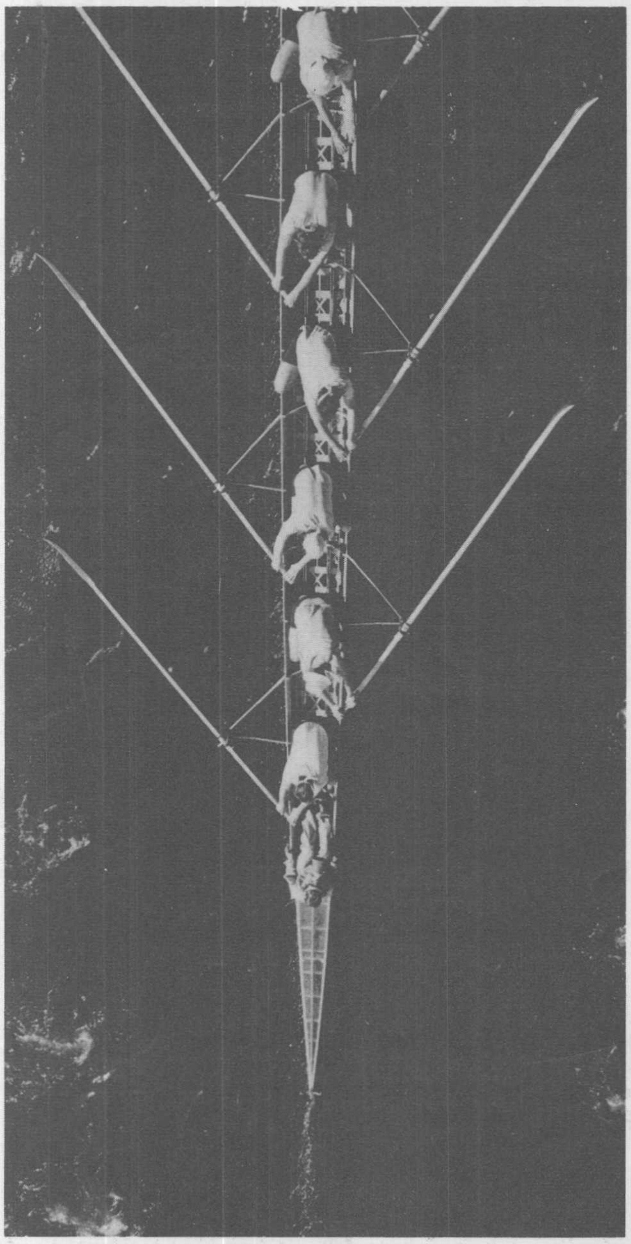
WORK, ENERGY AND SIMPLE MACHINES



The term **work** has different meanings to different people. To some people work means using muscles to do physical labor such as lifting or carrying heavy objects. To others, work could mean studying, doing homework or working on a science project. Scientists, however, have a more exact meaning for the term work.

To understand the scientific term **work**, you must know how scientists define **force**. Scientists define a force as a push or a pull acting on some object. If the force is great enough it will move the object. *Only when the force moves the object through a distance is work being done.* Suppose a block of wood resting on a table had a mass of 100 grams. To lift this block off the table you would, of course, have to apply a **lifting force** of slightly more than 100 gf. If you lifted this block through some distance, say 10 cm, the scientist would say you have done work (Fig. 6-1).

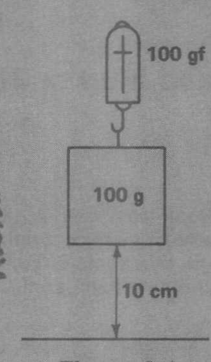


Figure 6-1

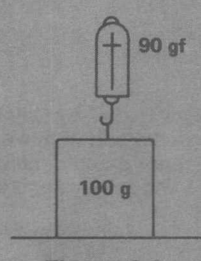


Figure 6-2

On the other hand, if you applied a lifting force of only 90 gf, you could not lift the block. No matter how long you applied the lifting force of 90 gf, if you did not move the block, *no work would be done* (Fig. 6-2).

The scientific meaning of work, therefore, involves two things—*force* and the *distance the force moves.*

Work is done when a force moves an object through a distance to produce work. Does a man who pushes all day against a brick wall without moving it do any work? Why? Is a weight lifter doing work as he holds a 100-lb. bell bar above his head? Why?

Forces involved in doing work do not have to be *lifting* forces. A man *pushing* a lawnmower through the grass is doing work because he is exerting force through a distance. When a carpenter hammers a nail into a piece of wood, he is doing work since a force is acting through a distance.

In order to do the work of driving the nail into the wood, the hammer had to have **energy** or *the ability to do the work.* Raising the hammer and then rapidly bringing it down on the nail gave the hammer the energy it needed to do the work of driving the nail into the wood. Energy, the ability to do work, is found in many different forms.

Throughout the years, man has been able to develop ways of doing work that were convenient for himself. He has done this with the use of machines.

Unit Opening Photograph

The combined force of the pull of each oarsman of the crew team moves this shell. When you complete this unit look again at the photo. What kind of machine is the oar? Can you locate a fulcrum, force, and resistance in relation to the oar? (Courtesy of Brown University.)

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

CAMBRIDGE BOOK COMPANY
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problem 6-1

To learn how to calculate the amount of work done in lifting and moving objects.

MATERIALS

Spring scale	Pegboard platform
Wood block	Support rod
Metric ruler	Rubber band

PROCEDURE

1. Study Reference Sheet 6-1.
2. Using the spring scale, lift the wood block 20 cm from the top of the table (Fig. 6-3).

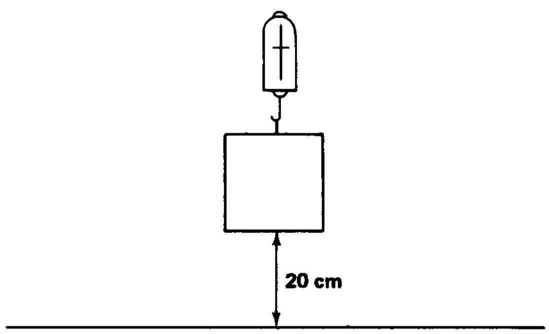


Figure 6-3

What force was required to lift the block from the table top? Record in Table 6-1. Complete Table 6-1.

TABLE 6-1

Force required to lift block	
Distance block moved	
Work done in lifting block	

3. With the spring scale, slide the wood block along the table top through a distance of 20 cm (Fig. 6-4). Complete Table 6-2.

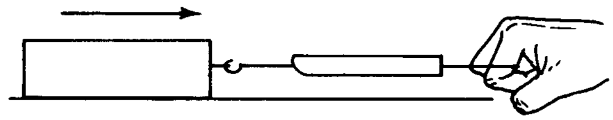


Figure 6-4

TABLE 6-2

Force required to slide block	
Distance block moved	
Work done in moving block	

In which case was more work done—in *lifting* the block 20 cm or *sliding* it along the table top? Explain your answer.

____

____

4. Set up the pegboard platform. Insert a support rod as shown in Figure 6-5. Hook one end of the rubber band to the support rod and the other end to the spring scale (Fig. 6-5).

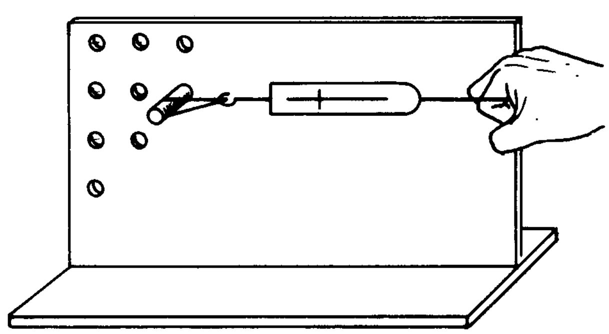


Figure 6-5

Apply just enough force so that the spring scale reads 0 gf. Measure the length in centimeters of the *unstretched* rubber band. Record in Table 6-3.

TABLE 6-3

Length of unstretched rubber band	
Length of stretched rubber band	
Amount rubber band was stretched	

5. Stretch the rubber band by pulling sideways on the spring scale with a force of 150 gf. Measure the length of the *stretched* rubber band. Record length in Table 6-3. Complete Table 6-3.

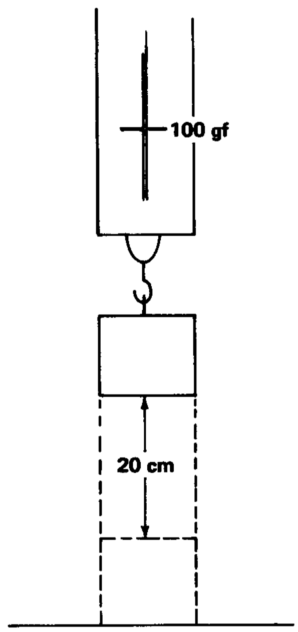
How much work was done in stretching the rubber band?

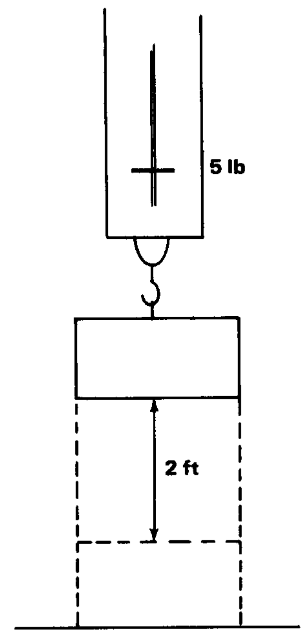
____

6. Complete Worksheet 6-1.

reference sheet 6-1

WORK = FORCE × DISTANCE FORCE MOVES



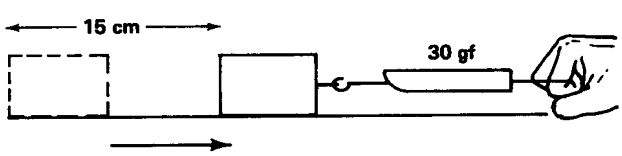


WORK = FORCE × DISTANCE

W = F × D
W = 100 grams of force × 20 centimeters
W = 2000 gram centimeters*

WORK = FORCE × DISTANCE

W = F × D
W = 5 pounds of force × 2 feet
W = 10 foot pounds*



W = F × D
W = 30 gf × 15 cm
W = 450 gram centimeters

*** COMMON UNITS OF WORK**

METRIC WORK = FORCE × DISTANCE
WORK = grams of force × centimeters
W = gf x cm
W = gcm (gram centimeters)

ENGLISH WORK = FORCE × DISTANCE
WORK = pounds of force × feet
W = lbs. × ft.
W = ft. lbs. (foot pounds)

worksheet 6-1

1. Explain the difference between the terms *force* and *work*.

____

____

2. How much work does an elevator do when it lifts a man weighing 150 lbs. through a distance of 20 ft.? ____

3. In which of the following examples is work being done? Answer by writing *yes* or *no* in the proper space.

a. A girl playing the piano ______________________

b. A boy climbing a tree ______________________

c. Holding a 100-lb. bag of sugar for one hour without moving ______________________

d. A dam holding back a lake of water ______________________

e. A pillar holding up a ceiling ______________________

4. Two men, one driving a truck and the other a small compact car discover that their machines have run out of gas. The man pushes against his truck, but cannot move it and finally stops after becoming very tired. The other man pushes his small compact car one block to a gas station and isn't tired at all. Did both men do work? Explain.

____

____

____

5. What *two* things would you have to know to determine how much work it would take to lift a box from the floor to a shelf?

____

6. Why is more work done when someone climbs a hill than if he walks the same distance on a level field?

____

7. A book weighing 200 g rests on a table. To slide the book along the table takes a force of 70 gf. How much work is done sliding the book 20 cm along the table?

---

8. Since the book is not being lifted, why must a force be used to move it?

---

9. Why can't we call "studying a lesson" a form of work?

---

10. In a tug-of-war two teams were equally matched. Although they pulled a rope for many minutes, neither team was able to move it. How much work was done? Explain.

---

11. A bricklayer who weighs 75 kilograms climbs a ladder 10 meters high with a load of bricks. Each load of bricks weighs 40 kilograms. If he makes 30 trips up and down the ladder, how much work does he do against the force of gravity? Show your work.

---

12. A box weighing 100 kilograms is pushed along the floor with a force of 20 kilograms. If the box is moved 10 meters, how much work is done?

---

13. An automobile weighing 3000 lbs. is lifted 2 feet off the ground using a lever jack. How much work is done?

---

14. How many feet did the handle of the jack in Question 13 have to move downward if a 20-lb. force was applied to lift the car? Assume that there was no friction to overcome.

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reference sheet 6-2

Although people often speak about energy, many of us have only a vague idea of what energy is. We hear people say that a certain person has a lot of energy. Or we hear that certain foods we eat provide us with more energy than other types of food. In spite of the fact that the meaning of the term energy is difficult to explain, it is very important to scientists. We are aware of energy only because it causes things to happen. **Energy** may be defined as *the ability to do work.*

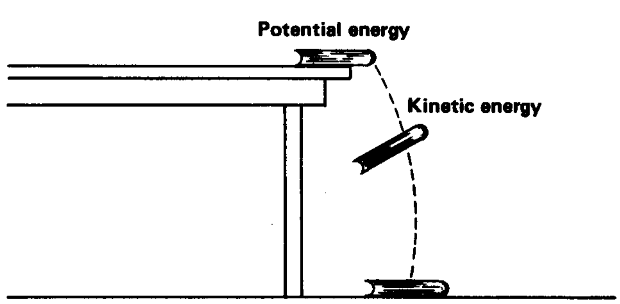
Energy exists in many different forms. Heat, light, sound, electricity are all forms of energy. Another form which may in time become our main source of energy is **nuclear** (new′-klee-er) or **atomic energy**. Whatever the form of energy, it gives something the ability to do work.

There are two general kinds of energy. A moving object has energy because it is moving. This type of energy is called **kinetic** (ki-net′-ic) **energy**, meaning energy of motion. A moving automobile has kinetic energy because of its motion. When a hammer is used to drive a nail into wood, the moving hammer supplies the kinetic energy to do the work.

Some objects, however, that are not in motion, may have a different kind of energy. These objects possess a form of *stored* energy called **potential** (po-ten′-shul) **energy**. A *stretched* rubber band or a *stretched* spring, because of its condition, possesses potential energy. An automobile battery has stored or potential energy, in the form of chemical energy, which it releases as the starter turns the engine. The gasoline in the tank of an automobile also has potential energy in the form of chemical energy. This chemical energy is released when the gasoline ignites and explodes in the engine of the car and causes the pistons to move.

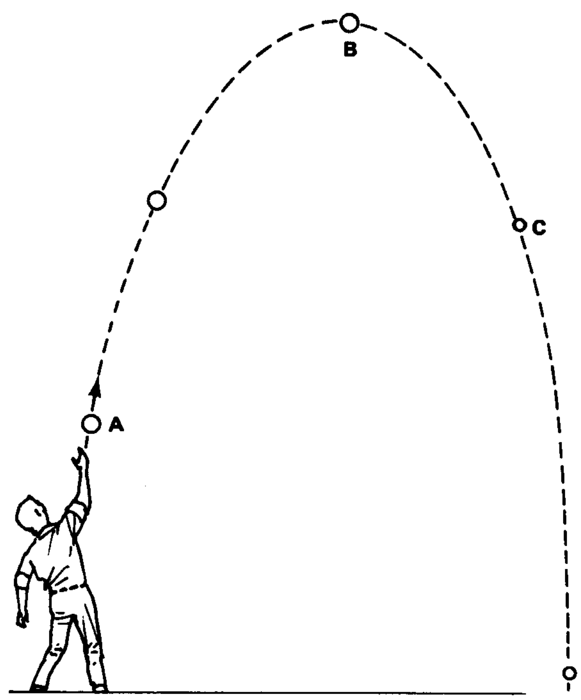
A book sitting on a table has more energy (potential) than the same book on the floor beneath the table. But, if the book fell to the floor from the table, it would be moving, and moving objects have the energy to do work. In this case the potential energy of the book was changed to kinetic energy as the book fell.

An interesting thing about energy is that *it cannot be created or destroyed.* All that happens is that energy changes or passes from one form to another. And, in some instances energy can be changed into matter. Here are some examples of energy change from one form to another. Electrical energy that



enters an electric light bulb in the form of an electric current, is changed into light and heat energy. The chemical energy stored in rocket fuel is changed into heat energy as the fuel burns. This heat energy is finally changed into the kinetic energy of motion as the gases rush from the jets of the rocket and push it into space. The brakes of an automobile change some of the kinetic energy of a moving car into heat energy because of the friction between the brake linings and the brake drums.

When a moving baseball bat strikes a ball, the kinetic energy of the bat is transferred to the ball. If a ball is thrown upward, it has kinetic energy at point *A*. As it rises, it gradually loses its kinetic energy, but gains potential energy *B*. Then, as it begins to fall, the potential energy again changes back to kinetic energy *C* until the ball strikes the ground.



In each of the examples mentioned, no *new* energy was created nor did any energy actually disappear. The total amount of energy in each instance remained the same even though it changed from one form to another.

Where did all the tremendous amount of energy found on the earth in its various forms first come from? If we traced the source of most of the energy on the earth, we would probably find that it originated on the sun and came to earth in the forms of radiant energy.

The study of energy and its changes probably makes up the most important part of a scientist's work. You will find in your later studies of chemistry, physics, and biology, that much of what goes on with living and nonliving matter deals in some way with the manner in which energy is changed from one form to another.

problem 6-2

To discover the relationship between different forms of energy and how the forms of energy are changed.

MATERIALS

Rubber band	Pendulum bob
Cart	Glass marble
Spring scale	Large steel ball bearing
Pegboard platform	Thermometer
Pegboard support rod	Alcohol lamp
Thread	Metric ruler

PROCEDURE

1. Study Reference Sheet 6-2.

2. Hook one end of the rubber band to the cart and the other end to the spring scale. Stretch the rubber band by pulling on it with a force of 150 gf. Hold the cart to keep it from moving (Fig. 6-6).

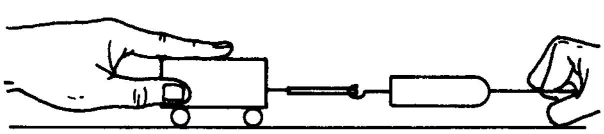


Figure 6-6

3. Release the cart and allow it to roll along the table.

a. Where did the cart get the energy to cause it to move?

____

b. What form of energy does the rubber band have in its stretched condition?

____

c. How much work was required to stretch the rubber band?

____

d. How much energy does the stretched rubber band have?

____

4. Set up the pegboard platform and suspend a simple pendulum from a support rod. Use whatever object you wish as a pendulum bob. Start the pendulum bob swinging by holding it to one side (position A) and then releasing it *without pushing*. Observe its motion (Fig. 6-7).

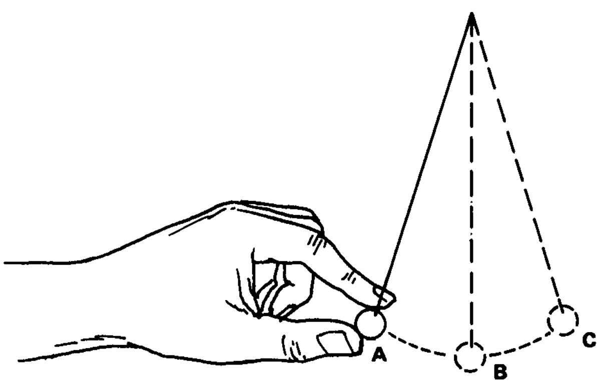


Figure 6-7

a. What force caused the pendulum to start to swing from position A?

____

b. What kind of energy does the swinging pendulum have at position A; at position B; at position C?

A__________ B__________ C__________

c. What happened to the energy as the pendulum slowed down and stopped?

5. Place your hand flat on your table, palm up. Drop a glass marble from a height of about one foot into your hand. Repeat, but this time drop the marble from a height of three feet.

a. At which height did the marble have the greatest potential energy?

b. From which height did the marble develop the greatest amount of kinetic energy as it struck your hand?

6. Instead of using a glass marble, repeat Procedure 5 using a large steel ball bearing. *Be sure to drop it from the same height.*

a. Describe the difference in the effect on your hand between the falling marble and steel ball bearing.

b. What conclusion can you come to as to the effect of mass on the kinetic energy of a moving object, other things being equal?

7. Place the palms of your hands together with the bulb end of a thermometer between them. Hold the thermometer between your thumb and forefinger (Fig. 6-8). Record in Table 6-4 the temperature of your palms in degrees centigrade. (Allow a few seconds for the thermometer to reach the temperature of your hands.)

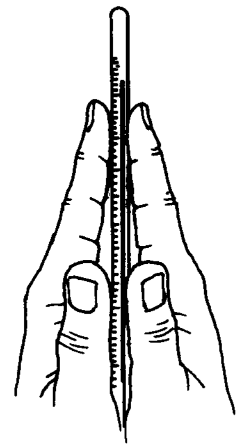


Figure 6-8

TABLE 6-4

Temperature of palms before rubbing	°C
Temperature of palms after rubbing	°C

Being careful not to drop the thermometer, rub the palms of your hands together vigorously for about ten seconds. Keep the thermometer between your palms as you do so. Check the temperature of your palms after rubbing. Record in Table 6-4.

a. What caused the change in temperature of your palms?

b. Explain how energy was converted from one form to another as you rubbed your hands.

8. Light your alcohol lamp and observe it for a moment.

a. Is the burning of the alcohol and the wick a physical or chemical reaction?

---

b. What kind of energy does the alcohol in the jar of the lamp have?

---

c. Into what kinds of energy is the alcohol converted as it burns?

BEYOND THE CLASSROOM

1. Hold a small rubber ball high above your head and then drop it to the floor, letting it bounce. Explain the changes in the types of energy the ball possesses as it bounces.

2. Examine a kettle of boiling water on a kitchen range. Describe the various transfers of energy that takes place.

3. Trace the transformation of energy from one form to another in the commercial production of electricity used in our homes.

problem 6-3

To investigate how a first class lever multiplies force.

MATERIALS
Book
Wooden ruler
Pencil

PROCEDURE

1. Select one of your hardbacked textbooks and place it on the desk or table. With one of your fingers lift the book by its edge (Fig. 6-9).

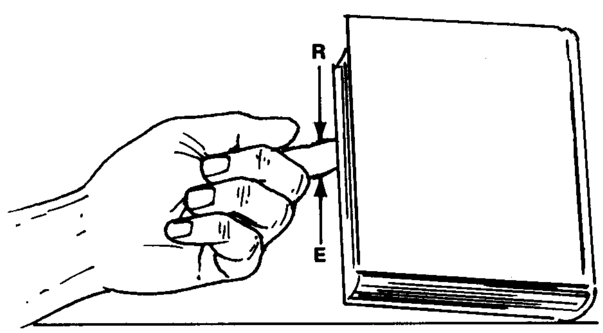


Figure 6-9

Call the force pressing down on your finger the **resistance force**, and the upward force applied by your finger the **effort force**. The effort force must just barely overcome the resistance force in order to raise the edge of the book. Notice the amount of force needed to lift the book with your finger.

2. Place one end of a wooden ruler under the edge of the book. Slip a pencil under the ruler about 3 cm from the edge of the book (Fig. 6-10).

Press down with your finger on the other end of the ruler to raise the book.

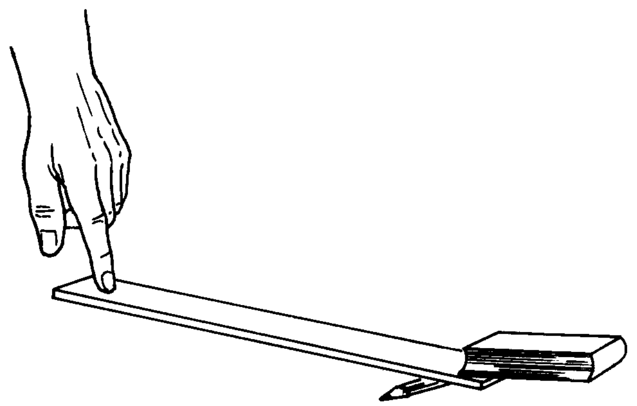


Figure 6-10

What do you notice about the force necessary to lift the book, using the ruler, compared to the force needed to lift it directly with your finger?

____

____

3. Move the pencil about 5 cm from the edge of the book and press on the end of the ruler again.

Is more, or less, force needed to lift the book than in Procedure 2?

____

4. Repeat, moving the pencil about 20 cm from the edge of the book.

What did you notice this time about the force required to lift the book?

5. Repeat Procedures 2, 3 and 4, and observe how far the book moves in comparison to how far your finger moves.

a. What effect does the position of the pencil have on how far the edge of the book moves in comparison to how far your finger moves?

b. What effect does the position of the pencil have on the *force* necessary to raise the edge of the book?

6. This diagram is a drawing of a first class lever (Fig. 6-11). Study it carefully and learn the names of all of the parts of a lever.

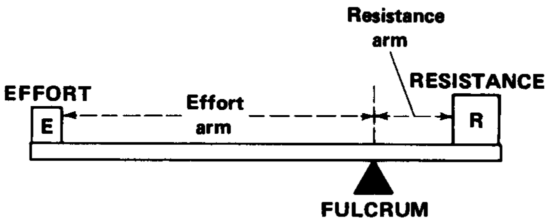


Figure 6-11

Compare this diagram with Fig. 6-10, in Procedure 2.

a. Using the terms in the diagram (Fig. 6-11), what would the book in Procedure 2 represent? __________

b. What would the pencil represent?

c. What would your finger represent?

d. What are the advantages and disadvantages of a first class lever?

Advantages __________

Disadvantages __________

e. First class levers are usually used to reduce the effort necessary to overcome a resistance. How must the effort arm compare in length to the resistance arm to do so?

BEYOND THE CLASSROOM

1. Open a can of paint with a screwdriver. Make a lever diagram of the screwdriver and the lip of the can. Label the parts as in the diagram in Procedure 6. Try different length screwdrivers to do the same job. Is there a difference in the force needed to open the can? Explain.

2. Make a list of the various items found in the home and workshop that can be classified as first class levers.

3. Archimedes (ahr-kih-me′-deez), a famous Greek scientist who lived over 2000 years ago, made a statement about moving the earth with a lever. Find out what that statement was and explain what Archimedes was trying to say.

problem 6-4

To discover the "Law of the Lever."

MATERIALS

Pegboard	Masking tape
Pegboard support	12-in. wooden ruler
Support rod	3 or 4 Paper clips
Thread	

PROCEDURE

1. Set up the pegboard platform. Tie a piece of thread tightly around the exact center of a 12-inch wooden ruler. Attach it firmly to the ruler with a small piece of masking tape to keep the thread from moving. Suspend the ruler by the thread from the support rod (Fig. 6-12). Be sure the scale on the ruler is upright so that it can be easily read.

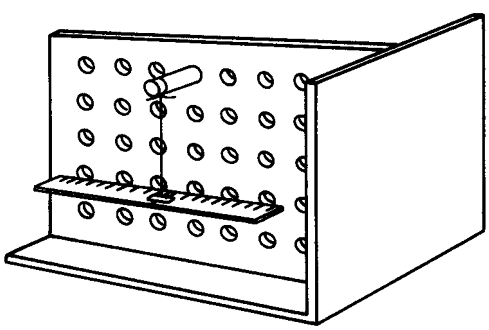


Figure 6-12

With the supporting thread at the 6-inch mark, the ruler should balance in a horizontal position. If it doesn't, place a small piece of masking tape on the side of the ruler which is raised. You may have to try placing the tape in various positions until you find the correct spot. The ruler may now be considered a first class lever.

Where is the fulcrum of the lever?

____

2. Form three paper clips of the same mass in the shape of a hook so they can be suspended from the ruler (Fig. 6-13).

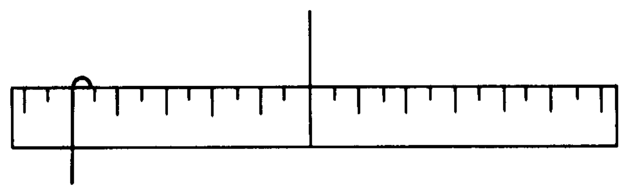


Figure 6-13

Place a clip on one side of the ruler on the one-inch mark (Fig. 6-13).

a. What happens to the balance of the ruler?

____

b. Keep the clip at the one-inch mark. What position on the ruler must another clip be placed to balance the ruler again?

____

Verify your answer.
(Remove clips before starting Procedure 3).

3. Place *two* clips on the 4-in. mark on the ruler, and *one* clip on the 10-in. mark. The ruler should be balanced with the clips in these positions (Fig. 6-14).

Since the weight of the clip in *gram* units is unknown, assume it to be in "clip" or c units.

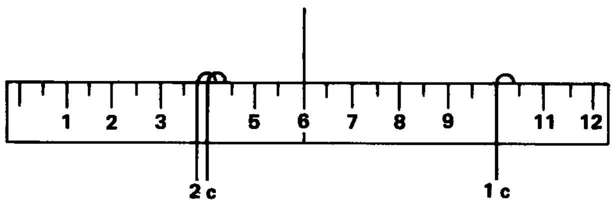


Figure 6-14

Therefore, the effort force would be two clip units or 2 c, and resistance force would be one clip unit or 1 c.

a. How many inches is the effort force, 2 c, from the fulcrum?

____

b. Multiply the effort force times its distance from the fulcrum.

2 c × ______ = ______

c. How many inches is the resistance force, 1 c, from the fulcrum?

____

d. Multiply the resistance force times its distance from the fulcrum.

____

Compare your answers for (b) and (d). If the ruler is balanced, they should be equal.

4. Place the *two* clips on the 7-in. position on the ruler. Find the position on the other side of the fulcrum where the *one* clip will exactly balance the ruler. Answer questions a, b, c, and d as in Procedure 3.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. In Procedures 2, 3, and 4, compare the products of the effort and effort distance to the products of the resistance and the resistance distance.

____

____

f. Complete the following rule which is known as the "Law of the Lever." "The product of the effort times the ________ distance equals the product of the ________ times the resistance distance."

5. Place one clip at the 1-inch mark on the ruler and another on the 3-inch mark (Fig. 6-15). Find the position on the ruler on the other side of the fulcrum where you must place two clips to balance the ruler.

a. ______________________________

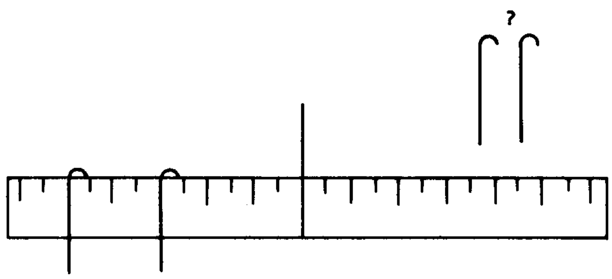


Figure 6-15

b. Do the positions of the effort and resistance forces in Procedure 5 satisfy the Law of the Lever? Show your work.

____

____

problem 6-5

To investigate how a second class lever multiplies force.

MATERIALS

Wooden block
Spring scale
Wooden metric ruler
Pegboard platform
Pegboard support rod
Thread

PROCEDURE

1. Lift the wooden block straight up with the spring scale and measure its weight.

Weight of wooden block = __________

2. Set up the pegboard platform. Suspend the block by a thread near the center of a ruler. Support one end of the ruler by a support rod and the other end by a spring scale (Fig. 6-16). Be careful not to let the ruler slide off the support rod.

3. Slowly lift the block by raising the scale at the end of the ruler *E*. Record the force necessary to do this.

Force necessary to lift block __________

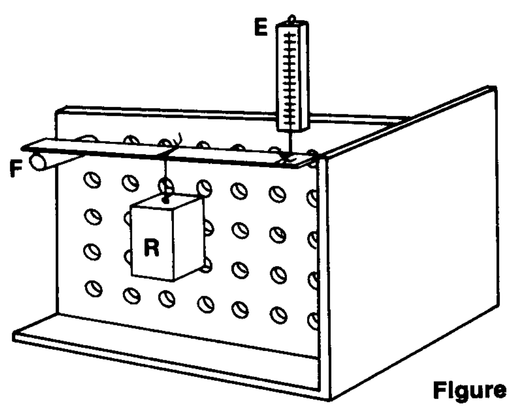


Figure 6-16

a. Compare the force necessary to raise the block in Procedure 3 to the weight of the block in Procedure 1.

____

____

b. Why would you call this device a simple machine? Refer to Reference Sheet 6-2.

____

____

____

4. Move the block *R*, 2 cm closer to the support *F*.

What effect did this have on the effort force needed to lift the block?

____

____

5. Continue to move the block *R* closer to the support *F*.

What do you notice about the effort force needed to lift the block as you moved the block closer to *F*?

____

____

6. Call the support rod position *F*, the **fulcrum** of the lever. Call the weight of the block at *R*, the **resistance**, and the force needed to lift the block at *E*, the **effort**. This simple machine is now a second class lever.

How do the positions of the effort, resistance and fulcrum of this lever differ from that of a first class lever?

---

7. Refer to the Fig. 6-16.

a. Why would you call the distance from *F* to *R* the resistance arm?

---

b. What would you call the distance from *F* to *E*? Why?

---

c. How does the length of the effort arm compare to the length of the resistance arm in this type of lever?

---

d. How does this comparison of the lengths of the effort arm to the resistance arm differ from that of a first class lever?

BEYOND THE CLASSROOM

1. Make a drawing of an ordinary wheelbarrow. On your drawing locate the positions of the effort, resistance, and the fulcrum. Why do many construction workers use wheelbarrows for carrying heavy loads?

2. Take a walnut that is still in its shell, and try to crush it with your bare hands. Then place it between the arms of a nutcracker and try to crush it again. Make a drawing of the nutcracker. Show the position of the effort, resistance, and fulcrum.

problem 6-6

To make a graph showing the relationship between the effort and resistance arm in second class levers.

MATERIALS

Wooden block	Pegboard platform
Spring scale	Pegboard support rod
Wooden metric ruler	Thread

PROCEDURE

1. Set up a second class lever as in Procedure 2, Problem 6-5. Place the fulcrum *F* at the 15-cm. position on the ruler instead of at the end. Hook the effort or spring scale at position *E*, at the 30-cm. mark on the ruler.

Suspend the block, position *R*, at the 17-cm. mark.

a. What is the length in cm of the resistance arm *FR*? Record the length on the first line in Table 6-5.

b. What is the effort in grams of force as shown on the spring scale at position *E*. Also record on first line in Table 6-5.

TABLE 6-5

Length of Resistance Arm	Effort

2. *Without changing the positions* of the fulcrum *F*, or the effort *E*, move the resistance *R* to the 19-cm mark on the ruler. Record the new *length* of the resistance arm and the effort, on the second line in Table 6-5.

3. Continue to increase the length of the resistance arm by 2 cm each time, until a length of 14 cm is reached. Record each length in Table 6-5 along with the effort needed to support the resistance in its new position.

4. On the graph, Practice Sheet 6-1, plot each of the points from the data in Table 6-5. Place your own numbers on the vertical axis using the values in the *Effort* column of Table 6-5 as a basis for the range of values. Draw a smooth curve between the points.

a. What are the two variables (conditions that change) being compared?

____

b. Which one is the independent variable (the condition you change as you wish)?

____

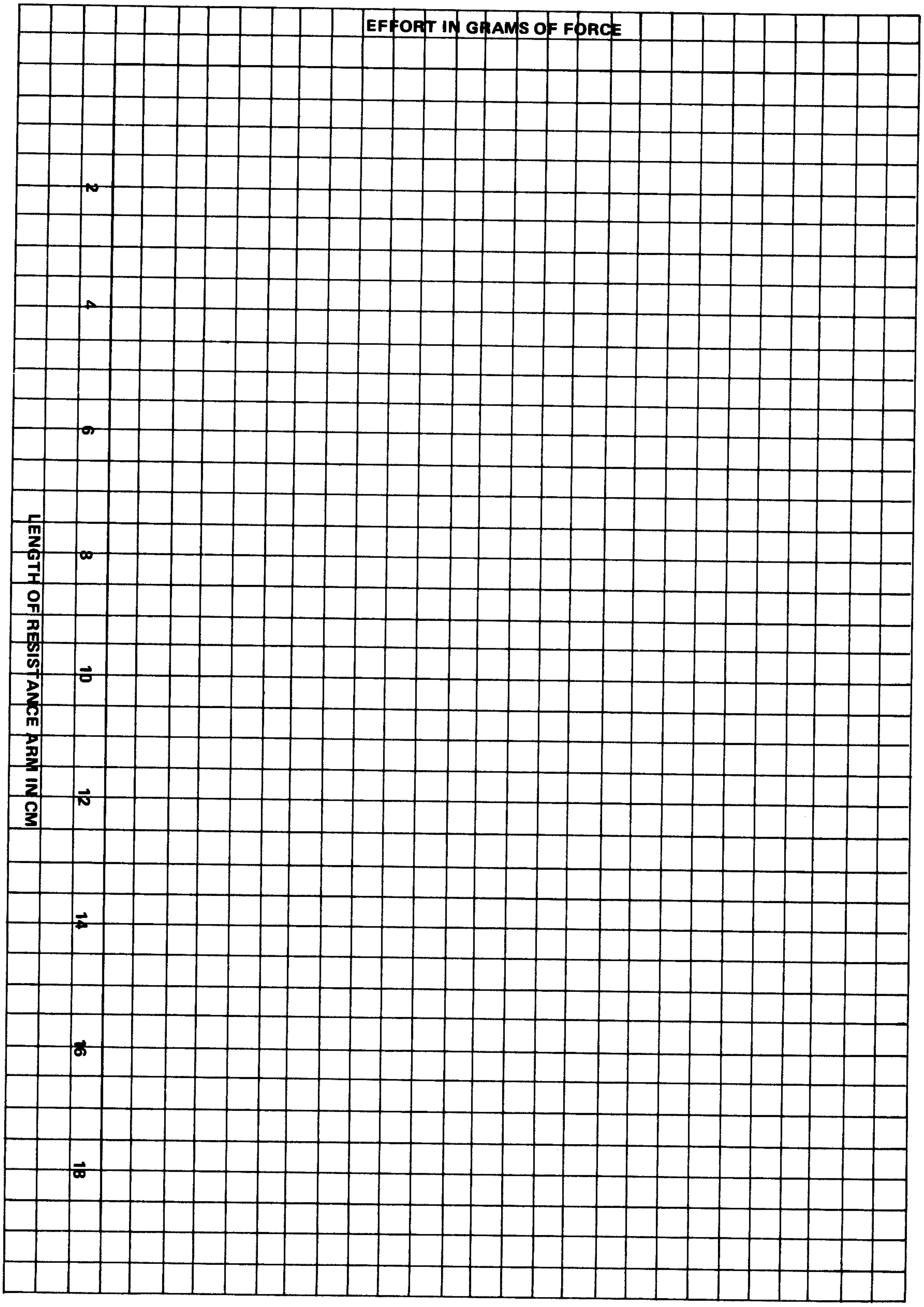
5. In setting up the second class lever for this activity, the fulcrum was placed approximately at the middle.

Can you suggest a reason why the fulcrum was placed at this position?

____

____

PRACTICE SHEET 6-1



reference sheet 6-3

All of us are familiar with the term **machine.** Often we think of a machine as being a rather complicated device such as a lathe or a typewriter. Actually, what we think of as a machine is really made up of a lot of so-called **simple machines.** These simple machines are nothing more than devices that help us to do work more easily.

Simple machines help us in many different ways. One way is to allow us to do work that we couldn't do without the machine. A machine can actually *multiply* the force applied to an object. If a carpenter wishes to pull a nail from a piece of wood, he does not use his bare hands. A hammer becomes a machine for a carpenter when he uses it to pull the nail from the piece of wood (Fig. 6-17).

When the family car has a flat tire, you do not try to lift the car with your arms and body. You use an automobile jack. The jack is a machine when it is used to lift a car (Fig. 6-18).

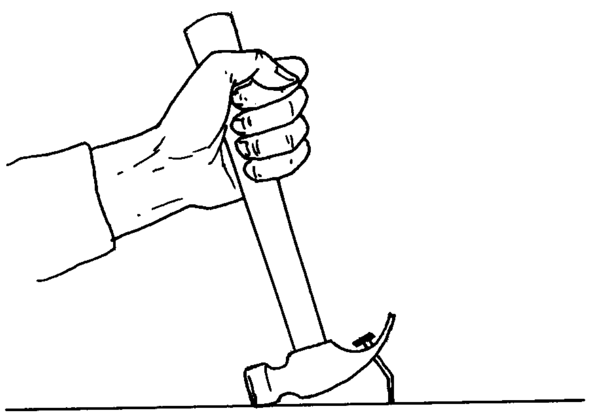


Figure 6-17

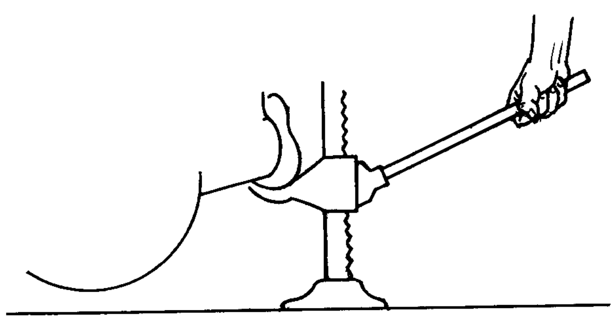


Figure 6-18

Some machines, however, help to do work with greater speed. This is a second use of machines. When you ride a bicycle, your pedals go around in small circles yet your bicycle moves *forward* through a much greater distance. You lose force but gain speed. *No machine can multiply both force and speed at the same time.*

Another use of machines is to change the *direction* of a force. When you run a flag *up* a flagpole, you pull *down* on the rope.

Machines are also used to *transfer* energy from one place to another. The gears, pulleys and belts found in the motor of an automobile are types of machines that transfer energy from one part of the engine to another (Fig. 6-19, 20).

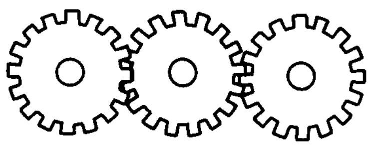


Figure 6-19

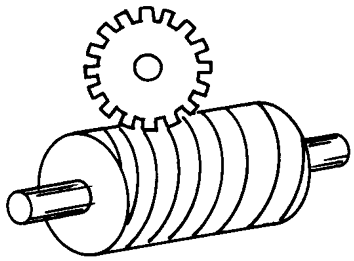


Figure 6-20

One thing a machine *cannot* do is *save* work. No one can ever get more work *out* of a machine than is put *into* it. When one gains force using a machine, distance is lost. If distance is gained, force is lost. Since work is equal to the product of force times distance no work is gained by using a machine.

Two common types of simple machines are the **lever** and the **inclined plane.** There are many other types of simple machines such as the wheel and axle, the pulley, the screw, the wedge, etc. When a number of simple machines are combined to make a more complex machine, we call that kind of machine a **compound machine.**

problem 6-7

To illustrate how a third class lever is used as a machine.

MATERIALS

Paper clip
Wooden metric ruler
Rubber band
Pegboard platform
Pegboard support rod
Spring scale
Thread
5 or 6 large metal washers

PROCEDURE

1. Shape the paper clip in the form of a hook. Place it over one end of the ruler and attach it firmly with a rubber band. Leave a small loop at the end of the ruler (Fig. 6-21).

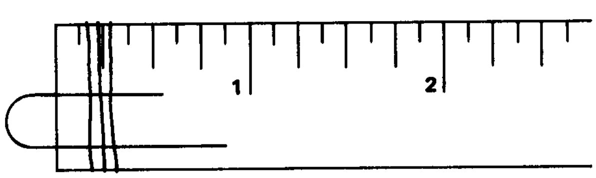


Figure 6-21

2. Set up the pegboard platform and attach the end of the ruler with the loop over the pegboard support rod. Support the ruler with a spring scale and a loop of thread placed at the 15-cm mark of the ruler (Fig. 6-22).

How much force in grams is required to support the weight of the ruler? ____________

3. Tie five or six metal washers together with a loop of thread.

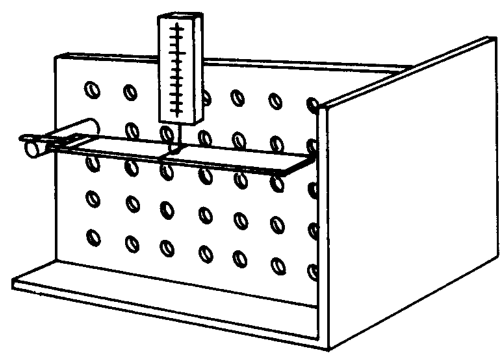


Figure 6-22

Using a spring scale, determine the weight of the washers in grams.
Weight of washers = ____________

4. Hang the five or six large metal washers by the loop of thread over the other end of the ruler. Support the ruler and washers with a spring

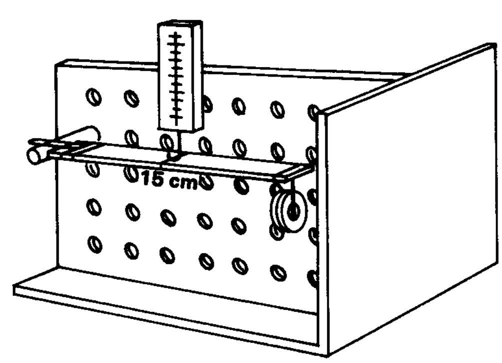


Figure 6-23

scale and a loop of thread at the 15-cm mark on the ruler (Fig. 6-23).

This arrangement of the effort, resistance and fulcrum is a third class lever.

a. What is the total force in grams required to support the ruler and washers?

b. How does the arrangement of the effort, resistance, and fulcrum in a third class lever differ from that of a first class lever?

c. Subtract the force that was required to support the weight of the ruler alone (Procedure 2) from the total force in (a). What force was required to support the weight of the washers alone?

d. Compare the force supporting the washers in this third class lever to the weight of the washers. Which is greater?

e. Does a third class lever multiply force? Explain.

f. Slowly move the spring scale (effort) up about 5 cm. How far do the washers (resistance) move?

g. What does a third class lever multiply? Explain.

BEYOND THE CLASSROOM

1. Examine a pair of tweezers. Identify where the effort, resistance and fulcrum are placed.

2. Watch someone sweep a floor using a broom (not the push type). See if you can locate the effort, resistance and fulcrum.

3. The human arm is a third class lever with the elbow as the fulcrum. Draw a simple diagram showing how the muscles of the arm are attached to make the arm a third class lever.

4. Visit a construction site where excavating is going on. Usually there are large machines which are used for removing huge quantities of earth. Make a drawing of one of the machines which uses a third class lever to do the work. On your drawing identify the positions of the effort, resistance and fulcrum.

5. Observe a hockey player as he uses his hockey stick as a third class lever. Try to determine where the fulcrum, effort, and resistance are located as he strikes the puck.

problem 6-8

To discover how an inclined plane is used as a simple machine.

MATERIALS

Spring scale	Inclined Plane (Wood board 1″ × 4″ × 36″)
Cart	
Books	
Metric ruler	

PROCEDURE

1. With the spring scale lift the cart from the table to the top of a pile of four or five books about 20 to 25 cm in height (Fig. 6-24).

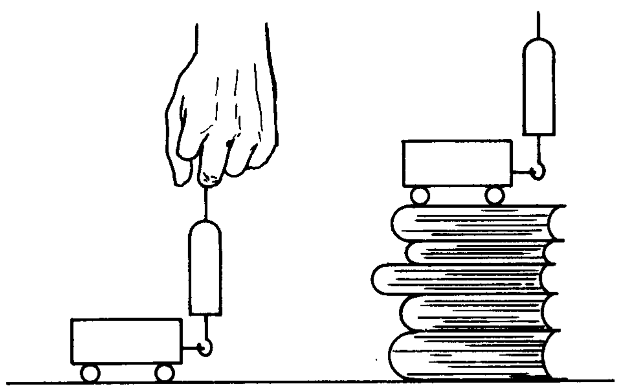


Figure 6-24

a. What force was required to *lift* the cart from the table to the top of the pile of books?

____

b. Through what distance was the cart raised?

____

c. How much work was done in raising the cart from the table to the top of the pile of books?

____

2. Place the board so that one end rests on the table and the other end on the same pile of books used in Procedure 1. Using the spring scale, move the cart up the board at a *constant speed* to the top of the pile of books (Fig. 6-25).

The board is considered an **inclined plane. Note:** The rear wheels of the cart should start at one end of the inclined plane, position 1, and finish at the other end of the plane, position 2.

a. What is the distance from position 1 to position 2? ______________

b. How much force was required to move the cart up the inclined plane? ______________

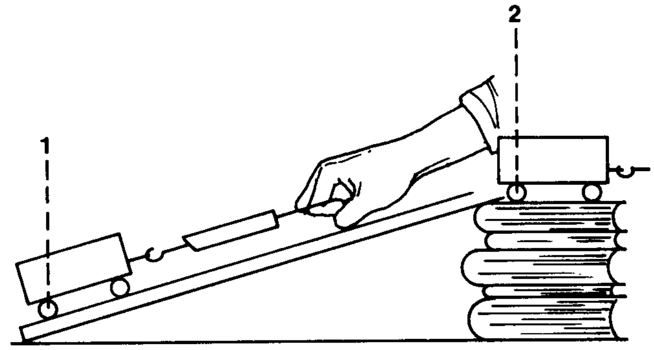


Figure 6-25

c. How much work was done to move the cart up the inclined plane? ______________

d. How does the amount of *force* required to do the work in Procedures 1 and 2 compare to each other?

____

e. How does the amount of *work done* in Procedures 1 and 2 compare to each other?

____

f. In what way does an inclined plane make it easier to do work?

____

____

g. Is less work done moving an object up an inclined plane than if it were lifted straight up? Explain.

____

____

____

BEYOND THE CLASSROOM

1. Watch a truck driver use an inclined plane to move a heavy load into his truck.

2. Examine the threads on an ordinary woodscrew. See if you can explain how a screw makes use of an inclined plane as a simple machine.

3. List as many ways as you can think of that an inclined plane is used at home or in industry to make work easier to do.

problem 6-9

To discover how the slope of an inclined plane affects the amount of effort required to overcome resistance.

MATERIALS

Books
Inclined plane
Spring scale
Cart
Metric ruler

PROCEDURE

1. Repeat Procedure 2 in Problem 6-8 using six or seven books. Record the total height of the books in Table 6-4. Also record the base length of the inclined plane (Fig. 6-26).

The **slope** of an incline is its height divided by its base length.

Record the slope of your inclined plane in Table 6-4. *Carefully* measure the force in grams necessary to move the cart up the incline, and record in Table 6-4. (**Note:** The slope very often is *less than 1* and should be represented as a *decimal value.*)

2. Change the slope of the incline by sliding the end of the inclined plane that is resting on the table approximately 5 cm closer to the pile of books. Record values in Table 4. (**Note:** the height does not change.)

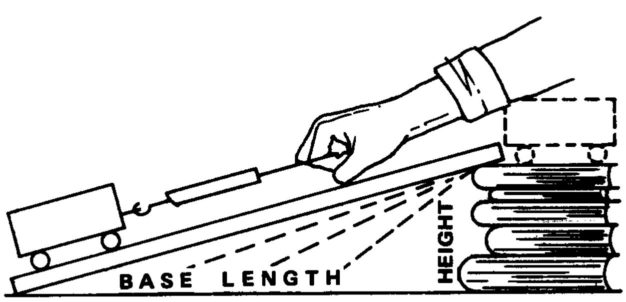


Figure 6-26

TABLE 6-4

Trial	Height of Books	Base Length	Slope* Height ÷ Base	Force
1				
2				
3				
4				
5				
6				

*Carry out division to the closest 0.1

3. Repeat Procedure 2 at least five more times reducing the base length by 5 cm each time. Record values in Table 6-4.

4. Plot a graph on Practice Sheet 6-2, showing how the slope affects the force required to move the cart up the incline. The scale on the vertical axis of the graph will have to be marked in decimal values. *Have your teacher check the scale on the vertical axis of your graph before proceeding.*

   a. From your graph, explain how the slope of an inclined plane affects the effort force necessary to overcome the resistance force.

   ____

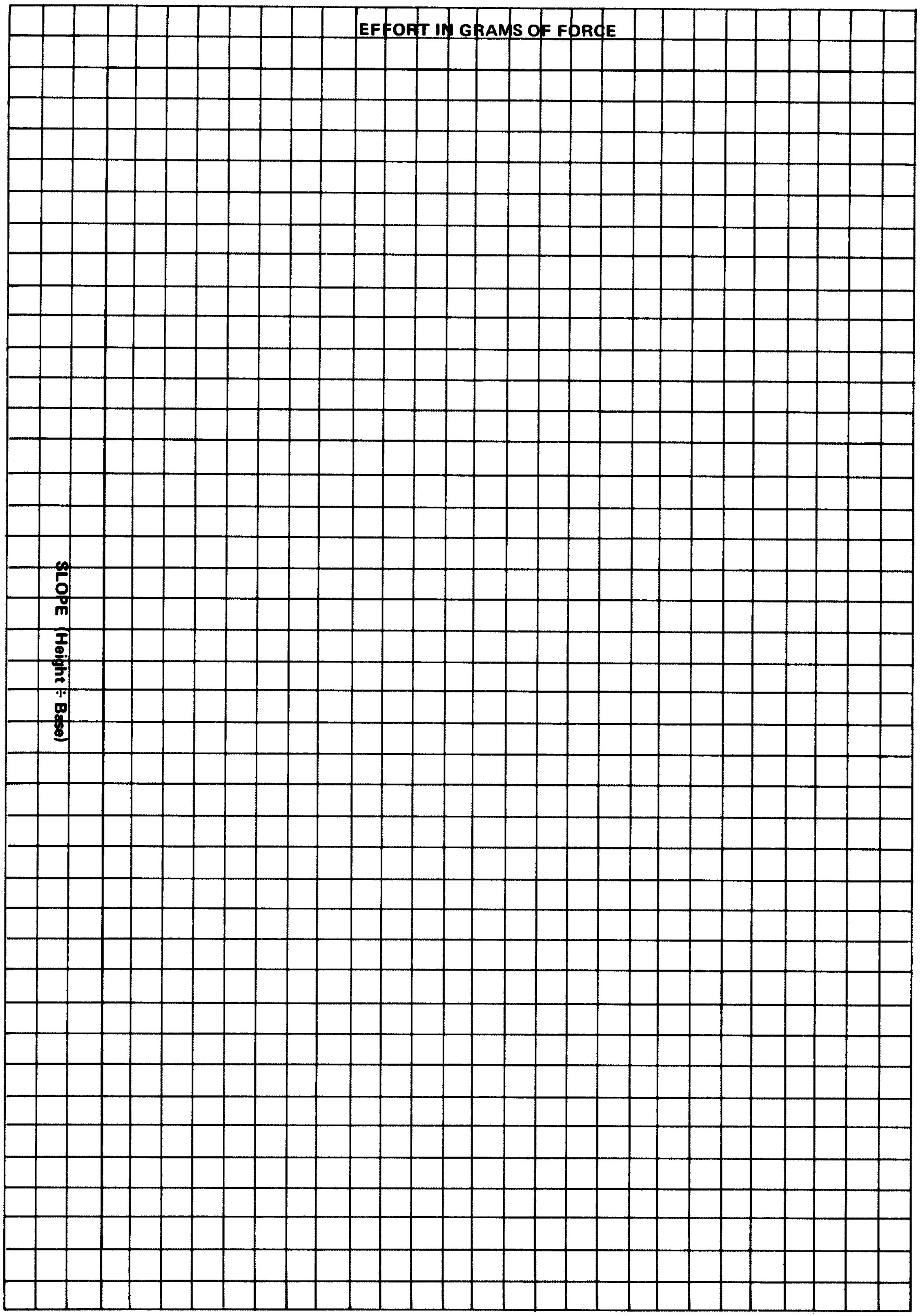
   b. What does a slope of *0* mean?

   ____

   c. What would the effort force be if the base length became 0?

   ____

PRACTICE SHEET 6-2



reference sheet 6-4

You have discovered by now that certain simple machines such as first and second class levers, and the inclined plane, enable you to accomplish tasks using less force. Many other simple machines such as the pulley, the wheel and axle, gears, etc., also help to make work easier to do. These machines are devices which multiply the force that is applied to them. They permit us to overcome a resistance force with a lesser effort force.

A man using a crowbar, which is a first class lever, can move a much greater weight than he would ordinarily be able to move without the crowbar (Fig. 6-27).

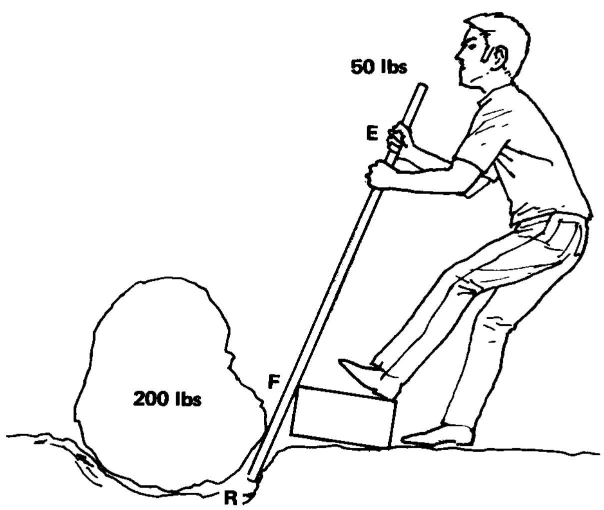


Figure 6-27

A measure of *how many times* a machine multiplies force is called its **mechanical advantage**. It can very easily be found *by dividing the resistance force by the effort force.* For instance, the boulder in Fig. 6-27, which is being lifted by one end of the crowbar, weighs 200 lbs. The effort applied to the other end of the crowbar by the man is 50 lbs. The mechanical advantage of the crowbar is, therefore, 200 lbs ÷ 50 lbs. or 4.

$$\text{Mechanical Advantage} = \frac{\text{Resistance Force}}{\text{Effort Force}} = \frac{200 \text{ lbs}}{50 \text{ lbs}} = 4$$

Notice that there are no units following the value of the mechanical advantage, 200 lbs is 4 times greater than 50 lbs.

In some instances the mechanical advantage of a simple machine may be *less than 1.* This is true in the case of the third class lever. In a third class lever the effort force is *greater* than the resistance force to be overcome.

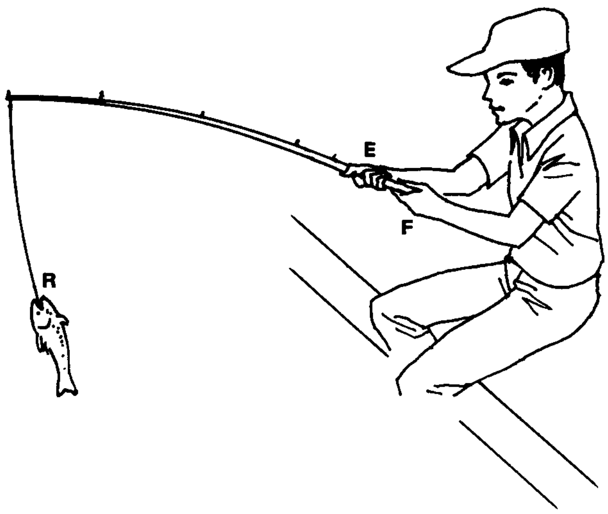


Figure 6-28

The fisherman in Fig. 6-28 must apply a *greater* force (E) to the rod than the weight of the fish (R). However, he can move the fish through a much greater distance than he moves the rod. Therefore, he gains distance and speed at the expense of force. The mechanical advantage of the fishing rod as a machine in this case is less than 1.

problem 6-10

To determine the mechanical advantage of a simple machine.

MATERIALS

Pegboard platform
Pegboard support rod
Spring scale
Wooden block
Paper clip
Wooden ruler
Rubber band
Thread
Inclined plane

PROCEDURE

1. Using your spring scale, determine the weight of the wooden block. Record in Table 6-5.

TABLE 6-5

(Resistance) Weight of block	
Effort force	
Mechanical advantage	

2. Attach the paper clip over the 1 in. position on the ruler with a rubber band. Allow just enough of the clip to extend from the end of the ruler to form a loop (Fig. 6-29).

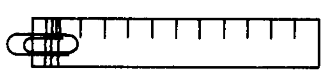


Figure 6-29

3. Hook the loop formed by the clip over the pegboard support rod. Suspend the wooden block by thread from the 6-in. position on the ruler. Support the other end of the ruler with the spring scale attached to a loop of thread (Fig. 6-30). Record in Table 6-5 the effort needed to support the block with the spring scale.

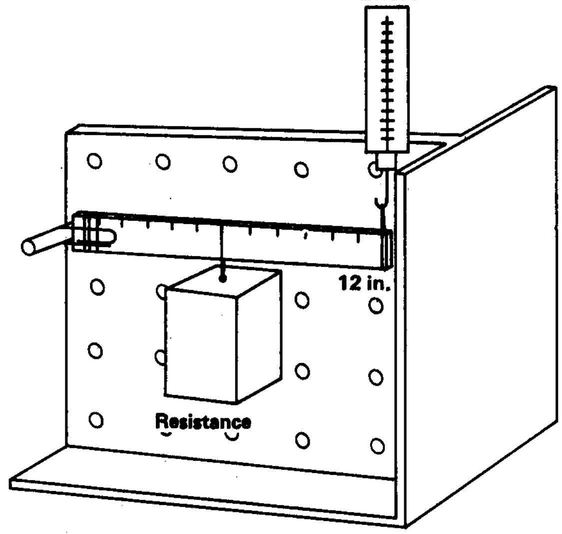


Figure 6-30

a. How would you find the mechanical advantage of this machine?

Record its value in Table 6-5.

b. What class lever is represented in Fig. 6-30?

4. Move the resistance force R (Fig. 6-30), to the 9-in. position on the ruler. Complete the first column in Table 6-6.

How did increasing the length of the resistance affect the mechanical advantage of the lever?

TABLE 6-6

Position of block	9 in.	3 in.
Weight of block		
Effort force		
Mechanical advantage		

5. Move the resistance force (R) to the 3-in. position on the ruler. Complete the second column in Table 6-6.

a. How did lessening the length of the resistance arm affect the mechanical advantage?

b. Write a rule which explains what happens to the mechanical advantage of a second class lever as the length of the resistance arm is changed.

c. Would the rule you wrote in (b) apply to first and third class levers as well? How could you find out?

6. Set up the inclined plane using a height of six books as in Fig. 6-31.

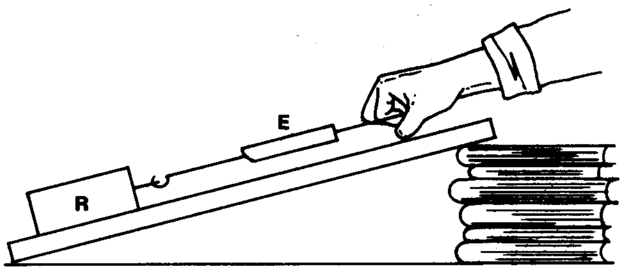


Figure 6-31

TABLE 6-7

	6 BOOK	3 BOOK
Weight of Block		
Effort Force		
Mechanical Advantage		

Determine the effort force necessary to slide the block up the inclined plane. Complete Table 6-7 placing your data in the "6 Book" column.

7. Reduce the height of your inclined plane by using only three books. Repeat Procedure 6 and complete the table, placing your data in the "3 Book" column.

a. How did lowering the height of the inclined plane affect the mechanical advantage?

b. Suggest another way to change the mechanical advantage of an inclined plane other than changing the height.

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