Unit 6: Circular Motion – Review Packet

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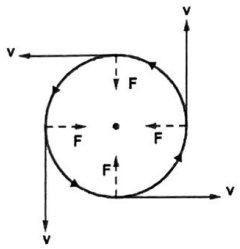
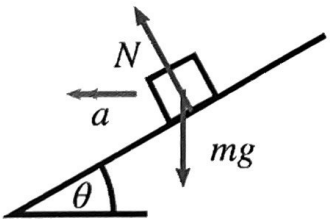
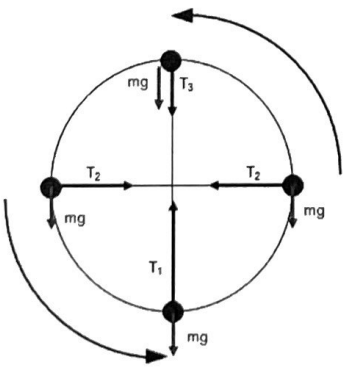
Background:

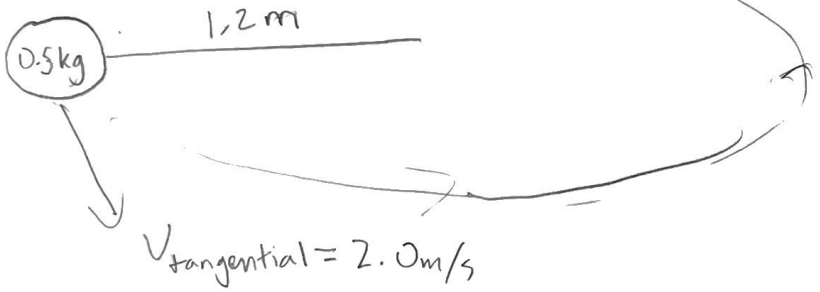
Circular motion is the physics behind an object moving around a circular path instead of a straight line. Because velocity is a vector quantity, a change in direction (i.e. turning in a circle) requires a force input to occur. In the case of circular motion, a continuous net force towards the center of the circular path is required, known as the centripetal force.

Topics/Vocabulary	Diagrams	Formulae
Friction: a force that opposes the relative motion of a body **Coefficient of Friction**: how "sticky" two surfaces are when placed together **Centripetal Force**: any force that makes an object move centripetally **Tension**: the force in a string being stretched **Tangential Velocity**: the linear velocity of a point moving around a circle **Angular Velocity**: rate of change of the angle of a point around a circle	  	$F_c = \frac{mv^2}{r}$ $F_s \leq \mu_s F_n$ $F_{net} = ma$ $A_c = \frac{v^2}{r}$ $\mu \leq \frac{F_f}{F_n}$

Let's do some problems!

1. [Easy] A 0.5 kg ball on the end of a string of negligible mass is swung in a horizontal circle of radius 1.2 m at a constant tangential velocity of 2.0 m/s. What is the tension in the string?
2. [Medium] A car travels around a flat circular track of radius 50 m. The coefficient of static friction between the tires and the road is 0.6. What is the maximum tangential velocity the car can have without skidding off the road?
3. [Hard] For some reason, there is a vertical loop which is sloped at an angle of 30 degrees. The loop is $2\sqrt{3}$m wide with an outer radius of 20m. Can a car whose wheels have a coefficient of static friction of 0.5 make it around the loop without sliding off the side of the loop? Consider the car to be driving in the middle of the path of the loop. Calculate for a 100kg car traveling at 14 m/s.

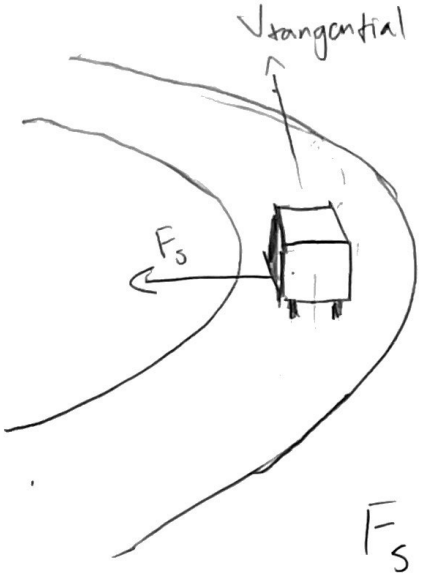
1)



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

$$F_c = \frac{(0.5kg)(2.0 m/s)^2}{(1.2m)} = \boxed{1.67N}, \text{ towards the center}$$

2)



$r = 50m$

$\mu_s = 0.6$

Centripetal force is entirely static friction.

$$F_s = \mu_s F_n = \mu_s m g$$

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

$$\mu_s \cancel{m} g = \frac{\cancel{m}v^2}{r}$$

$$\mu_s g = \frac{v^2}{r}$$

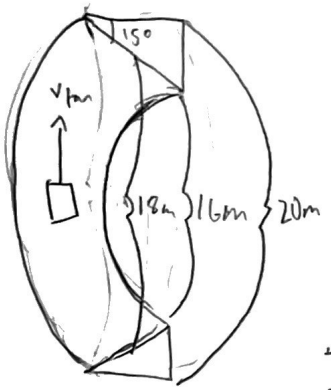
$$v^2 = \mu_s g r$$

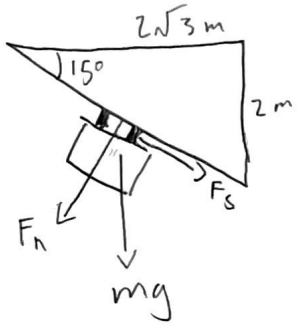
$$v = \sqrt{\mu_s g r}$$

$$v = \sqrt{(0.6)(9.8 m/s^2)(50m)}$$

$$v = \boxed{17.1 m/s}$$

3)





$m = 100kg$

$\theta = 15°$

$V = 14 m/s$

$r_{outer} = 20m$

$\mu_s = 0.5$

Is the car fast enough to even go around the loop?

Find the minimum velocity to go around:

$F_g = F_c$

$mg = \frac{mv^2}{r}$ $r = 18$, because of the triangular track and driving in the middle of the track.

$V = \sqrt{gr} = \sqrt{9.8 \cdot 18}$

$\boxed{V_{min} = 13.3 m/s}$

Find the vertical component of normal force:

$F_c = F_g + F_{n,vert}$

$\frac{mv^2}{r} = mg + F_{n,vert}$

$\frac{(100)(14)^2}{(18)} - (100)(9.8) = F_{n,vert}$

$F_{n,vert} = 108.9 N$

$F_{n,vert} = F_n \cos\theta$

$F_{n,horiz} = F_n \sin\theta$

$F_{n,horiz} = F_{n,vert} \cdot \tan\theta = 108.9 \cdot \tan(15) = \boxed{29.2N}$

Find the horizontal component of static friction:

$F_s = \mu_s F_n = 0.5 \cdot 112.7 = 56.4$

$F_{s,horiz} = F_s \cos\theta = \boxed{54.5N}$

$54.5N > 29.2N$, so the car will NOT slide off the loop