SCIENCE 807
USING MACHINES

CONTENTS

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VOCABULARY

Study these words to enhance your learning success in this section.

accelerate (ak sel′ u rāt). Increase velocity.

diagonal (dī ag′ u nul). A straight line running from one corner of a four-sided figure to the opposite corner.

force (fôrs). A push or a pull.

gravity (grav′ u tē). The force that objects exert on each other because of their mass.

inertia (in ėr shu). The tendency of an object at rest to remain at rest; the tendency of an object in motion to continue in the same direction and speed.

magnitude (mag′ nu tüd). Size.

newton (nü′ tun). The unit of force in the metric system.

proportion (pru pôr′ shun). Relation in size of one thing to another.

scalar (skā′ lur). A quantity that has size only.

vector (vek′ tur). Any quantity which has both size and direction.

velocity (vu los′ u tē). Speed in a given direction.

THE MEANING OF FORCE

A force is a push or a pull. In physical science force is a **vector** quantity. Vector quantities have both **magnitude** and direction. A force cannot be seen, but the results of a force may be seen. You can see a baseball move from the pitcher's hand to the bat. The force of the bat causes the ball to change direction and move back toward the pitcher. A ball thrown into the air reaches a peak and returns to earth.

Gravity. An ever-present example of force is **gravity.** Gravity is the force of the earth on objects near it. The first recorded scientific observations of gravity were made by Galileo. He related the distance to the time required for a metal ball to roll down a slanted board. He also demonstrated that heavy objects and light objects fall at the same rate.

Galileo's hypothesis was tested but he could not measure either speed or time accurately with the instruments available.

Measurement. In the metric system a force is measured in **newtons** (N). Newtons can be measured in terms of mass, distance, and time. A newton is equal to 2.2 lbs.

Today, instead of measuring an object rolling down a slanted board as Galileo did, we can study an object in free-fall. The force causing it to fall is the attraction of earth's gravity on the object.

Galileo. Galileo Galilei was an Italian who was born in Pisa in 1564. His father was interested in music and classical literature. Galileo was sent to the University of Pisa to study medicine. There, he invented a pendulum timer to take pulse rates. During his studies he became interested in the physical sciences and mathematics.

When he was twenty-six years old, he became professor of mathematics at Pisa. Because he disagreed with the established theories of his time, he made enemies of other professors. He left Pisa and went to Padua where he studied astronomy and, again, disagreed with the other professors. These studies conflicted with the established Roman Church views. The church held that the earth was the center of the universe. Galileo, on the other hand, taught that the sun was the center of our part of the universe and that the earth moved around the sun. He also wrote books that enraged other professors. He was tried for heresy by a church court. He was forced

to confess that he taught ideas of which the church disapproved. Then Galileo was placed under house arrest. Galileo believed in God, but he wanted freedom to investigate.

Complete these sentences.

2.1 A push or a pull is a(n) _____.

2.2 Quantities that must be defined by their size and direction are called _____.

2.3 The force of attraction that the earth exerts on all objects is called _____.

2.4 The metric unit of force is the _____.

2.5 The most powerful social institution of Galileo's time was the _____.

Write *true* or *false*.

2.6 _____ Galileo was limited by a lack of money.

2.7 _____ Galileo was able to accurately test his hypothesis.

2.8 _____ Galileo believed that the planets revolved around the sun.

2.9 _____ Galileo's scientific views were accepted soon after they were published.

Try this investigation: Measuring Force Using a Force Scale

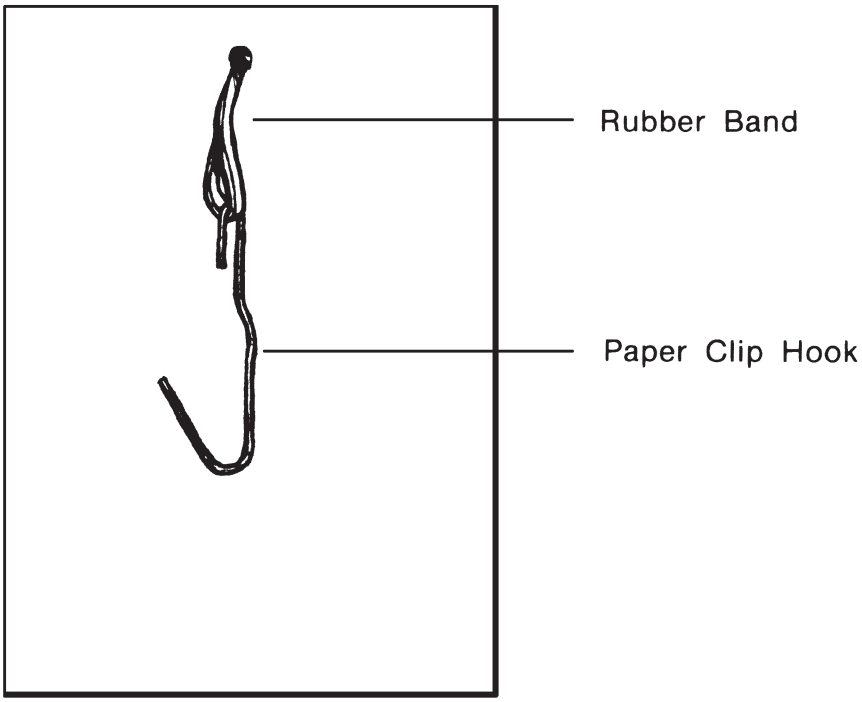
These supplies are needed:

strong cardboard (8½" x 11")
rubber band
paper clips
25 identical washers
a hole punch

Follow these directions. Put a check in the box when each step is completed.

☐ 1. Punch a small hole near the top center of cardboard. Insert a section of one rubber band and loop a paper clip through the rubber band on the back of the cardboard to keep it from pulling out.

☐ 2. Unbend a paper clip to form a hook. Hang the clip from the rubber band on the front side of the cardboard.



☐ 3. Add washers to the hook until the rubber band begins to stretch. Number of washers _____. These washers are to be considered part of the hook and should not be listed on the data table. If the rubber band does not need to be straightened, do not use any washers.

☐ 4. Mark the cardboard at the bottom of the hook and label the mark "O."

☐ 5. Add washers, two at a time. Mark the position of the hook for each addition: 2, 4, 6, and so on. Use good judgment about the maximum number of washers the rubber band can hold without breaking. You now have a calibrated scale that can be used in any position. The unit of force (weight) is 1 washer.

☐ 6. Weigh several common items on your scale.

2.10

Item	Weight (washers)
key ring	
wallet	
pen	
paperback book	
eraser	
hat	
calculator	

THE LAWS OF NEWTON

Before Newton's time, other scientists had been aware of an attraction the earth has for all objects near it. Galileo, for one, had experimented; but he was limited by the lack of appropriate measuring devices. Newton's genius led him to state physical relationships that he had never observed operating and to invent a system of mathematics (calculus) that enabled him to explain them.

Sir Isaac Newton. Isaac Newton was born on Christmas Day in 1642. He was a poor farm boy in Woolsthorpe, Lincolnshire, England. Reading, invention, and mathematics were his favorite pastimes. An uncle enabled him to attend Trinity College of Cambridge University when he was eighteen. He graduated in 1665 with no significant list of achievements.

The young student spent much time thinking. He noticed that as an apple fell from the tree it always fell straight toward the center of the earth. Newton explained this observation in terms of the pull that exists between the earth and all other objects. This pull is called the *force of gravity.*

Gravity cannot be explained; it is a pull that exists between all objects, however large or small. The best that scientists can do is to say that it exists and to express it mathematically. Job said, God ". . . hangeth the earth upon nothing" (Job 26:7). Gravity, electrostatic force, and magnetic force hold the universe together. The writer to the Hebrews (Hebrews 1:3) explains these forces as a part of Christ's power.

Among Newton's other mathematical and scientific discoveries were his three laws of motion:

1. An object that is moving will continue to move at the same speed in a straight line, and an object standing still will continue to stand still, *unless* a push or pull (a force) causes a change.
2. If a force does cause a change in an object's speed, the change in speed will be large if the force is large or small if the force is small. The change in speed will be large for small objects (small mass) and small for large objects (large mass). A small car is easier to push than is a large car. The same engine (the same push) in a small car and in a large car would give the small car a greater **acceleration.**
3. Forces never occur singly. Each force (action) is accompanied by another force (reaction) that is the same size, but is opposite in direction. For example, when you push on a door, the door pushes back on you.

Newton returned to Cambridge to be named professor of mathematics. He wrote books and presented many papers to the Royal Society. Isaac Newton was also a theologian who studied the Bible. His main interest was the chronological dates of Biblical events. This was one of Newton's favorite pastimes.

About 1692 Newton had a nervous breakdown, which ended his new discoveries. In 1699 Newton was named master of the mint. He almost completely eradicated counterfeiting in England. He also served in Parliament representing Cambridge University.

Sir Isaac Newton died in 1727.

First law of motion. This law states that any object moving at a constant speed or any object at rest tends to stay that way unless some force acts on it. When you are riding in a car that stops suddenly, you continue to move forward. If the car is standing still and suddenly starts, your body is pushed back into the seat.

The first experience is an example of an object (your body) remaining in motion in a straight line unless a force (the car's brakes acting through your seat belt) acts on it. The second experience is an example of an object (your body) at rest remaining at rest unless a force (the car seat back) acts on it.

This tendency of mass to resist change is **inertia**. Experiments have shown that the

mass and inertia of a body are **proportional**.

When the car in which you are riding stops suddenly, your body (unless you have on your seat belt) wishes to continue moving straight ahead. When the stopped car starts, your body wants to stay where it is and pushes against the seat when the car's seat moves forward. The faster an object is moving the greater is its objection to stopping.

The effect of inertia on the spinning earth is the bulge at the equator. The earth's surface wants to continue in a straight line, but it is pulled into a circular path by the cohesion of the rock beneath.

Second law of motion. The second law of motion explains how force, acceleration, and mass are related. There will be a change of motion when force is applied to a moving body. The force applied and the mass of the object determine the change. As the mass increases, the force needed to accelerate it must increase also. In the metric system, force is in newtons and mass is in kilograms.

Third law of motion. "Action-reaction" is a term commonly applied to the third law of motion. A climber on a sand dune pushes the sand downward. Yet the resistance of the sand is equal to the upward progress of the climber. When a swimmer dives off a raft, his push on the raft results in the movement of the raft. The equal push that the raft exerts on the swimmer causes him to be propelled forward into the water.

The statement that every action is accompanied by an equal and opposite reaction explains the "kick" of a gun. The force of the bullet leaving the gun is equal to the force the powder gives the gun in the opposite direction. Another example of this force is a jet engine.

Complete this activity.

2.11 Paraphrase Newton's laws of motion.

first law: _____

_____

_____

_____

_____

2.12 second law: _____

_____

_____

_____

_____

_____

2.13 third law: _____

_____

_____

_____

_____