

Marble Roll

Safety Precautions

- Be sure to place a barrier near the bottom of the track so that the objects don't roll away.

Vocabulary

- kinetic energy - energy due to motion
- mass - the amount of matter in an object
- moment of inertia - an object's resistance to angular acceleration
- potential energy - energy due to an object's position
- radius - half the distance across a circle
- rotational energy - energy due to rotation
- weight - force exerted by an object due to gravity

Materials and Equipment

- plastic or wooden tracks or inclines
- small and large marbles, small disks or checkers, ping-pong balls
- a partner

Questions

1. Will the objects reach the bottom of the track at the same time?
2. Does their *mass (weight)* or *radius* (size) determine which one reaches the bottom first?
3. Is there something else about the objects that might affect which reach the bottom of the track first?

Research

When you drop objects from the same height and at the same time they will land at the same time, even if they have different masses (weights).

If you roll two objects with the same shape, for example, a large marble (solid sphere) and a small marble (solid sphere), they will reach the bottom of the track at the same time, even if their masses (weights) are different. The same is true for the yellow checker (solid disk) and the red checker (solid disk).

If the objects have a different shape, for example, a large marble (solid sphere) and a checker (disk), the marble (solid sphere) will reach the bottom first even if its mass (weight) is less than that of the checker.

Before you release the objects, they have only *potential energy*. Rolling objects have both *kinetic energy* and *rotational energy*.

Rotational energy is determined by an object's *moment of inertia*, which depends on the object's shape.

Hypothesis

What is your hypothesis? Be sure to include your "best guess" answers to the 3 questions above.

- 1.
- 2.
- 3.



Experiment

1. One partner places two of the tracks next to each other with their tops at the same height and holds the tracks.
2. The other partner places one of the objects at the top of one track and one of the other objects at the top of the other track. Be sure that the front parts of the objects are lined up before releasing them.
3. The partner holding the objects releases them at the same time from the tops of the tracks.
4. Observe and record which object reaches the bottom of the track first.
5. Repeat the experiment for each of the pairs of objects and record which reaches the bottom of the track first.

Data and Observations

Objects	Which landed first?
large marble and small marble	
large marble and yellow checker	
large marble and red checker	
large marble ping-pong ball	
small marble and yellow checker	
small marble and red checker	
small marble and ping-pong ball	
yellow checker and red checker	
yellow checker and ping-pong ball	
red checker and ping-pong ball	

Analysis

1. Did the marbles reach the bottom of the track at the same time? They should.
2. Did the checkers reach the bottom of the track at the same time? They should.
3. Did their *mass (weight)* or *radius (size)* determine which one reached the bottom first?
4. What else determined the order in which objects reached the bottom of the track?

Conclusions

The most important concepts in this experiment are:

1. the mass (weight) and the radius (size) of the objects have no effect on their speed and which reaches the bottom of the incline first;
2. the shape of the objects and where their mass (weight) is distributed, uniformly like marbles and checkers) or at the edges, like ping-pong balls and washers does affect their speed;
3. the marbles were the fastest, followed by the checker, the ping-pong ball, and the washers, which were the slowest.



Additional Questions

1. If you drop any two of the objects from the same height and at the same time, rather than rolling them down the track, what happens? Try it! Dropped objects don't have rotational energy.
2. If you want any of the objects, other than the two marbles and the two checkers, to reach the bottom of the track at the same time, what do you need to change? Try it!

Science and Math (optional information)

Shape	Moment of inertia	Speed at bottom of the track
solid sphere (marbles)	$\frac{2}{5}mr^2 = 0.40mr^2$	$\sqrt{\frac{10}{7}gh} = 1.20\sqrt{gh}$
disk (checkers)	$\frac{1}{2}mr^2 = 0.50mr^2$	$\sqrt{\frac{4}{3}gh} = 1.15\sqrt{gh}$
hollow sphere (ping-pong ball)	$\frac{2}{3}mr^2 = 0.66mr^2$	$\sqrt{\frac{6}{5}gh} = 1.10\sqrt{gh}$
hoop (washers)	$mr^2 = 1.00mr^2$	$\sqrt{gh} = 1.00\sqrt{gh}$

With the help of a little algebra, we only need to look at 4 important numbers:

Shape	Velocity ratio
solid sphere (marbles)	1.20
disk (checkers)	1.15
hollow sphere (ping-pong ball)	1.10
hoop (washers)	1.00

m = mass of the object, in kilograms

r = radius of the object, in meters

g = acceleration of gravity, 9.81 meters/second²

h = height of the top of the incline, in meters

