# General Physics I
# Homework Chapter 5 & 6

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# Homework: Chapter 5 & 6

## Chapter 5 - Problem (9)

A baseball player with mass $m = 79\ kg$, sliding into second base, is slowed by a frictional force of magnitude 440 $N$. What is the coefficient of kinetic friction $\mu_k$ between the player and the ground?

**R:**

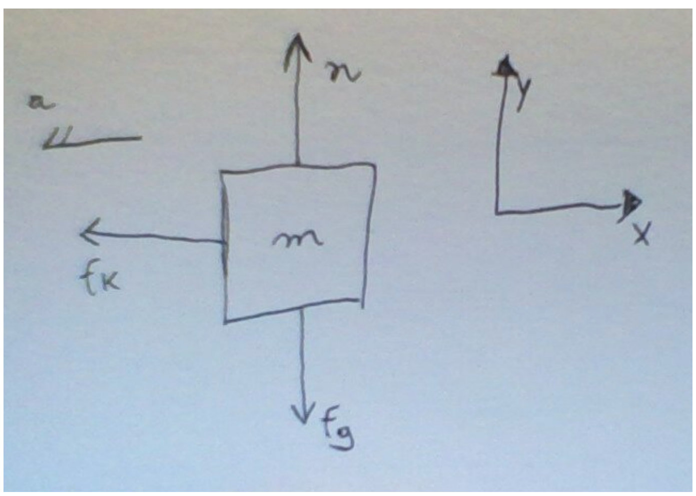


Figure 1: Free-Body Diagram (Problem 9)

$$f_k = \mu_k n$$

Newton's $2^{nd}$ Law to discover $n$:

$$\sum F_y = ma_y$$
$$n - mg = m(0)$$
$$n = mg$$

$$\mu_k = \frac{f_k}{mg} = \frac{440\ N}{(79\ kg)\,(9.80\ m/s^2)} = 0.568 \quad (1)$$

# Chapter 5 - Problem (10)

The floor of a railroad flatcar is loaded with loose crates having a coefficient of static friction of 0.56 with the floor. If the train is initially moving at a speed of 47 $mi/h$, in how short a distance can the train be stopped at constant acceleration without causing the crates to slide over the floor?

**R:**

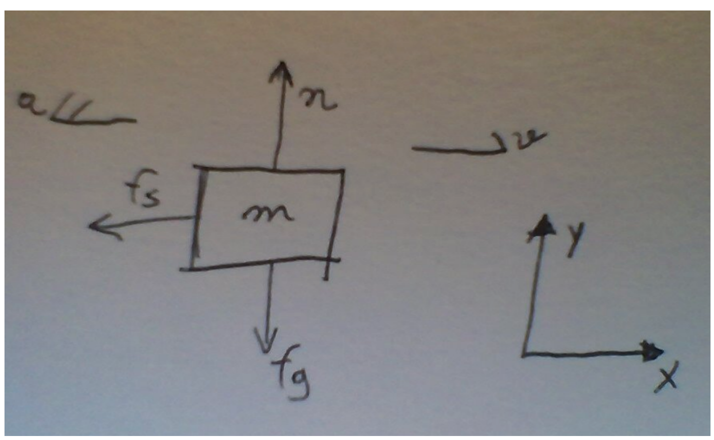


Figure 2: Free-Body Diagram (Problem 10)

Newton's $2^{nd}$ Law:

$$\begin{aligned}
\sum F_y &= ma_y \\
n - mg &= m(0) \\
n &= mg \\
\sum F_x &= ma_x \\
-f_s &= m(-a) \\
f_s &= f_{s_{max}} \\
ma &= \mu_s mg \\
a &= \mu_s g \\
a &= (0.56)\left(32.2\ ft/s^2\right) \\
a &= 18.032 ft/s^2
\end{aligned}$$

$$\begin{aligned}
a &= -18.032\ ft/s^2 \\
x_0 &= 0 \\
v_0 &= 47\ mi/h \times \left(\frac{5280\ ft}{1\ mi}\right) \times \left(\frac{1\ h}{3600\ s}\right) = 68.9\bar{3}\ ft/s \\
v &= 0 \\
2a(x - x_0) &= v^2 - v_0^2 \\
2\left(-18.032 ft/s^2\right)(x - 0) &= (0)^2 - (68.9\bar{3}\ ft/s)^2 \\
\left(-36.064\ ft/s^2\right) x &= -4751.3449\ ft^2/s^2 \\
x &= \frac{-4751.3449\ ft^2/s^2}{-36.064\ ft/s^2} = 131.8\ ft
\end{aligned} \tag{2}$$

## Chapter 5 - Problem (11)

You must push a crate across a floor to a docking bay. The crates weighs 180 *lb*. The coefficient of static friction between crate and floor is 0.57, and the coefficient of kinetic friction is 0.35. Your force on the crate is directed horizontally.

## Question (a)

What magnitude of your push puts the crate on the verge of sliding?

**R:**

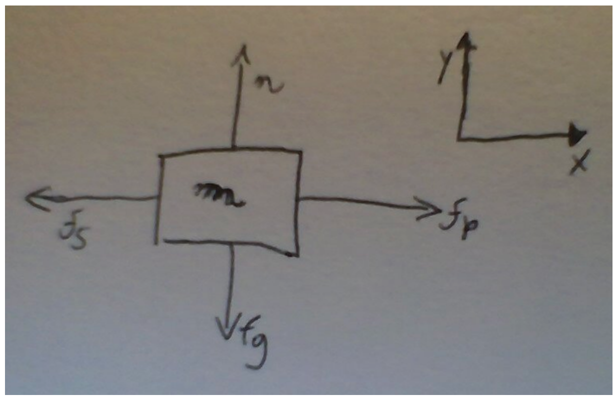


Figure 3: Free-Body Diagram (Problem 11 (a))

$$f_s = f_{s_{max}} = \mu_s n$$

Newton's $2^{nd}$ Law to discover $n$:

$$\begin{aligned}\sum F_y &= ma_y \\ n - f_g &= m(0) \\ n &= f_g\end{aligned}$$

$$\begin{aligned}f_s &= (0.57)(180\ lb) \\ &= 102.6\ lb\end{aligned} \tag{3}$$

The push needs to be greater than 102.6 $lb$ in order to slide the crate.

## Question (b)

With what magnitude must you then push to keep the crate moving at a constant velocity?

**R:**

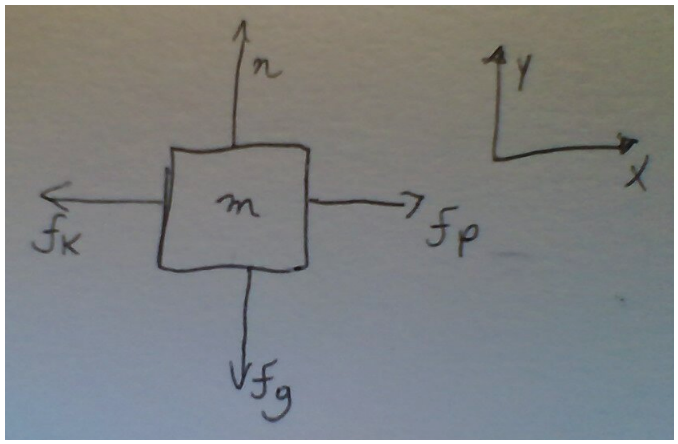


Figure 4: Free-Body Diagram (Problem 11 (b))

$$\begin{aligned} f_k &= \mu_k n \\ &= (0.35)(180\ lb) \\ &= 63\ lb \end{aligned} \tag{4}$$

The push needs to be exactly 63 *lb* in order to keep the crate moving at a constant velocity.

## Question (c)

If, instead, you then push with the same magnitude as the answer to *(a)*, what is the magnitude of the crate's acceleration?

**R:**

Newton's $2^{nd}$ Law:

$$\begin{aligned}
\sum F_x &= ma_x \\
f_p - f_k &= ma \\
m &= \frac{f_g}{g} \\
&= \frac{180\ lb}{32.2\ ft/s^2} = 5.59\ sl \\
a &= \frac{f_p - f_k}{m} \\
&= \frac{(102.6\ lb) - (63\ lb)}{5.59\ sl} \\
&= 7.084 ft/s^2 \qquad (5)
\end{aligned}$$

## Chapter 5 - Problem (12)

A 3.8 $kg$ block is pushed along a horizontal floor by a force $\vec{F}$ of magnitude 17 $N$ at an angle $\theta = 29^o$ with the horizontal. The coefficient of kinetic friction between the block and the floor is 0.33.

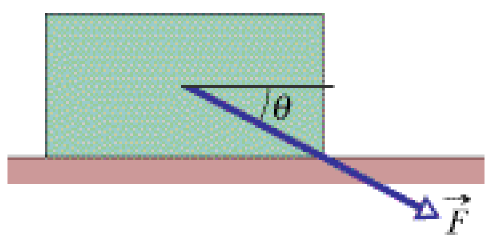


Figure 5: Illustration of Problem 12

### Question (a)

Calculate the magnitude of the friction force on the block from the floor:

**R:**

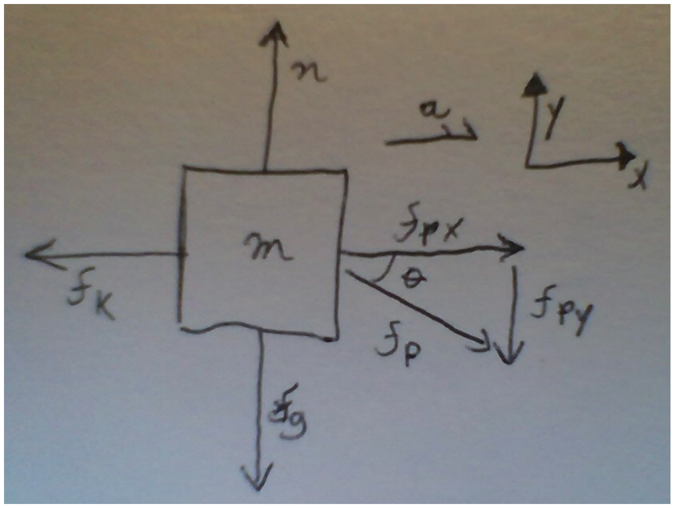


Figure 6: Free-Body Diagram (Problem 12)

$$f_k = \mu_k n$$

Newton's $2^{nd}$ Law to discover $n$:

$$\begin{aligned}
\sum F_y &= ma_y \\
n - mg - f_{p_y} &= m(0) \\
n &= mg + (f_p \sin 29^o) \\
&= \left[(3.8\ kg)\left(9.80\ m/s^2\right)\right] + [(17\ N)(0.48481)] \\
&= (37.24\ N) + (8.2418\ N) \\
&= 45.482\ N
\end{aligned}$$

$$\begin{aligned}
f_k &= (0.33)(45.482\ N) \\
&= 15.009\ N
\end{aligned} \tag{6}$$

### Question (b)

Calculate the magnitude of the block's acceleration:

**R:**

Newton's $2^{nd}$ Law:

$$\begin{aligned}
\sum F_x &= ma_x \\
f_{p_x} - f_k &= ma_x \\
a &= \frac{[(17\ N)\cos 29^o] - (15.009\ N)}{3.8\ kg} \\
&= \frac{(14.869\ N) - (15.009\ N)}{3.8\ kg} \\
&= \frac{-0.14\ N}{3.8\ kg} \\
&= -\,0.037\ m/s^2 \qquad (7)
\end{aligned}$$

## Chapter 5 - Problem (13)

The coefficient of static friction between Teflon and scrambled eggs is about 0.044. What is the smallest angle from the horizontal that will cause the eggs to slide across the bottom of a Teflon-coated skillet?

**R:**

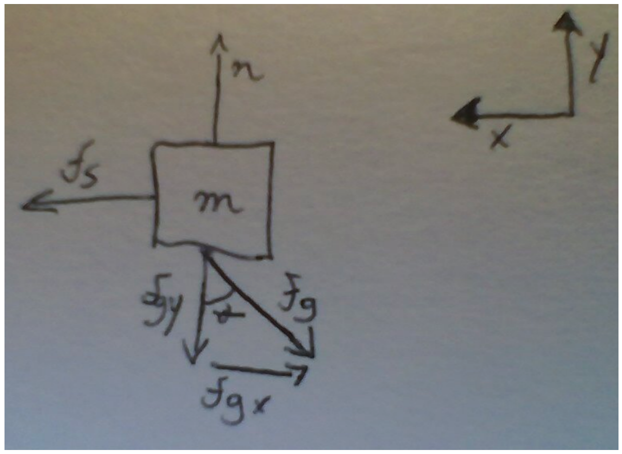


Figure 7: Free-Body Diagram (Problem 13)

$$f_s = f_{s_{max}} = \mu_s n = (0.044)n$$

Newton's $2^{nd}$ Law:

$$\begin{aligned}
\sum F_y &= ma_y \\
n - (mg\cos\theta) &= m(0) \\
n &= mg\cos\theta \\
\sum F_x &= ma_x \\
f_s - (mg\sin\theta) &= m(0) \\
(0.044)(mg\cos\theta) &= mg\sin\theta \\
\frac{mg\sin\theta}{mg\cos\theta} &= 0.044 \\
\tan\theta &= 0.044 \\
\theta &= \tan^{-1} 0.044 \\
&= 2.52^o \qquad (8)
\end{aligned}$$

# Chapter 5 - Problem (14)

A 120 $g$ hockey puck sent sliding over ice is stopped in 9.7 $m$ by the frictional force on it from the ice.

## Question (a)

If its initial speed is 8.2 $m/s$, what is the frictional force?
**R:**

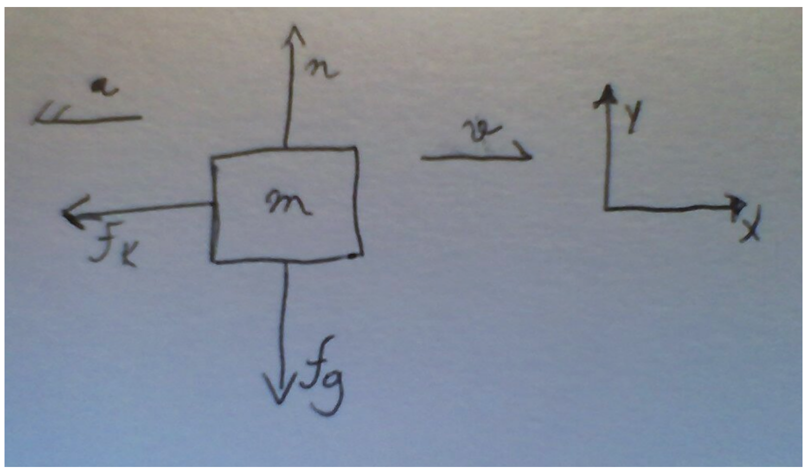


Figure 8: Free-Body Diagram (Problem 14)

Newton's $2^{nd}$ Law:

$$\begin{aligned}
\sum F_x &= ma_x \\
-f_k &= m(-a) \\
2a(x - x_0) &= v^2 - v_0^2 \\
a &= \frac{v^2 - v_0^2}{2(x - x_0)} = \frac{-v_0^2}{2x} \\
-f_k &= m\left(-\frac{-v_0^2}{2x}\right) \\
f_k &= -\,(120\ g)\left(\frac{(8.2\ m/s)^2}{2(9.7\ m)}\right) \\
&= -\,(0.120\ kg)\left(\frac{67.24\ m^2/s^2}{19.4\ m}\right) \\
&= -\,0.416\ N \qquad (9)
\end{aligned}$$

## Question (b)

What is the coefficient of friction between the puck and the ice?

**R:**

$$f_k = \mu_k n$$

Newton's $2^{nd}$ Law to discover $n$:

$$\begin{aligned}
\sum F_y &= ma_y \\
n - f_g &= m(0) \\
n &= f_g
\end{aligned}$$

$$\begin{aligned}
f_k &= \mu_k f_g \\
\mu_k &= \frac{0.416\ N}{(0.120\ kg)\,(9.80\ m/s^2)} \\
&= 0.354 \qquad (10)
\end{aligned}$$

## Chapter 5 - Problem (15)

Block $A$ in the figure has mass $m_A = 0.24$ $sl$, and block $B$ has mass $m_B = 0.13$ $sl$. The coefficient of kinetic friction between block $B$ and the horizontal plane is $\mu_k = 0.45$. The inclined plane is frictionless and at angle $\theta = 36^o$. The pulley serves only to change the direction of the cord connecting the blocks. The cord has negligible mass.

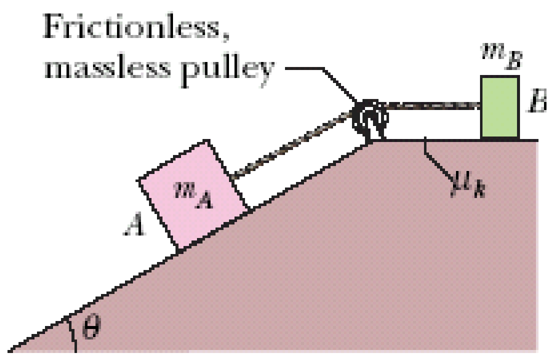


Figure 9: Illustration of Problem 15

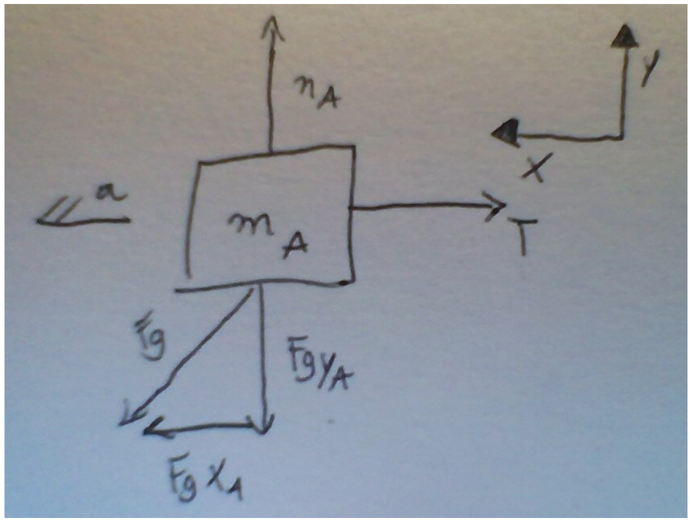


Figure 10: Free-Body Diagram (Problem 15 (Block $A$))

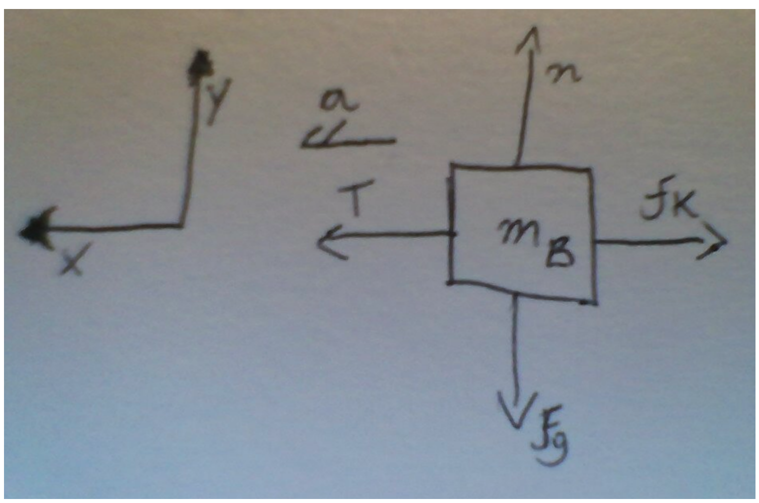


Figure 11: Free-Body Diagram (Problem 15 (Block $B$))

## Question (a)

Find the tension in the cord:

**R:**

Newton's $2^{nd}$ Law on Block $A$:

$$\begin{aligned}\sum F_{x_A} &= m_A a_{x_A}\\ f_{g_{x_A}} - T &= m_A a\\ T &= m_A g \sin\theta - m_A a\end{aligned}$$

$$\begin{aligned}\sum F_{y_A} &= m_A a_{y_A}\\ n_A - f_{g_{y_A}} &= m_A(0)\\ n_A &= m_A g \cos\theta\end{aligned}$$

Newton's $2^{nd}$ Law on Block $B$:

$$\begin{aligned}\sum F_{x_B} &= m_B a_{x_B}\\ T - f_k &= m_B a\\ T &= m_B a + \mu_k n_B\end{aligned}$$

$$\begin{aligned}\sum F_{y_B} &= m_B a_{y_B}\\ n_B - f_{g_{y_B}} &= m_B(0)\\ n_B &= m_B g\end{aligned}$$

Finding the acceleration:

$$\begin{aligned}m_A g \sin\theta - m_A a &= m_B a + \mu_k n_B\\ m_A a + m_B a &= m_A g \sin\theta - \mu_k n_B\\ a &= \frac{m_A g \sin\theta - \mu_k n_B}{m_A + m_B}\end{aligned}$$

$$\begin{aligned}m_A g \sin 36^o &= (0.24\ sl)\left(32.2\ ft/s^2\right)(0.588)\\ &= 4.542\ lb\end{aligned}$$

$$\begin{aligned} \mu_k n_B &= (0.45) m_B g \\ &= (0.45)(0.13\ sl)\left(32.2\ ft/s^2\right) \\ &= 1.884\ lb \end{aligned}$$

$$\begin{aligned} a &= \frac{m_A g \sin\theta - \mu_k n_B}{m_A + m_B} \\ &= \frac{(4.542\ lb) - (1.884\ lb)}{(0.24\ sl) + (0.13\ sl)} \\ &= \frac{2.658\ lb}{0.37\ sl} \\ &= 7.184\ ft/s^2 \end{aligned} \tag{11}$$

Finding the tension:

$$\begin{aligned} T &= m_A g \sin\theta - m_A a \\ T &= (4.642\ lb) - (0.24\ sl)\left(7.184\ ft/s^2\right) \\ T &= (4.642\ lb) - (1.724\ lb) \\ T &= 2.918\ lb \end{aligned} \tag{12}$$

### Question (b)

Find the magnitude of the acceleration of the blocks:
**R:**

As seen on eq. (11):

$$a = 7.184\ ft/s^2$$

## Chapter 6 - Problem (1)

Suppose the coefficient of static friction between the road and the tires on a car is 0.92. What speed will put the car on the verge of sliding as it rounds a level curve of 83 $ft$ radius?

**R:**

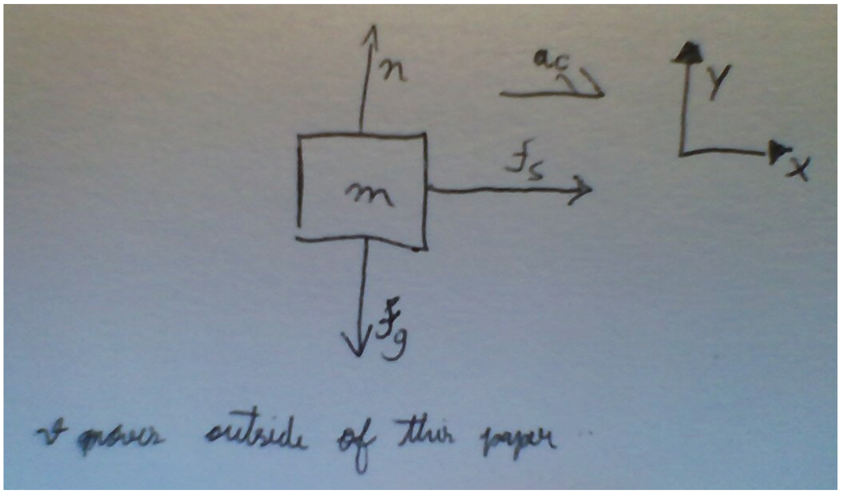


Figure 12: Free-Body Diagram (Problem 1)

$$f_{s,max} = \mu_s n$$

Newton's $2^{nd}$ Law:

$$\begin{aligned}\sum F_x &= ma_x \\ f_s &= ma_c\end{aligned}$$

$$\begin{aligned}\sum F_y &= ma_y \\ n - f_g &= m(0) \\ n &= f_g\end{aligned}$$

$$\begin{aligned}
f_s &= f_{s,max} \\
ma_c &= \mu_s mg \\
a_c &= \mu_s g \\
&= (0.92)\left(32.2\ ft/s^2\right) \\
&= 26.404\ ft/s^2
\end{aligned}$$

$$\begin{aligned}
a_c &= \frac{v^2}{r} \\
v &= \sqrt{a_c r} \\
&= \sqrt{(26.404 ft/s^2)(83\ ft)} \\
&= \sqrt{2191.5\ ft^2/s^2} \\
&= 46.814\ ft/s
\end{aligned} \tag{13}$$

# Chapter 6 - Problem (2)

A roller-coaster car has a mass of 1300 $kg$ when fully loaded with passengers. As the car passes over the top of a circular hill of radius 19 $m$, its speed is not changing.

## Question (a)

At the top of the hill, what is the normal force on the car from the track if the car's speed is $v = 7.9\ m/s$?

**R:**

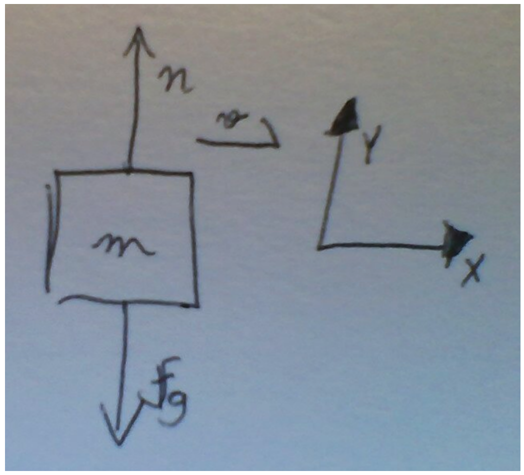


Figure 13: Free-Body Diagram (Problem 2)

Newton's $2^{nd}$ Law:

$$\begin{aligned}
\sum F_y &= ma_y \\
n - mg &= ma_c \\
n &= mg + ma_c \\
&= m\left(g + \frac{v^2}{r}\right) \\
&= (1300\ kg)\left[\left(9.80\ m/s^2\right) + \frac{(7.9\ m/s)^2}{19\ m}\right] \\
&= (1300\ kg)\left[\left(9.80\ m/s^2\right) + \frac{62.41\ m^2/s^2}{19\ m}\right] \\
&= (1300\ kg)\left[\left(9.80\ m/s^2\right) + (3.285\ m/s^2)\right] \\
&= (1300\ kg)\left(13.085\ m/s^2\right) \\
&= 17\ 010.5\ N
\end{aligned} \tag{14}$$

## Question (b)

What is the normal force if $v = 17m/s$?

**R:**

$$\begin{aligned}
n &= m\left(g + \frac{v^2}{r}\right) \\
&= (1300\ kg)\left[\left(9.80\ m/s^2\right) + \frac{(17\ m/s)^2}{19\ m}\right] \\
&= (1300\ kg)\left[\left(9.80\ m/s^2\right) + \frac{289\ m^2/s^2}{19\ m}\right] \\
&= (1300\ kg)\left[\left(9.80\ m/s^2\right) + (15.211\ m/s^2)\right] \\
&= (1300\ kg)\left(25.011\ m/s^2\right) \\
&= 32\ 514.3\ N
\end{aligned} \tag{15}$$