Rolling, rumbling, racing

Purpose:
To observe the motion of objects rolling down an inclined plane; compare the effects, on the motion, of the rolling object's mass, size, and shape; observe the transfer of gravitational potential energy to linear and rotational kinetic energy.

Set-up:
Stick a long strip of masking tape across the back (rough side) of a whiteboard, parallel to the shorter edges of the board, and close to one of them, as shown in ***Diagram 1*** below.

Place the whiteboard on your table so the edge close to the tape is held up, by a wooden bar provided, to a height of roughly 1.5 cm, as shown in ***Diagram 2*** below. The rough surface of the board should be placed upward/upside so that there is enough friction between the surface and the rolling objects to prevent them from slipping while rolling.

You should put a plastic tub close to the bottom of the whiteboard so that the rolling objects, once on the table, are stopped by the tub and do not drop on the floor or on your toes.

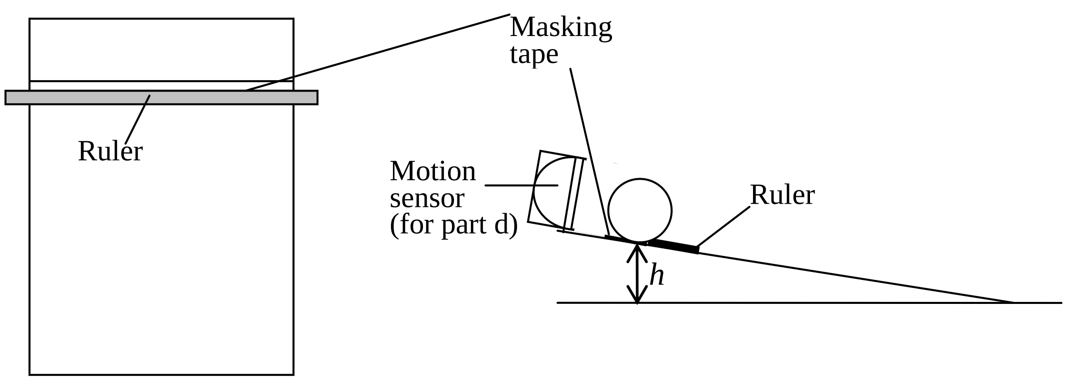

Diagram 1: top view ***Diagram 2: side view***

Data Collection:

Run 1: variable mass

a) Choose three different solid cylinders, from the stock you are given, that have the same radii and lengths, but different masses. Record their radius, length, and masses.

b) Hold a thin ruler parallel to and next to the masking tape, as shown in the diagrams. Place the objects on the tape so that they touch the ruler. They should not touch one another. When you are ready, quickly remove the ruler so as to let the objects start rolling down from the same height above the table at the same time. Observe the objects rolling down to the bottom of the surface.

c) **Does *mass* affect the time taken to reach the bottom?** If not, then note that down, and go to the next Run. If it does, then **list the objects in order from the fastest to the slowest.**

d) Measure and record the height *h* of the lower edge of the tape above the table. Attach a motion sensor to the middle of the elevated side of the whiteboard, as shown in ***Diagram 2***. Move the tub about 1 ft away from the bottom of the board so as to allow the rolling objects to continue to roll another 1 ft after it leaves the board, with a constant speed. Now let the objects roll down the board, one by one, so that the sensor can register each motion individually. From the GLX output, record the velocity of each rolling object when it reaches a constant velocity, which is that at the bottom of the plane.

e) Calculate, from your knowledge of the height *h*, the expected velocity of each object at the bottom the plane. Compare this calculated velocity with the one you found using the sensor. Find the ratio between these two quantities for each object. Find the average and standard deviation of these ratios.

Run 2: variable radius

a) Choose three different solid cylinders that have the same masses and lengths, but different radii. Record their mass, length, and radii.

   Then follow the same steps b) through e) above, except that this time the variable quantity is not *mass*, but *radius*.

Run 3: variable length

a) Choose two different solid cylinders that have the same masses and radii, but different lengths. Record their mass, radius, and lengths.

   Then follow the same steps b) through e) above, except that this time the variable quantity is *length*.

Run 4: variable shape

a) Choose a solid cylinder, a hollow cylinder, and a sphere, that have the same masses and radii. Record their mass, and all the dimensions.

   Then follow the same steps b) through e) above, except that this time what is varying from one object to another is its *shape*.

Moment-of-inertia formulae that might be useful:

Rotating object	Moment of inertia, I
Solid cylinder of radius R, mass M, rotating around its central axis	$I = \frac{1}{2}MR^2$
Hollow cylinder of outer radius R, inner radius r, mass M, rotating around its central axis:	$I = \frac{1}{2}M(R^2 + r^2)$
Sphere of radius R, mass M, rotating around its central axis	$I = \frac{2}{5}MR^2$

Here is a photo of one set of the rolling objects that will be used for this experiment: