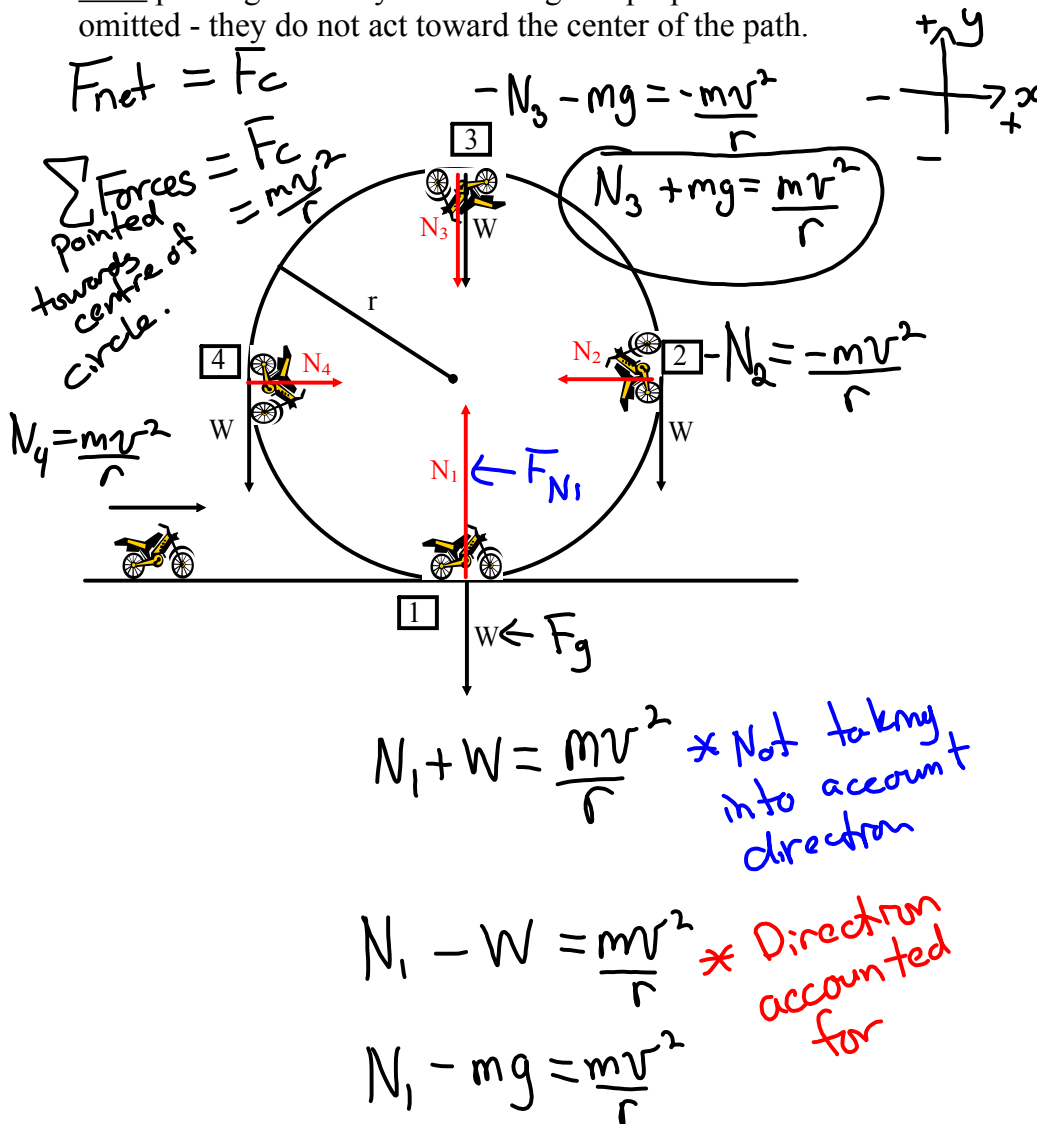# Vertical Circular Motion -> Non-Uniform

Let's look at the situation in which a motorcycle stunt driver drives his motorcycle around a vertical circular track. The speed varies in this stunt - the motion is non-uniform.

As the cycle goes around, the normal force changes because the speed changes and the weight does not have the same effect at every point.

We'll look at four points along the circular path. At each point, F_c is the net sum of all the force components acting parallel to the radius of the circular path. The drawing shows the weight of the motorcycle and rider (imagine the rider) and the normal force pushing on the cycle. Braking and propulsion forces are omitted - they do not act toward the center of the path.

$$F_{net} = F_c$$

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

Pointed towards centre of circle.

$$-N_3 - mg = \frac{-mv^2}{r}$$

$$\boxed{N_3 + mg = \frac{mv^2}{r}}$$

$$N_4 = \frac{mv^2}{r}$$

$$-N_2 = \frac{-mv^2}{r}$$

$$N_1 + W = \frac{mv^2}{r} \quad \text{* Not taking into account direction}$$

$$N_1 - W = \frac{mv^2}{r} \quad \text{* Direction accounted for}$$

$$N_1 - mg = \frac{mv^2}{r}$$
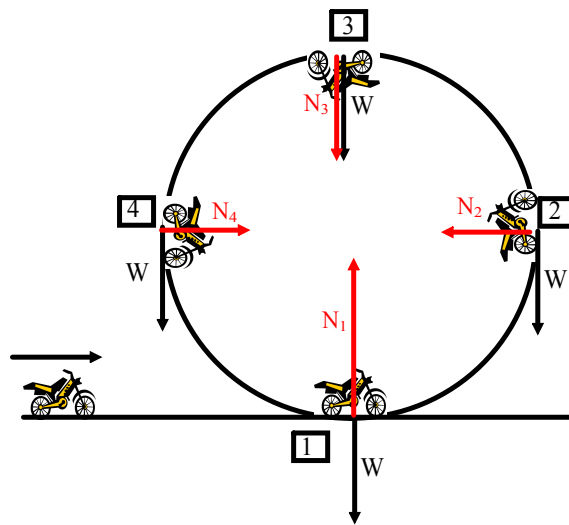
$W \leftarrow F_g$

$\leftarrow F_{N_1}$

☆

$$F_{c3} = \frac{mv_3^2}{r}$$

$$-N_3 + -W = -\frac{mv_3^2}{r}$$

$$N_3 + W = \frac{mv_3^2}{r}$$

$$F_{c4} = \frac{mv_4^2}{r}$$

$$N_4 = \frac{mv_4^2}{r}$$

$$F_{c2} = \frac{mv_2^2}{r}$$

$$-N_2 = -\frac{mv_2^2}{r}$$

$$N_2 = \frac{mv_2^2}{r}$$

$$F_{c1} = \frac{mv_1^2}{r}$$

$$N_1 - W = \frac{mv_1^2}{r}$$

Riders must have at least a minimum speed at the top of the circle to remain on the track. This speed can be determined by considering the centripetal force at point 3. The v_3 is a minimum when N_3 is zero. At this speed the track does not exert a normal force to keep the motorcycle on the path because the weight provides all of the centripetal force. The rider experiences apparent weightlessness - rider and motorcycle are falling freely toward the center of the circle.

Mass Moving in Vertical Circular Path
(Object on a Rope)

An object is swung in a vertical circle with a radius of 0.75m. What is the minimum speed of the object to make it around the loop (2.7 m/s)
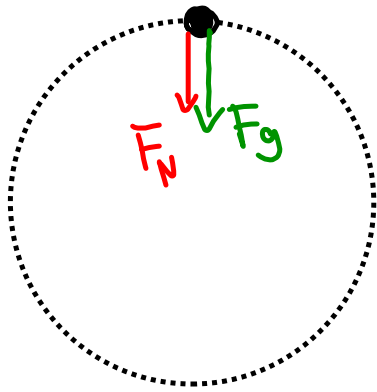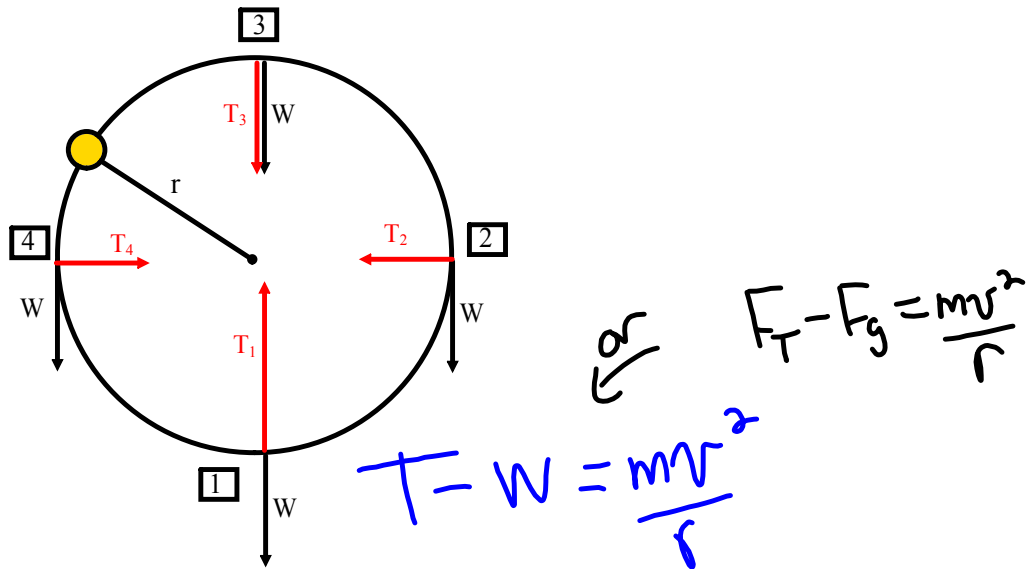
$F_N = 0$ @ min Vel.

$r = 0.75m$

$g = 9.81 m/s^2$

$\cancel{F_N}^{\,0} + F_g = \dfrac{mv^2}{r}$

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

$v = \sqrt{gr}$

$= \sqrt{(9.81)(0.75)}$

$\boxed{V_{min} = 2.7 m/s}$

Object on a String, Rope, Etc.

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

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

A string requires 135 N force in order to break it. A 2.0 kg mass is tied to this string and whirled in a vertical circle with a radius of 1.10m. What is the maximum speed that this mass can be whirled without breaking the string? (8.0 m/s)

$$F_T - F_g = \frac{mv^2}{r}$$ ＊Direction accounted for.

$$135 - (2)(9.81) = \frac{2v^2}{1.10}$$

$$115.38 = 1.82v^2$$

$$\boxed{8_{m/s} = v}$$

Problem Set Page 37

Answers from MHR questions are on page 66 under Chapter 11.