Physics 200 (Stapleton)
Unit 5 Handout:
Circular Motion and The Law of Gravitation

Name: A5/6

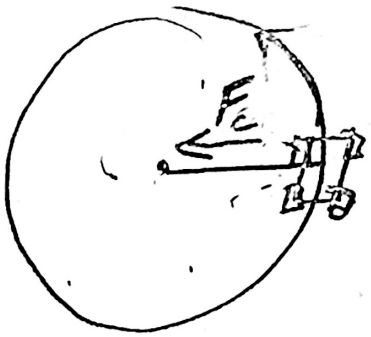
Circular Motion Formulas: *** These formulas only apply to objects undergoing "uniform circular motion" (i.e. **circular motion** at a **constant speed**

$a_{centripetal} = v^2/r$ $F_{net\ centripital} = ma_{centripetal} = mv^2/r$

$a_{centripetal}$ is directed toward the center of the circle.

Circular Motion Example Problems:

1. (horizontal circle) A 500kg car drives in a circle with a radius of 20m. If the car maintains a constant speed of 20m/s, what centripetal force acts on the car? If the driving surface is flat and horizontal, what provides the centripetal force?

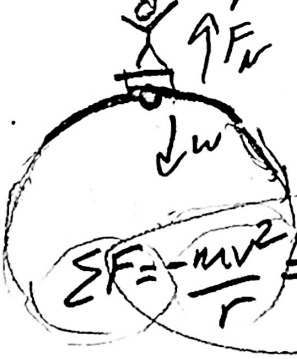


$\Sigma F = \frac{mv^2}{r} = \frac{500kg\,(20m/s)^2}{20m} = 10{,}000N$ Toward the Center

$\Sigma F = F_c = F_{Friction}$

2. (vertical circle) A 60kg teenager is riding a Ferris Wheel at the county fair. She is traveling in a uniform circular path with a radius of 4m, and her speed is constant at 7m/s. She is standing on a bathroom scale.
   a. What is the scale reading when she is at the top of the circle?
   b. What is the scale reading when she is at the bottom of the circle?

Top



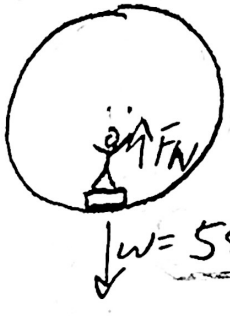
$\Sigma F = \frac{-mv^2}{r} = F_N - W$

$\frac{-60kg\,(7m/s)^2}{4m} = F_N - 588N$

Oh no! F_N is negative, which means she flies off!

$F_N = -147N$

Bottom



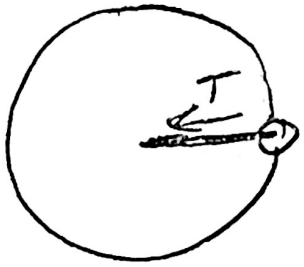
$\Sigma F = \frac{mv^2}{r} = F_N - 588N$

$\frac{60kg\,(7m/s)^2}{4m} = F_N - 588N$

$F_N = 1323N$

Circular Motion Practice Problems:

3. [Horizontal circles] A 0.4kg ball on a string is swinging in circles (in a horizontal plane) at a constant speed of 3m/s. The radius of the orbit (i.e. the string length) is 0.5m and the string is horizontal (because this is happening in the absence of gravity). What is the tension in the string?



$\Sigma F = \frac{mv^2}{r} \Rightarrow T = \frac{mv^2}{r} = \frac{0.4kg\,(3m/s)^2}{0.5m}$

$\Sigma F = T$

$T = 7.2N$

4. [Vertical Circles] A car is approaching a "loop-the-loop" with a radius of 15m. What speed does the car need to maintain in order to experience a normal force at the top of the loop that is equal to the weight of the car? At this speed, what normal force does the car experience when it is just entering the loop?

1000kg

At Top

$\Sigma F \downarrow \quad W \downarrow \quad F_N \downarrow$

$\Sigma F = \frac{mv^2}{r} = -W - F_N$

Net force is negative, since it's toward the center, which is down.

$-\frac{mv^2}{r} = -W - W$

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

$v = \sqrt{2gr}$

$v = \sqrt{2(9.8m/s^2)(15m)}$

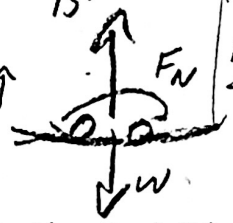
$v = 17.2\,m/s$

At Bottom

$\Sigma F = \frac{mv^2}{r} = F_N - W$

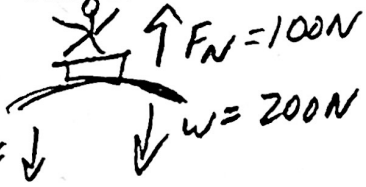
$\frac{1000kg(17.2)^2}{15m} = F_N - 9800N$

$F_N = 29,400N$ (3x weight)



5. [Vertical Circles] A child weighing 200N is standing on a bathroom scale inside a Ferris Wheel that is rotating at a constant rate. If the radius of the circles made by the child is 10m, and the scale reads 100N at the top, what is the child's speed? What does the scale read when the child is at the bottom?

16p



$m = 20.4kg$

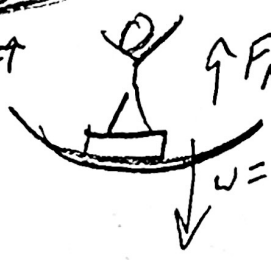
$\Sigma F = \frac{-mv^2}{r} = 100N - 200N$

Center of circle is downward

$\frac{-20.4kg(v^2)}{10m} = -100N$

$v = 7m/s$

Bottom



$\Sigma F = \frac{mv^2}{r} = F_N - 200N$

$\frac{20.4kg(7m/s)^2}{10m} = F_N - 200N$

$F_N = 300N$