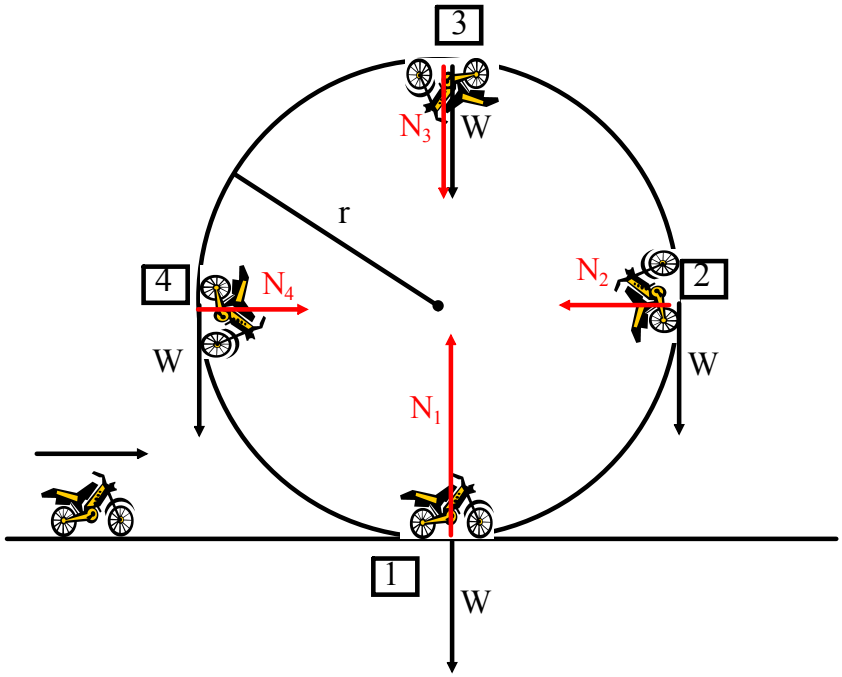
Vertical Circular Motion -> Non-Uniform

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.



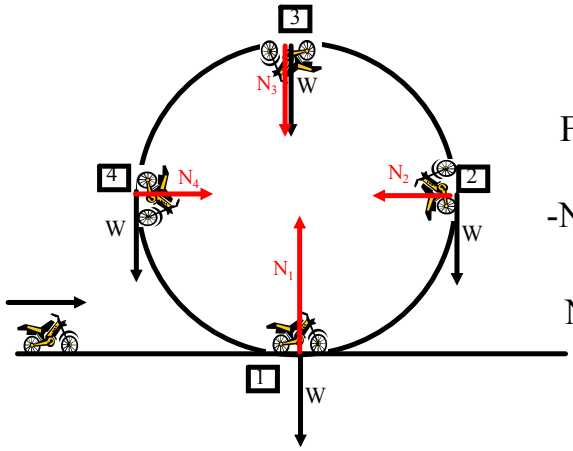
$$F_{c3} = \frac{mv_3^2}{r}$$

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

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

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

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



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

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

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

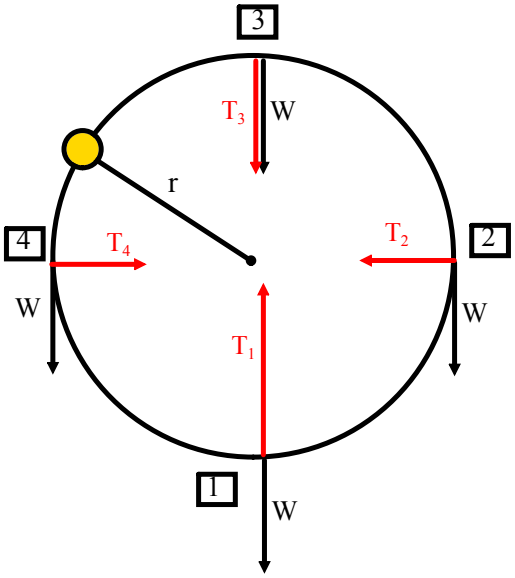
$$F_{c1} = \frac{mv_1^2}{r}$$

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

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.

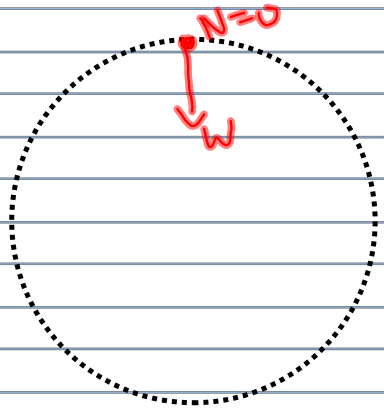
Mass Moving in Vertical Circular Path (Object on a Rope)

Object on a String, Rope, Etc.



Example:

An object is swung in a vertical circle with a radius of 0.75m. What is the minimum speed of the object at the top of the motion for the object to remain in circular motion? (2.7 m/s)



$$N + w = \frac{mv^2}{r}$$

$N = 0$ @ v_{min}

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

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

$$gr = v^2$$

$$\sqrt{gr} = v$$

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

$$2.7 \text{ m/s}$$

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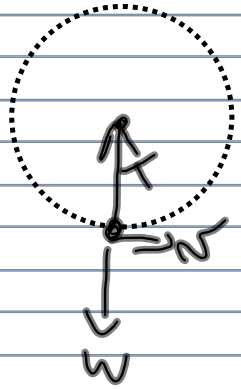
Example:
A string requires a 135 N force in order to break it. A 2.00 kg mass is tied to this string and whirled in a vertical circle with a radius of 1.10m. What is the maximum speed that this mass can be whirled without breaking the string? (7.97 m/s)



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

$$135 - (2)(9.81) = \frac{2v^2}{1.1m}$$

$$115.4 = \frac{2v^2}{1.1}$$

$$126.9 = 2v^2$$

$$63.4 = v^2$$

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