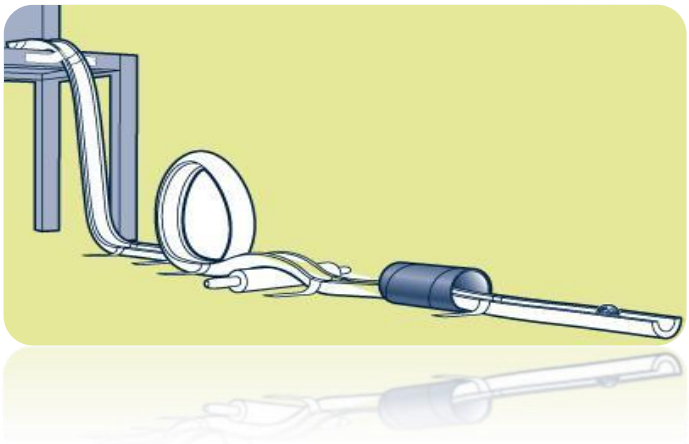
Engineering Challenge

# Rollercoasters

*Allotted Time: 90 mins*

This challenge will have students design a mini rollercoaster from household items. This will reinforce the concept of conservation of energy and converting energy from potential to kinetic.



## Materials needed (per group):

- Foam pipe insulation (3-4 pieces)
- Masking tape (1 roll)
- Marbles (1)
- Tissue paper (2-3 sheets)
- Disposable cups (1)
- Rubber bands (1)
- BBQ skewers (20)
- Popsicle Sticks (20)
- Newspaper (20 sheets)
- Timer (1)
- Calculator (1)
- Ruler/Metre stick (1)
- Measuring scale (1 for entire class)

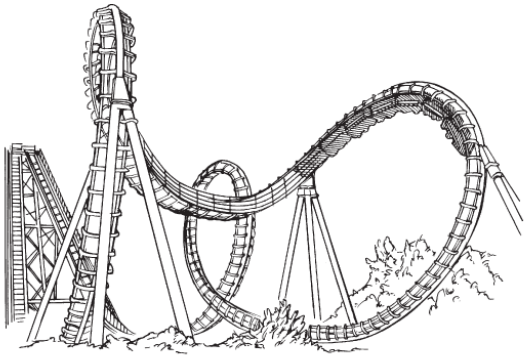
Method

1. Split the class into groups of 2-3.
2. Each group will complete the ***Rollercoaster Worksheet***.
3. Each group is given the materials listed above.
4. The group must construct their individual roller-coaster for the marble. At the end of the track the marble must stop at a tissue paper.
    a. Points are awarded to complexity of the rollercoaster
        i. Turn – 5 points
        ii. Hill – 5 points
        iii. Loop – 10 points
        iv. Spiral – 10 points
        v. Other unique feature – 5 points
    b. Points are deducted for safety
        i. Marble goes off track – minus 10 points
        ii. Marble doesn't stop/tissue paper breaks – minus 10 points
5. The team with the most points wins!!



Ref: teachengineering.org

# Engineering Rollercoasters



roller coaster

Rollercoasters are meant to go FAST! But what makes a Rollercoaster go fast? ***Energy.***

Energy comes in many forms, but rollercoasters mostly use ***Potential Energy*** and ***Kinetic Energy***.

**Potential Energy** is stored energy.

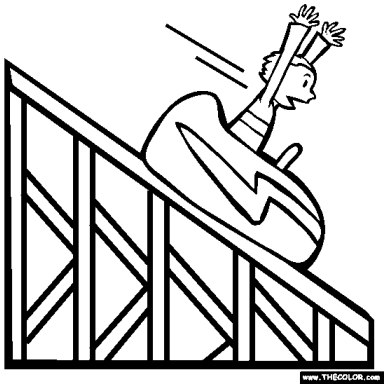
- Rollercoasters use ***gravitational potential energy*** which is stored when objects go up high.
- The equation for gravitational potential energy is $\mathrm{E_p} = \mathrm{mgh}$

**Kinetic Energy** is the energy of a moving object.

- The equation for kinetic energy is $\mathrm{E_k} = \frac{1}{2}\mathrm{mv}^2$

***Energy is always conserved***. That means the energy at the start will equal the energy at the end.

- At the beginning of the rollercoaster you are up high but you are not moving yet. That means all of the energy is Potential energy.
- At the bottom of the rollercoaster you are down low but you are going very fast. That means all of the energy is Kinetic energy.
- In between, you have both Potential and Kinetic Energy



**Rollercoaster Worksheet**

If you design a marble rollercoaster that is **50cm high**, *what would be the potential energy*?

$$E_p = mgh$$

What is the mass of the marble (m)? _____grams or _____kg

What is the acceleration due to gravity (g)? $9.8 m/s^2$

What is the height (h)? 50cm or _____m

What is $E_p$? _____Joules (kg $m/s^2$)

If the energy at the beginning equals the energy at the end, then:

$$E_p(\text{at the top}) = E_k(\text{at the bottom})$$

$E_k = \frac{1}{2}mv^2$ rearranging we get $v = \sqrt{\frac{2E}{m}}$

For the 50cm high rollercoaster, what would be the velocity at the bottom?

Velocity (v) = _____m/s

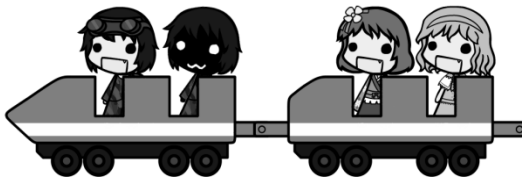
What would the Potential energy be if you designed a rollercoaster 120cm high? _____Joules

What would be the velocity at the bottom? _____m/s

What would the Potential energy be if you designed a rollercoaster 10cm high? _____Joules

What would be the velocity at the bottom? _____m/s

Friction Force





How do we get our roller-coaster to stop? Using *Brakes*.

Brakes work by creating ***Friction***.

**Friction Force** changes ***kinetic energy*** in ***heat energy.***

- The friction force is related to the ***Normal Force*** or Weight of an object on a surface.
- The friction force is also related to the *material of the surface*. Different materials have different ***Coefficients of Friction***.
- The equation for Friction is $\mathrm{F_f} = \mu \mathrm{F_n}$
- The normal force is equivalent to the weight $\mathrm{F_n} = W = mg$
- The **heat energy** released from friction is $\mathrm{E_h} = \mu \mathrm{F_n} d$ where d is the distance travelled over the surface.

Now we must modify our equation

$$\mathrm{E_p}(\text{at the top}) = E_k(\text{at the bottom}) + E_h(\text{released due to friction})$$

Build a simple rollercoaster.

What is the mass of your marble: m= _____

Measure the height of your rollercoaster: h= _____

What is the gravitational potential energy of the marble at the top? $E_p$ = _____

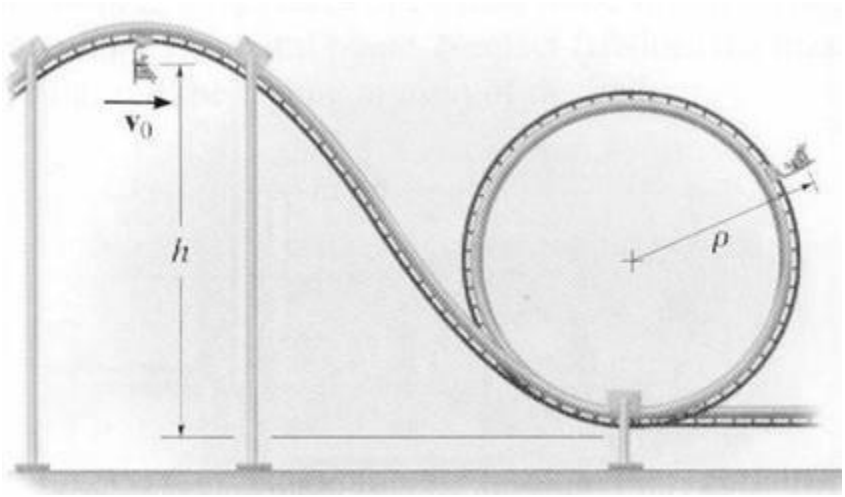
Let your marble go down the roller-coaster.

What is the velocity (speed) of the marble? v=d/t = _____

What is the kinetic energy of the marble? $E_k$ = _____

Can you calculate the Heat Energy released due to Friction? $E_h$ = _____

Centripetal/Centrifugal Force




One of the most fun parts of a roller coaster is a loop-de-loop.

How does a rollercoaster go upside down on the loop-de-loop without falling?

This is due to ***Centripetal Force*** and the ***Reactive Centrifugal Force***.

**Centripetal Force** is the force of an object moving along a curve or in a circle.

**Reactive Centrifugal Force** is equivalent to the centripetal force but in the opposite direction, and stops the rollercoaster from falling when it is upside down.

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

To make sure that the marble does not fall when it goes upside down, the centrifugal force must be greater than the weight of the marble. $W = mg$

The roller coaster also needs to have enough *Kinetic Energy* to convert into *Gravitational Potential Energy* so it can reach the ***maximum loop height ($h_L$)*** at the top of the loop.

Add a loop to your rollercoaster.

What is the mass of the marble? m= _____

What was the velocity at the bottom (just before you added the loop)? v= _____

What is the maximum radius your loop can have? r = _____

What is the maximum loop height that your roller coaster can have? $h_L$ = _____