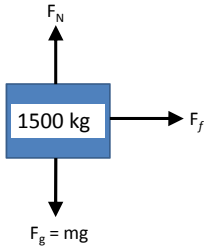
Centripetal Force & Circular Motion

CENTRIPETAL FORCE

- A force that causes an object to move in a circle.
- Centripetal force points toward the CENTER of the circle.
- Types of Centripetal forces include
  - Gravitational Force $F_g = \frac{GM_1M_2}{r^2}$
  - Tension
  - Friction $F_f = F_N\mu$
  - Friction for a car on a road $F_f = mg\mu$

Sample Problem

A 1500 kg car rounds a corner with a radius of 25 meters. If the coefficient of friction between the tires and the pavement is 0.5, what is the maximum speed that the car can take the corner?



$$F_f = ma_c$$

$$mg\mu = m\frac{v^2}{r}$$

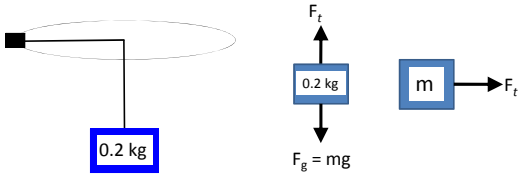
$$9.8m/s^2(0.5) = \frac{v^2}{25m}$$

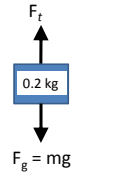
$$v = 11m/s$$

Sample Problem

By swinging a rubber stopper in a horizontal circle (r = 0.6 meters) such that it will complete ten revolutions in 5.5 seconds a 200 gram mass suspended from a string will neither rise or fall. (See the diagram below)

What is the mass of the stopper?

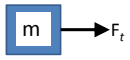




$$\Sigma F_y: \quad F_t - F_g = ma_0$$

$$F_t = mg = (0.2kg)(9.8m/s^2)$$

$$F_t = 1.96N$$



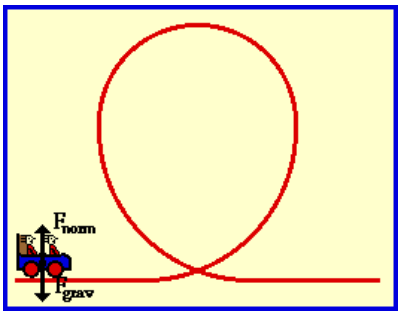
$$\Sigma F_x: \quad F_t = ma_c$$

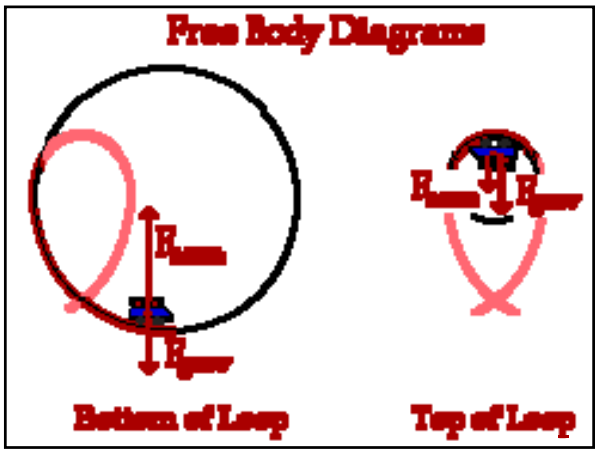
$$F_t = m\frac{4\pi^2 r}{T^2}$$

$$1.96\ N = m\frac{4\pi^2 0.6\ m}{(5.5\ s / 10\ rev)^2}$$

$$m = 0.025\ kg$$

Vertical Circular Motion

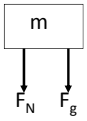




Sample Problem

Anna Litical has a mass of 65 kg and is riding on The Demon at Great America. Anna experiences an acceleration of 15.0 m/s^2 at the top of the loop. What is the normal force? (i.e., How much force is pushing her rear end into the seat?)

At the top of the Loop



$$-F_N - F_g = -ma_c$$

$$-F_N - (65)(9.8) = -(65)(15)$$

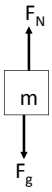
$$+F_N + (65)(9.8) = +(65)(15)$$

$$\boxed{F_N = 338\,N}$$

Sample Problem

How much force would you feel against your rear-end at the bottom of a roller-coaster loop with a diameter of 30 meters if your mass is 75 kg and the roller coaster car is traveling at 25 m / s?

At the bottom of the Loop



$$F_N - F_g = m\frac{v^2}{r}$$

$$F_N - (75)(9.8) = 75\frac{(25)^2}{15}$$

$$F_N - 735 = 3125$$

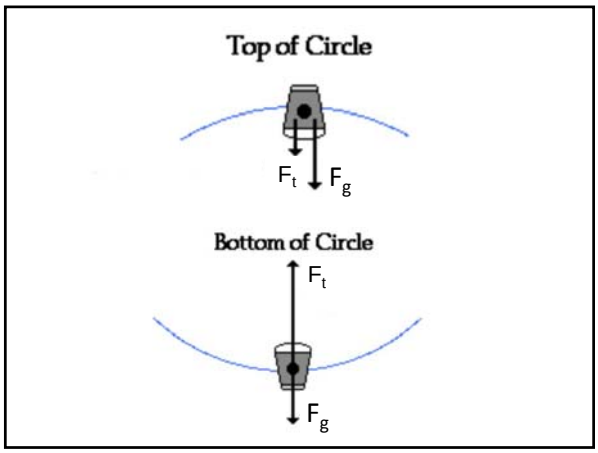
$$\boxed{F_N = 3860\,N}$$

Practice

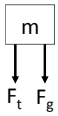
A 0.65 kg ball on the end of a string is swung in a vertical circle of radius 2 meters and makes 6 revolutions in 2 seconds.

What is the tension in the string at the very top of the circle?

What is the tension in the string at the bottom of the circle?



Top

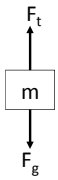


$$-F_t - F_g = -m\frac{v^2}{r} \qquad v = \frac{2\pi r}{t}$$

$$+F_t + (0.65)(9.8) = +(0.65)\frac{(38.08)^2}{2}$$

$$\boxed{F_t = 464.91N} \qquad v = \frac{2\pi\ 2}{0.33}$$

Bottom



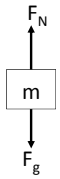
$$F_t - F_g = m\frac{v^2}{r}$$

$$F_t - (0.65)(9.8) = (0.65)\frac{(38.08)^2}{2}$$

$$\boxed{F_t = 477.65N}$$

Practice

How fast would you have to be traveling in your red Ferrari to feel weightless at the top of a perfectly rounded hill if the radius of the hill is 50 m?



$$F_N - F_g = -m\frac{v^2}{r}$$

$$0N - m(9.8m/s^2) = -m\frac{v^2}{50m}$$

$$-m(9.8m/s^2) = -m\frac{v^2}{50m}$$

$$v = 22.14m/s$$