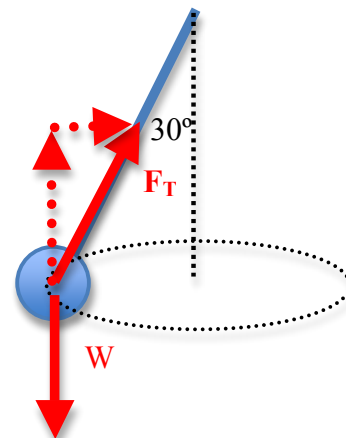


Name: \_\_\_\_\_

## Honors Physics - UCM Challenge Problems Solutions

1) A 0.200-kg yo-yo is swung in a horizontal circle at the end of a 0.65-m string such that the string makes a  $30^\circ$  angle with vertical (see diagram). Determine the period of the yo-yo.

- Two forces act on the yo-yo: tension force and the weight ( $W = 1.96 \text{ N}$ ).
- Break the tension into its vertical and horizontal components (as shown).
  - The vertical component is equal to the weight (no vertical acceleration).
  - The horizontal component is the centripetal (net) force.
  - Angle between tension force and vertical component is  $30^\circ$ .
- Radius of circle is base of right triangle whose hypotenuse is 0.65 m.



Find radius:

$$\sin 30^\circ = \frac{r}{0.65\text{m}} \rightarrow r = 0.325\text{m}$$

Find Centripetal Force:

$$\tan 30^\circ = \frac{F_{Tx}}{F_{Ty}} = \frac{F_c}{1.96\text{N}} \rightarrow F_c = 1.13\text{N}$$

Find speed:

$$F_c = m \frac{v^2}{r} \rightarrow v = \sqrt{\frac{F_c r}{m}} = 1.36\text{m/s}$$

Find period:

$$v = \frac{2\pi r}{T} \rightarrow T = \frac{2\pi r}{v} = 1.51\text{s}$$

2) Three 0.5-kg blocks are placed on a turntable. Block A is placed 5 cm from the center of the turntable, Block B is placed 10 cm from the center, and Block C is placed 15 cm from the center. If the coefficient of static friction between the blocks and the turntable is 0.30, determine the rotation rate (in RPMs) at which each of the blocks will start to slide.

- The only vertical forces are normal (up) and weight (down); these forces are equal ( $F_N = W = mg$ )
- Static friction is the force that holds the blocks on the turntable as it spins, in other words the centripetal force causing the circular motion.
- Static friction has a maximum magnitude; if the centripetal force required to cause circular motion is greater than this, the block will slide.
- At a fixed radius and mass, the speed of the block determines how much force is required.
- The speed of the block is determined by its radius and the rotation rate.

**For all blocks:**

Weight (and normal force):  $W = F_N = mg = 4.9\text{N}$

Max. static friction force:  $F_f \leq \mu_s F_N \rightarrow F_{f\text{MAX}} = 1.47\text{N}$

**Block A:**

Maximum speed:

$$F_c = m \frac{v^2}{r} \rightarrow v = \sqrt{\frac{F_c r}{m}} = 0.383 \text{ m/s}$$

Period:

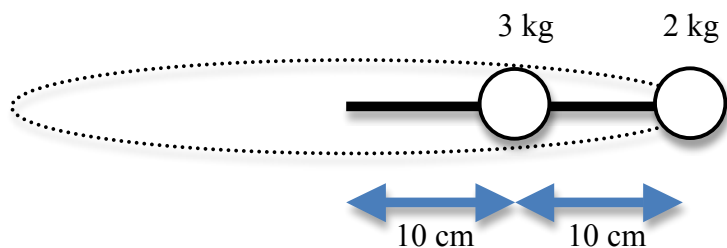
$$v = \frac{2\pi r}{T} \rightarrow T = \frac{2\pi r}{v} = 0.819 \text{ s}$$

RPMs:

$$0.819 \frac{\text{sec}}{\text{revolutions}} \times \frac{1 \text{ min}}{60 \text{ sec}} = 0.137 \frac{\text{min}}{\text{rev}} \rightarrow 73.2 \text{ RPM}$$

**Block B:** 51.7 RPM**Block C:** 42.3 RPM

3) The two connected spheres shown in the diagram travel in a horizontal circle at constant speed. They make one full rotation every 0.8 s. Determine the tension in each string.

**2-kg sphere:**

Speed:

$$v = \frac{2\pi r}{T} = \frac{2\pi(0.2\text{m})}{0.8\text{s}} = 1.57 \text{ m/s}$$

Centripetal (net) force:

$$F_c = m \frac{v^2}{r} = (2\text{kg}) \frac{(1.57\text{m/s})^2}{0.2\text{m}} = 24.7 \text{ N}$$

There is only one force acting on the 2-kg sphere in the radial direction: the tension in the outer string. Therefore the tension in this string must be the net centripetal force of 24.7 N.

**3-kg sphere:**

Speed:

$$v = \frac{2\pi r}{T} = \frac{2\pi(0.1\text{m})}{0.8\text{s}} = 0.785 \text{ m/s}$$

Centripetal (net) force:

$$F_c = m \frac{v^2}{r} = (2\text{kg}) \frac{(0.785\text{m/s})^2}{0.1\text{m}} = 18.5 \text{ N}$$

18.5 N is the net centripetal force acting on the 3-kg sphere. The direction of this net force is towards the center of the circle. There are two forces acting on the 3-kg sphere: the inner string is pulling towards the center of the circle and the outer string is pulling away from the center of the circle. The inner string tension is winning by 18.5 N, meaning it is 18.5 N more than the tension in the outer string. Therefore the tension in the inner string is 43.2 N.