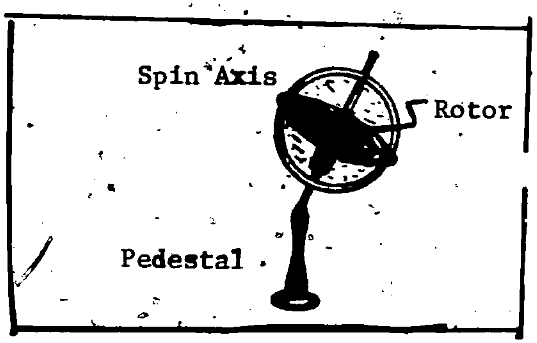
Observe that a centripetal force must be impressed to keep the balls going in a circle. The trick to operating a Double Banshee is to provide centripetal acceleration to both spheres simultaneously. While you operate the Double Banshee, have a classmate look at the rotations of the spheres from behind, from the front, and from the sides.

The following questions are to be answered after you have finished playing with this toy and reading the resource material concerning it. Turn these in for evaluation.

1) What contribution is made to the motion of the spheres by the motion of the hand? Hint: Consider friction, mechanical energy, and sound (acoustical) energy.
2) Why does an observer who faces the operator perhaps say that "they are going in the same direction"?
3) How do these hollow chambers "speak" or "howl"? Explain the physics of this very simply, perhaps by comparison to human body vocal parts and functions.

THE GYROSCOPE

The gyroscope is a device which can demonstrate angular momentum. The gyroscope consists principally of a wheel (rotor) whose weight is concentrated around its rim and whose axle is mounted so as to spin freely. See Fig. 16. Gyroscope effects can be observed when the wheel is spinning.



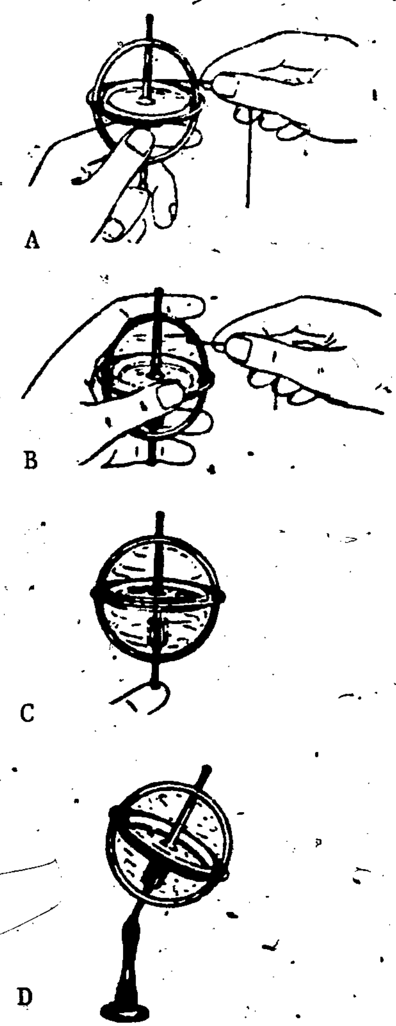
GYROSCOPE
Fig. 16

Place the end of the string used to spin the rotor just barely through the hole in the shaft. (See Fig. 17A). Then turn the rotor until the string is wound completely along the shaft. (See Fig. 17B). Now, hold the gyroscope frame, and pull firmly on the string to set the rotor in motion. As the rotor starts to turn and the string starts to unwind, increase the pull to achieve a maximum rotation.

Place the spinning gyroscope on the tip of your finger and notice how it tends to hold its position in space even when you move your hand. (See Fig. 17C).

Next, place the spinning gyroscope on the pedestal. (See Fig. 17D). Observe that as the force of gravity tries to topple the gyroscope over on its side, the gyroscope takes a sideward motion around the pedestal stand. This motion of the gyroscope axis is known as precession. Did you know that the rotor earth processes and "dips"* cyclically as it moves about the sun?...this "wobble" of the earth's rotational axis has given rise to the theory that the earth is losing rotational energy because of tidal and atmospheric and other frictional effects and is behaving somewhat like a top which is slowing down.

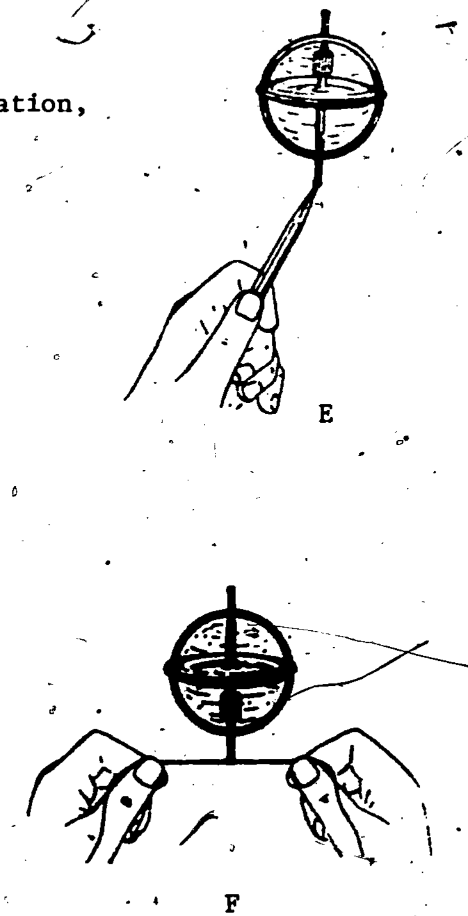
*If you are further interested, have your instructor refer you to some simple treatments of the earth's procession and nutation.



THE GYROSCOPE
Fig. 17

If you place the rapidly-spinning gyroscope on the end of a pencil held in a straight-up position and then slant the pencil at different angles of inclination, the gyroscope remains upright (See Fig.17E). This is the basic principle used to maintain man-made satellites and space ships in spin-stabilized flight.

Now grasp the spinning gyroscope by both projecting tips (stems), and move your hands quickly around in such a way that you change the direction in which the tips are pointing. The resistance that the gyroscope sets up against such rapid changes is called inertial moment. When a fin-stabilized rocket is fired into a space it may experience considerable wobbling until it reaches the flying speed for which it was designed. Here again, a gyroscope is often used to assure smoother flight. Huge gyroscopes have even been used to stabilize ships at sea.



THE GYROSCOPE
Fig. 17 (cont.)

Last, place the slotted end of the gyroscope stem on a piece of string held tautly between your hands or tied between two objects. (See Fig. 17F.) By raising or lowering one end of the string, the gyroscope can be made to "walk" back and forth.

The behavior of the gyroscope can be accounted for using the concepts of force, torque, Newton's Laws of Motion, inertial moment, and angular momentum. <u>Duplicate</u> the following chart on a sheet of paper, complete the blank spaces, and submit this for evaluation:

Figure	Applicable Newton's Law	Applicable Physics Principle
17C		
17D		
17E		
17F		

To understand better the principle of conservation of angular momentum, consider Fig. 18 below.

CONSERVING ANGULAR MOMENTUM
Fig. 18

a) If the axle of the spinning wheel is carefully placed in the robot's hands, no motion of the robot-wheel combination results. The robot remains motionless and the wheel spins undisturbed.

b) If the axle of the spinning wheel is placed directly overhead in the robot's hands, as in (a) above, and the robot is commanded to support the axle with one hand and to reach up and stop the spinning wheel rim with its free hand, then conservation of angular momentum would require that the robot and stopped wheel must rotate together with an angular momentum IDENTICAL to that of the wheel when it was spinning freely. This means that although the freely-spinning wheel is stopped with respect to the robot, the two now rotate together in the same initial direction of wheel rotation, but at a lesser speed.

c) If the robot had first been handed a motionless wheel to hold directly overhead in a vertical position and then had been commanded to reach up with its free hand and to set the wheel into a spinning motion, precisely equal in spin magnitude and in spin direction to the initial spinning wheel of (b) above, then the robot must end up spinning with an angular momentum precisely equal to that of the wheel it has set spinning freely, but in the opposite spin direction to the wheel; again, angular momentum must be conserved.

Do you get the idea of rotational momentum conservation?

Ask your instructor for a bicycle wheel and rotating stool, or similar pieces of equipment. Duplicate the preceeding wheel-and robot-activities a, b, and c.

Also, try holding the spinning wheel in front of you and turning yourself and your stool by rotation of the axle of the spinning wheel. Can you see how "gyro" steering and "gyro" positioning might be used in space?

THE OLD-FASHIONED TOP

The old-fashioned top (Fig. 19) is a device that may be used to relate torque to angular momentum. This top is cone-like in shape, is solid, and has a metal peg on one end. A string is wound around the top in a single layer from the peg end upward. This string is used to pull on the top and thereby provide the torque necessary to set it spinning. Wind the string about the top, and hold the free end of the string tightly in your fingers. Throw the top down toward the floor, and at some angle to the vertical. As the top falls, the string pulls on the top. As the string unwinds the top is spun faster and faster until finally it is spinning upright on the floor balanced on its peg. The surface on which it lands should be rough enough for slipping not to occur.

OLD-FASHIONED TOP
Fig.19

When the unbalanced torque (due to the string) is applied to the top, the top is accelerated angularly. This angular acceleration results in an increase in angular velocity. In other words, the torque acts through some angular distance and does <u>angular work</u>. The work done on the top must result in an energy change (Work-Energy Principle) for the top; this shows up as the rotational kinetic energy the top acquires ($KE = \frac{1}{2} I \omega^2$, where I is the <u>inertial moment</u>, and ω^2 is the square of the size of the angular velocity).

So if the string force does rotational work in the top, it changes its motional state.) At the same time that the motional state is changed, the momentum state must change. This means that as the rotational kinetic energy, $\frac{1}{2} I \omega^2$, changes, so does the angular momentum $I \vec{\omega}$.

RESOURCE PACKAGE 1-2

READINGS - FORCE AND MOTION

Books

*1) Kelly, William C., and Thomas D. Miner, Physics for High School, Ginn and Company Publishers, Boston, Massachusetts, 1967:

Motion in a Straight Line	pages 29-47
Forces that Accelerate Bodies	pages 100-115
Gravitation and Projectiles	pages 120-136
Momentum and its Conservation	pages 141-155

**2) Miller, Julius Sumner, Physics Fun and Demonstrations, First Edition, Central Scientific Co. Publisher, Chicago, Illinois, 1968:

The Water Rocket	pages 15-17
The Rocket Balloon	pages 47-48
The Musical Yo-Yo	pages 11-14
The Double Banshee	pages 20-21
The Gyroscope	pages 27-29
The Old-Fashioned Top	pages 30-31
The Water-Jet Boat	pages 3-5

***3) Schaum, Daniel, Schaum's Outline of Theory and Problems of College Physics, 6th Edition, McGraw-Hill, New York, New York, 1961.

*It is not necessary to read all of these references. Be selective, but do try to read a little about each topic. Research studies indicate that the more you read about something the more you know about it!

**This one should be especially interesting to you.

***To understand the problem-solving aspects of physics, this easily-read paperback is highly recommended.

4) Verwiebe, Frank L., and Others, <u>Physics, A Basic Science</u>, Fifth Edition, American Book Co., Dallas, Texas, 1970:

Velocity and Speed	pages 15-20
Accelerated Motion	pages 21-28
Circular Motion	pages 29-36
Simple Harmonic Motion	pages 37-41
Falling Bodies and Projectiles	pages 42-48
Newton's Three Laws of Motion	pages 62-90
Universal Gravitation	pages 91-97

RESOURCE PACKAGE 1-3

FILMS AND FILM STRIPS

Films:

Laws of Motion (11 minutes)

Rockets: How They Work (16 minutes)

Film Strips:

Force Called Gravity

How Do Jets Fly?

Rocket Power For Space Travel

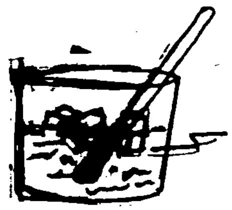
Rocket To The Moon

RESOURCE PACKAGE 2-1

TOYS THAT DEMONSTRATE PRINCIPLES OF HEAT AND THERMODYNAMICS

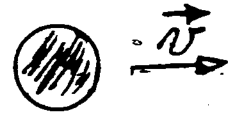
Heat and Temperature. The word heat is defined operationally in technical physics. This means that heat is a blanket-kind of word (a generic word) defined in terms of what can be observed "in operation." For example, if a "hot" potato is placed alongside a "cold" potato in an insulated container, the "hot" potato cools and the "cold" potato warms and both potatoes eventually reach the same temperature. In this example, heat can be defined as the energy which always "flows" from a hotter to a colder body. This operational definition proposes only that heat is an energy phenomenon and it transfers always in the "hotter - to - colder" direction. The operational definition is based not upon what heat is, but upon - what heat does (how heat "operates").

Heat energy is not an easy thing to measure. We never measured the heat energy of the "hot" potato, we simply implied that it was at a higher energy condition than the "cold" potato. But temperature is easy to measure, and such a measure would assure us that the hot potato had a higher temperature than the cold potato. It would also assure us that the two potatoes were at the same temperature, finally. But at no time would the thermometer ever actually measure the heat energy of either potato! All any thermometer can do is compare the temperature condition of two systems; it can never measure heat energy.



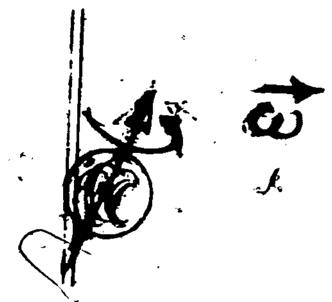
ICE AND WATER
(A)

Diagram (A) shows ice and water at the same temperature. But ice definitely has less heat energy at this $0^{\circ}C$ temperature. The heat energy state of the water must have been reduced to freeze it!



SPHERICAL MOLECULE TRANSLATING
(B)

Diagram (B) shows a spherical molecule translating; this molecule has translational kinetic energy. When we measure the temperature we really measure the additive (cumulative) effects of the translational motions of a bunch of gas molecules (You can easily measure your body temperature, but how could you possibly measure the temperature of a single body molecule?). It turns out that for a gas, its temperature results only from the translational kinetic energy of its molecules.



SPHERICAL MOLECULE SPINNING
(C)

Diagram (C) shows a spherical molecule spinning; this molecule has rotational kinetic energy. The heat energy of a gas includes the effects of such contributions as a molecule's rotational kinetic energy. But the <u>temperature</u> measure due to the spin contributions of a system of gas molecules is zero! (Because there is no translational motion.) Can you see that to measure the heat energy of a gas would include measuring more than simply the temperature of the gas?

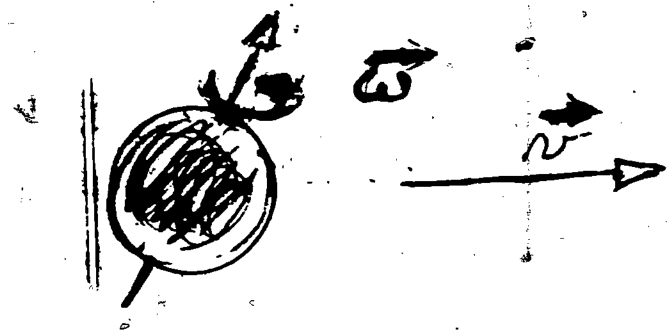
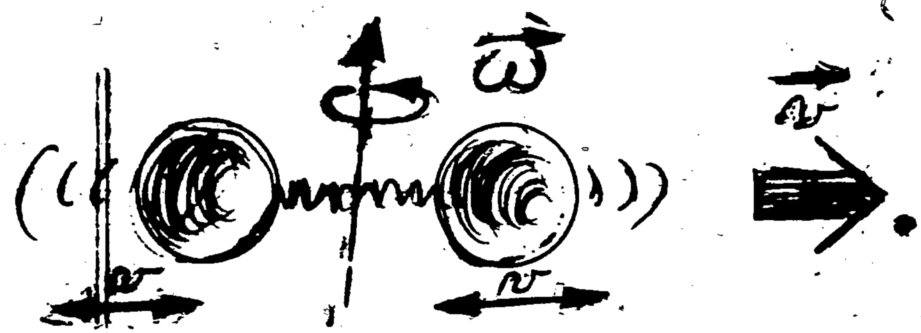


Diagram (D) shows a spherical gas molecule which is simultaneously translating and rotating. <u>Temperature</u> of a gas composed of such molecules would represent the sum of the average <u>translational</u> <u>kinetic</u> <u>energies</u> of all of the gas molecules, but heat energy would represent the averaged sum of both the <u>linear</u> <u>and</u> <u>rotational</u> <u>energies</u> of all of the gas molecules.



(E)

Diagram (E) shows a diatomic (2-atom) molecule translating with a velocity $\vec{v}$, while each atom is linearly vibrating back forth ($\leftrightarrow$); and all the while the molecule spins with angular velocity $\vec{\omega}$. This is a more complicated example of possible modes of molecular vibrations and energies. Heat represents a measure of all the molecular energy modes of a system of gas molecules; temperature represents only a measure of a gas system's translational kinetic energy modes.

In a summary, heat can be thought of as a higher energy condition of matter, and temperature as a comparison of a special energy condition of two systems of matter (where the thermometer is one system, and the other system is the object whose temperature is to be compared).

Thermometers. Ordinary thermometers are based upon a precisely defined temperature, the so-called triple point of water. Under very special conditions of temperature, pressure, and volume a "balance" of liquid water, water vapor, and ice can exist. We say that the three phases (states) of water coexist in thermodynamic* equilibrium, and it is this triple point temperature (0.01° Celsius**) which is used to calibrate modern thermometers.

It turns out that the standardized freezing point of water is 0° Celsius (32° Fahrenheit), and its boiling point is 100° Celsius (212° Fahrenheit).

* Thermodynamics is the branch of technical physics devoted to heat and related phenomena.
** Sometimes called centigrade.

In technical work, an absolute or Kelvin temperature scale is often used. This scale reading can be found by adding 273 to the Celsius reading; for example, $30^\circ C \Rightarrow 30 + 273 = 293^\circ K$.

An equation for converting from Fahrenheit to Celsius is, $C = 5/9\ (F - 32)$.

TO DO: Place tap water and ice in a calorimeter (a styrofoam container will do). Insert a thermometer and stir the mixture until the thermometer reading becomes relatively stable (stops falling). Immerse your fingers in the ice and water mixture.

1) Is the ice or the water colder?
2) Should the ice and water have the same heat value?
3) Are heat and temperature the same thing?

Write out these answers and submit them for evaluation.

Thermodynamics. Heat has been defined as the sum of the molecular energy conditions of a system, and temperature as has been defined as the comparison of a special energy condition of two systems. Now thermodynamics is defined as the study of the energy states of a system. For example, in a system made up of gas molecules the system's state is determined by such variables as temperature, pressure, and volume. A thermodynamic equation (description) of such a system is the gas law:

$$PV = kT$$

Where P stands for the gas pressure
V stands for the gas volume
k is a constant (universal gas constant)

If numbers and equations are not your "trip," then $PV = kT$ may appear a little "spooky." But the equation is merely a shorthand way of saying that for a fixed amount of gas, a change in any one of the properties P, V, or T will have a predictable effect on the remaining two properties. So if we are clever we can know in advance, for example, what will happen to the pressure of a gas of fixed volume when its temperature is raised.

Thermodynamics of a gas can be used to explain the operation of the automobile gasoline engine. A volume of gas (gasoline-air mixture) is changed in temperature (spark plug ignited), causing the pressure in the piston chamber (cylinder) to rise. This pressure moves the piston and ultimately does the work of moving the automobile.

Thermodynamic Definitions. These technical thermodynamic definitions may be useful:

a) calorie. Heat required to change the temperature of 1-gm mass of water by 1 degree Celsius (specifically from 14.5°C to 15.5°C).

b) BTU (British Thermal Unit). Heat required to change the temperature of 1-lb mass of water by 1 degree Fahrenheit (specifically from 63°F to 64°F).

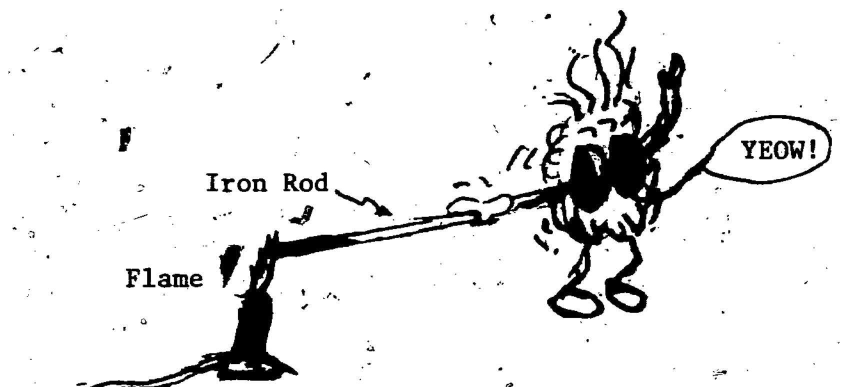
c) specific heat. Heat required to change the temperature of a unit amount (gm, lb) of a substance by 1 degree.

Different substances change temperatures by different amounts when the same amount of heat is added to each! Specific heat is a measure of this difference.

d) mechanical equivalent of heat. A calorie of heat is about the equivalent of 3 ft·lb of mechanical work, or about 4 joules of mechanical work. A BTU of heat is the equivalent of 778 ft·lb of mechanical work.

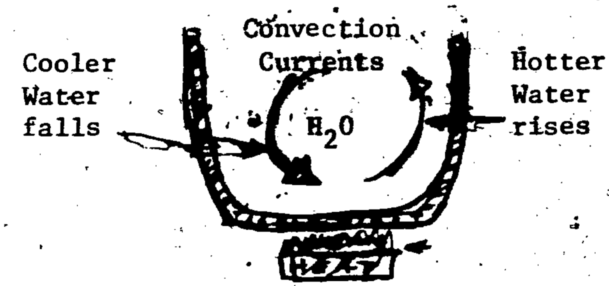
Mechanical energy can be transformed into heat form and vice versa.

e) conduction. Transfer of heat energy by contact on a body-to-body basis, as between two solids in contact (See diagram on following page).



CONDUCTION

f) convection. A "conduction" transfer of heat energy due to convection of the individual particles of a fluid. A cooler portion of a fluid system moves first toward a heat source, is heated as its constituent particles contact the source, moves away from the source as a now-hot fluid, and is replaced by cooler fluid moving in to be heated by conduction at the heat source. The name for this cycling of colder and warmer portions of a fluid is convection.

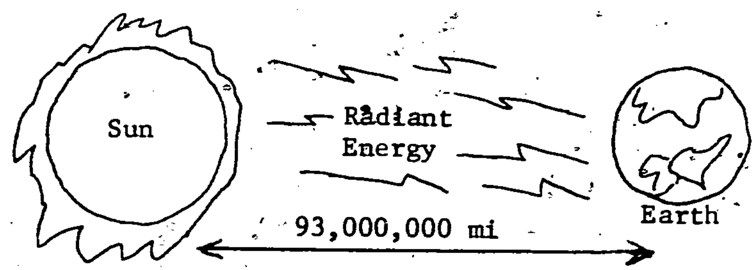


CONVECTION

The rising of the mass of water particles heated by contact with the vessel bottom (conduction) and the falling of the non-heated heavier mass of water particles constitute what are known as convection currents. These currents result in transport of portions of the water first toward and then away from the heat source. The individual particles (water molecules) receive heat energy by conduction when they contact the hot surface of the vessel. Convection, then, is just a special case of conduction transfer for fluid systems.

g) radiation. Indirect means of obtaining heat transfer. All bodies emit (give off) and absorb (take in) energy known as electromagnetic energy. This energy can be converted to heat energy.

Radiant Energy and Heat Energy. Consider an object high in heat energy as compared to its environment. It will radiate more electromagnetic energy to its environment than it will absorb. It will cool off as it radiates, and the environment will warm up (conservation of energy) even if the object never touches (contacts) its surroundings. Study the following diagram.



The sun radiates electromagnetic energy to the earth. The earth never touches the sun and there are no materials between sun and earth for conduction or convection transfer to occur, yet the earth is heated by solar energy absorbed from the sun.

What happens? Well, very simply, the sun's atoms emit radiant energy. When the radiant energy is absorbed by earth atoms it is transformed into heat energy. This transformation is a microscopic phenonemon (happening) at the atomic level.

So you see, heat energy is <u>not</u> really transferred by radiation. Heat energy does <u>not</u> transport through space! Radiant energy travels from source to absorber, where it is then transformed into heat energy.

In radiant energy transfers, materials having rough and dark surfaces make good absorbers and good radiators while materials having bright and polished surfaces make poor absorbers and poor radiators.

<u>Some Special Cooling Effects</u>. Cooling effects can be produced by melting (ice cubes), by evaporation (wet clothes on a winter day) and by expansion (orifice of a pressurized can.)

Matter is sometimes classified as to its <u>state</u> (or <u>phase</u>). Three common categories are solid state, liquid state, and gas (vapor) state. A fourth is the <u>plasma</u> state, a gas-like state characterized by extremely high temperatures and electrically-charged particles.

Whenever a substance undergoes a change of phase, heat energy is either taken into the substance or released from the substance. When water evaporates for example, the effect is cooling because water must <u>absorb</u> heat energy from its surroundings in order to change from the liquid phase to the vapor phase.

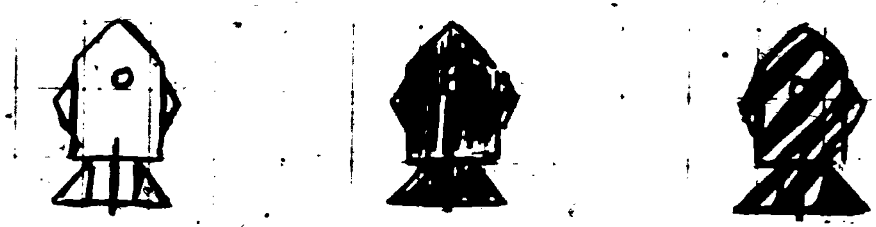
Energy-wise, the solid phase is less energetic than the liquid phase, which is less energetic than the vapor phase for a given substance. For example, if one removes heat energy from water the liquid solidfies, and if one adds heat energy the liquid boils.

Steam Engines. Steam engines are usually classified according to their working parts (reciprocating of rotary), according to their exhaust systems (non-condensing and condensing), and according to their steam expansion systems (simple or compound).

Internal combustion engines. These engines are classified according to fuel (gasoline, diesel, etc), according to number of cylinders (4,8, etc.), according in cylinder arrangement (V, in-line, opposing, etc), and according to their intake-compression-combustion-exhaust cycle. Gasoline engines are usually four-cycle or two cycle.

Evaluation. Write out responses to the following and submit them for evaluation.

1) Consider these three spacecraft, identical except for paint:



All Silvered (a) | All Black (b) | Striped (c)

As these craft orbit they are exposed to the sun for 12 hours and to the darkness for 12 hours. During the sun hours, which craft would likely overheat? Which craft would likely cool off slowest during the dark hours? Which craft represents a compromise between the extremes? Do you know that spacecraft are sometimes painted alternately light and dark for the reasons pertinent here?

2) Ask your teacher for a hand pump (bicycle pump, athletic ball pump, or the like). Pump vigorously against some back pressure, (a) Does the pump barrel get warmer? (b) Discuss the energy relationships involved in this body - pump - air system. Include chemical energy (food), mechanical energy (muscles, air pressure), heat energy, and Conservation of Work-Energy Principle.

3) Many people are "calorie conscious", yet are mis-informed as to the true nature of the word calorie when it is used to represent the heat equivalent of foods. In science, a calorie has a mechanical equivalent. For example, one calorie is the heat energy sufficient to do about 3 ft-lb of mechanical work. But where the calorie values for foods are concerned, the food industry's calorie is 1,000 times larger than the scientific one! In other words, a food industry rating of a "150-calorie" soft drink would be a scientific rating of 150 kilocalories; i.e. 150,000 calories!

How many ft-lb of work represents the mechanical equivalent of a 150-calorie soft drink? If 1 horsepower equals 550 ft-lb/sec, approximately how many horses would be needed to perform an amount of work in one second which would be equivalent to the energy (work) of this soft drink? Perform these calculations and submit them for evaluation.

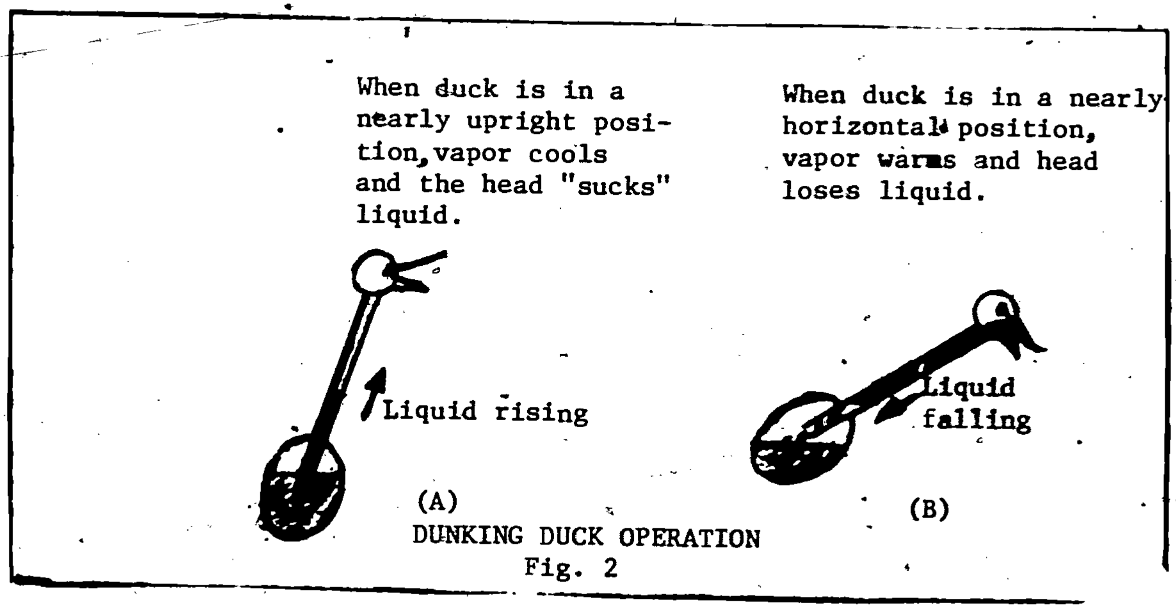
THE DUNKING DUCK

The Dunking Duck is a toy which operates on thermodynamic principles. The toy consists of two glass bulbs (a "head bulb" and a "belly bulb") connected by a glass tube which is mounted on a transverse (wing-to-wing) axle. The bulbs contain a liquid which vaporizes readily, usually ether. The upper bulb is decorated with eyes and a beak to resemble a duck or other bird, and the stand is shaped to resemble the bird's feet. The head is covered with felt or some other porous liquid-absorbing material. See Fig. 1.

DUNKING BIRD
Fig.1

First, immerse the heat part completely in some water to get it wet. Then balance the bird by inserting the crosspiece in the two slots provided in the stand. Take care not to bend the crosspiece. Also, the bird toy is delicate and must be handled with care.

The bird is now placed in a <u>nearly</u> upright position and has a soaked head. Naturally, evaporation of water will take place from the wetted head part. The cooling that results will decrease the ether gas pressure inside the head, and ether gas pressure in the lower bulb will drive liquid ether up the tube neck toward the head (The <u>lower end of the neck tube</u> is <u>below</u> the surface of the liquid ether in the lower body). See Fig. 2 (A).



DUNKING DUCK OPERATION
Fig. 2

This rising fluid gives rise to a tipping moment about the axis, and the duck dips its head downward. The tipped duck's neck gets in such a position that the <u>lower open end of the neck tube</u> is <u>above</u> the surface of the liquid in the lower body. See Fig. 2 (B). The liquid in the head now runs back into the lower body and the duck tips back up. Once started, the cycle is repeated as long as there is water available to the head.

<u>Cooling During Evaporation</u>. When a liquid evaporates, it absorbs heat energy from its surroundings. In the case of the duck's head, heat energy is taken from the ether vapor and it cools. As the ether vapor cools, its vapor pressure must drop if the tube volume is constant. This follows from the

law for ideal gases: $PV = kT$. If V is constant, $P = \frac{k}{V}T$. Another way of looking at the gas law for constant volume is $P = CT$, where C is a new constant $(\frac{k}{V})$. Can you see that if T drops, and V is constant, P must decrease also? If you don't see this, consult your teacher and Resource Package 2-2.

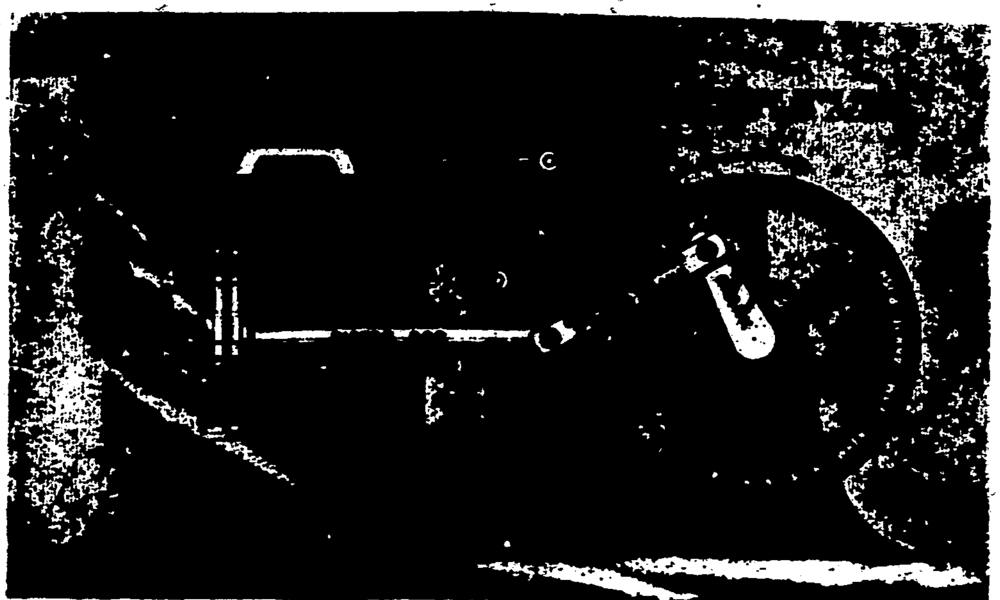
Pascal's Principle. This Principle is sometimes stated as "Whenever the pressure of a confined liquid is changed by a given amount, the change is transmitted equally to all parts of the liquid." Can you relate this Principle to the operation of the Dunking Duck toy?

Questions. Write out answers to these, and turn them in for evaluation:

1) Would you expect the frequency of dipping to be increased by wetting the head with a liquid more volatile than water? Why or why not?
2) What observable effects are produced by operating the duck: (a) in the sun? (b) in the breeze (in a fan path, a ventilating duct outlet, etc)? Actually place the duck in different situations of this kind before answering these questions. Account for your answers.

THE STEAM ENGINE

The toy steam engine is a device which demonstrates the conversion of heat energy to mechanical energy. Steam engines may be classified according to their working parts (reciprocating and rotary); according to their exhaust systems (non-condensing and condensing); and according to their steam expansion systems (simple or compound).



THE STEAM ENGINE
Fig. 1

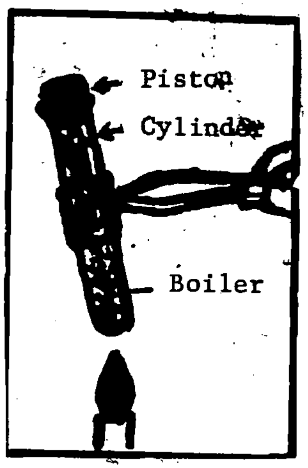
Fig. 1 illustrates the components of the engine so that you can see how it works. The steam comes from the boiler through pipe 1. It enters the steam chest 2, and moves past the slide valve 3. Then it passes through an opening into the cylinder, where it presses against all sides of the cylinder and the piston 4. Thus the steam pushes the piston to the right and turns the flywheel. Soon the piston stops because the crank will not let it go any farther.

Just before the piston stops, the rods attached to the slide valve move the valve to the left of the position shown by dotted lines so that the steam can escape from the left end of the cylinder and go out through the <u>exhaust pipe</u> 5. At the same time, the steam from the boiler can go into the right end of the cylinder and push the piston back. When the piston reaches the left end, the slide valve changes and again the piston is pushed to the right. This cyclic action is repeated over and over again. The <u>connecting rod</u> and the <u>crank</u> change the linear motion of the piston into rotary motion of the flywheel.

There are two points at which the piston cannot move the crank and flywheel, no matter how great is the steam pressure. These points are at the "dead" ends of the cylinder when the connecting rod and the crank are in a straight line (when the piston is extreme left or extreme right in Fig. 4.). These two places are sometimes called the "dead points", and the crank is said to be on "dead center." The flywheel is massive and thus has a large inertial moment property. Therefore, when it has been started by the push of the piston it acquires an appreciable angular momentum and tends to keep on turning and carrying the crank past the dead points.

First fill the boiler of the engine to the halfway mark on the water guage. Next, close the <u>whistle valve</u> and the <u>steam valve</u> to the cylinder. Then plug the connecting cord into an electrical outlet. When steam has built up sufficiently, open the steam valve and observe how the engine gradually builds up speed as the steam pressure rises.

You know that coal and other fossil fuels contain a large amount of potential energy (chemical energy). Early researchers and inventors wondered how the chemical energy hidden in fuel might be made to turn the wheels of machines and thus do work? Historical records show that ancient inventors studied this problem 1,800 years ago and that the problem was finally solved quite successfully about 175 years ago. This solution marked the beginning of the so-called Industrial Revolution and laid the foundation for our current technological society (machine-oriented society).



PISTON-CYLINDER ANALOG
Fig. 2

Heat, water and a test tube fitted with a loose cork stopper is a steam power plant of sorts. One end of the tube is the boiler where water is converted to steam, the other end is the cylinder with cork piston (See Fig. 2) Of course the steam engine has a separate boiler to produce steam, has a piston that fits closely inside the cylinder, and which never leaves the cylinder, etc. But if the test tube steam pressure moves the cork, there it has performed mechanical work and thus met the criteria for a very simple kind of steam power plant. CAUTION: DO NOT TRY THIS TEST TUBE EXERCISE! The glass will explode if the cork becomes stuck! Ask your teacher for a cork with manometer; then you can safely do this steam piston demonstration. You can also ask your teacher for a Hero's engine apparatus. This is a Greek steam toy invented about 2,000 years ago. You will have fun watching it operate.

After you have finished playing with the steam engine and reading resource material about it, do the following:

1) Write a simple description of how each component listed below affects the <u>flywheel</u> of a steam engine:

   (a) piston (b) piston rod (c) crank (d) slide valve (e) slide valve <u>eccentric</u>.

2) Relate the components of exercise 1, above, to a modern automobile internal combustion engine. Consider such factors as number of cylinders, source of energy, number of pistons, connecting rods, crankshaft, piston rings, carburetors, etc.

RESOURCE PACKAGE 2-2

READINGS—HEAT AND THERMODYNAMICS

1) Kelly, William C. and Miner, Thomas D., Physics for High School, Ginn and Company Publishers, Boston, Massachusetts, 1967:

Heat—the Disorderly Motion	pages 298-313
Heat and Work	pages 317-331

2) Miller, Julius Sumner, Physics Fun and Demonstrations, Central Scientific Co., Chicago, Illinois, 1968:

The Dunking Duck

*3) Schaum, Daniel, Schaum's Outline of Theory and Problems of College Physics, 6th Edition, McGraw-Hill, New York, New York, 1961.

4) Verwiebe, Frank L., and other, Physics, A Basic Science, 5th Edition, American Book Col, Dallas, Texas, 1970:

Temperature and Expansion	pages 149-154
Heat and Energy	pages 155-164

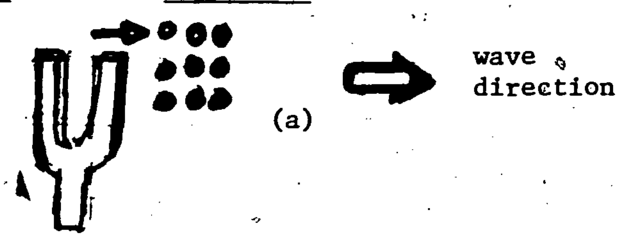
*This one is really helpful in problem-solving and in presenting a thumb-nail sketch of a physics topic.

RESOURCE PACKAGE 3-1

TOYS THAT DEMONSTRATE WAVE MOTION AND SOUND

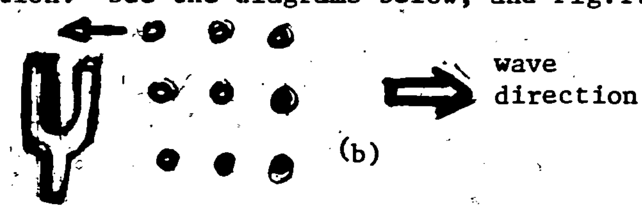
The science of sound is called acoustics, and sound plays a large part in our daily lives. Think what a world without sound might be like: no talking, no bird calls, no music, no telephones, no radios, etc. A silent world would seem alien, indeed! Sound adds such a rich and varied dimension to our lives. Yet how many of us have any understanding of what makes the differences between the wide varieties of sound we hear?

The Nature of Sound. Sound is produced by vibrating objects. Vibrating objects cause sound waves in air by alternately pressing air tightly together (making it more dense) and then relaxing to let the air "thin out" (making it less dense). This rhythmic compression and expansion of air produces longitudinal type waves. A longitudinal wave is a wave which travels (propagates) through a material by making its particles vibrate (oscillate) to the direction of wave propagation. See the diagrams below, and Fig.1.



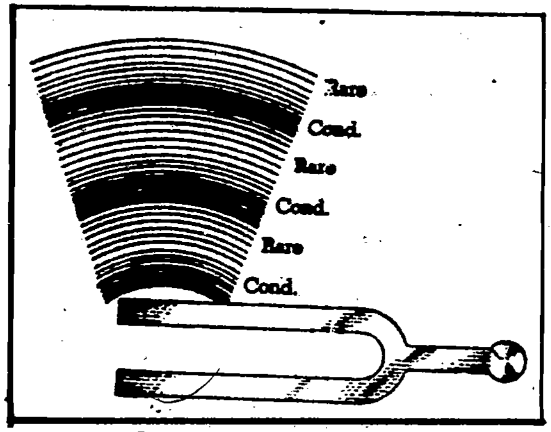
(a)

Tuning fork tine moves right compressing the air molecules (producing what is known as a compaction)



(b)

Tine moves left de-compressing the air molecules which spring apart (producing an anti-compression, known as a rarefraction)

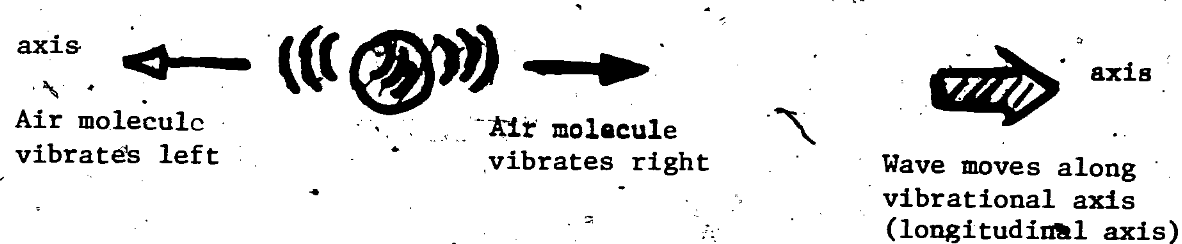


LONGITUDINAL WAVES

Fig. 1

As the tine moves alternately left to right, the air is alternately compressed and released. The tine does mechanical work in compressing the air molecules; this results in a transfer of tine energy to air molecule energy. As the compressed (energized) air molecules fly apart they compress the molecules next to them, which in turn expand and compress their neighbor molecules. As long as the tine continues to vibrate, the transfer of energy from molecule to molecule continues. This transfer of energy is the sound wave. Each stroke of the tine produces a wave pulse and a series of pulses sets up the wave train. Most sound is associated with a wave train, although a sharp pulse is detectable as a noise. Voice, for example, results when repeated pulses from the vibrating vocal cords produce a wave train.

Sound waves represent energy in transit. (It can be said that ALL waves represent energy in transit). Notice that the sound wave travels along the same axial direction that the air molecules vibrate. See the diagram below:



Can you see that in a longitudinal wave the particles of the material through which the wave energy propagates vibrate parallel to the wave direction?

Longitudinal waves must have a material (medium) through which to propagate. They cannot travel in a vacuum. Can you see why these waves cannot travel in a vacuum? See Fig. 2 on page 65.

Frequency is the number of vibrations the tine makes per second. Changes in the pitch of the sound (higher or lower tones) are due to a change in frequency. Loudness (intensity) depends on the amplitude (size) of the forward and backward motion of the vibrator.

Sound travels from the source in all directions at a definite speed in air. The speed of sound is slowest in gases (such as air), faster in liquids, and fastest in solids. Speed is affected by the temperature of the medium and increases in air as the temperature rises. Under standard conditions, the speed of sound is nearly 1100 ft/sec. This is about the speed of a .22 calibre long rifle bullet (about 750 mph). This speed is called mach 1, and is the speed of a sonic boom.

How much faster than in air, is sound in water?

...in wood?

...in steel?

Sample Speeds of Sound at Room Temperature (20° C)

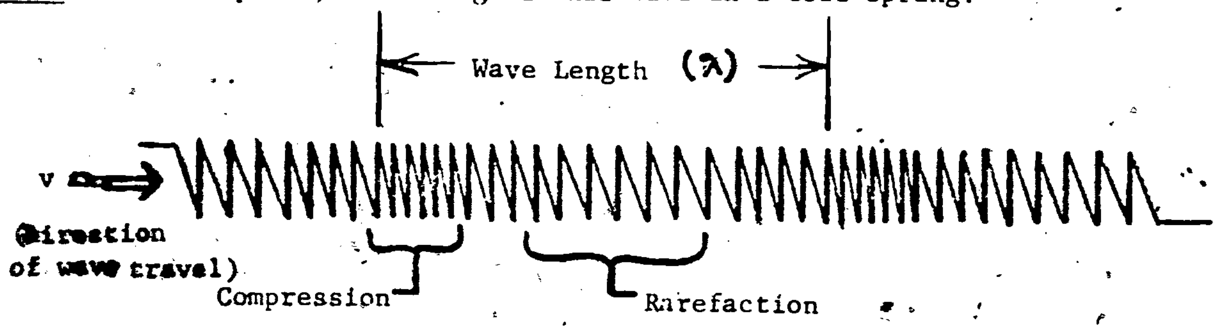
MATERIAL	FEET PER SECOND	MILES PER HOUR
iron and steel	16,500	11,200
wood	11,000	7,200
water	4,800	3,250
air	1,130	770

The mathematical relationship between the speed, frequency, and length of ALL waves is given by

$$v = f\lambda$$

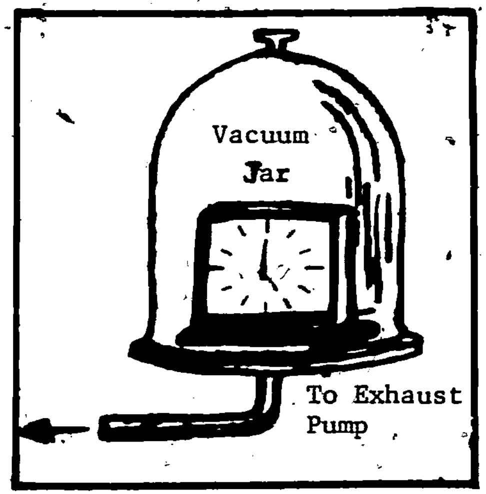
where v is the propagation speed
f is the oscillator frequency
λ (pronounced "lambda") is the wave length

Speed is measured in the usual units of distance per unit time (ft/sec, mi/sec); frequency is measured in cycles/sec, or <u>hertz</u>; and wavelength is in the usual units (ft,m). See the diagrams below for the <u>nomenclature</u> (names of parts) of a longitudinal wave in a coil spring.



Notice that the wavelength is indicated as the distance between two repeated "like points" on the wave train (compression-center to compression-center distance, or rarefraction-center to rarefraction-center distance, etc).

When sound reaches a hard, smooth surface it can bounce back (reflect); but if the surface is rough and soft most of the sound is absorbed. Echoes (bouncing back of sound) can be heard only if a reflected

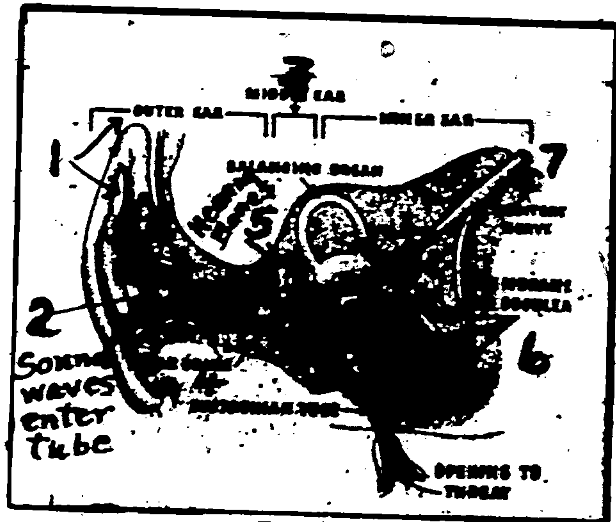


SOUNDLESS VACUUM
Fig. 2

sound wave pulse returns longer than 1/10 of a second after the first sound pulse was sent out (i.e., only if the reflecting surface is at least some 55 feet away) since the ear can only distinguish this small a separation of echo pulse.

How We Hear Sound. Examine Fig. 3. Sound enters the outer ear (1) and moves through a tube (2) into the middle ear (3). The eardrum (4) and the hearing bones (malleus, incus, and stapes) (5) vibrate and pass this motion to the hearing organ of the inner ear (6). The brain gets the sensory message through the auditory nerve (7).

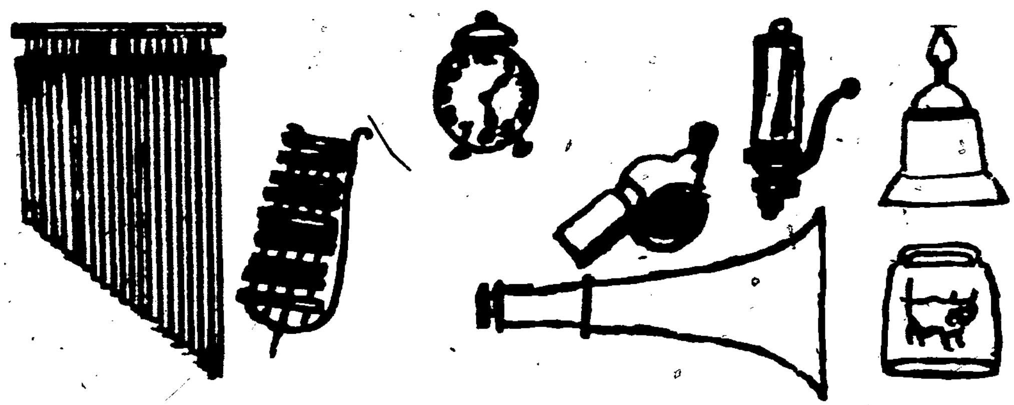
The sound frequencies (pitch) your ear can detect is determined in the coiled-shaped part of the inner ear, which is tubular and filled with a liquid. In this small tube are about 30,000 nerve endings which are acted upon by pressure changes in the fluid. Certain of these 30,000 nerve endings respond only to low-frequency vibrations (down to 50 Hz or so) while others respond only to higher-frequency vibrations (up to about 20,000 Hz). Dogs can hear "silent" whistles, which are simply devices whose frequencies



THE EAR
Fig. 3

are above the human ear threshold (above 20,000 cps), yet well within the high frequency response range of the nerve endings in Fido's ears.

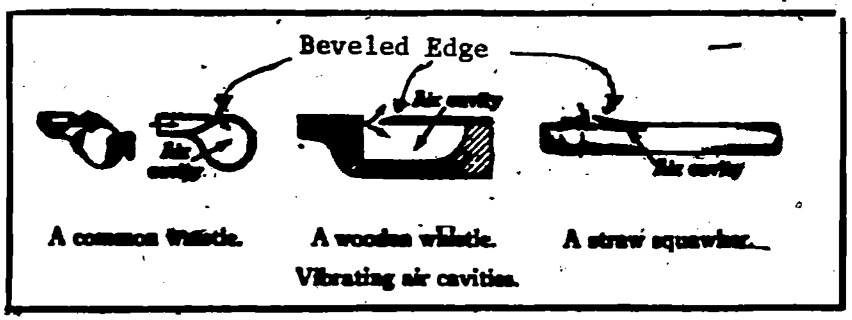
More On How Sounds Differ. There are low-pitched sounds and there are high-pitched sounds; there are loud sounds and there are soft sounds. There are noises, and there is music. All sounds result from vibrations; therefore, differences in sounds must have something to do with the way the vibrations take place. Fig. 4 illustrates some sound-producing instruments all of which are induced to vibrate by striking, blowing, rubbing, or plucking. In general, pitch is higher when the vibrating objects are thinner, shorter and more elastic. To concentrate the sound in one region is a way to increase intensity (loudness), as is done in a megaphone or stethoscope.



SOUND GENERATORS
Fig. 4

TOY WHISTLE

The whistle is a device which produces sound by setting up vibrating volumes of air. This air is set into motion by vibration of the walls (cavity walls) of the whistle. Although whistles vary in shape, they usually have a convential mouthpiece consisting of a thin slit. Air blown through the mouthpiece strikes a bevelled (angled) edge of the slit, causing it to vibrate. This, in turn, causes the whistle walls to vibrate, and they cause the air within the walls to vibrate. See Fig. 1.



WHISTLES
Fig.1

Blow the whistle and listen to the sound. What do you notice about the pitch: high? low? variable? constant?

Make a straw squawker using a paper strip (blade of grass, etc.) and your cupped hands. A blast of air directed against the sharp edge of the strip should produce sound. Now try the same thing with a soda straw using a slit in the straw itself (See Fig. 1).

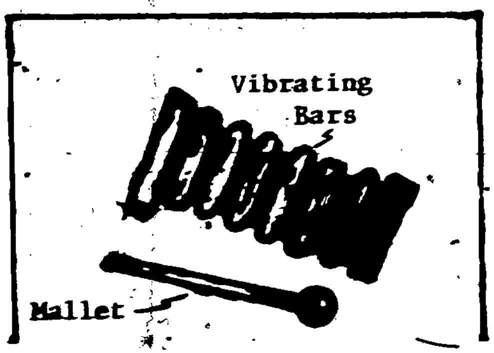
Last, using various empty bottles and by blowing across their open necks, make bottle "whistle". List the factors which your observations indicate produce different sound forms: size of neck, depth of air cavity in neck, shape of sides of bottle, thickness of bottle, angle of blowing, force of blowing, etc.

Submit these for evaluation.

THE XYLOPHONE

The xylophone is a device used to demonstrate sounds resulting from the vibration of solid bars.

The toy xylophone is an array of thin metal bars mounted on two nearly parallel rods. Struck with the mallet, the bars vibrate. See Fig. 1.



XYLOPHONE
Fig. 1

Play with the xylophone and think about how it works.

Can you relate it to the sound produced by the tuning fork?

THE SLINKY (COIL SPRING)

Slinky is a trade name for a kind of coiled-spring toy. See Fig.1. It can be used to illustrate a variety of technical physics principles including wave motion, Hooke's Law, (a law for elastic* materials) and simple harmonic motion. The Slinky differs from most coil springs because it is made of rectangular wire. It is "edge-wound", steel, and relatively elastic.

THE SLINKY
Fig. 1

Try the following exercises:

1) Lay the slinky (or any coil spring) on its side on a table top. With an end in each hand, pull the spring apart. Now create a "pulse" or condensation by moving one hand sharply toward the other, and then quickly back to its initial position. Observe the pulse advance along the spring with a velocity that is governed by the spring's tension, elasticity, and linear density. Tension is the stretching force; elasticity is the measure of the spring's ability to restore itself to its initial shape after it has been stretched; linear density is a measure of the spring's inertial mass; i.e. its resistance to being acclerated. The greater the tension and the elasticity, the faster the wave travels; but the greater the spring density, the slower the wave travels. Note that the pulse is reflected at the fixed end. If you stretch the spring farther, the velocity of propagation is greater because of the greater tension in the spring.

2) Use the longest spring available. Get someone to work with one end while you take care of the other. Send a compressional (longitudinal) wave down the spring by a thrust of the hand, or by using your free hand to pinch a section of spring together and then to quickly release the pinched section. Have a third partner measure the speed of the pulse. Report this value to your teacher.

3) Wind some tight-fitting rubber tubing along half the length of a spring. Then suspend the entire

*Be careful with the word elastic. It is another word whose scientific meaning differs from the meaning given it by T. C. MOTS (The Celebrated Man-On-The-Street). For example, steel is more elastic than rubber, and so is glass!

spring by threads fixed to every tenth loop or so and fastened to a horizontal bar supported above the floor or desk top. Set up a compressional wave at one end and observe the velocity in the unloaded (non-wrapped) part of the spring and in the loaded (rubber-tube wound) part. Record your observations. Hint: watch for reflections!

4) (Optional). Set the spring upright in a vertical coil on the table top. Grasp the entire spring in one hand and lift it above the table. Let a few coils slip out of your fingers. You should now see a section of stretched spring with successive loops increasingly closer together as one looks downward from the hand. The separation of these loops will be observed to satisfy Hooke's Law. Read about Hooke's Law and relate the Law to this observation.

The lower-most array of loops is closely packed and acts as a load on the spring. This load can execute simple harmonic motion (SHM). More of the loops can be freed from your hand, whereupon the load is increased. Do you think load changes the vibrating time (period). Write up your answer, with reasons therefor, and turn this in for evaluation.

5) The spring can be used in the classical sense of a toy by "walking it" down an inclined plane or a set of stairs. Practice "walking the Slinky." Write a short paragraph or two on the physics (or physical properties) associated with "Slinky walking."

THE "TIN CAN" TELEPHONE

The "tin can" telephone can be used to show that sound waves can travel through a string. Although the name is derived from earlier kinds of telephones made from tin cans, the telephone you are to use consists of two plastic or paper drinking cups connected by a string (light strong twine is best). (See Fig. 1).

TIN-CAN TELEPHONE

Fig. 1

Observation 1. Tie the center of a 3-ft length of string around the handle of a metal spoon (or similar object). Allow the spoon to swing freely against the edge of a desk and listen to the "clinking" sound produced. Next, wrap the free ends of the string around each index finger (forefingers). Insert an index finger tip in each ear, while swinging the spoon freely against the edge of the desk. Why do you hear a ringing, musical tone through the string but not through the air? Turn in a short written explanation to your teacher.

Observation 2. Punch a small hole in the bottom of each of two paper or plastic drinking cups. Place one end of a string through the holes in the cups and tie a piece of match stick (or paper clip) to the end so it cannot be pulled back out of the hole. You and a lab partner stretch the string reasonably taut, as shown in Fig. 1. Take turns listening and talking. When your phone is tested and working:

a) Hold your finger lightly on the string while the other student talks. Can you feel a disturbance traveling through the string?
b) Place your finger on the bottom of the cup on the receiving end of the telephone line. Can you feel the bottom of the cup vibrate?
c) Does touching the string affect the intensity of the sound conducted?
d) Try talking around a corner.

RESOURCE PACKAGE 3-2

READING-WAVE MOTION AND SOUND

1) Conn, Harry, <u>Noise</u>,"The American Federationist Magazine," October 1971, pp 13-19, Washington, D. C.

2) Kelly, William C. and Miner, Thomas D., <u>Physics for High School</u>, Ginn and Company, Boston, Massachusetts, 1967:

Wave Motion	pages 242-256
Sound	pages 260-270

3) Miller, Julius Sumner, <u>Physics Fun and Demonstrations</u>, 1st Edition, Central Scientific Co., Chicago, Illinois, 1968:

The Singing Four Pipes	pages 24
The Xylophone	page 34
Slinky	pages 54-55

4) White, Harvey E. and others, <u>Physics, An Experimental Science</u>, d. Van Nostrand Company, Inc., Princeton, New Jersey, 1968:

Vibrations and Waves	pages 303-306
Sound Waves	pages 308-311
Resonance, Beats, and Doppler Effects	pages 313-316
Sound, Energy and Hearing	pages 318-322
Standing Waves and Vibrating Strings	pages 324-329
Wind and Percussion Instruments	pages 330-337
The Quality of Sound	pages 338-342

RESOURCE PACKAGE 3-3

FILMS AND FILM STRIPS

Films

Exploring the Instruments (Science in the Orchestra Series)

Fundamentals of Acoustics (2nd Edition)

Looking At Sounds (Science in the Orchestra Series)

Progressive Wave: Transverse and Longitudinal

Sound Waves and Their Sources

Sounds and How They Travel

Film Strips

How We Produce Sound and Speech

RESOURCE PACKAGE 3-4

NOISE POLLUTION

Noise has become more than a nuisance and occasional health hazard. Noise has emerged as possibly the third most crucial pollution problem in our mechanized society. Most citizens are concerned about air pollution and water pollution, but few are even aware that noise is the ear pollutant which poses severe occupational hazards to large segments of industrial workers.

In the earlier days of the Industrial Revolution, evidence of noise dangers arose. In 1830, English doctors were reporting that noise was the cause of deafness in blacksmiths. By 1860, a recognized occupational hazard was the hearing loss common to those in the boilermaker trades.

Modern technology often saturates the worker with noise on the job and also surrounds him with it during his leisure hours. Surely, noise pollution is a concern for all citizens and especially for those workers in certain vocational and technological areas. Hearing loss is only an obvious sympton of noise pollution. Noise pollution can also result in changes in respiration rate, blood pressure, heartbeat, and oxygen consumption.

Noise-hazardous environments are prevalent in chemical and clothing (textile) manufacture, in heavy machinery and lumber products manufacture, in shipbuilding and heavy construction, in aircraft construction and operation and maintenance, etc. Such devices as power mowers, power saws, power hedgecutters, portable air compressors and welders, pneumatic pavement and rock drills, bulldozers, motorcycles, snowmobiles, outboard boat motors, and electronic amplifiers can be prime sources of noise pollution.

Efforts to legislate for safe and harmonious noise levels in our Nation have come mostly from organized labor. Although as many as an estimated five million workers in the United States are experiencing unsafe noise conditions, not much will likely be done about this condition until public pressure causes Congress to take action.

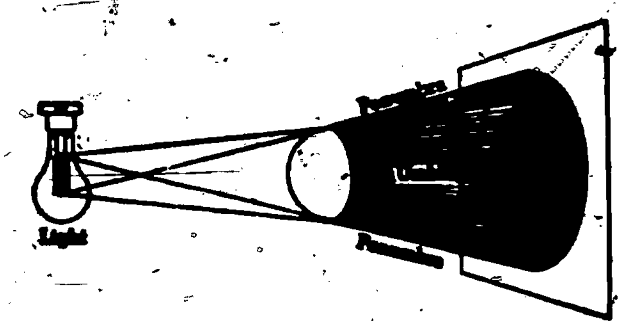
Turn in the following for evaluation:

1) Prepare a short bibliography on noise pollution (a half-dozen or so references).
2) Recall the last 24 hours of your life. List those <u>devices</u> and <u>environmental</u> factors which may have exposed you to unnecessary and unsafe noise.
3) The Clean Air Act of 1970 <u>authorized</u> $30 million dollars for an investigation of noise and its effects upon the public. However, less than 1/15th of this amount was actually budgeted for fiscal year 1971-1972. Do you feel this was wise governmental "non-spending"? Write a short paragraph or two defending your feeling.

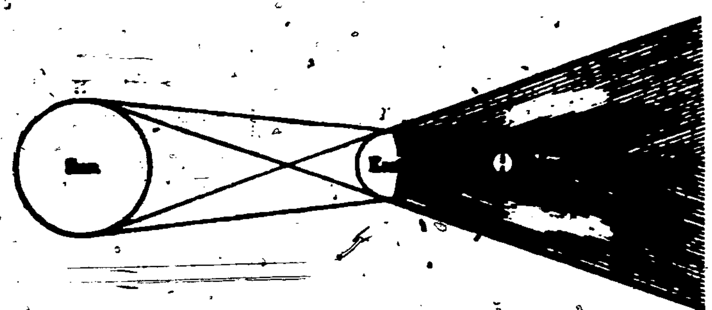
RESOURCE PACKAGE 4-1

TOYS THAT DEMONSTRATE PRINCIPLES OF LIGHT

Common sources of light are hot objects such as the tungsten wire filament in a light bulb, the mantle in a gas lamp, and the sun (stars). But many sources of light are comparatively cold such as a fire-fly, a neon lamp, etc.



UMBRA AND PENUMBRA OF A SHADOW
Fig.1



MOON ECLIPSED IN THE EARTH'S UMBRA
Fig.2

Light plays an important part in our lives. We could not see without light and in our modern civilization artificial light extends our working and leisure hours. Light can perform work and is classed as a form of energy. Plants utilize light in their growth and storage of the food energy which supports the animal kingdom.

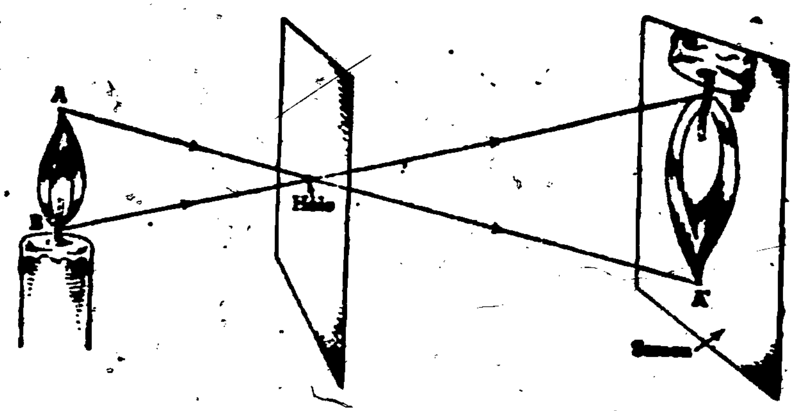
The study of light is called optics. An understanding of optics is the basis of many commercial and industrial professions and vocations. You can probably think of several jobs related to each of the following words: camera, telescope, microscope, portrait, television, motion pictures, contact lens, and lights.

The speed of light in space is about 186,000 mi/sec, which is about 30,000,000 m/sec. At this speed, you could travel completely around the earth (circumnavigate it) at the equator more than seven (7) times each second! A single circumnavigation took Magellan's crew about four years!

Light travels outward from a source in all directions and in straight lines. Shadows are produced by obstructing the straight line travel of light (See Fig. 1).

Eclipses of the moon are produced when the moon moves into the earth's shadow. The sun is eclipsed when the shadow of the moon falls upon the earth. (See Fig.2).

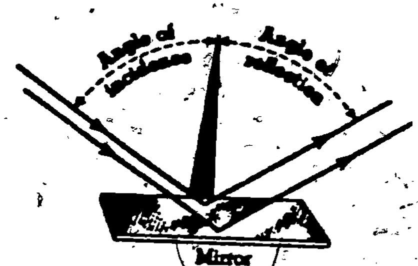
Pinhole images of objects are produced when light from them passes through a small opening and falls upon a screen (See Fig.3).



INVERTED PIN HOLE IMAGE
Fig.3

The intensity of light is often measured in candle power. The illumination on a surface is often measured in foot-candles, where a candle-foot is the illumination produced by a single standard candle at a distance of one foot. Illumination is inversely proportional to the square of the distance from a point source of light; which means that if the distance is doubled the illumination decreases four-fold, and if trebled the decrease is nine-fold, etc.*

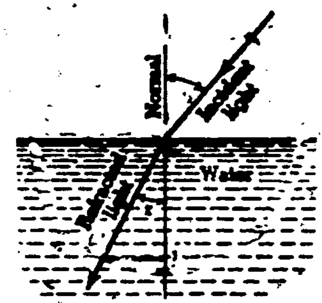
When light strikes an object the light may be transmitted, reflected, absorbed, or some combination of all three. When reflected, the angle of incidence equals the angle of reflection (See Fig. 4).



EQUAL INCIDENT AND REFLECTION ANGLES
Fig. 4

When light passes at an angle from one medium to another, it bends "toward" the more optically-dense medium and "away from" the less optically-dense medium; this bending is called refraction. For example, when light enters water from air it is bent toward the perpendicular (normal) of the denser medium (See Fig. 5). If the light were emerging from the water, it would bend away from the normal.

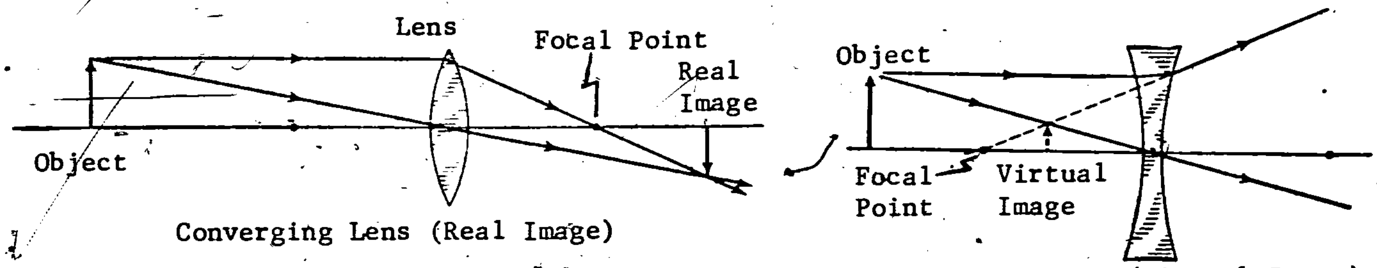
* Your instructor and texts can help you understand this inverse-square relationship for light.



REFRACTION
Fig. 5

Devices to bend light by refracting it are called lenses. Simple lenses can be convex or concave. They are often classified as converging (convex) or diverging (concave). See Fig. 9 and notice that a flat or straight side is called plano. Lines showing light paths are called rays. Fig. 5 is an example of a ray diagram, a diagram showing the light path.

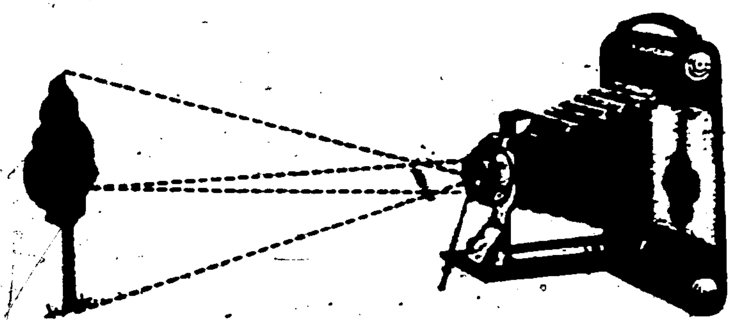
SOME LENSES
Fig. 6



REAL AND VIRTUAL IMAGES
Fig. 7

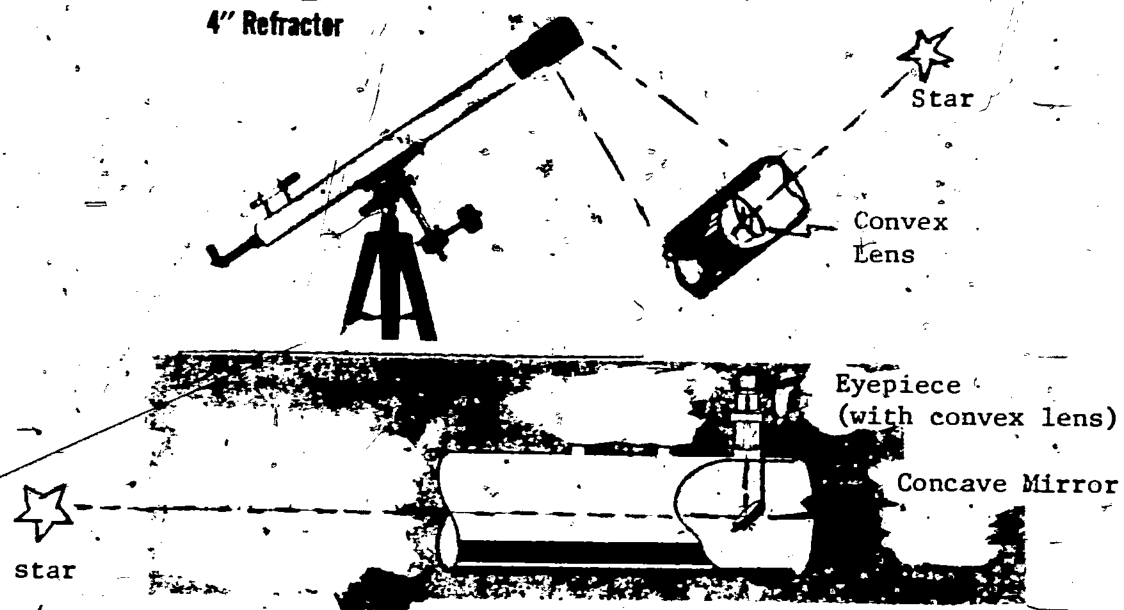
Look at the ray diagrams of Fig. 7. These diagrams show object-image formation by lenses. The principal focus of a lens is the point where parallel rays of light will be bent (focused). Since a convex lens converges light, its principal focus is real; "real" implies that the rays actually pass through the focal point (See Fig. 7). But since a concave lens diverges light, its focus is virtual; "virtual" implies that only imaginary, extended rays reach the focal point (See the dashed line, Fig. 7). The optical center of a lens is a point through which rays from the object can pass without undergoing a change in direction (bending).

The camera and the eye are similar examples of a convex lens application (See Fig. 8). The simple magnifier ("burning glass") makes use of one convex lens; the compound microscope uses at least two.



CONVEX LENS APPLICATION
Fig. 8

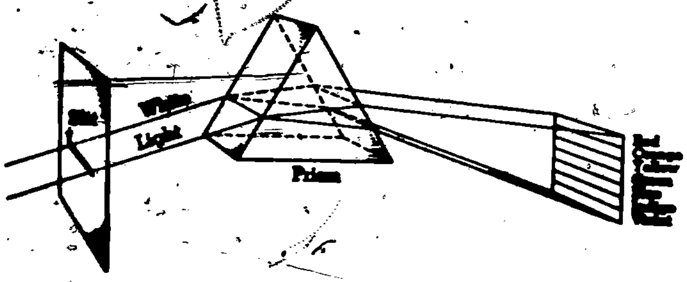
Astronomical telescopes are either of the "light bender" type (<u>refractors</u>) or of the reflecting type (<u>reflectors</u>); however, in refracting telescopes the <u>objective</u> lens is convex, while in the reflecting telescope the <u>objective</u> <u>mirror</u> is concave (See Fig. 9). Convex mirrors are the kinds used as wide-area anti-theft mirrors in department stores; they are also used extensively as rear-view mirrors on trucks. Binoculars consist essentially of two refracting telescopes mounted side-by-side.



REFRACTOR AND REFLECTOR TELESCOPES*
Fig. 9

* Telescope vary in arrangement of these components

Ordinary white light can be separated into its component colors. A common way to accomplish this is by means of a prism (See Fig. 10) and this separation phenomenon ("happening") is called dispersion. It is the nature of light to behave as waves behave. Visible light can be thought of as waves which vary in length from 4/100,000 centimeters (4×10^{-5} cm) to 7/100,000 centimeters (7×10^{-5} cm); this is indeed small! The color of an illuminated object is related to the wave-length of the light which it reflects to the eye, whereas the color of a transparent body depends upon the wavelength of light it transmits to the eye.



DISPERSION
Fig. 10

Rainbows are produced by the refraction and reflection of sunlight by raindrops, which behave as a multitude of spherical prisms.

When sunlight is observed after it has passed through a set of very narrow, parallel slits*, (or through

* Transmission-type diffraction gratings consist of a series of fine, closely-spaced slits.

a glass prism) the light appears broken by numerous dark lines called absorption lines (Fraunhofer lines). The band of light coming out of the slit is called a spectrum. Dark lines are produced by the absorption of light of certain wavelengths as sunlight passes through the solar atmosphere. Different atoms and molecules in the solar atmosphere absorb light of certain wavelengths and transmit the rest; the dark lines seen in the light coming through the slit can be identified with the absorption by specific atoms and molecules. Because of specific absorption of light by specific atoms and molecules, and because specific atoms and molecules can emit only certain wavelengths of light, astronomers and astrophysicists can look at a star and tell what it is made of!

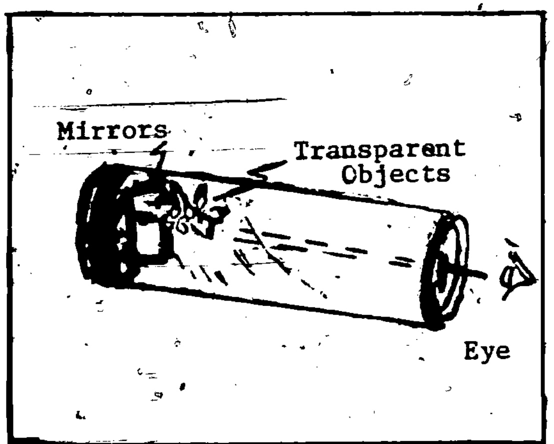
The spectroscope is the name of the device used to obtain spectra (plural of spectrum) for detailed study, and much of modern astronomical discovery is based upon studies using this instrument.

The bending of light as it passes the edge of an obstacle is called diffraction. You will construct a diffraction spectroscope in this minicourse since this bending can be used to bend and to separate colors of light.

For a more complete treatment of optical effects, see the Photography minicourse. (Did you know that photography is one of the fastest growing businesses in the United States?).

THE KALEIDOSCOPE

The kaleidoscope is a toy which can illustrate how multiple images can be produced with a particular mirror arrangement. See Fig.1. This instrument is well-known but its construction (through simple) is a complete mystery to most people. In one kind of kaleidoscope, two rectangular plane mirrors are joined along their lengths at a special angle which determines the number of multiple images produces. These mirrors are fixed to one end of a cardboard tube and at the other end of the tube is a peep-hole. Between the peep-hole and the mirrors is a housing containing some "bits of transparent colored stuff." In another kind of kaleidoscope, the mirrors lie along the sides of the tube and the bits of colored stuff are housed in the end of the tube that is opposite the peep-hole.

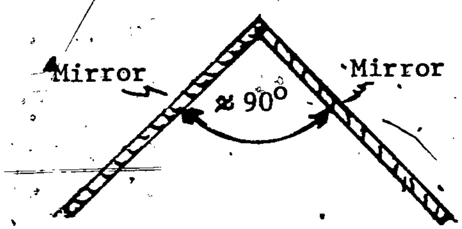


KALEIDOSCOPE
Fig.1

Hold the tube with the peep-hole near your eye and rotate the "housing." The "bits of stuff" will fall into different positions and an endless variety of patterns will be observed. Next enhance the kaleidoscope effect by holding two sheets of polaroid at the peep-hole. Point the kaleidoscope toward a bright light and rotate the polaroid sheets with respect to one another during viewing.

<u>How The Thing Works</u>. The kaleidoscope's plane mirrors are set at an angle to one another so as to produce multiple images. Work through the following section to learn how these images are produced.

Place two plane mirrors on a flat surface at an angle of about 90^{o} from one another as shown in Diagram (a). Then place a small object on the viewing line shown on Diagram (b). Place your head in the "eye position" shown below and move the small object (bent paper clip, or?) along the viewing



Top View

Diagram (a)

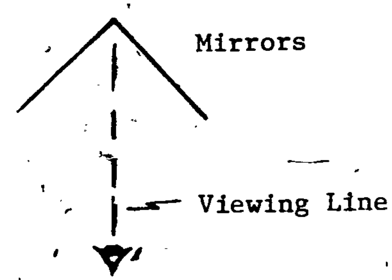


Diagram (b)

line. Move it both toward and away from the corner formed by the two mirrors. Record:

a) number of images seen
b) the measured angle formed by the mirrors (Be careful. Ask your teacher for a <u>protractor</u>. Be precise to the nearest degree or two.)
c) the changes in number of images with position of the object. Does there appear to be a space along the viewing line where placement of the object insures that the maximum number of images will be seen?

Now re-set the mirrors at a 60^{o}-angle and repeat steps (a) through (c) above. Do the same for an angle of 45^{o}. Record all observations.

The technical physics of the number of kaleidoscope images seen is expressed by the equation

$$N = \frac{360^\circ}{A} - 1$$

where N is the number of images, and A is the mirror angle (in degrees).

Here is a solution for 90°:

$$N = \frac{360^\circ}{A} - 1$$

$$= \frac{360^\circ}{90^\circ} - 1$$

$$= 4 - 1$$

$$= 3 \text{ images}$$

See how simple is the mysterious kaleidoscope when one understands a little physics?

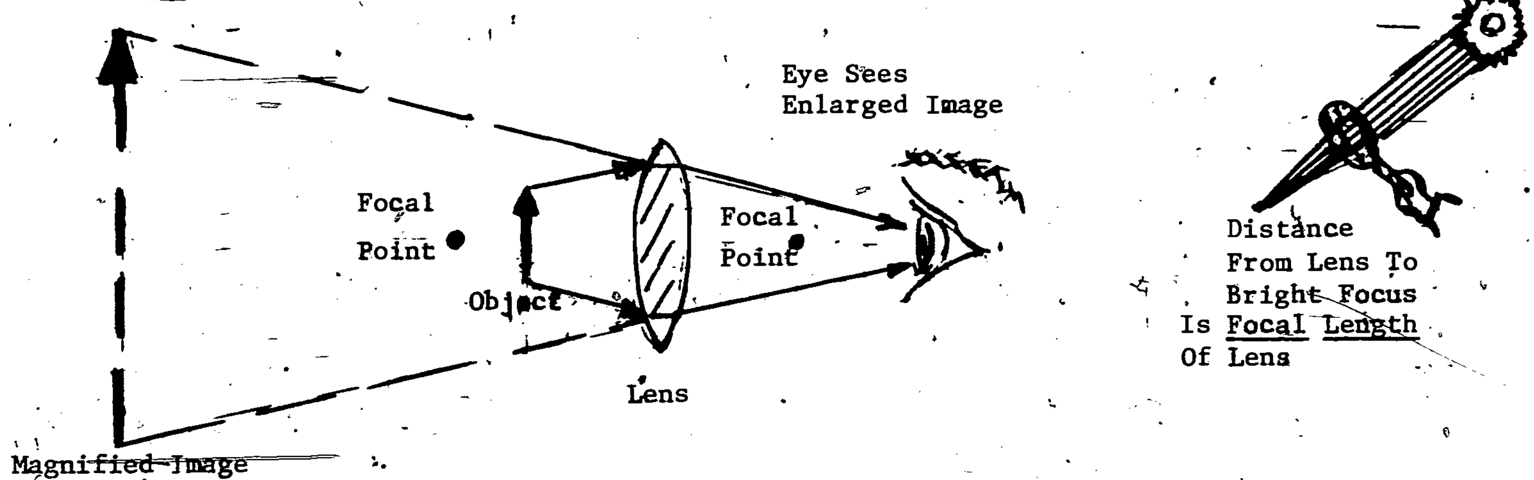
Calculate the expected number of images for 60° and 45° and see if they correspond to your observations.

Suppose you worked for a toy manufacturer and he wanted you to design a kaleidoscope to produce 23 images. What mirror angle would you recommend? Turn all your calculations and observations in to your teacher for evaluation.

THE HAND LENS (MAGNIFIER)

The hand lens, "magnifier lens", or "burning glass" is a convex (converging) lens of short focal length (See Fig.1). You may have seen such a lens used to start a fire. Sometimes glassware acts as a convex lens and causes fires in homes. If a lens can focus (concentrate) light rays, and if these rays can start fires, then energy must be associated with these rays. Can you see why light is referred to as a form of energy?

The convex lens is frequently used in the eyepieces of binoculars, telescopes, compound microscopes, hunting rifle scopes, surveyor transits, etc. A convex lens magnifies when it is <u>less</u> than one focal length from its object, and when the eye (viewer) is very close to the lens on the side opposite the object. See Fig.1



MAGNIFICATION AND FOCAL LENGTH
Fig.1

The image is virtual, erect, enlarged, and appears to the viewer to be on the same side of the lens as the object.

Linear magnification of a lens is expressed mathematically as the ratio (fraction) of the image size (S_i) to the object size (S_o); as shown.

$$M = \frac{S_i}{S_o}$$

The normal adult eye focuses distinctly on objects as near as approximately 25 cm (10 in).

Have the instructor give you a convex lens. Find:

a) its focal length
b) its linear magnification

Turn this in for evaluation.

THE TOY TELESCOPE

The toy telescope will be used to investigate how lenses are used in simple telescopes. Follow the instructions carefully.

Materials:

1 Objective lens (10"-20" focal length)
1 Eyepiece lens (1"-2" focal length)
2 cardboard tubes, one to telescope inside the other and whose extended length is greater than the sum of the focal lengths of the lenses
Tape (cellophane, adhesive, or masking)

Investigation: By studying Fig. 2, examining Fig. 1, and being clever, you can construct a telescope similar to the one shown in Fig. 1. It is easily assembled if you follow these illustrations.

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REFRACTOR TELESCOPE
Fig. 1

You should discover that the objects viewed are inverted (turned upside down) by this lens system, which incidentally, is the same one used in modern astronomical telescopes.*

The objective lens forms an inverted image at the focal plane inside the tubes (the inverted image is just in front of the eyepiece lens). The eyepiece lens (because the objective lens image plane lies inside the eyepiece lens focal length) simply magnifies the inverted image formed by the objective lens. The power of the telescope is the quotient of the objective lens' focal length divided by the eyepiece lens' focal

*When viewing a star, does upside down matter?

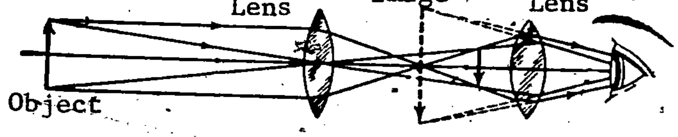


DIAGRAM OF A REFRACTING TELESCOPE
Fig. 2

length. For example,

$$\text{Power} = \frac{\text{Focal length of object lens}}{\text{Focal length of eyepiece lens}}$$

$$\frac{10''}{2''} = 5$$

A ten-power telescope is adequate for observing many details of the craters on the moon, the moons of Jupiter, the rings of Saturn, etc.

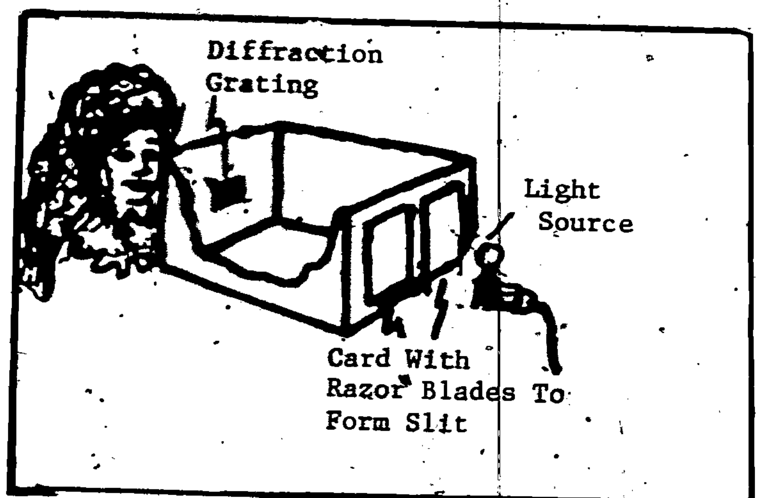
Show your telescope to your teacher, and turn in all your written material for evaluation.

THE SPECTROSCOPE

The spectroscope can demonstrate how the light from a substance can be used to precisely identify that substance.

<u>Materials</u>

Neon lamp
25-watt lamp bulb with plug-in socket
Diffraction grating (about 15,000 lines per inch)
Cellophane, adhesive, or masking tape
Shoe box
Extension cord
File cards
2 razor blades
Mercury-vapor lamp



SHOE BOX SPECTROSCOPE
Fig.1

Make a spectroscope like the one shown in Fig.1.

First, cut a hole in each end of the shoe box. Next tape the diffraction grating over one hole, and place the two cards (with razor blades attached so that a razor edge extends just slightly beyond an edge of each card) over the other hole to form a vertical slit no wider than one-eighth inch. Now tape the cover on the box, and then look through the grating toward a lighted lamp bulb near the slit. What do you see? If you do not see a rainbow spectrum on each side of the slit try removing the grating, giving it a quarter turn, and then retaping it in place.

Replace the light bulb with the neon lamp. What colors do you see? In spectroscopy, when an unbroken array of colors appears the spectrum is called continuous; when only some of the colors appear, the terms discontinuous or line spectrum are used. How would you classify the neon spectrum?

Other gas lamps produce other spectral color combinations, each of which is unique and characteristic of the particular gas. Try other gas lamps if you have them, available. Can you see that scientists can tell what a material is made of if they can get the material to emit light? If your instructor agrees, heat some crystals in a flame and look at the spectra (ordinary table salt should do).

Read how light is emitted from substances when they are heated.* Write a short paragraph or two on electron energy states and electron transitions. Discuss this with your instructor.

*Ask your instructor for suitable, available reading on this subject. General Physics by Blackwood, Kelly, and Bell, Fourth Edition, John Wiley & Sons, New York, New York, 1973, could be a real help.

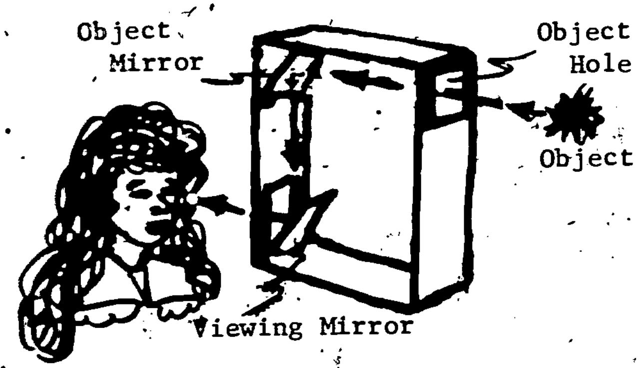
THE PERISCOPE

A mirror periscope is a good way to observe some reflecting properties of plane mirrors.

Materials

- Cardboard box
- 2 pocket mirrors
- Plastic clay

Cut holes about 2 inches square in the box, as shown in Fig. 1. Mount the mirrors at angles of about 45^{o}. Check for proper mirror alignment by pointing the upper object-opening toward the object and seeing the object's reflection in the lower viewing-mirror. When mirrors seem properly aligned, tape the box lid in place. Play with the homemade periscope and discover how it will allow you to see around corners without being seen.

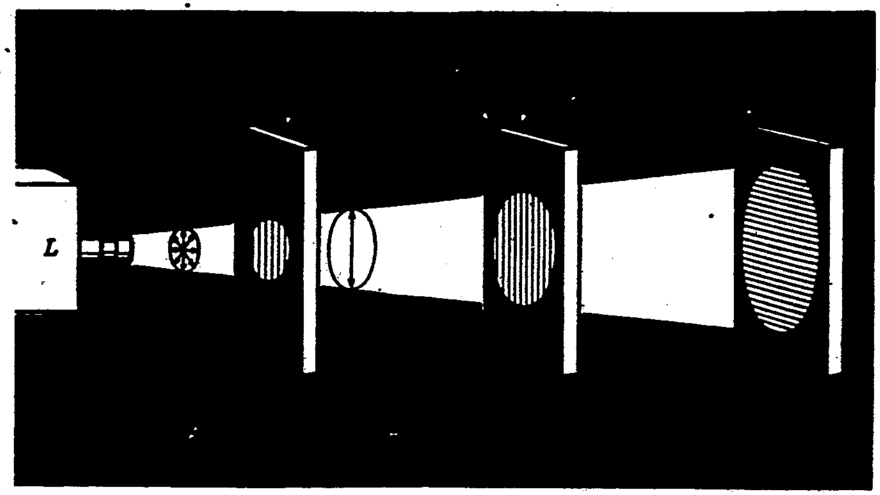


PERISCOPE
Fig. 1

The point of this toy, physically speaking, is that the path of a light wave can be "bent" by mirrors. By use of a light ray diagram, show how light travels from the object through the periscope to the eye of the observer. Label the mirror angles. Would some other color of light follow this same path? Turn this diagram, and your answer to the question, in for evaluation.

*POLARIZING DISKS (OPTIONAL)

Polarizing disks can be used to illustrate some of the special properties of polarized light.



Polarization of light is shown here. Light from an ordinary source L vibrates in all planes as shown in region A. A polarizing crystal passes only the portion of the beam which vibrates in one plane as indicated in region B. Other polarizing crystals can be rotated until they transmit this polarized beam as indicated in region C or until they absorb and eliminate it as is evident beyond C.

POLARIZATION
Fig. 1

<u>Materials</u>

2 Polaroid disks
Block of enameled wood
Cellophane strips mounted between glass plates
U-shaped piece of transparent plastic
Piece of glass from broken molded bottle

Look at a light source through one of the polaroid disks. Slowly rotate the disk. Does the intensity of light vary? Do the same thing with the other disk. Compare the result for each disk. Now hold both disks together and rotate one of them while you look at the light source through both disks. What do you observe? How much do you have to turn one disk to go from maximum brightness to maximum darkness? Write out your responses. Polarization of light results from special conditions of <u>transmission</u>* or <u>reflection</u>. Place a piece of wood painted with black enamel in a location where a maximum amount of

* There are several natural crystals, such as <u>tourmaline</u> and <u>calcite</u>, which possess the property of polarizing light that passes through them.

sunlight from a window is reflected from the surface of the block (This kind of reflection is commonly called glare). Examine this glare through a single polaroid disk. In what plane did you find the glare reflected from the polished surface to be polarized (horizontal plane or vertical plane)?

Hold the polaroid disks so that their transmitting plane is at right angles to the plane in which the glare is polarized, one over each eye. Compare the amount of glare through the Polaroid disks with the amount without the polaroid disks. From this give a practical application of polaroid material. In what plane would you orient the polaroid disk if it were to be the lens of a pair of sunglasses?

Polarized light is used in technical fields to determine structural strains. View a small U-shaped piece of transparent plastic between crossed polaroid disks. A good light source behind the plastic will improve observations. Pinch the open ends of the piece of plastic between your fingers and note the effect this causes. Write down how you can detect where the strain is greatest?

Examine a piece of glass broken from a molded bottle, using crossed polarizers. Are there strains in the glass?

Can you see how easily and conveniently one might test transparent materials for strain using a polaroid technique? Such kinds of testing are called non-destructive testing and constitute an important vocation in modern industry. Through the use of polarized light many scientific and industrial applications not possible with ordinary light may be made. For example, polarized light is used in identifying certain chemical compounds and in determining the thickness of crystals and fibers.

Turn in your notes and your answers to the questions in this section.

RESOURCE PACKAGE 4-2

READINGS - PRINCIPLES OF LIGHT

1) Miller, Julius Sumner, Physics Fun and Demonstrations, First Edition, Central Scientific Co., Chicago, Illinois, 1968.

The Kaleidoscope	page 49

2) Oxenhorn, Joseph M., Pathways in Science, Physics 3--Sound and Light, Globe Book Co. Inc., New York City, New York, 1970:

The Nature of Light	pages 87-93
The Travels of Light	pages 95-100
Living Things Receive Light	pages 102-108
When Light Looks Back	pages 111-115
Mirrors in Our Lives	pages 118-123
Bent Light Rays From Images	pages 125-130
Lenses in Our Lives	pages 132-137
Our Colorful World	pages 139-144
The Light We Cannot See	pages 146-152
Packaged Light	pages 160-164

3) White, Donald H., and others, Physics: Experimental Science, d. Van Nostrand Company, Inc., Princeton, New Jersey, 1968:

The Nature of Light	pages 351-362
Reflection From Curved Surfaces	pages 363-367
Refraction	pages 369-374
Lenses	pages 376-381
The Eye and Optical Instruments	pages 383-389
Dispersion	pages 392-398
Color	pages 399-404
The Diffraction Grating	pages 411-414
Polarization of Light	pages 415-420

RESOURCE PACKAGE 4-3

FILMS AND FILM STRIPS

Films

Nature of Color
Reflection and Refraction
Speed of Light

Film Strips

Polarized Light
Story of Lenses
The Mount Wilson and Palomar Telescopes
Wave Motion--A Key to Modern Science
What is Color?

RESOURCE PACKAGE 5-1

ELECTRICITY AND MAGNETISM

Electricity and magnetism are as related as "Mom and apple pie" or "the Flag and the Fourth of July". You would do well to remember that electric charge carriers can be at rest without producing magnetic effects, but electric charge carriers in motion ALWAYS produce magnetic effects. In other words, magnetism results from electric currents (charge carriers in motion).

In technical physics, the study of electricity at rest is called electrostatics and the study of motional electricity is called electrodynamics. Similar designations are made for magnets (magnetostatics) and for kinetic (moving) magnetic effects (magnetodynamics).

Your text and the references in Resource Package 5-2 should be studied carefully so that you can better understand the brief comments and descriptions which follow.

All electric phenomena (happenings) relate ultimately to the behavior of the basic unit of negative charge associated with the electron and to the behavior of the basic unit of positive charge associated with the proton.

Study the following statements, laws, and definitions:

A) MAGNETOSTATICS

I) Characteristic properties of a magnet include: (a) attraction or repulsion effects, (b) <u>polarity</u> (c) field strength and direction, and (d) inverse square force*.

II) The rules of attraction and repulsion between magnetic poles are: (a) like poles repel; unlike poles attract, (b) the force of attraction or repulsion is directly proportional to the product of the strength of each pole and is inversely proportional to the square of the effective distance between them**, and (c) the force of attraction or repulsion is affected by the <u>medium</u> surrounding the poles.

III) Magnetic lines of force exit from a north pole and form <u>closed</u> curves by re-entering a magnet through its south pole. There are no broken lines of magnetic force dangling in space.

IV) When a magnetic field is represented by magnetic lines of force, the stronger the field the closer together are the lines of force.

B) ELECTROSTATICS

I) Characteristic properties of charged objects include: (a) attraction or repulsion effects, (b) <u>sign</u>, (c) field strength and direction, and (d) inverse square force**.

II) Positive electricity is defined as the kind that is associated with a glass rod when it is rubbed with silk; negative electricity is the kind that is associated with a rubber rod when it is rubbed with wool***.

III) <u>Electrification</u> is a process of adding electrons to, or taking them from, a body. An <u>excess</u> of electrons results in a negative charge condition, and a <u>deficiency</u> of electrons results in a positive charge condition.

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*If you do not know the meaning of this phrase, consult your references and then your instructor.
**If you do not know the meaning of this phrase, consult your references and then your instructor.
***This <u>operational</u> <u>definition</u> of positive and negative electric charge is attributed to the great American statesman, inventor, philosopher, and scientist Benjamin Franklin!

IV) The rules of attraction and repulsion between objects charged electrostatically are: (a) charged objects of like electric sign repel; charged objects of unlike electric sign attract, (b) the electrostatic force of attraction or repulsion between two charged objects is directly proportional to the product of their respective charges, and is inversely proportional to the square of the effective distance between them, and (c) the force of attraction or repulsion depends upon the nature of the medium surrounding the charged objects.*

V) A body charged by conduction has a charge of the same sign as that of the charging body.

VI) A body charged by induction has a charge of the opposite sign to that of the charging body.

VII) A conductor is a substance through which electrons pass readily; a non-conductor (called a dielectric or insulator) is a substance through which electrons cannot pass readily; and a semi-conductor has a conduction property somewhere between that of the conductor and the non-conductor.

C) ELECTRODYNAMICS

I) An electric current is a stream of charge carriers.

II) A device for "storing" separated charge carriers is known as a capacitor (sometimes called a condenser).

III) Charge carriers in motion constitute an electric current and such currents can be established by a seat of emf (electromotive force), such as a generator, an alternator, or a battery. CAUTION! Another historical misnomer! Emf is NOT force; it is an energy "source"; it has energy dimensions (volt) and not force dimensions (newton, pound).

IV) For direct current in a linear conductor**, Ohm's law expresses the relationship between the current in amperes, the emf or potential difference in volts, and the resistance in ohms. Mathematically, this relationship is $E = IR$. As a kind of mechanical analog you can think of

*Since both magnetostatics and electrostatics and gravity-statics share the same basic inverse square force relationship, ask your instructor for additional reading references. Then ask her/him to explain these inverse-square laws to you. Try to get a feeling for some of the physics expressed in these mathematical expressions: $F_G = (G)\frac{M_1 M_2}{d^2}$; $F_M = (K)\frac{P_1 P_2}{d^2}$; and $F_E = (k)\frac{Q_1 Q_2}{d^2}$

**If you do not know this phrase, consult the referenced readings and your instructor.

the voltage as the push, the current as the load, and the resistance as the friction.

V) For most metallic conductors:

a) The resistance of the conductor is directly proportional to its length.
b) The resistance of the conductor is inversely proportional to its cross-sectional area.
c) The resistance of the conductor depends upon the material of which it is composed.
d) The resistance of the conductor increases as its temperature increases.

VI) A coulomb is defined as that quantity of electric charge associated with a current of one ampere for one second.

VII) A volt is defined as the electromotive force, emf, or potential difference sufficient to cause a current of one ampere in a circuit having a resistance of one ohm.

VIII) Electric power can be measured in watts. The watt is defined mathematically as a volt times an ampere, or P = EI. Electric companies sell their product in terms of the kilowatt hour. So a watt-hour must = volt-amp-hour, and a kilowatt-hour must = (1,000) volt (amp) hour. Can you see that the kilowatt hour is an energy unit?

D) MAGNETODYNAMICS

I) Whenever a conductor moves in a magnetic field so as to cut across lines of force, or whenever lines of force cut across a conductor, an induced emf occurs in the conductor. Notice that no battery need exist; simply moving a wire loop across magnetic field lines will cause electric current in the loop, and simply passing a magnetic field across a wire loop will cause a current in the loop.

II) The magnitude of the induced emf depends upon the number of lines cut in a given time interval.

III) Lenz' Law tells us that when a conducting loop is moved across a magnetic field something happens electromagnetically which causes a current in the loop. Further, this "happening" always opposes the loop motion; conversely, if an attempt is made to pass a field across the loop something happens electromagnetically which causes a current in the loop and this current opposes the field.*

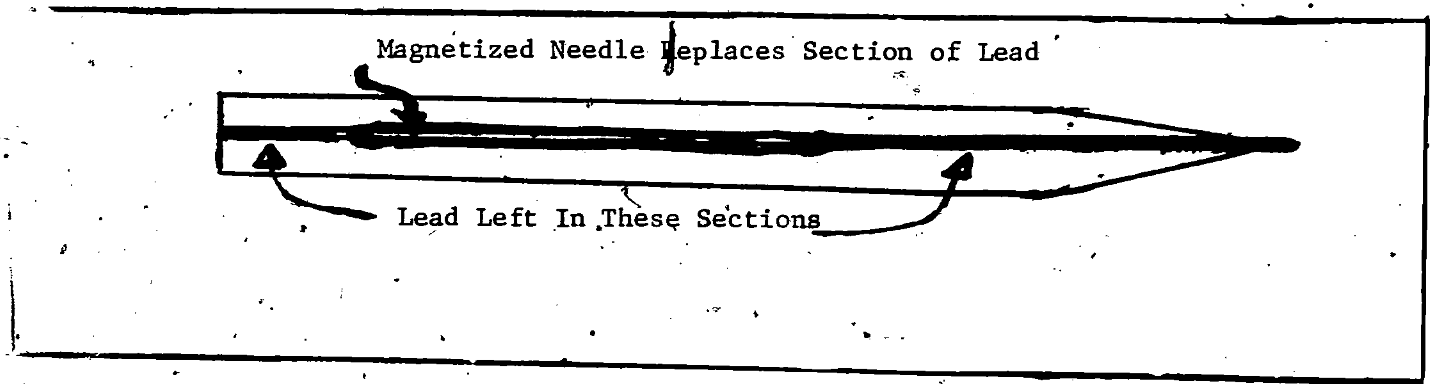
*Lenz' Law be "heavy". Consult your instructor if this "hangs you up", causes excessive internal dis-harmonies, creates unbearable educational dis-equilibrium, etc. Actually, you can get along very well in this course with only a moderate understanding of Lenz' Law ... so don't lose your "cool"!

IV) Alternating current consists of charge carriers which move first in one direction and then in the opposite direction. As the current continually changes direction, it also continually changes size. For this reason most AC meters are constructed to read effective or average voltage and amperage values.

MAGNETIC NAVY

Toy boats can be made which will respond to a magnetic command. You can become the Admiral of a Magnetic Navy whose movements can be directed with a "magic wand".

Materials: 1 vessel of water (an ocean)
2 pieces of wood
2 nails or needles
1 piece of paper
1 pencil

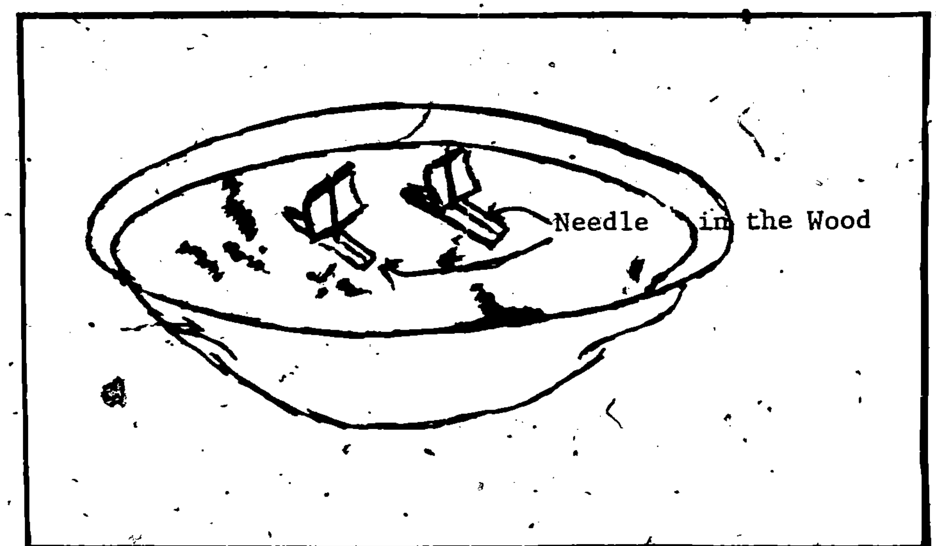


MAGIC PENCIL
Fig. 1

First, construct a "magic wand." Use an ordinary lead pencil and carefully split the wood shaft in two pieces. (A pencil is glued together during manufacture and should split easily into its two halves.). Remove portion of the lead as shown in Fig. 1. Magnetize a steel needle about the same thickness as the pencil lead and replace the removed portion of lead with the needle. (A steel needle can be magnetized by holding it in a fixed position and by stroking it with a strong magnet several times <u>in the same direction</u>.)

Glue the pencil together again and you now have a "magic wand" which will attract small pieces of iron and steel.

Use a compass needle to determine the polarity of your "magic wand". Record this in your notes.



MAGNETIC NAVY
Fig.2

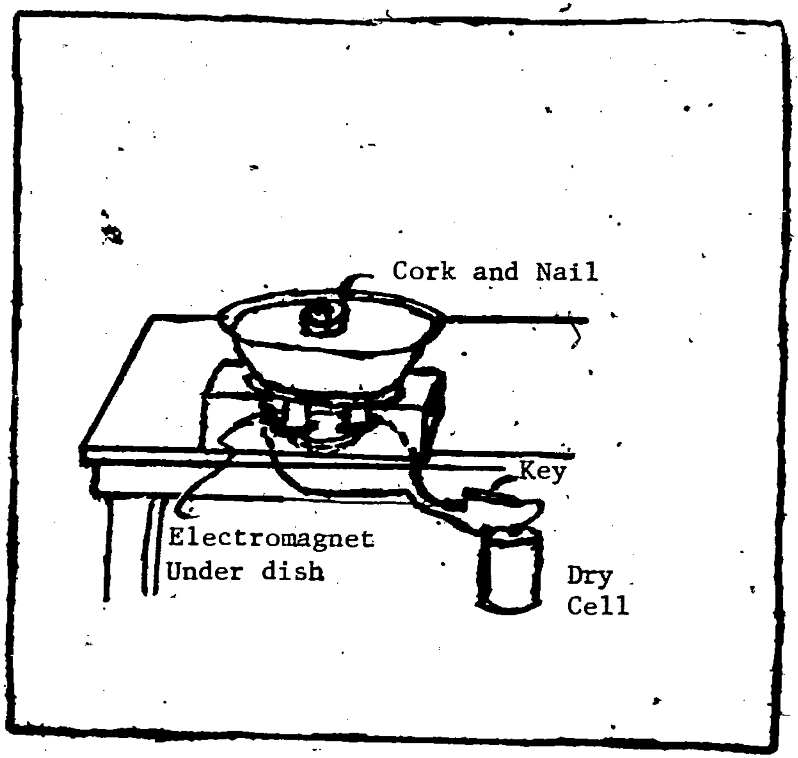
Next make some small, carved wooden boats such as shown in Fig. 2. Use paper for the sails. Drill a hole and place a nail or needle through the length of each wooden hull. By moving your "magic wand" in the vicinity of these boats, your navy will sail around at your command. Write a short paragraph or two which will explain the observed naval activity, in terms of magnetic effects. Submit your notes for evaluation.

MAGIC CORK

A "magic cork" toy consists of a cork with a nail in it. The cork floats in a bowl of water. An electromagnet sits underneath the bowl.

<u>Materials</u>:
- 1 electromagnet
- 1 cork
- 1 nail
- 1 dry cell battery
- 1 bowl
- 1 key switch
- few feet of copper wire

Conceal a nail or large needle in a cork. Place the cork in a shallow dish of water under which you have hidden an electromagnet. Connect the wires of the electromagnet to a dry cell. Make a key switch using two pieces of brass or copper. Arrange this under the table so you can press it with your foot.



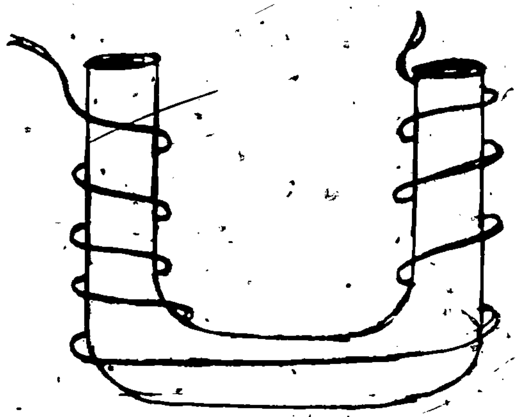
MAGIC CORK
Fig.1

Connect the electromagnet assembly as shown in Fig.1. Put the cork-with-nail in the bowl of water. Now touch the key switch and notice the results. Tell some of your classmates that you can make the cork sink or swim at your command. When you want it to sink, close the electric circuit and the magnet will pull the nail in the cork toward the bottom of the dish. It will bob up again ("swim") when you remove your foot from the key switch and the circuit is opened.

Answer the following questions in writing and submit them for evaluation:

1) In what way is this experiment like the magnetic navy experiment?
2) In what way is this experiment different?

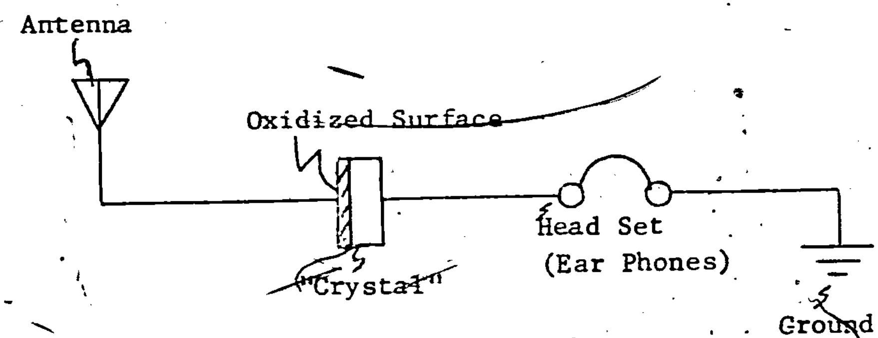
Note: You can make your own electromagnet using a U-shaped piece of iron and some cloth-covered copper wire. Bend a piece of soft iron (a large spike will do) into a U-shape. Carefully wrap several turns of wire around each "horn". To make a stronger electromagnet, you can "layer" the loops and use two or more dry cells in series. See the Fig. 2.



ELECTROMAGNET
Fig. 2

"POOR BOY" RADIO RECEIVER

The "Poor Boy" radio receiver can be built easily. Buy a cheap commercial crystal or make a "crystal" by oxidizing an edge of a piece of metal. To oxidize is to combine with oxygen. Burning is oxidizing. If you place the edge to be oxidized in a flame, such as a Bunsen burner flame, you will crystalize the edge. Or use a "ready-made crystal" such as a rusty razor blade (A Gillette Blue Blade ought to work well). Connect one side of the crystal to an antenna or to any large metal object; connect the other side through the head set to a ground (a water pipe, for example). See the diagram below.



CIRCUIT DIAGRAM OF "POOR-BOY" CRYSTAL RADIO RECEIVER

This radio should pick up the strongest station in your area.

For a fancier radio receiver which can be easily constructed from only a half dozen parts, see Resource Package 6-1, Physics of Communication minicourse.

RESOURCE PACKAGE 5-2

READINGS ELECTRICITY AND MAGNETISM

1) Oxehorn, Joseph M., Pathways In Science: Physics 3--Sound and Light, 1st Edition, Globe Book Co. Inc., New York, New York, 1970:

The Electric Circuit	pages 5-8
The Electric Current	pages 10-12
Measuring Electricity	pages 14-16

2) Verwiebe, Frank L., and others, Physics, A Basic Science, 5th Edition, American Book Co., Dallas, Texas, 1970:

Electrostatics	pages 270-290
Electrical Properties of Matter	pages 300-315
Magnetism	pages 324-338
Electrical Applications	pages 349-394

3) White, Harvey E., and others, Physics, An Experimental Science, d. Van Nostrand Company, Inc., Princeton, New Jersey, 1968:

Electricity at Rest	pages 425-429
Capacitance	pages 440-443
Battery Cells	pages 445-451
Ohm's Law	pages 452-455
Series and Parallel Resistances	pages 456-459
Compound Circuits	pages 461-465
Electric Energy and Power	pages 467-470
Magnetism	pages 475-478
Magnetic Fields	pages 479-488
Magnetic Forces	pages 490-493
Electromagnets	pages 494-498
Induced Electric Currents	pages 500-501
Lenz's Law and Self Induction	pages 506-510
Transformers	pages 511-516
Alternating Current	pages 517-522
Resonant Circuits	pages 524-531
Electronics	pages 539-590

RESOURCE PACKAGE 5-3

FILMS AND FILM STRIPS

Films

Electricity Ready-Made Magic	11 min.
Electromagnetic Waves	33 min.

Film Strips

Current Electricity
Electricity--From Generator to You
Electromagnets
Magnets
Static Electricity