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LEVEL 6: CENTRIFUGAL AND CENTRIPETAL FORCES

IDEAS TO BE DEVELOPED

1. If an object moves along a circular path a force continuously acts ***on the object*** in a direction ***toward the center*** of the circular path. This force, which tends to pull the object "inward," is called CENTRIPETAL FORCE.
2. The "equal and opposite" force present is called CENTRIFUGAL FORCE. It is exerted ***by the object*** in a direction ***away from the center*** of the circular path.
3. The amount of centrifugal force which a rotating object exerts is affected by its weight, velocity, and the radius of its orbit.

INVESTIGATIONS

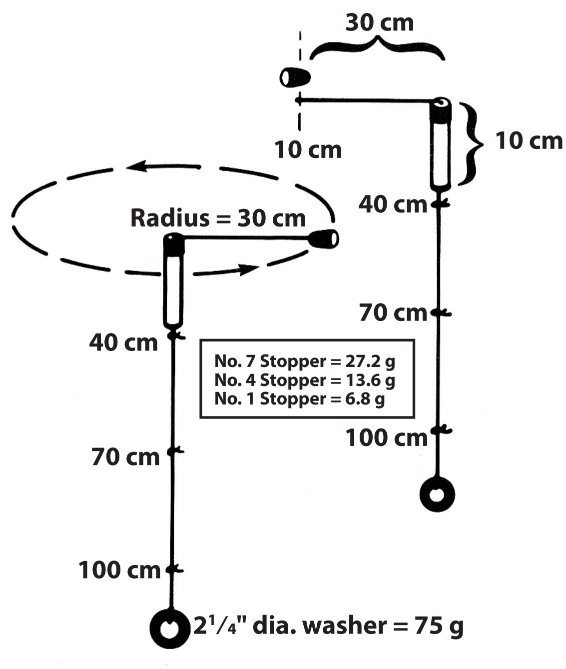
MATERIALS REQUIRED:

1 "whirling tube," 10 cm
4 ft. length of kite string
Digital stopwatch
1 washer, 2 1/4" diameter
2 washers, 1-3/8 diameter
1 each No. 1, 4, and 7 one-hole rubber stopper
Meter stick
* 1 ft. colored yarn
*(Needed but not included in kit)

EFFECT OF CHANGING RADIUS ON CENTRIFUGAL FORCE AND VELOCITY

Thread one end of a 4 ft. length of kite string through the hole in the No. 7 rubber stopper. Tie it securely. Locate positions on the kite string exactly 40 cm, 70 cm, and 100 cm from the midpoint of the stopper. Tie a 3" length of colored yarn at each of these positions to serve as a marker.

Pass the kite string through the hole in the end cap of the 10 cm "whirling tube." Tie the 2 1/4" diameter washer to the free end of the string. (See diagram. NOTE: the No. 7 stopper weighs 27.2 g; the 2 1/4" washer weighs 75 g.)



1. Hold the whirling tube in one hand, in front of and slightly above the head. Grasp the string below the tube with the other hand. Set the rubber stopper into circular motion. As the centrifugal force exerted by the stopper begins to pull outward, allow the force to support the weight of the washer. ROTATE THE STOPPER FASTER. WHAT HAPPENS TO THE WASHER? ROTATE SLOWER. WHAT HAPPENS TO THE WASHER?

   Adjust the speed of the rotating stopper so that it is just fast enough to hold the washer steady while the yarn, tied at the 40 cm mark, is even with the bottom of the whirling tube. This makes the radius of the rotating rubber stopper exactly 30 cm.

   After developing a "feel" for this interaction use the stopwatch to measure the time required to complete 10 revolutions. Repeat this measurement three times. Record all data.
2. Pull the cord through the whirling tube until the yarn at the 70 cm mark is even with the bottom of the tube. Swing the stopper into rotational orbit. Adjust the speed so that the centrifugal force directed "outward" is great enough to support the weight of the washer while the radius of rotation remains constant at 60 cm.

   After developing a "feel" for this interaction measure the time to complete 10 revolutions. Repeat the measurement three times. Before making these measurements, ask the students to predict how this time per revolution will differ from the trials with the 30 cm radius.
3. Pull the cord through the whirling tube until the yarn tied at the 100 cm mark is even with the bottom of the tube. Swing the stopper into rotational orbit. Adjust the speed so that the centrifugal force exerted by the stopper is equal to the weight of the washer while the radius of rotation remains constant at 90 cm. Measure the time required to complete 10 revolutions. Make three trials.

HOW CHANGES IN THE WEIGHT OF AN OBJECT ROTATING AT CONSTANT RADIUS AFFECT CENTRIFUGAL FORCE AND VELOCITY

In this series of investigations the radius of rotation will be held constant at 60 cm. the weight of the object rotated will be varied. The weight being supported will be 36 grams.

1. Replace the 75 g washer with two 1 3/8" washers, 18 g. each. Adjust the length of the cord so that the yarn tied at the 70 cm mark is even with the bottom of the whirling tube. Swing the stopper into circular orbit. Adjust its speed so that the centrifugal force exerted by the stopper is equal to the weight of the two washers. Measure the time to complete 10 revolutions. Do three trials.
2. Replace the No. 7 rubber stopper with the No. 4 stopper which weighs half as much, 13.6 g. Swing this stopper into a rotational orbit of 60 cm with precisely the speed needed to support the 36 g weight.

   Ask the students to predict how the time per revolution will differ from the trial with the heavier stopper.

   Swing the stopper into a 60 cm rotational orbit and measure the time required to complete 10 revolutions. Repeat three times.
3. Replace the No. 4 rubber stopper with No. 1 stopper per which weights 6.8 g. Swing the stopper in an orbit of 60 cm radius with just the speed needed to support the 36 g weight. Measure the time required to complete 10 revolutions. Repeat three times.

NAME ______________________________

DATA SHEET

FORCES

LEVEL 6: CENTRIFUGAL AND CENTRIPETAL FORCE

1. Effect of Changing Radius

RADIUS OF ORBIT	WEIGHT ROTATED	C.F. = WEIGHT SUPPORTED	TIME FOR 10 REVOLUTIONS			AVERAGE TIME FOR 1 REVOLUTION	AVERAGE VELOCITY cm/sec.
			1ST TRIAL	2ND TRIAL	3RD TRIAL		

Calculate the average velocity of the stopper for each radius.

$$\text{velocity} = \frac{\text{distance}}{\text{time}} = \frac{\text{circumference}}{\text{avg. time/rev.}} = \frac{2\pi r}{t} = \frac{?\ \text{cm}}{\text{sec.}}$$

CONCLUSION #1

a. If the centrifugal force exerted by a rotating object is to remain constant, as the radius of its orbit increases, its velocity must ______________________________.
(increase) (decrease) (remain constant)

2. How changes in the Weight of an Object, Rotating at Constant Radius, Affect Centrifugal Force and Velocity

RADIUS OF ORBIT	WEIGHT ROTATED	C.F. = WEIGHT SUPPORTED	TIME FOR 10 REVOLUTIONS			AVERAGE TIME FOR 1 REVOLUTION	AVERAGE VELOCITY cm/sec.
			1ST TRIAL	2ND TRIAL	3RD TRIAL		

CONCLUSION #2

b. If the weight of a rotating object is to be decreased, but the radius and centrifugal force are to remain unchanged, velocity must ______________________________.
(increase) (decrease) (remain unchanged)

NAME ____________________

DATA SHEET

FORCES

LEVEL 6: CENTRIFUGAL AND CENTRIPETAL FORCE

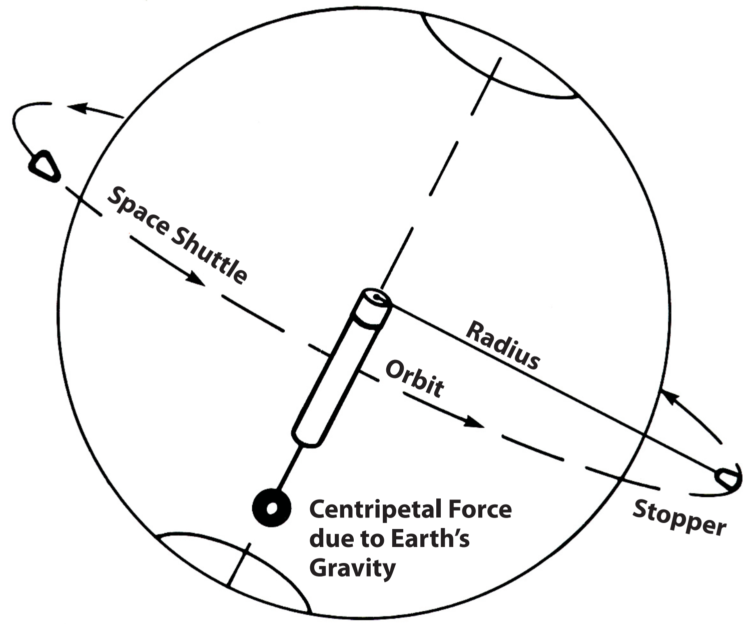
SOMETHING TO THINK ABOUT

The forces in our experiment which kept the stopper traveling in a circular pathway around your hand are the same as the forces which act upon the space shuttle to keep it in orbit around the earth.

The earth's gravity force tends to pull the shuttle back to earth just as the washers in our experiment pulled on the "orbiting" stopper, counteracting its centrifugal force.

The space shuttle is the orbiting stopper. The radius of the string corresponds to the shuttle's distance from earth. The centripetal force exerted on the orbiting stopper corresponds to the earth's gravitational pull on the shuttle.

In order to counteract the earth's gravitational pull and retain its same distance, as it whirls around the earth, the shuttle must maintain a constant velocity.



QUESTION

1. Since the earth's gravity and the weight of the shuttle are practically constant, what must the shuttle pilot do in order to come closer to the earth to land? ____________________

   Use date from the experiment to prove that you are correct.

2. What would the pilot have to do to move the shuttle outward and make a larger orbit around the earth?

   ____

   Use date from the experiment to prove that you are correct.

NAME ____________________

EVALUATION SHEET

FORCES

LEVEL 6: CENTRIFUGAL AND CENTRIPETAL FORCE

1. If the velocity of an object traveling along a circular path is increased and its weight remains constant, the radius of the orbit would ____________________.
(increase) (decrease) (not change)

2. If the velocity of a satellite orbiting the earth decreases, its distance from the earth would ____________________.
(increase) (decrease) (not change)

3. The force which an orbiting object exerts, in an outward direction, upon some other body is called ____________________ force.
(centrifugal) (centripetal)

4. The sideways force when you exert against the seat belt of a car while the car travels around a sharp turn is an example of ____________________ force.

In order to reduce this force, the driver of the car should ____________________ .

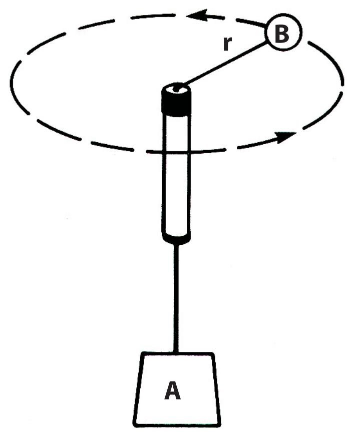
5. With reference to the diagram shown:

a. If the velocity of object B was increased, object A would move upward.

True ☐ False ☐

b. If the radius of object B was to be increased, its velocity would have to be increased to prevent object A from moving downward.

True ☐ False ☐



6. If the radius of a rotating object is increased the velocity required to maintain the same centrifugal force would ____________________.
(increase) (decrease) (remain constant)

7. Two objects rotate about the same radius. Each exerts the same amount of centrifugal force. If one of the objects weighs less, it must be rotating at a ____________________ rate.
(faster) (slower) (same)

8. Three factors affect the centrifugal force of a rotating object. These factors are the ____________, ____________, and ____________ of the rotating object.

II. MECHANICAL ENERGY AND WORK

LEVEL 4: POTENTIAL ENERGY AND WORK

IDEAS TO BE DEVELOPED

1. The Mechanical Energy which any object possesses, while it is at rest, is called POTENTIAL ENERGY or STORED ENERGY.

2. The mechanical POTENTIAL ENERGY of an object will be increased if WORK done on the object:

a. Raises the object to a higher level or,

b. ***Temporarily*** changes the shape of the object. (For example: stretches, twists, bends, or compresses the object)

3. The POTENTIAL ENERGY (PE) gained by an object = WORK done on the object.

a. If height is raised, PE gained = WEIGHT × DISTANCE raised

b. If shape is changed, PE gained = FORCE × DISTANCE changed

INVESTIGATIONS

MATERIALS REQUIRED:

Spring Scale
Meter Stick
Cotton Spring
Masking Tape
"C" Clamp
Rubber Bands (thin) about 3" long
* 1 book, about 1 pound

*(Needed but not included in kit)

INTRODUCTION

1. Introduce the term POTENTIAL ENERGY.

2. Involve the class in a discussion of how the mechanical energy "stored" by an object (its PE) can be increased.

Example:
a. Lift an object from the tabletop to a higher level.
b. Temporarily change the shape of a rubber band.
c. Wind up a spring.

Demonstrate that if the PE of an object is increased the object can do things it could not do before.
Example:
a. The book can fall.
b. The stretched rubber band can "snap" or "fly away."

3. Develop the ideas that:

a. The energy stored by an object (its PE) cannot be increased, unless WORK is done on the object.

b. PE gained = WORK done = FORCE × DISTANCE or WEIGHT × DISTANCE raised.

INCREASING PE BY INCREASING HEIGHT

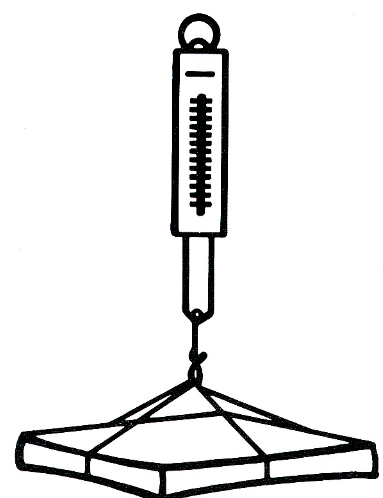
1. Distribute copies of the Data Sheet. Use the spring scale to measure the weight of the book. Measure the distance from the floor to the tabletop. Record the data.

Lay the book on the floor. Have a student lift the book up and set it on the table. Have the students calculate the PE gained.

2. Tie a string around the book. Hook the spring balance to the string. Raise the book with ***constant*** speed to the top of the table. While the book is moving with constant speed, read the spring scaled to determine the force acting. Record all data.

(Note: If the book is moving with constant speed, the reading on the spring scale will be the same as the weight of the book.)

3. Have the students calculate the WORK done.



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INCREASING PE BY CHANGING SHAPE

1. Attach a piece of masking tape to the tabletop. Loop the thin rubber band around the screw of the "C" clamp. Attach the clamp to the tabletop so that the base of the screw is on top of the masking tape.
2. Attach the spring scale to the other loop of the rubber band. Adjust the metal tab, if needed, to get a zero reading when just enough tension is applied to take up the slack in the rubber band.
3. Draw a line on the masking tape to mark the "starting" length of the rubber band.
4. Pull on the spring scale until it reads 50 g. Mark the length of the rubber band. Repeat at 100 g, 150 g, 200 g, and 250 g intervals. Measure the total change in length, from zero, for each trial.
5. Record all data. Have the students complete and then compare and share their results.