

Homework 9 - Circular Motion

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1 Book

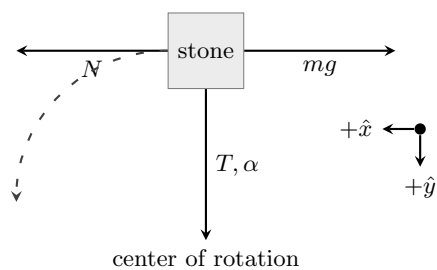
1.1 5.43

$$m = 0.80 \text{ kg}$$

$$L = 0.90 \text{ m}$$

$$T = 60.0 \text{ N}$$

(a) Draw a free-body diagram of the stone.



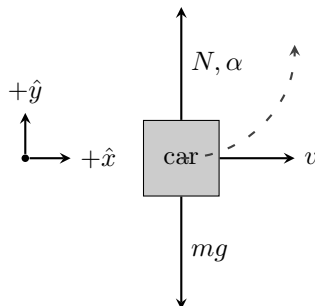
- (b) Find the maximum speed the stone can attain without the string breaking.

$$\begin{aligned}\sum F_c &= m\alpha \\ T &= m \left(\frac{v_{max}^2}{L} \right) \\ v_{max} &= \sqrt{\frac{TL}{m}} \\ v_{max} &= \sqrt{\frac{(60.0 \text{ N})(0.90 \text{ m})}{0.80 \text{ kg}}} \\ v_{max} &= 8.22 \text{ m s}^{-1} \\ \boxed{v_{max} = 8.22 \text{ m s}^{-1}}\end{aligned}$$

1.2 5.45

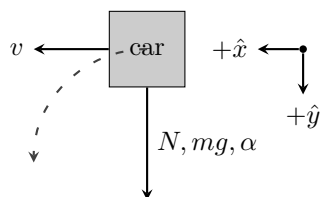
$$\begin{aligned}m &= 1.60 \text{ kg} \\ v &= 12.0 \text{ m s}^{-1} \\ r &= 5.00 \text{ m}\end{aligned}$$

- (a) What is the normal force at point A ?



$$\begin{aligned}\sum F_c &= m\alpha \\ N &= m \left(\frac{v^2}{r} \right) + mg \\ N &= (1.60 \text{ kg}) \left(\frac{(12.0 \text{ m s}^{-1})^2}{5.00 \text{ m}} \right) + (1.60 \text{ kg})(10.0 \text{ m s}^{-2}) \\ N &= 62.1 \text{ m s}^{-2} \\ \boxed{N = 62.1 \text{ m s}^{-2}}\end{aligned}$$

- (b) What is the normal force at point B ?



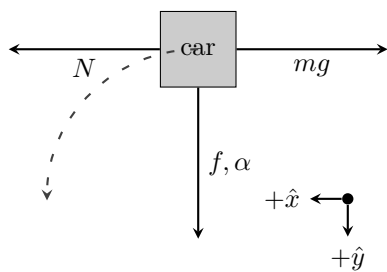
$$\begin{aligned}\sum F_c &= m\alpha \\ N + mg &= m \left(\frac{v^2}{r} \right) \\ N &= m \left(\frac{v^2}{r} \right) - mg \\ N &= 1.60 \text{ kg} \left(\frac{(12.0 \text{ m s}^{-1})^2}{5.00 \text{ m}} - 10.0 \text{ m s}^{-2} \right) \\ N &= 30.1 \text{ m s}^{-2}\end{aligned}$$

$$\boxed{N = 30.1 \text{ m s}^{-2}}$$

1.3 5.48

$$\begin{aligned}r &= 230.0 \text{ m} \\ v &= 28.0 \text{ m s}^{-1}\end{aligned}$$

(a) What is the minimum coefficient of static friction that will prevent sliding?



$$\begin{aligned}\sum F_x &= 0 \\ N &= mg\end{aligned}$$

$$\begin{aligned}
\sum F_y &= m\alpha \\
f &= m \left(\frac{v^2}{r} \right) \\
\mu N &= m \left(\frac{v^2}{r} \right), \quad N = mg \\
\mu &= \frac{v^2}{rg} \\
\mu &= \frac{(28.0 \text{ m s}^{-1})^2}{(230.0 \text{ m})(10.0 \text{ m s}^{-2})} \\
\mu &= 0.341
\end{aligned}$$

$$\boxed{\mu = 0.341}$$

- (b) Suppose that the highway is icy and the coefficient of static friction between the tires and pavement is only one-third of what you found in part (a). What should be the maximum speed of the car so that it can round the curve safely?

$$\begin{aligned}
\sum F_y &= m\alpha \\
\frac{\mu}{3} mg &= m \left(\frac{v^2}{r} \right) \\
v &= \sqrt{\frac{\mu gr}{3}} \\
v &= \sqrt{\frac{(0.341)(10.0 \text{ m s}^{-2})(230.0 \text{ m})}{3}} \\
v &= 16.2 \text{ m s}^{-1}
\end{aligned}$$

$$\boxed{v = 16.2 \text{ m s}^{-1}}$$

1.4 5.54

$$\begin{aligned}
D &= 100 \text{ m} \\
r &= \frac{D}{2} = 50.0 \text{ m} \\
\text{rpm} &= 1 \text{ rev min}^{-1}
\end{aligned}$$

- (a) Find the speed of the passengers when the Ferris wheel is rotating at this

rate.

$$v = \frac{2\pi r}{T}$$

$$v = \frac{2\pi(50.0 \text{ m})}{60.0 \text{ s}}$$

$$v = 5.24 \text{ m s}^{-1}$$

$$\boxed{v = 5.24 \text{ m s}^{-1}}$$

- (b) A passenger weighs 902 N at the weight-guessing booth on the ground. What is his apparent weight at the highest and at the lowest point on the Ferris wheel?

$$m = \frac{w}{g} = \frac{902 \text{ N}}{10.0 \text{ m s}^{-2}} = 90.2 \text{ kg}$$

$$\sum F_y^{\text{top}} = m\alpha$$

$$mg = m\left(\frac{v^2}{r}\right) + N_{\text{top}}$$

$$N_{\text{top}} = m\left(-\frac{v^2}{r} + g\right)$$

$$N_{\text{top}} = (90.2 \text{ kg})\left(-\frac{(5.24 \text{ m s}^{-1})^2}{50.0 \text{ m}} + 10.0 \text{ m s}^{-2}\right)$$

$$N_{\text{top}} = 852.5 \text{ N}$$

$$\sum F_y^{\text{bottom}} = m\alpha$$

$$N_{\text{bottom}} = m\left(\frac{v^2}{r}\right) + mg$$

$$N_{\text{bottom}} = m\left(\frac{v^2}{r} + g\right)$$

$$N_{\text{bottom}} = (90.2 \text{ kg})\left(\frac{(5.24 \text{ m s}^{-1})^2}{50.0 \text{ m}} + 10.0 \text{ m s}^{-2}\right)$$

$$N_{\text{bottom}} = 951.5 \text{ N}$$

$$\boxed{N_{\text{top}} = 852.5 \text{ N}, N_{\text{bottom}} = 951.5 \text{ N}}$$

- (c) What would be the time for one revolution if the passenger's apparent weight at the highest point were zero?

$$v = \frac{2\pi r}{T}$$

$$T = \frac{2\pi r}{v}$$

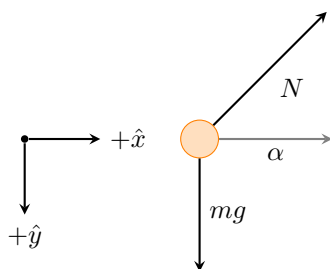
$$\begin{aligned}
\sum F_y^{top} &= m\alpha \\
mg &= m \left(\frac{v^2}{r} \right) + N \\
v &= \sqrt{gr - \frac{N}{m}}, \quad N = 0 \\
v &= \sqrt{gr} \\
v &= \sqrt{(10.0 \text{ m s}^{-2})(50.0 \text{ m})} \\
v &= 22.4 \text{ m s}^{-1}
\end{aligned}$$

$$\begin{aligned}
T &= \frac{2\pi(50.0 \text{ m})}{22.4 \text{ m s}^{-1}} \\
T &= 14.0 \text{ s}
\end{aligned}$$

$$\boxed{T = 14.0 \text{ s}}$$

1.5 5.107

$$\begin{aligned}
r &= 0.100 \text{ m} \\
\text{rpm} &= 4.80 \text{ rev s}^{-1}
\end{aligned}$$



(a) Find the angle β at which the bead is in vertical equilibrium.

$$\begin{aligned}
\sum F_x^{bead} &= m\alpha \\
N_x \sin(\beta) &= m\alpha \\
N_x &= \frac{m \frac{v^2}{r}}{\sin(\beta)} = \frac{mv^2}{r \sin(\beta)}
\end{aligned}$$

$$\begin{aligned}
\sum F_y^{bead} &= 0 \\
N_y \cos(\beta) &= mg \\
N_y &= \frac{mg}{\cos(\beta)}
\end{aligned}$$

$$\begin{aligned}
N_x &= N_y \\
\frac{mv^2}{r \sin(\beta)} &= \frac{mg}{\cos(\beta)} \\
v^2 \cos(\beta) &= gr \sin(\beta) \\
\tan(\beta) &= \frac{v^2}{gr} \\
\beta &= \arctan\left(\frac{v^2}{gr}\right) \\
\beta &= \arctan\left(\frac{\left(\frac{2\pi r}{T}\right)^2}{gr}\right) \\
\beta &= \arctan\left(\frac{4\pi^2 r}{gT^2}\right) \\
\beta &= \arctan\left(\frac{4\pi^2(0.100 \text{ m})}{(10.0 \text{ m s}^{-2}) \left(\frac{1}{4.80} \text{ s}\right)^2}\right) \\
\beta &= 83.7^\circ \\
\boxed{\beta = 83.7^\circ}
\end{aligned}$$

- (b) Is it possible for the bead to “ride” at the same elevation as the center of the hoop?

$$\beta = 90.0^\circ$$

$$\begin{aligned}
\frac{v^2}{r \sin(\beta)} &= \frac{g}{\cos(\beta)} \\
v &= \sqrt{\frac{gr \sin(\beta)}{\cos(\beta)}} \\
v &= \sqrt{\frac{(10.0 \text{ m s}^{-2})(0.100 \text{ m}) \sin(90.0^\circ)}{\cos(90.0^\circ)}} \\
v &= 0
\end{aligned}$$

No it is not possible as the velocity would have to be zero, but would instead mean that the bead isn't moving.

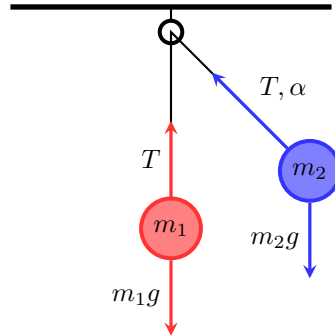
- (c) What will happen if the hoop rotates at 1.00 rev s^{-1} ?

$$\begin{aligned}
\beta &= \arctan\left(\frac{4\pi^2(0.100 \text{ m})}{(10.0 \text{ m s}^{-2})(1.00 \text{ s})^2}\right) \\
\beta &= 21.5^\circ
\end{aligned}$$

The bead ends up swinging at an angle lower and closer to the vertical axis.

2 Lab Manual

2.1 1072



$$\sum F_y^{m_1} = 0$$

$$T = m_1g$$

$$\sum F_y^{m_2} = m_2g$$

$$T \cos(\theta) = m_2g$$

$$\sum F_x^{m_2} = m_2\alpha$$

$$T \sin(\theta) = m_2 \left(\frac{\left(\frac{2\pi c}{t} \right)^2}{c} \right)$$

2.2 1073

2.3 1082

2.4 1087

2.5 1088