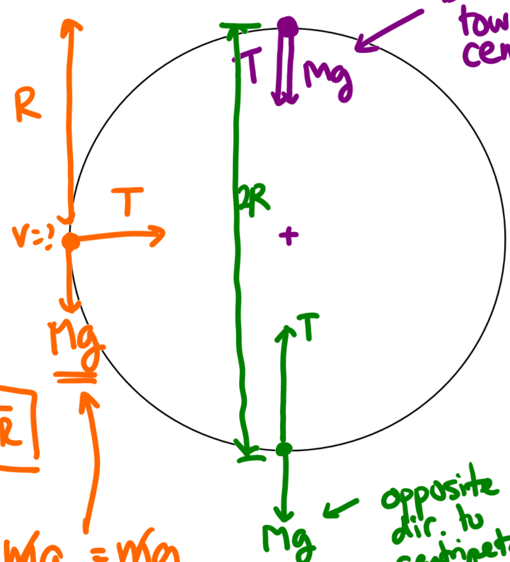
Example 4: You are playing with a yo-yo with a mass of M. The full length of the string is R. You decide to see how slowly you can swing it in a vertical circle while keeping the string fully extended, even when the yo-yo is at the top of its swing.

A. Calculate the minimum speed at which you can swing the yo-yo while keeping it on a circular path.

B. Find the tension in the string when the yo-yo is at the side and at the bottom of its swing.



both point toward center

opposite dir. to centripetal force

$$F_c = T + Mg = \frac{Mv^2}{R}$$

slowest v occurs when T = 0

$$\hookrightarrow Mg = \frac{Mv^2}{R}$$

$$v^2 = gR \rightarrow \boxed{v = \sqrt{gR}}$$

minimum speed at the top.

$$\underbrace{U + K}_{\text{top}} = \underbrace{K'}_{\text{side}}$$

$$MgR + \frac{1}{2}MgR = \frac{1}{2}Mv^2$$

$$\frac{3}{2}gR = \frac{1}{2}v^2$$

$$v^2 = 3gR$$

$$\boxed{v = \sqrt{3gR}}$$

$$F_c = T = \frac{Mv^2}{R}$$

$$= \frac{M(3gR)}{R}$$

$$\boxed{T = 3Mg}$$

$$Ma_T = Mg$$

$$\boxed{a_T = g}$$

$$\alpha = \frac{a_T}{R} = \boxed{\frac{g}{R}}$$

$$F_c = T - Mg = \frac{M(v^2)}{R}$$

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$$\underbrace{U + K}_{\text{top}} = K'$$

$$Mg(2R) + \frac{1}{2}M(gR) = \frac{1}{2}Mv^2$$

$$2gR + \frac{1}{2}gR = \frac{1}{2}v^2$$

$$\frac{5}{2}gR = \frac{1}{2}v^2$$

$$v^2 = 5gR \rightarrow \boxed{v = \sqrt{5gR}}$$

$\times\sqrt{5}$ faster than at the top.

$$T = Mg + \frac{M(v^2)}{R}$$

5gR

$$= Mg + 5Mg$$

$$\boxed{T = 6Mg}$$