611-1855 (40-115) Deluxe Loop the Loop

What you will need:
A meter stick to measure the height of the drop point relative to the base.

Warranty and Parts:
We replace all defective or missing parts free of charge. Additional replacement parts may be ordered toll-free. We accept MasterCard, Visa, checks and School P.O.s. All products warranted to be free from defect for 90 days. Does not apply to accident, misuse or normal wear and tear. Intended for children 13 years of age and up. This item is not a toy. It may contain small parts that can be choking hazards. Adult supervision is required.

Introduction:
The 40-115 Loop the Loop apparatus easily demonstrates the transformation of gravitational potential energy to kinetic energy and centripetal force. Rollercoasters which contain loops use this principal to keep people from falling out of their seats as they spin upsithe down. Like a rollercoaster car, the ball must be released at a point high enough to keep the ball from leaving the track. Use the built in ruler to measure the distance the ball has dropped from its starting point at the top to the bottom of the loop. The Loop the Loop features a two-sided back drop plastic disk that allows for measurements in degrees or cm when the ball traverses the loop.

We can calculate the minimum height of release to keep the ball on the track. When the height of release is not sufficient to allow the ball to maintain contact with the track, the angular measurements of the disk allows for calculation of the angle of release from the track.

Assembly:
The 40-115 Deluxe Loop the Loop needs to be set up prior to operation in the following manner:
1. Unpack all of the components.
2. The plastic cup is used to catch the ball. Place the ball catching cup onto the end of the track and push in the piece of foam to secure it..
3. Mount the track support to the wooden base using the screws provided. Allow the bottom of the catch cup to rest against the protruding screw.
4. Attach the protractor / gauge to the frame using the thumbscrew provided.

Terms Used:
m is the mass of the ball being used.

h is the height of the release point over the lowest point that the ball travels. This can be measured with a meter stick.

r is the radius of the loop. The 40-115 comes with a 20cm loop, which should be measured for accuracy.

θ is the angle at which the ball leaves the track. This can be measured from the black measurement disk (degrees side).

g is the acceleration due to gravity, which is $9.8 m/s^2$ (at sea level).

v is the linear velocity at the top of the loop.

w is the angular velocity.

N is the normal force exerted on the ball by the track.

I is the moment of inertia of the ball.

How to use:
Begin by lifting a ball to the top of the track and hold it there. To get the ball from the tabletop to the top of the track, potential energy has now

been given to the ball. Release the large steel ball from the top of the track. The ball will stay in contact with the track the entire distance through the loop.

Next, release the ball from a point a few centimeters below the top of the track, but still above the mid point of the loop (the radius (**r**)). The ball will not make it all the way through the loop, and will release from the track at some point along the loop.

What is happening?

The principal of conservation of energy is at work here.

The potential energy of an object is the energy of position with respect to a given reference position. The reference level is the bottom of the loop, the potential energy at the top of the ramp is ***mgh***. The potential energy at the bottom of the loop is 0.

The ball falls from a position of rest at a high elevation ***h*** to a lower elevation the bottom of our loop. As the ball drops, its potential energy decreases as the elevation *h* decreases, and its kinetic energy increases as its velocity increases.

kinetic energy is given by
$$KE = 1/2\, mv^2$$

Potential energy is given to the ball when it is lifted to the top of the track. This potential energy is then transformed into kinetic energy.

The amount of potential energy lost during the fall is equal to the kinetic energy acquired as the velocity increases due to the acceleration of gravity.

Why the ball falls off at lower heights:

The ball needs enough energy to create the necessary centripetal force to stay on the track. The centrifugal force on the ball must be enough to overcome the gravitational force acting on the ball throughout the loop.

In a frictionless environment, it is possible to calculate the minimum height necessary to keep the ball from falling off the track and the angle at which the ball will fall off the loop. In our demonstration additional energy will be needed to compensate for the energy loss due to friction.

The diagram shows the needed measurements to calculate the forces at work in the demonstration.

To calculate a minimum height at which the ball needs to be dropped from:

The centrifugal force on the ball must be equal to or greater than the gravitational force on the ball:

$$mg = (mv^2)/r$$
which converts into
$$v^2 = gr$$

Conservation of energy applies to the moment of inertia and the angular velocity:

$$Iw + mv + 2mgr = mgh$$

The moment of inertia of a solid spherical ball is:

$$I = (2/5)mr^2$$

From this we solve for the height and derive the minimum starting point of our ball:

$$h = 2.5r$$

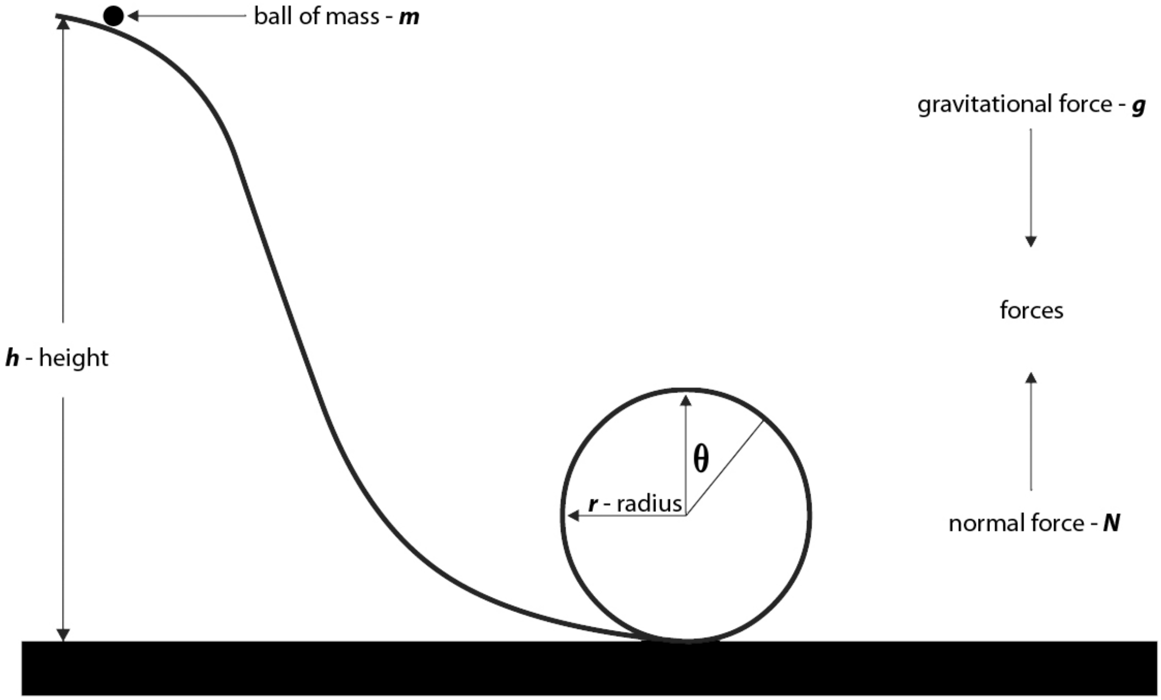
The formula will not work perfectly in our demonstration for a couple of reasons. There is friction; the ball will slow down just because of the contact with the track and there is a minute amount of friction with the air.

In a frictionless environment, the orientation of the ball would remain stable, and only the curvature of the track would affect it. In our example friction will start the ball rolling down the track. This actually helps to reduce overall friction as the ball rolls through the loop instead of sliding through the loop. This effect can be seen by rolling each of the three balls from the same height. The rubberized ball with the most friction begins to roll immediately; this motion creates a rotational inertia not seen by the plain steel ball but which assists the rubber ball through the loop.

Advanced properties:

The 40-115 Loop the Loop may also be used in a more advanced settinto calculate the angle of release of the ball from the track where:

$$\cos\theta = 2/3\,((h/r) - 1)$$


ball of mass - m
gravitational force - g
forces
h - height
θ
r - radius
normal force - N