NAME ______________________ PERIOD ______ DATE ______ GRADE ______

CENTRIPETAL FORCE

EXPERIMENT 9

An object moving with changing speed in the same direction is undergoing acceleration. If an object moves with constant speed but in changing directions, it is also undergoing acceleration. Both types of acceleration require forces. A change in direction is called centripetal acceleration, and the force producing it is called centripetal force.

The equation relating centripetal force, mass, and velocity is

$$F_c = \frac{mv^2}{r}$$

where F_c is the centripetal force, m is the mass of the moving object, v is its velocity, and r is the radius of the orbit of the object. In this experiment each of the factors in this equation will be varied as an object is whirled on the end of a string. Centripetal force will be supplied by masses tied to a string that passes through a vertical tube. See Figure 9-1. The effect of gravity on the whirling object is offset by the resulting angle of the string with the horizontal. Thus, r can be taken as the length of the string between the tube and the object (even though the string is not perpendicular to the tube) without introducing a significant error.

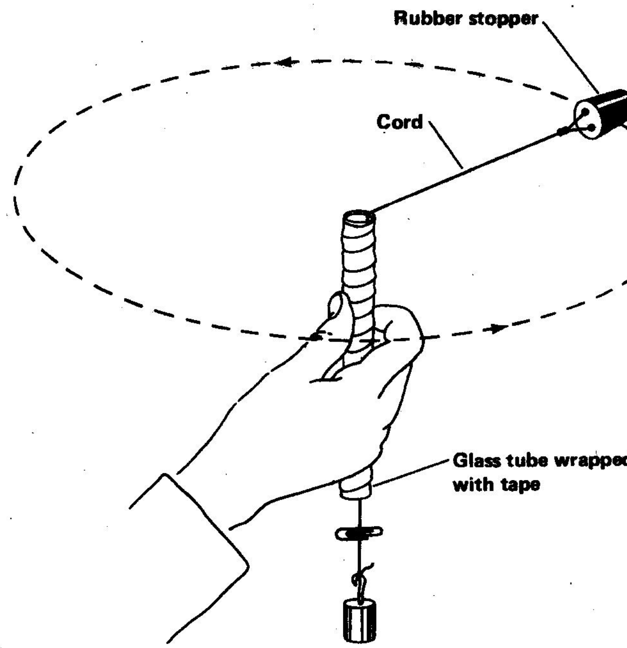

Figure 9-1

OBJECTIVE

After completing this experiment, you should be able to verify the relationship between centripetal force, mass, and velocity in a whirling object.

APPARATUS

glass tube, about 15 cm long and 1 cm in diameter, fire-polished at both ends and wrapped with masking tape
nylon cord, about 1.5 m long
several 2-hole rubber stoppers of different sizes
1 100-g mass
2 200-g masses
stopwatch, or clock with sweep second hand
meterstick
paper clip

PROCEDURE

Fasten one end of the nylon cord securely to the rubber stopper. Pass the other end through the glass tube and fasten a 100-g mass to it. Adjust the cord so that there is about 0.75 m of cord between the top of the tube and the stopper. Attach a paper clip to the cord just below the bottom of the tube.

Support the 100-g mass with one hand and hold the glass tube in the other. Whirl the stopper by moving the tube in a circular motion. Slowly release the 100-g mass and adjust the speed of the stopper so that the paper clip stays just below the bottom of the tube. Make several trial runs before recording any data.

When you have learned how to keep the velocity of the stopper and the position of the paper clip relatively constant, have a classmate measure the time required for 20 revolutions. Record this time. Stop the whirling of the stopper, place the apparatus on the top of the lab table with the cord extended the way it was during the experiment (as indicated by the position of the paper clip), and measure the distance from the center of the glass tube to the center of the rubber stopper. Record this distance in the data table as *r*. Record the mass of the stopper.

Repeat the procedure for Trials 2–4. Keep the radius the same as in Trial 1 and use the same rubber stopper, but increase the mass at the end of the cord. For Trial 2, use 200 g, for Trial 3 use 300 g, and for Trial 4 use 400 g. Record all data.

For Trials 5–8 keep the same rubber stopper and use a mass of 100 g for each trial, but vary the radius of revolution. The radius for the four trials should range from about 0.5 m to about 1.0 m.

For Trials 9–12, keep the radius constant at about 1.0 m and keep 200 g of mass at the end of the cord, but vary the size of the rubber stopper. To get a wide range of mass for the stopper, you may wish to tie two stoppers together in order to increase the mass. Record the centripetal mass, time for 20 revolutions, and mass of the stopper for each trial.

DATA AND CALCULATIONS TABLES

DATA

TRIAL	***Hanging mass*** (kg)	***Mass of stopper*** (kg)	***Total time*** (s)	***Radius*** (m)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

CALCULATIONS

Centripetal force (N)	***Period*** (s)	***Circumference*** (m)	***Velocity*** (m/s)

CALCULATIONS

Show the calculations for Trial 1 in the spaces provided below. Enter the results of the calculations for all trials in the appropriate spaces above.

1. Calculate the weight of the hanging mass and enter it in the table as the centripetal force.

2. Find the period of revolution by dividing the total time by the number of revolutions. Calculate the circumference of revolution from the radius.

3. Use the circumference and period to find the velocity.

GRAPHS

1. Plot a graph for Trials 1–4 using velocities as abscissas and centripetal forces as ordinates. Start the scales and curve at 0,0.
2. Plot a second graph for Trials 5–8 using radii as abscissas and velocities as ordinates. The curve should again start at 0,0.
3. Plot a third graph for Trials 9–12 using the masses of the stoppers as abscissas and velocities as ordinates. This curve will *not* start at 0,0.

QUESTIONS

1. On the basis of the first graph, what is the relationship between the velocity of a whirling object and the centripetal force that is exerted on it?

2. What is the relationship between the radius of revolution and the velocity of a whirling object?

3. What is the relationship between the mass and velocity of a whirling object?

4. How would the shapes of the first two graphs change if the squares of the velocities were used?