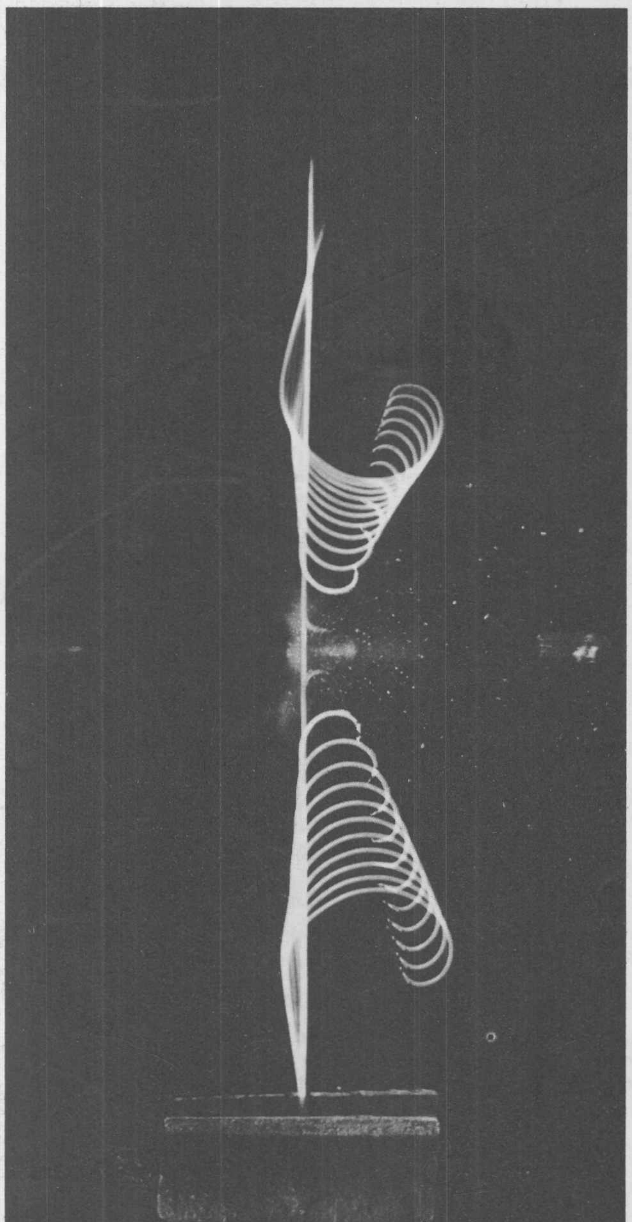
FORCE AND MOTION



Richard D. Heckathorn

Most people have rather vague and varying ideas of the meaning of the term **force**. Force means different things to different people. To an army general, the term *armed forces* means many soldiers. To a politician a *forceful* speaker is a person who can influence people with the use of words.

To a scientist, however, the term "force" has still different meanings. When one object *pushes* or *pulls* another object it is exerting a force. Forces can either cause motion, or slow down or stop the motion of things that are moving. Forces can also change the direction of motion.

If you ever pushed one of your friends in a wagon, you probably noticed that at first quite a bit of force was needed to start the wagon. But, once the wagon was rolling along, you perhaps noticed that it was easier to keep the wagon moving than it had been to start it moving.

You may have also noticed that a locomotive, attached to a long line of freight cars, at first starts to move very slowly as it begins to exert a force and pull the train. Then, as the engine continues to pull, it gradually moves faster and faster or accelerates (ack-sell'-er-ates) until the entire train of cars is moving quite rapidly at a constant speed. There are other kinds of forces with which you are familiar. A magnet exerts a force on a piece of steel because it pulls the steel to it. This is called **magnetic force**.

Gravity exerts a force on all objects on the earth. As you sit in a chair, the earth's **gravitational force** is trying to *pull* you down to the earth's surface. The chair you are sitting on, at the same time, exerts a force pushing up against the force of gravity to keep you from falling to the floor.

Certain forces keep the earth rotating on its axis, while other forces keep it revolving around the sun. There are even very powerful forces acting inside of the atoms of all substances. These forces, when released, can be very beneficial to mankind if they are properly used.

So you see there are many different kinds of forces acting all around us and, since they affect our lives very much, it is important that we know more about them and also how to measure some of them. As you do the following problems, you will discover many interesting things about force and motion.

Unit Opening Photograph

Observe the multiple image of the bullet piercing a thin strip of metal. The force of the bullet can be seen in the stream of metal particles shooting forward, and in the metal's tearing, and bending in the opposite direction of the applied force. The camera has captured this sequence before, during, and after the bullet's impact, as well as the progressive stages of the metal's bending. Note the slippage of the metal strip from its original position at top when pierced by the bullet. (Photographer: Dr. Harold Edgerton, Courtesy of Polaroid Corporation.)

Lab-Inquiry Texts
PHYSICAL SCIENCE

TITLES

Methods of Science
Measurement
Using Line Graphs
Properties of Matter
Force and Motion
Work, Energy and Simple Machines
Magnetism and Electricity
Behavior of Light and Sound

By Sanford M. Eisler and Murray Stock

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problem 5-1

To determine one way of measuring force.

MATERIALS
Spring scale

PROCEDURE

1. Examine the spring scale to see how it works. Handle it carefully since it is a piece of scientific equipment.

   Why is it called a "spring scale?"

Notice that the face of the scale has two sets of markings, *g* and *oz.* Do not confuse the *g* readings on the spring scale with grams of *mass.* The gram (and ounce) readings on the scale represent units of *force,* and have a different meaning than units of *mass.* This difference between a gram of mass (g) and a gram of force (gf) will be explained more clearly in a later activity.

2. Hold the scale by the ring at the top and let it hang freely. Check to see if the upper surface of the pointer lines up exactly with the 0 line (Fig. 5-1). If it doesn't, ask your teacher to adjust it for you.

3. Study the face of the scale and answer the following questions:

   a. How many grams of force (gf) does each space between the lines measure?

   b. How many ounces of force?

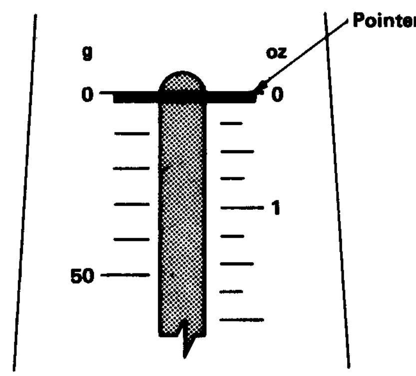


Figure 5-1

   c. According to the scale, a reading of 50 gf equals a reading of how many ounces?

   d. You have to estimate or guess the position of the pointer when it rests in the spaces between the lines. What is the smallest unit of grams of force you can *estimate* on this scale? The smallest unit in ounces?

   e. The thickness of the pointer affects the reading. What can you do to avoid the problem?

4. On Practice Sheet 5-1 are diagrams of various scale readings. Record on the sheet the position of the pointer in grams and ounces for each diagram. Remember to read the position of the *upper* surface of the pointer.

5. With one hand, hold the scale by the top ring. With the other hand *gently* pull or exert a force on the bottom hook.

Why can it be said that this spring scale may be used to measure force?

____

____

6. Exert the following forces on the spring scale: 50 g, 100 g, 175 g, 32 g, 4 oz., 6.5 oz., 7.25 oz., 150 g.

Which hand is doing the pulling? Are you sure? Explain why.

____

____

____

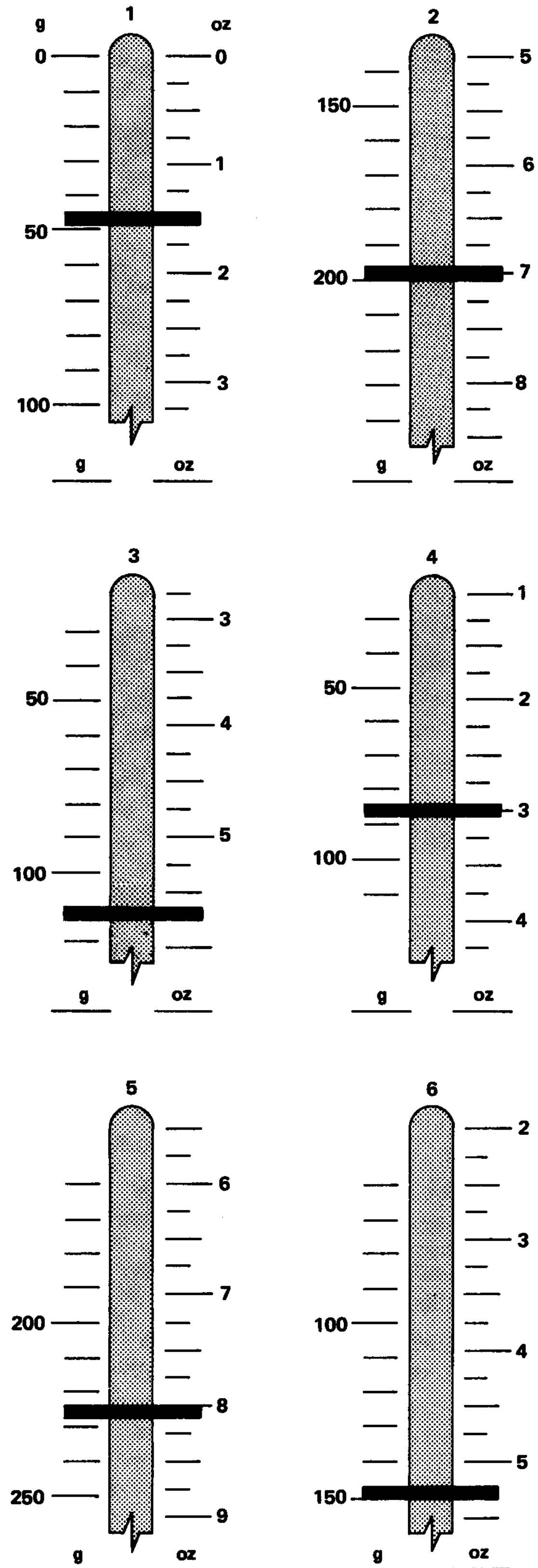
____

BEYOND THE CLASSROOM

1. Examine an ordinary bathroom scale and try to discover how it measures force.

2. Some markets still use spring scales for weighing meat and vegetables. Look for a seal or stamp on the scale placed there by a city inspector. What is the purpose of the seal or stamp?

PRACTICE SHEET 5-1



problem 5-2

To investigate the relationship between force and motion.

MATERIALS

Small cart
Heavy thread
2 Spring scales
Graph paper
5 Lead sinkers
Metric ruler

PROCEDURE

1. Place the small cart on the floor. Attach a thread about 50 cm long to the cart. Tie a loop on the other end of the thread and hook the spring scale to the loop. Hold the cart firmly with one hand to prevent it from moving and pull the scale until it registers 50 gf of force (Fig. 5–2). *Notice that on the diagram an arrow is used to represent the direction in which the force is being exerted.*

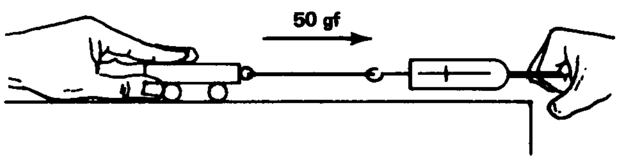


Figure 5-2

Release the cart by suddenly removing your hand from the cart.

a. What caused the cart to move when you released it?

b. Other than *pulling* the cart, how else could you have made it move?

c. Can you think of any motion that is not caused by either a push or a pull (force) of some kind?

2. Repeat Procedure 1 using 100, 150, 200, 250 grams of force to move the cart.

a. As you increased the force, what effect did it have on the speed or movement of the cart?

b. Give other examples where, if force is increased, speed increases.

3. Measure the distance in centimeters that the cart moved when each of the forces was applied in Procedures 1 and 2. Use chalk marks to show starting and stopping positions of the cart. Record distances in Table 5-1.

TABLE 5-1

Force	50 gf				
Distance	cm				

4. On Practice Sheet 5-2, construct a graph showing that how far the distance the cart moves is dependent on the force that causes it to move.

a. What two variables (conditions that change) are involved?

____

b. Which is the independent variable (the condition that you change)?

____

c. How would you define the term dependent variable?

____

____

5. Repeat Procedure 1, placing lead sinkers in the cart to increase the mass. Add one sinker at a time. In this case, use 200 grams of force to pull the cart. Record in Table 5-2 the distances the cart moved with each load. Complete the table.

TABLE 5-2

FORCE = 200 gf

Load	Distance cart moved
1 sinker	cm

Using the same force, what was the effect on the distance the cart moved as the mass was increased?

____

____

____

____

6. Use two spring scales for this procedure. Hook one scale to the front end of your cart and the other to the rear of the cart. Exert a force of 50 gf on each scale in opposite directions at the same time.

Does the cart move? Why?

____

____

____

7. Repeat Procedure 6, increasing the force on one scale of 100 gf but keeping the force on the other scale at 50 gf.

a. What happens to the cart now?

____

b. In which procedure would you say the forces were *balanced?* Why?

____

c. In which procedure would you say the forces were *unbalanced?*

____

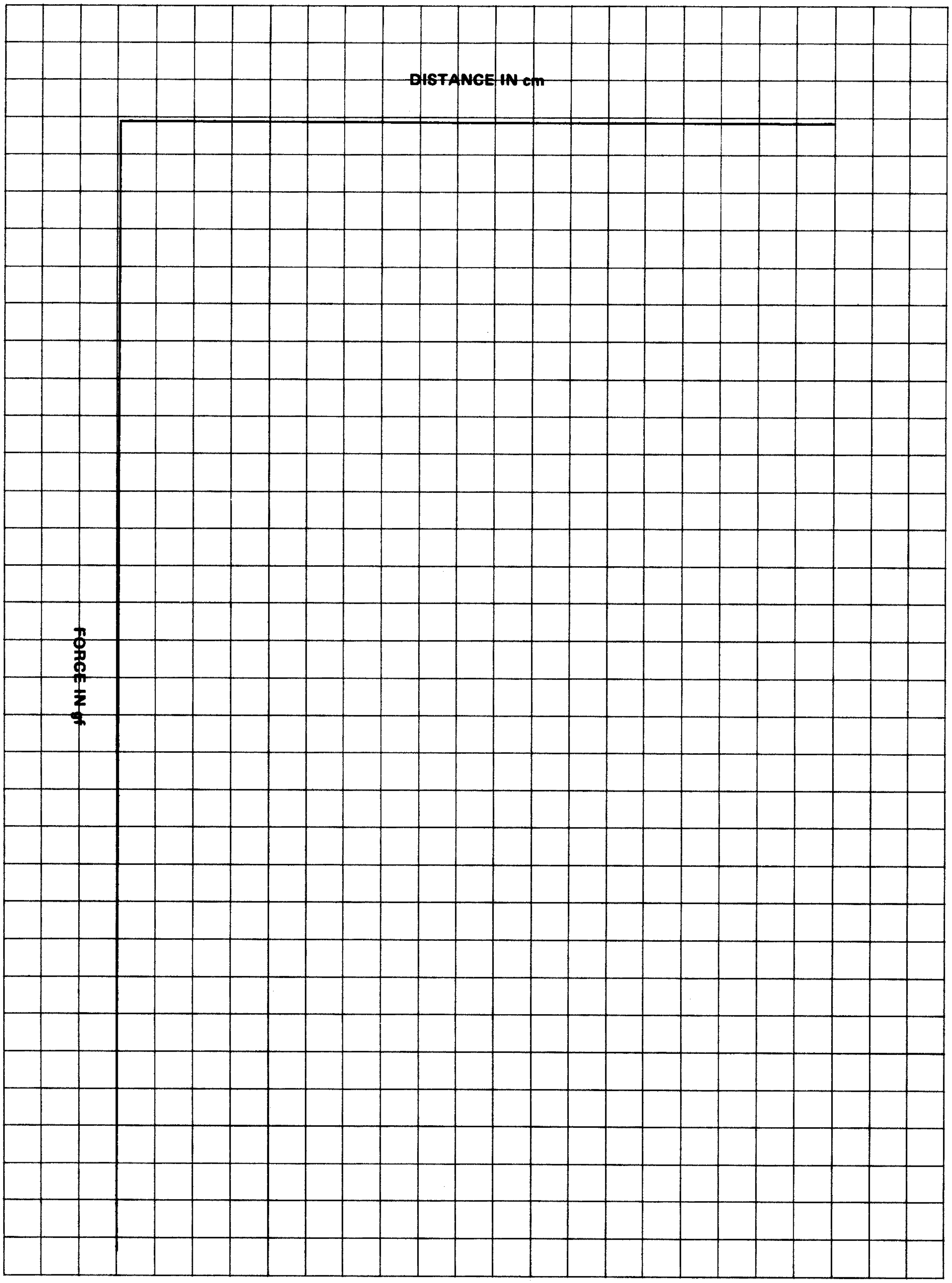
d. As a result of what you did in Procedures 6 and 7, what can you say about the kind of forces needed to produce motion?

____

BEYOND THE CLASSROOM

On your way home from school, observe various objects that are in motion. Since forces are necessary to produce motion, try to determine the force that is causing the motion in each case.

PRACTICE SHEET 5-2



problem 5-3

To investigate the effect of the force of gravity on a spring scale.

MATERIALS

Spring scale
Large lead sinker
Large metal washer
Pegboard
Pegboard support

PROCEDURE

1. Attach the spring scale to the pegboard support as shown (Fig. 5-3). Check to see that the pointer is at the zero position.

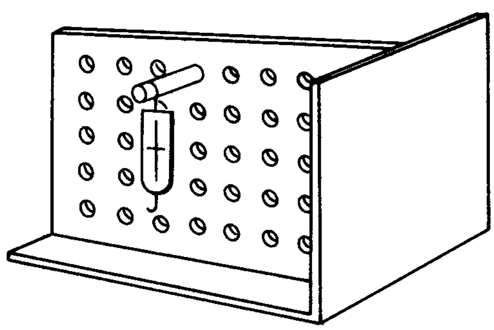


Figure 5-3

2. Hang the large metal washer from the hook of the scale. Notice the position of the pointer. Remove the washer and attach the large lead sinker. Again notice the position of the pointer.

Why did the lead sinker exert a greater pull on the scale than did the washer?

____

____

____

3. Hold the washer and the sinker in one hand as high as you can above the floor.

a. If you dropped both the washer and the sinker at the same time, which do you predict will strike the floor first?

____

b. Verify your prediction by dropping both from your hand at exactly the same time. Was your prediction correct?

____

c. What does this prove about the effect of weight on how fast an object falls?

____

4. Study Reference Sheet 5-1 carefully.

BEYOND THE CLASSROOM

1. Visit your library and learn what you can about Galileo and his famous experiment at the Leaning Tower of Pisa.

2. Investigate the experiment performed by astronaut David Scott in which he dropped a hammer and a feather on the surface of the moon (Apollo 15). What did this prove or disprove?

reference sheet 5-1

You know that if you drop an object it will tend to fall, and you say that **gravity** pulls it down. Since gravity appears to be a *pulling* action and the term "force" is defined as a push or a pull, it can therefore be said that gravity is a kind of force. This force of gravity seems to be always trying to pull all things toward the earth's surface. It is this force, or pull of gravity, that gives **weight** to all things.

If a man steps on a weighing scale and the pointer shows 150 pounds, it means that the force of gravity pulling on that man is 150 pounds. If the washer which you suspended from your spring scale causes it to read 10 grams, it means that the force of gravity is pulling down on that washer with 10 grams of force (10 gf).

Do not confuse a gram of *mass* (g), with a gram of *weight* or force (gf). You may remember that the mass or quantity of matter in an object does not change but remains the same no matter where it might be in the entire universe. This is not true of the *weight* of an object.

All matter has another property closely related to mass. This property is called **inertia** (in-er′-she-a) and, like mass, it is not affected by the force of gravity. Anyone who has ever attempted to push a stalled automobile knows that it takes a considerable force to start a car moving from a fixed position. However, as the car begins to move, it requires less and less force to keep it moving until it reaches a constant speed.

The inertia of an object is one reason why it requires force to start the object moving. Inertia is the property of matter that tends to cause an object to resist a starting motion (Fig. 5-4a). The pushing force must overcome inertia (and other factors) before the car will start moving.

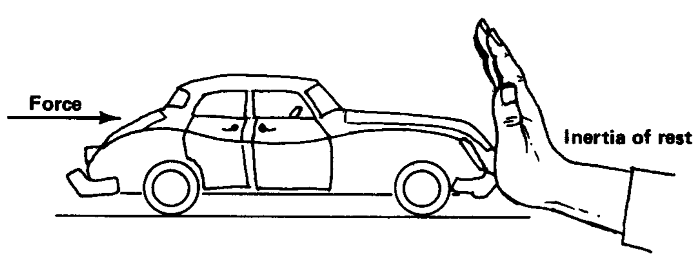


Figure 5-4a

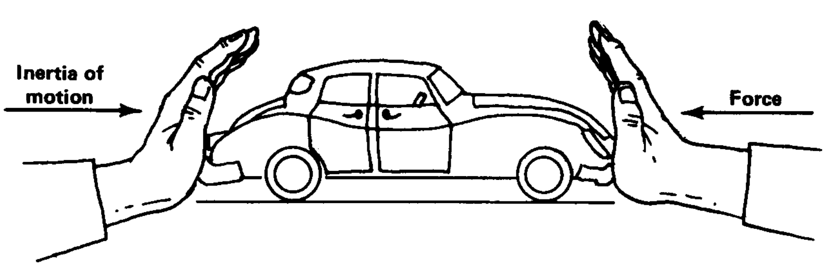


Figure 5-4b

It is also true that it takes a great deal of force to slow down an automobile, once it is moving. This is why automobiles require brakes. Inertia also can be described as the property of matter which tends to keep an object in motion once it starts to move (Fig. 5-4b). The braking force must overcome the inertia of the moving car in order to stop it.

Many years ago, an English scientist, Sir Isaac Newton, expressed the effect of inertia on objects by a rule that is known as **Newton's First Law of Motion.** Newton's law states that any object at rest will tend to remain at rest unless acted on by some force; and any object that is moving, will tend to continue to move in a straight line at constant speed, unless acted upon by some outside force.

The amount of inertia an object has depends on its mass. The greater the mass of an object, the greater is its inertia. Because of inertia, it takes much more force to *start* to move a heavy truck than it does a small automobile. It also takes more force to *stop* a moving truck than it does a small car traveling at the same speed because the moving truck has the greater inertia. Although an object's weight might change as it gets farther from the earth, its inertia never changes. Even in outer space, where there is weightlessness, objects would have the same inertia as they would have on earth. This is because the mass of the object is the same in outer space as it is on earth.

Inertia is measured in units called **g's.** (Do not confuse this unit with g, the metric unit of mass). One g of inertia is the force of the normal pull of gravity on an object.

Over 300 years ago Sir Isaac Newton investigated many problems in science. He discovered some very important facts about mass, force and motion which still hold true today.

A rocket carrying a spacecraft into outer space accelerates, or increases, its speed very rapidly at liftoff. This very rapid increase in speed during liftoff exerts great inertial forces on the astronauts inside the spacecraft. Astronauts making these flights have had to withstand forces of 8 to 16 g's on liftoff. This means that they were acted upon by forces which were 8 to 16 times their normal weight on earth.

That is why, on liftoff, they are strapped in a lying-down position on specially designed seats. This prevents injury to the astronauts due to the increase in g forces to which they are subjected.

problem 5-4

To demonstrate Newton's First Law of Motion.

MATERIALS
Beaker
Metal washer
Index card
Small cart
Wooden block (10 cm × 5 cm × 2 cm)

PROCEDURE

1. Place the index card and the metal washer over the beaker (Fig. 5-5).

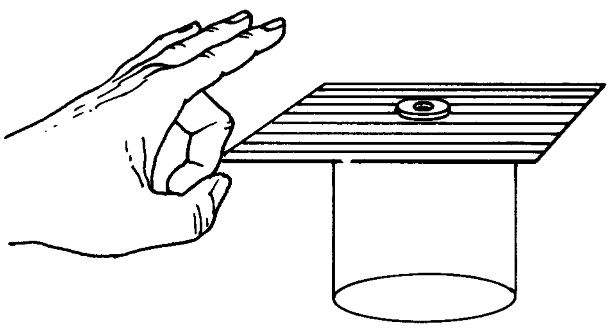


Figure 5-5

Snap the card from the beaker with a quick flip of your finger. Do not touch the washer.

a. What happened to the washer as the card was flipped away?

____

b. What caused the washer to remain in place although the card was moving?

____

c. Write the part of Newton's First Law of Motion that explains the reason for what happened to the washer.

____

____

2. Stand the wooden block with its smallest base on the cart (Fig. 5-6).

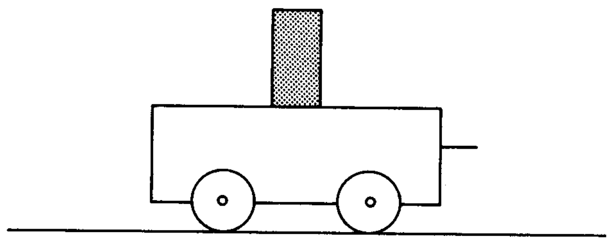


Figure 5-6

a. If the cart were pushed forward suddenly, what do you predict would happen to the wooden block? Explain why.

____

____

b. If the cart were moving with the block in position, predict what would happen to the block if the cart was stopped suddenly. Explain why.

____

____

Prove your predictions by experimenting with the block and cart.

3. Complete Worksheet 5-1.

BEYOND THE CLASSROOM

1. Next time you ride in a bus, stand instead of taking a seat. Find something to hold onto. Explain what happens to you as the bus starts and stops suddenly. What would happen if you had nothing to hold onto?

2. Visit a tall building that has elevators that move up and down rapidly. Explain the effect on your body as the elevator starts up; as it starts down.

worksheet 5-1

1. Which exerts a greater pull, a gram or an ounce of force?

2. What causes an object to have weight?

3. How does mass differ from weight?

4. Why shouldn't a spring scale be used to measure mass?

5. If an object is pulled north by a force of 10 gf and south by a force of 10 gf, in what direction will it move? Why?

6. How does a game of tug of war illustrate the principle that *unbalanced* forces cause motion?

7. Can an object be set in motion if no forces act on it? Explain.

8. Name the various forces that act on an object as it is thrown into the air.

9. Why are seal belts now required on all new automobiles sold in the U.S.A.?

10. Suppose you were standing on a scale in an elevator and the elevator started to move up rapidly. Would your weight seem to increase, decrease, or stay the same? Explain.

problem 5-5

To discover the factors that affect the amount of frictional force between moving objects.

MATERIALS

Large wooden block	Sandpaper
Thread	Dowels (4″ × ½″)
Spring scale	Bead chain
Sheet of notebook paper	Hook

PROCEDURE

1. Study Reference Sheet 5-2. Hang the large wooden block on the hook of the spring scale and record its *weight* in grams of force (gf).

____

2. Place the block with one of the largest flat sides on the table. Attach the spring scale to the block with a short piece of thread and slowly drag the block along the table at a *constant speed*. This pulling force is called the **applied force**.

Determine the number of grams of applied force required to keep the block moving along the top of the table at a constant speed. Repeat the procedure three times. Record data in Table 5-3 and find the average applied force.

TABLE 5-3

Trial	Applied Force
1	gf
2	
3	
Average Force	

3. Study Reference Sheet 5-2 carefully. Why is the applied force required to pull the block along the table different than the weight of the block?

____

____

____

4. The applied force necessary to overcome the frictional force between two surfaces that slide over each other depends on many things.

How do you think the sizes of the surfaces, or *areas*, of the surfaces in contact with each other would affect the frictional force between them? State your guess or **hypothesis.**

____

____

____

5. Using the block and spring scale, prove or disprove your hypothesis by performing an experiment.

Remember, your block has surfaces of different areas. Record your results in Table 5-4.

TABLE 5-4

Trial	Applied Force	
	Large Area	Small Area
1		
2		
3		

a. Was your hypothesis correct?

____

b. Do the areas of the sliding surfaces have a *significant* (sig-nif'-i-cant) effect on the frictional forces?

____

c. Why should you do three trials and take the average reading of the applied force?

____

6. Repeat Procedure 2, using first a sheet of notebook paper, and then a sheet of sandpaper as the surface on which to slide the wooden block.
Record your results after averaging three trials.

Applied Force

Notebook paper _______________

Sandpaper _______________

What do the results in Procedure 6 show?

____

____

____

7. Repeat Procedure 2 but place a book on the block as you pull it across the table top (Fig. 5-7). Record data.

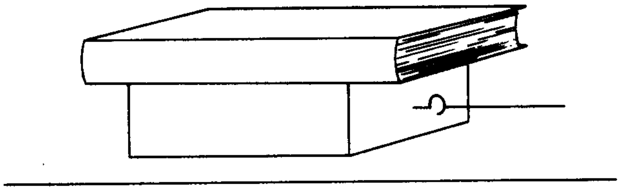


Figure 5-7

Applied Force

With book _______________

Without book (from Table 5-3) _______________

The *total* force pressing the sliding surfaces together, in this case the weight of the book *plus* the weight of the block, is called the **normal** force (Fig. 5-8).

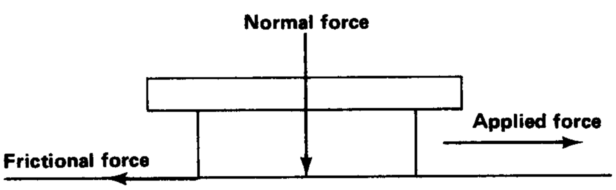


Figure 5-8

Compare the frictional forces in this procedure with those in Procedure 2.

____

____

8. Try placing different weights on the block and measure the applied force necessary to overcome frictional force. (Do not record this data.)

What do the results of this procedure tend to prove concerning the effect of the normal force on the frictional force?

____

____

____

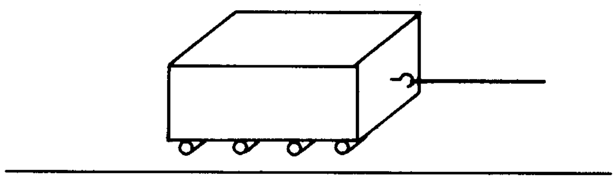


Figure 5-9

9. Place the wooden block on four or five wooden dowels (Fig. 5-9).

Measure the applied force needed to move the block at a constant speed. Repeat, using short lengths of bead chain under the block. Record your results.

Applied Force

Dowel ______________________

Bead chain ______________________

The applied force is now overcoming **rolling friction** instead of **sliding friction.**

How does the applied force necessary to overcome rolling friction compare to the force necessary to overcome sliding friction?

____

____

10. Complete Worksheet 5-2.

BEYOND THE CLASSROOM

1. Look for different places at home where friction is involved (door hinges, etc.). Make a list, and indicate whether the frictional force to be overcome is sliding friction or rolling friction.

2. Bring to class some ball or roller bearings from discarded bicycles, wagons, roller skates etc. Explain how they differ in reducing friction.

3. Get pieces of different kinds of brake linings from a neighborhood garage and compare them to find out which would be best for automobile brakes.

4. Report to class about a new type of vehicle called a hydroplane that rides on a thin layer of air.

reference sheet 5-2

There are other conditions that play important parts in the motion of objects. One of these is **frictional force** (frick'-shun-al). If you were to examine the surface of almost any object with a microscope, even though it looks perfectly smooth to the naked eye, you would find that it is quite rough, with many bumps and grooves. When two such surfaces are placed together, many of these bumps and grooves fit into each other, making it harder for the surfaces to slide one over the other (Fig. 5-10).

Figure 5-10

In fact, this roughness has the same effect on sliding surfaces as if some invisible force were pulling *against* the applied force. This invisible force on sliding surfaces is called **sliding frictional force**. It always acts in a direction *opposite* to the applied force (Fig. 5-11). When the object being moved slides at a constant speed, the applied force is always greater than the frictional force. In other words, if it requires 100 gf to slide the block at a constant speed, then the frictional force being overcome is less than 100 gf in the opposite direction.

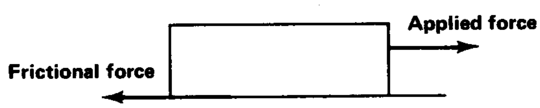


Figure 5-11

Whenever two surfaces of any materials rub or slide against each other, the sliding motion is opposed by frictional force. However, frictional force can often be helpful.

For instance, friction keeps an automobile from slipping on an icy road. Can you imagine trying to walk if there were no friction between the soles of your shoes and the floor? On the other hand, in most machines that have moving parts, friction is a hindrance and must be overcome. Therefore, the problem concerning friction is to try to reduce it as much as possible wherever it is not wanted, and to increase it where it is needed.

worksheet 5-2

1. In most machines, friction is undesirable. Give some examples where friction is very important and necessary in our daily lives.

2. Give a reason why tennis shoe soles and automobile tires are made of rubber.

3. What is the most common way of reducing friction between sliding or rolling surfaces?

4. Two automobiles—a large, heavy car and a small compact car—both have the same kind of tires. Which of the two will skid farther if they try to stop suddenly from 40 miles per hour on the same kind of pavement. Why?

5. Can friction be completely eliminated between sliding or rolling surfaces? Explain your answer.

6. Which would tend to reduce skidding of an automobile—adding or removing some air from the tires. Why?

7. If it requires an applied force of 200 g to pull an area of 1000 cm^2 over a surface, how much force will be required to pull an area of 500 cm^2 of the same material over the same kind of surface?

8. Which of the following would be easier to push along a floor—an empty wooden box with a sliding surface area of 20 ft^2 or a wooden box of the same weight, with a sliding surface area of only 5 ft^2 but with 30 lbs. of material in it? Why?

9. In what way does oil reduce friction between two sliding surfaces?

10. Why do the blades of ice skates need to be "sharpened?"

problem 5-6

To demonstrate Newton's Third Law of Motion.

MATERIALS

2 Spring scales
Rubber band
Pegboard platform
Pegboard support
Support rod
Metric ruler

PROCEDURE

1. Study Reference Sheet 5-3.

2. Borrow an extra spring scale from your teacher or from another group. Hook each of the scales to the opposite ends of a rubber band. Pull on each scale, stretching the rubber band (Fig. 5-12). Observe the readings of each scale as you increase the pull on the rubber band.

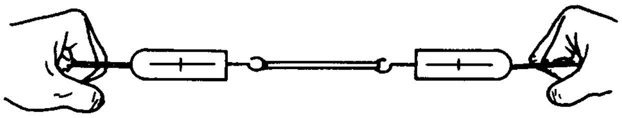


Figure 5-12

How did the reading on the two scales compare with each other as the rubber band was stretched?

Using the two scales, try to stretch the rubber band so that the readings on the two scales differ quite a bit. Can you do it?

3. Stretch the rubber band by pulling on each scale with a force of 100 gf. Measure the length of the stretched rubber band and record its length in cm in Table 5-5.

4. Repeat Procedure 3, pulling with a force of 150 gf and also with 200 gf. Record in Table 5-5.

TABLE 5-5

Force Left Scale	Force Right Scale	Length of Stretched Rubber Band
100 gf	100 gf	cm
150 gf	150 gf	cm
200 gf	200 gf	cm

5. Place one end of the same rubber band used in Procedure 2 over a rod attached to the pegboard support. Hook a spring scale to the other end of the rubber band (Fig. 5-13).

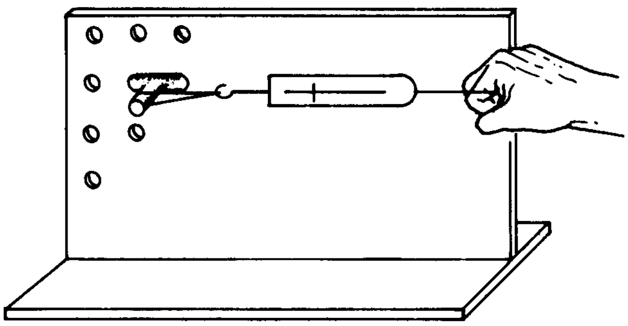


Figure 5-13

Before experimenting, how far would you guess that the rubber band would stretch if only *one* spring scale would pull on it with a force of 100 gf?

6. Now apply a force of 100 gf by pulling on the rubber band with only *one* spring scale. Measure the stretch of the rubber band and record your result in Table 5-6. Repeat, pulling with a force of 150 gf and then 200 gf.

TABLE 5-6

Force Using One Scale	Length of Stretch of Rubber Band
100 gf	cm
150 gf	cm
200 gf	cm

7. Compare the data in Tables 5-5 and 5-6.

a. How does the stretch of the rubber band pulled with *one* scale compare to the stretch when pulled with *equal forces* by each of the two scales?

b. Study Reference Sheet 5-3 and from what you read explain the answer you gave to question 7a.

BEYOND THE CLASSROOM

1. Blow up a balloon. While it is inflated, throw it into the air, allowing the air in the balloon to escape. Explain its motion based on Newton's *Third Law of Motion.*

2. Investigate the principle of rocket engines and how it relates to the law of action and reaction.

reference sheet 5-3

Sir Isaac Newton, in his *Third Law of Motion*, stated that "for every action there is an equal and opposite reaction." This tells us that if a force is applied to any object, the object itself tends to exert a force that is equal in amount to the applied force but acts *against* it in the opposite direction.

For instance, if a book is placed on a table, you know that the book exerts a downward force on the table due to gravity. But why doesn't the book fall to the floor? Because the table is pushing up against the book with a force exactly equal to the weight of the book. The heavier the book, the greater the force pulling down on the book, and the greater the force pushing up against the book by the table (Fig. 5-14).

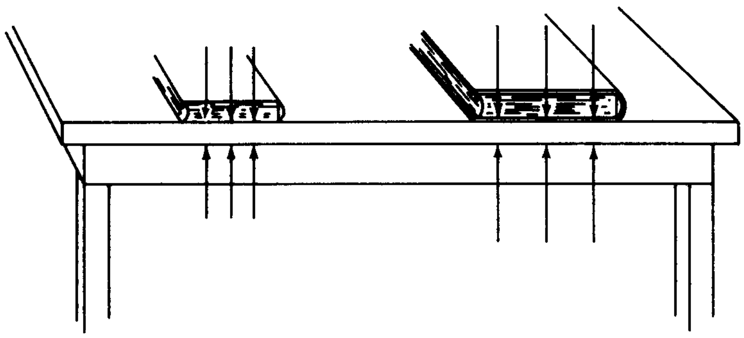


Figure 5-14

Try pushing your hand against a wall. You will notice that as you push, the wall seems to be pushing against your hand. And *the harder you push*, the harder the wall seems to push back (Fig. 5-15). You would surely realize that this were true if your hand pushed against the point of a nail in the wall. The harder you pushed, the deeper the nail would be pushed into your hand by the wall.

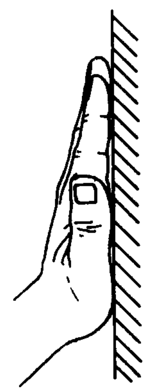


Figure 5-15

All forces act in *pairs*. No force acts alone. This means that no force can be exerted by an object unless another body exerts a force *against it* in the opposite direction.

Anyone who has played tug-of-war knows that someone must be pulling in the opposite direction on the other end of the rope in order to play the game. Suppose one end of a rope were connected to a post, and you pulled on the rope. Although you applied a force to the rope, it didn't move. Why?

Study Figure 5-16 and see if you can describe the various forces that are acting on the objects in the diagram.

There are many other examples which might help you to understand how forces act and react against each other. For instance, why is it easier to walk on a dry pavement than on one covered with ice? The answer, of course, is that on

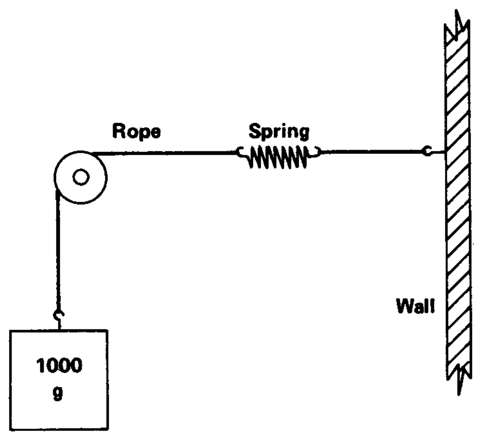


Figure 5-16

a dry pavement, the *backward* push (force) of your foot is reacted against by the *forward* push of the pavement. On an icy pavement there is very little force to act *against* the backward push of your foot and your foot slides.

A rocket is another example of how the action of one force produces another force in the opposite direction. In a rising rocket, the hot gases escape from the end of the rocket with a terrific force. As the gases escape, they push or exert a force against the rocket in the opposite direction and cause it to rise off the ground (Fig. 5-17).

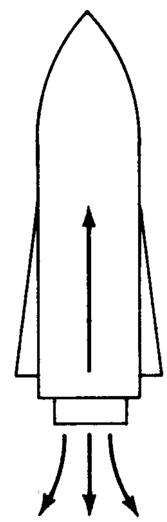


Figure 5-17

You may wonder why nothing has been mentioned about Newton's *Second Law of Motion.* Newton's second law deals with the *momentum* of a moving object. Momentum has to do with both the mass and the speed at which an object moves. The greater the mass of an object and the faster it moves, the greater is its momentum.

A football player weighing 250 pounds would have greater momentum than another player weighing 150 pounds running at the same speed. A car traveling 60 miles per hour has a greater momentum than the same car traveling 40 miles per hour. You will learn more about momentum and Newton's Second Law of Motion when you study physics.

problem 5-7

To illustrate the effect of centripetal force.

MATERIALS

Heavy thread
Metal washers
Aluminum foil
Plastic soda straws
Paper clip

PROCEDURE

1. Take a piece of aluminum foil about a foot square and form it into the shape of a ball about 3 to 4 cm in diameter. Tie it to one end of a piece of heavy thread, about one meter long. Cut about 10 cm from the end of a plastic soda straw and pass the loose end of the thread through it. Make a hook from a paper clip and tie it to the loose end of the thread (Fig. 5-18).

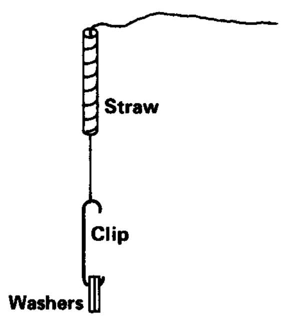


Figure 5-18

Add three large metal washers to the hook.

Which has the greater mass, the aluminum ball or the metal washers?

Study Reference Sheet 5-4.

2. Hold the straw in one hand and start the ball whirling (Fig. 5-19). Allow the thread to slide up and down through the straw. *(Be careful not to strike anyone with the whirling ball.)*

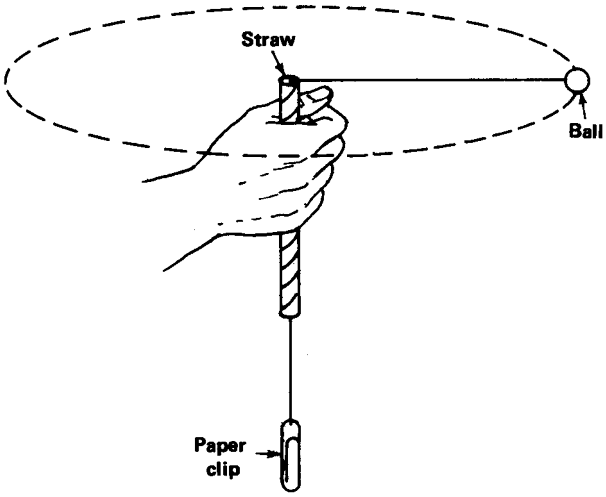


Figure 5-19

a. What force is pulling on the aluminum ball causing it to move in a circular path instead of a straight line?

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b. What is supporting the weight of the washers?

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3. Whirl the ball slowly at first, and then faster and faster.

What effect does the speed of the moving ball have on the centrifugal effect?

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4. Whirl the ball in a small circle and then whirl it in a large circle. Try to keep the speed of the ball the same in each case.

What effect does the size of the circular path have on the centrifugal effect?

5. Keep adding washers to the hook.

How many can be supported by the moving ball?

6. Complete Worksheet 5-3.

reference sheet 5-4

There are forces other than friction which play an important role in the motion of objects. According to Newton's First Law of Motion, an object in motion continues moving in a *straight line* unless acted upon by another force.

Many objects in motion, however, move in curved paths instead of straight lines. An automobile turning a corner is an example of an object moving in a curved path. Therefore, according to Newton, some force must be acting on these objects to cause them to move in a curved path.

All of the planets in the solar system are moving very rapidly through space. Why don't these planets fly off into space in straight lines instead of traveling around the sun in nearly circular orbits? Some force must be keeping the planets in orbit around the sun (Fig. 5-20).

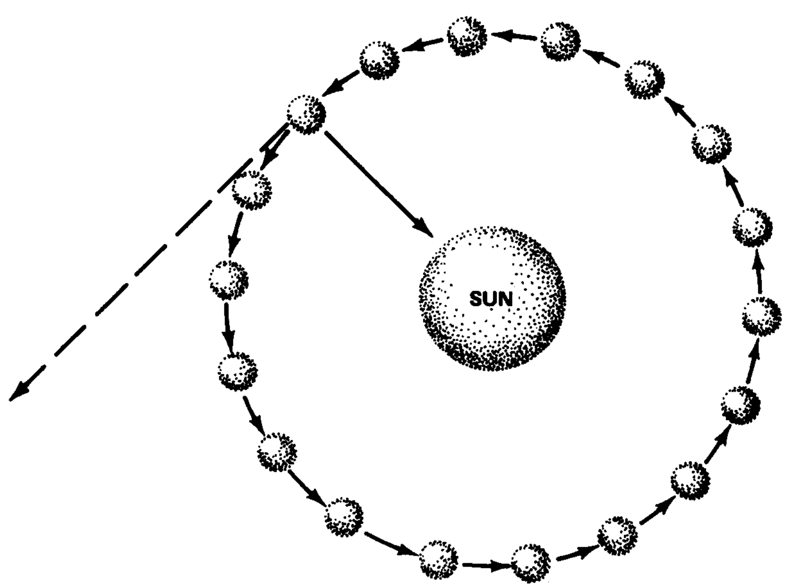


Figure 5-20

The force which causes objects to move in curved paths is called **centripetal force**. Suppose a boy ties a stone to a string and whirls it rapidly around his head. It travels in a circular path (Fig. 5-21).

As the stone moves it is constantly trying to fly off in a straight line AB. However, the pull of the string, which is the centripetal force, pulls *inward* and keeps the stone moving in a circular path. Due to its *inertia,* the stone also

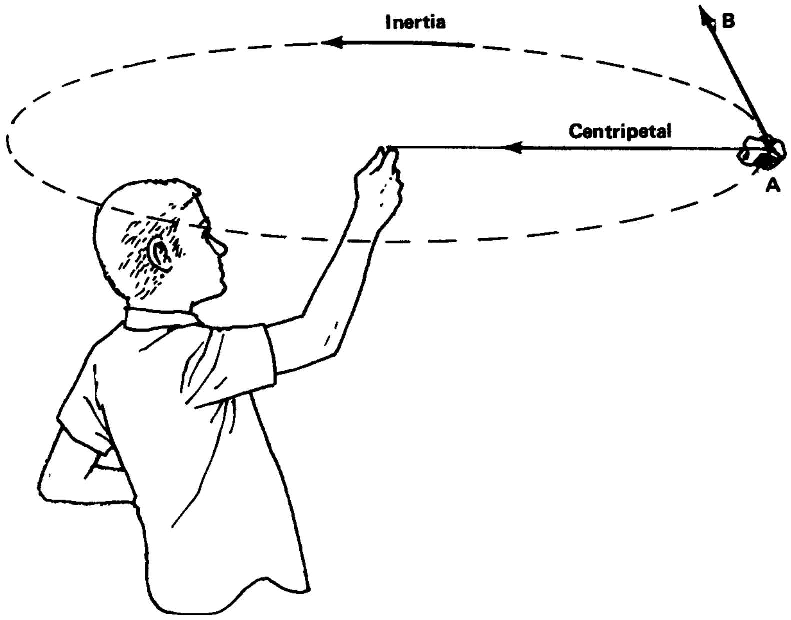


Figure 5-21

exerts an *apparent* reaction force *outward* on the string by trying to move in a straight line. This outward pull on the string is often mistakenly called centrifugal force. Let us call this outward pull the **centrifugal effect.**

Although you may not realize it, centripetal forces are in action all around us, even in our homes. For instance, in the spin dryer of a laundry machine, the tank containing the wet clothes spins very rapidly creating a centripetal force that acts on each drop of water. When the spinner reaches a certain speed, because of the centrifugal effect the drops of water fly off the clothes and out of the many small holes in the spinning tank. This leaves the clothes almost dry.

There are other effects of applying centripetal force. Have you ever noticed an airplane making a turn? The pilot always banks or tilts the plane. The banking produces the necessary centripetal force to cause the plane to turn instead of sliding straight ahead.

The curves at every speedway at which auto races are held are banked. This is necessary to provide the centripetal force to help turn the fast moving cars on the curves. If these curves were not banked, the cars traveling at high speeds would tend to travel in a straight line (Newton's First Law) and would skid or roll off the track.

Today there are many satellites in orbit around the earth. When a rocket is launched, it usually travels upward with increasing speed. When it reaches a vertical speed of approximately 18,000 miles per hour, it changes its course and begins to move in a path around the earth (Fig. 5-22).

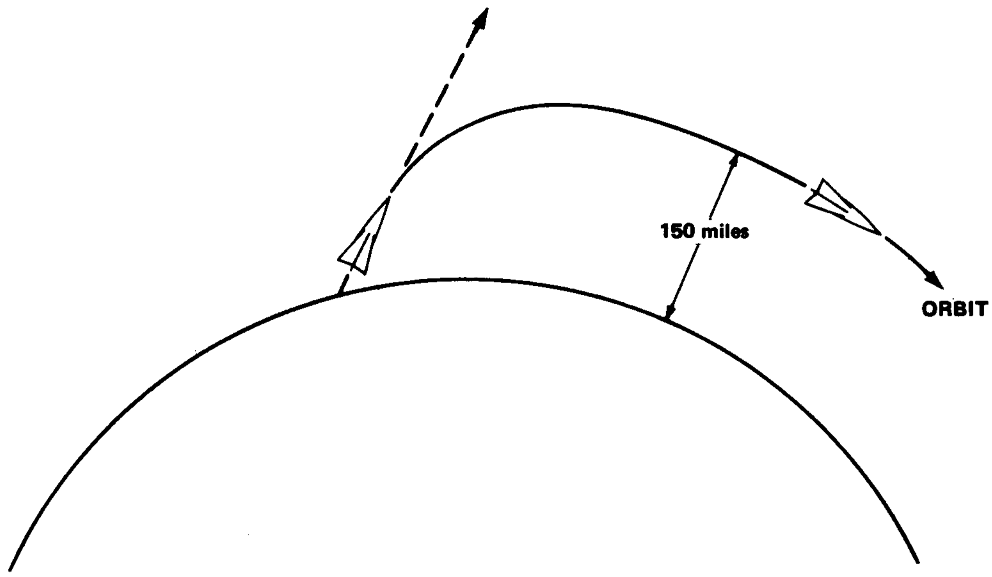


Figure 5-22

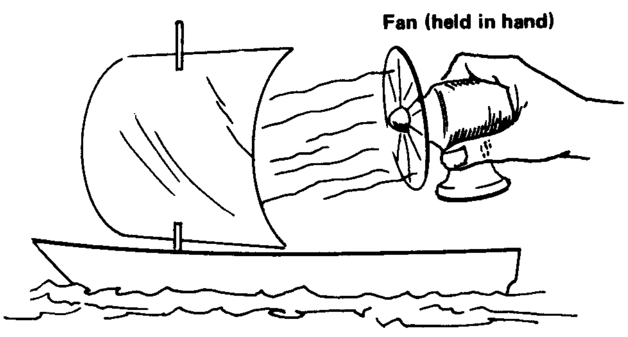
Scientists have determined that at a speed of 18,000 miles per hour, the centripetal force due to the earth's gravitational pull keeps the satellite from either falling to earth or going out into space.

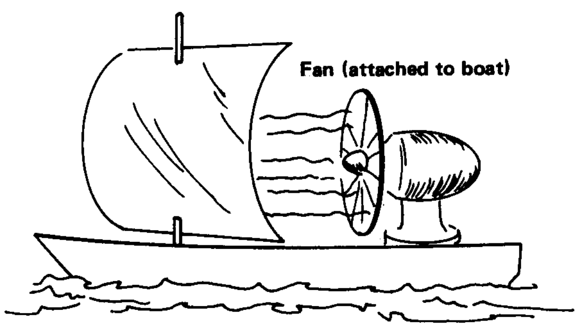
worksheet 5-3

1. When you push against a wall with your hand, you apply a force to that wall. If the wall does not move, how could you prove that the wall is also pushing against your hand?

2. What causes the "kick" of a rifle when it is fired?

3. You are in the middle of a pond of ice. Suppose there were no friction. How would you get off?





4. Explain why the boat on the left will move, while the boat on the right will remain stationary?

5. Why are passengers in a car thrown to the right when the car makes a sudden left turn?

6. In what way do centripetal force and centrifugal effect illustrate Newton's Third Law of Motion?

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7. What would happen to any one of the satellites orbiting the earth if its speed were reduced for some reason? Explain.

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8. Why do most bicycles have mudguards over the wheels?

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