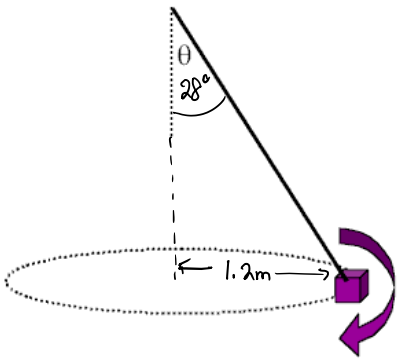
Lesson 4.1B: Centripetal Force and Acceleration

Unit 4: Circular Motion and Gravitation

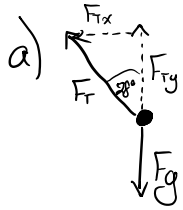
The Conical Pendulum

- Object moves in a horizontal circle, but the string is at an angle
- Tension has 2 components
  - Vertical: balances weight
  - Horizontal: provides centripetal force

Example 1: A toy plane, as shown, is connected to a rope with a tension of 1.8 N, 28° from the vertical. The plane swings in a circular path of radius 1.2m. *Find the a) mass of the plane and b) period of the orbit.*



a)



$\sum \vec{F}_y = 0$

$F_{Ty} - F_g = 0$

$F_T \cos 28 = mg$

$m = \frac{1.8 \cos 28}{9.8}$

$\boxed{m = 0.16\,kg}$

b) $\sum \vec{F}_x = ma_c$

$F_T \sin 28 = m \cdot \frac{4\pi^2 r}{T^2}$

$T = \sqrt{\frac{4\pi^2 rm}{F_T \sin 28}}$

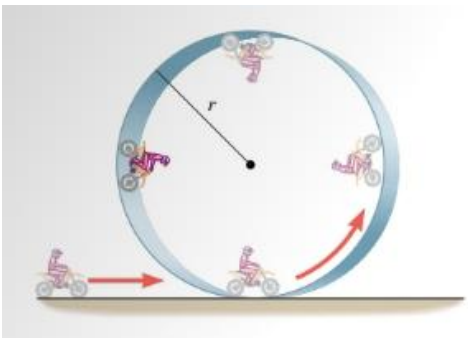
$T = \sqrt{\frac{4\pi^2 (1.2)(0.162)}{(1.8)\sin 28}}$

$\boxed{T = 3.0\,s}$

Vertical Circular Motion and Normal Force:

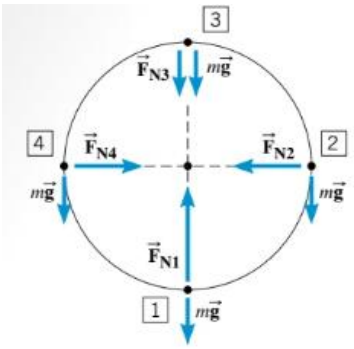
- In vertical motion, gravity is always downward, but normal force (or tension) changes depending on position.
- The centripetal force is NOT a new force—it's the net force toward the center.

Consider a motorcycle doing a loop-de-loop



$= F_{c4}$

$F_{N4} = \frac{mv^2}{r}$



$= F_{c3}$

$F_{N3} + mg = \frac{mv^2}{r}$

$* F_{N3} = F_c - F_g$

$= F_{c2}$

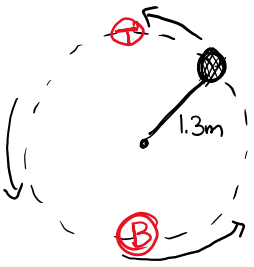
$F_{N2} = \frac{mv^2}{r}$

$F_{N1} - mg = \frac{mv^2}{r}$

$= F_{c1}$

$* F_{N1} = F_c + F_g$

Example 2: A 2.0 kg mass attached to a rope 1.3 m long is swung vertically in a circle with velocity 5.0 m/s. Find the tension in the rope at the top and bottom positions.



At the top

$$F_{net} = ma$$

$$F_T + F_g = ma_c$$

$$F_T = \frac{mv^2}{r} - mg$$

$$F_T = m\left(\frac{v^2}{r} - g\right)$$

$$F_T = 2\left(\frac{5^2}{1.3} - 9.8\right)$$

$$\boxed{F_T = 18.9\,N}$$

At the bottom

$$F_{net} = ma$$

$$F_T - F_g = ma_c$$

$$F_T = m\left(\frac{v^2}{r} + g\right)$$

$$F_T = 2\left(\frac{5^2}{1.3} + 9.8\right)$$

$$\boxed{F_T = 58.1\,N}$$