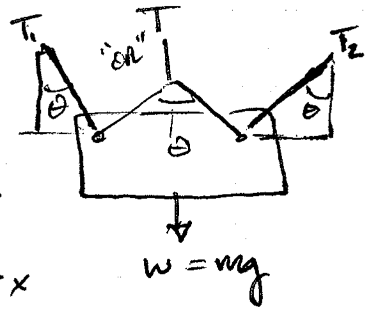
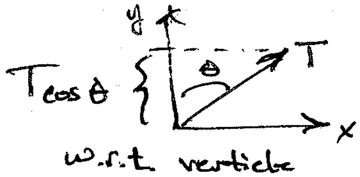
CH 5 EXERCISES:

#1. (5.5)





Apply: $\sum_i \vec{F} = m\vec{a}$

for $T = 0.75w$, $\theta = ??$

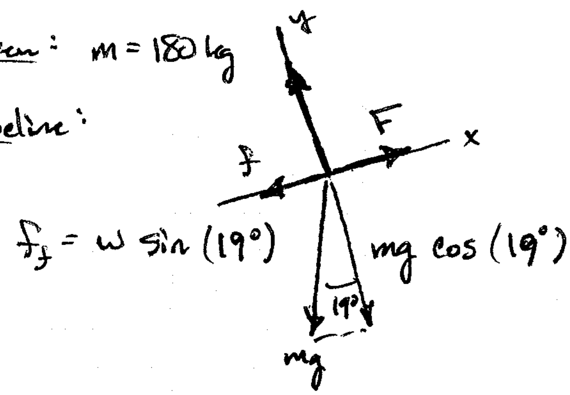
Note: the tension in each wire $= \frac{w}{2}$
(half the weight of the picture)

$\Rightarrow \frac{\cancel{w}}{2} = \frac{3}{\cancel{4}}\cancel{w}\cos\theta$ where $T = \frac{3}{4}w\cos\theta$

$\Rightarrow \cos\theta = \left(\frac{1}{2}\right)\left(\frac{4}{3}\right) = \frac{2}{3}$ $\theta = \cos^{-1}\left(\frac{2}{3}\right) = \boxed{48°}$

#2. (5.9) Given: $m = 180$ kg

(a) Parallel to incline:



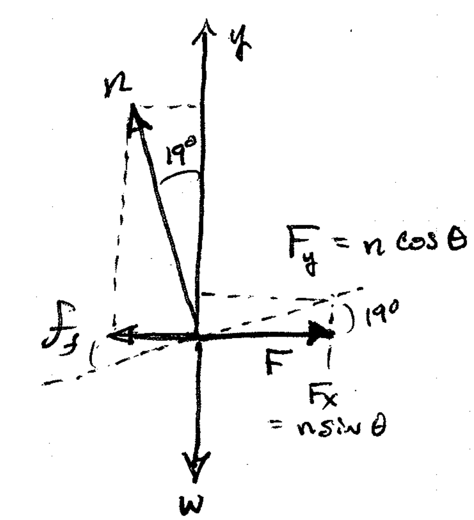
$\sum_i F_x = 0$

$\Rightarrow F - w\sin(19°) = 0$

$F = (180\text{ kg})(9.8\text{ m/s}^2)\sin(19°)$

$= \boxed{574\text{ N}}$

(b) Parallel to floor:



$f_f = n\sin(19°)$

$\sum_i F_y = 0$

$\Rightarrow F_y - w = 0$

$\Rightarrow n\cos(19°) = mg$

$\Rightarrow n = \frac{mg}{\cos\theta}$

$\sum_i F_x = 0$

$\Rightarrow F_x - f_f = 0$

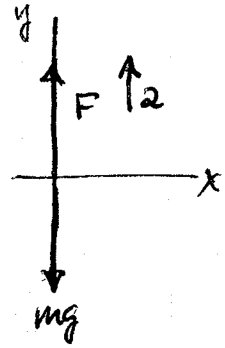
$\Rightarrow F - n\sin(19°) = 0$

$\Rightarrow F = n\sin(19°) = \left(\frac{mg}{\cos\theta}\right)\sin(19°)$

$= (180\text{ kg})(9.8\text{ m/s}^2)\tan(19°)$

$= \boxed{607\text{ N}}$

#3 (5.13)



Given: $v_{oy} = 311 \cdot 10^3 \frac{m}{hr.} \times \left(\frac{1\ hr}{3600 s}\right) = -86.4\ m/s$ (downwards)

$m = 210\ kg$

(a) what acceleration did it crash at?

USE: $v_y^2 = v_{oy}^2 + 2a_y(y - y_o)$ where $\Delta y = -0.81\ m$

$$\Rightarrow a_y = \frac{\cancel{v_y^2} - v_{oy}^2}{2(\Delta y)} = \frac{(-86.4\ m/s)^2}{2(-0.81 m)} = \boxed{4610\ m/s^2}$$

(b) what force did it exert on the ground?

(dynamic) $\sum F_y = m a_y$

$$\Rightarrow F - mg = m a_y$$

$$F = m(g + a_y) = (210\ kg)(9.8 + 4610)\ m/s^2$$

$$= \boxed{9.70 \cdot 10^5\ N}$$

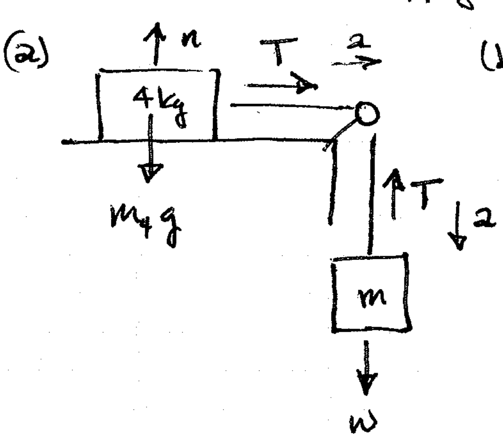
(c) How long did force last?

USE: $\Delta y = \frac{1}{2}(v_0 + \cancel{v_y})t$ $\Rightarrow t = \frac{2(\Delta y)}{v_0} = \frac{2(-0.81 m)}{(-86.4\ m/s)}$

$$= \boxed{0.019\ s}$$

#4 (5.17) ... apply $\sum F = ma$ to each block

(a)



(b) Block "A" (4 kg): $\sum F_x = m a_x$

$$\Rightarrow T = (4\ kg)\, a_x \quad \text{where } T = 15N$$

$$\Rightarrow a_x = \frac{(15N)}{4\ kg} = \boxed{3.75\ m/s^2}$$

(same for block mass "m")

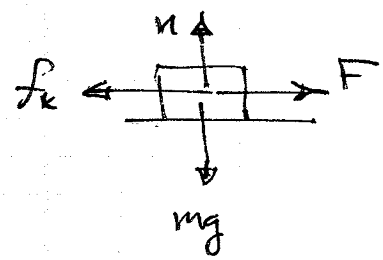
(c) Solve for m ... $\sum F_y = m a_y$

$$\Rightarrow mg - T = ma$$

$$\Rightarrow m(g - a) = T$$

$$\therefore m = \frac{T}{(g - a)} = \frac{(15N)}{(9.8 - 3.75)\ m/s^2} = \frac{(15N)}{6.05\ m/s^2} = \boxed{2.48\ kg}$$

#5 (5.27) Given: $\mu = 0.2$, $m = 16.8\text{ kg}$ } dynamic: $\sum_i \vec{F_x} = m a_x$



Noted: constant speed ($v = 3.5\text{ m/s}$) $\Rightarrow a_x = 0$

$$\sum_i F_x = m a_x$$

$$\Rightarrow F - f_k = 0$$

$$\Rightarrow F = f_k = \mu m g = (0.2)(9.8)(16.8)$$

$$= \boxed{33N}$$

$$f_k = \mu_k n = (0.2) mg$$

(b) Now, $F = 0$ solve for a_x... (noted $v_0 = 3.5\text{ m/s}$, how far does box slide?)

$$\sum_i F_x = m a_x$$

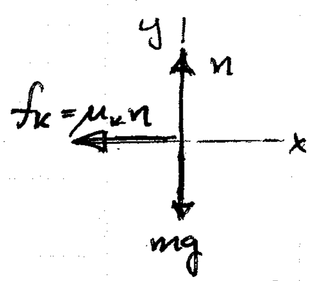
$$\Rightarrow 0 - f_k = m a_x$$

$$\Rightarrow a_x = \frac{-f_k}{m} = \frac{33N}{(16.8\text{ kg})} = \underline{-1.96\text{ m/s}^2}$$

USE: $\overset{\to 0}{\cancel{v_x^2}} = v_{0x}^2 + 2a_x(\Delta x)$ to solve for Δx...

$$\Rightarrow \Delta x = \frac{-v_0^2}{2a_x} = \frac{-(3.5\text{ m/s})^2}{2(-1.96\text{ m/s}^2)} = \boxed{3.1\text{ m}}$$

#6 (5.39) Given: $\mu_k = 0.8$, $v_0 = 28.7\text{ m/s}$



(a) $\sum_i F = m a_x$ ... solve for a_x

$$-f_k = m a_x$$

$$\Rightarrow a_x = \frac{-f_k}{m} = \frac{-\mu_k \cancel{m} g}{\cancel{m}} = -(0.8)(9.8\text{ m/s}^2) = \underline{-7.84\text{ m/s}^2}$$

USE: $v_x^2 = v_0^2 + 2a_x(\Delta x)$ where $v_x = 0$, solve for Δx

$$\Rightarrow \Delta x = \frac{-v_0^2}{2a_x} = \frac{-(28.7\text{ m/s})^2}{2(-7.84\text{ m/s}^2)} = \boxed{52.5\text{ m}}$$

(b) Given Δx and $\mu_k = 0.25$, now solve for $v_0 = ?$ where $a_x = -\mu_k g$

$$v_0 = \sqrt{-2a_x \Delta x} = \sqrt{-2(\mu_k g)\Delta x}$$

$$= \sqrt{+2(0.25)(9.8\text{ m/s}^2)(52.5\text{ m})} = \boxed{16.0\text{ m/s}}$$

#7 (5.40) Given drag force $\propto Dv^2$ where $f = mg$

(a) At half terminal speed, drag $\Rightarrow (\frac{1}{2}v)^2 \propto \frac{1}{4}mg$

Apply $\sum F = ma = Dv^2 - mg$ ... solve for v

noted: when $a = 0$ ... $\Rightarrow v^2 = mg/D$ "OR" $v = \sqrt{mg/D}$

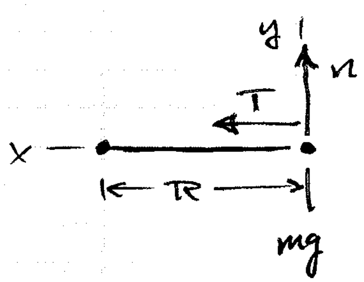
half terminal speed $\frac{v}{2} = \frac{1}{2}\sqrt{mg/D}$

When $\frac{1}{2}$ ~~terminal~~ speed up: $F = Dv^2 + mg$

$$= \cancel{D}\left(\frac{1}{4}\frac{mg}{\cancel{D}}\right) + mg = \frac{5}{4}mg$$

(b) when falling... $F = Dv^2 - mg = \cancel{D}\left(\frac{mg}{\cancel{D}}\right)\frac{1}{4} - mg = -\frac{3}{4}mg$

#8 (5.43) Given $m = 0.8$ kg, $R = 0.9$ m, $T = 60$ N



recall: $a_{rad} = \frac{v^2}{R}$

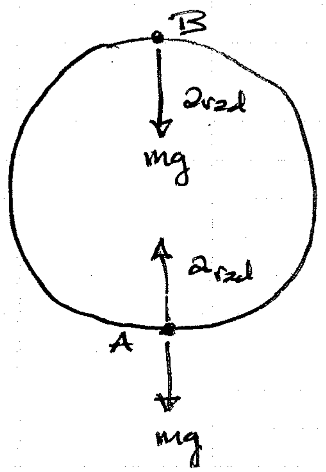
Apply $\sum F_x = ma_x$

$\Rightarrow T = m a_{rad} = m\left(\frac{v^2}{R}\right)$

$\Rightarrow v^2 = \frac{TR}{m}$

$\therefore v = \sqrt{\frac{TR}{m}} = \sqrt{\frac{(60\,N)(0.9\,m)}{(0.8\,kg)}} = \sqrt{67.5\,m^2/s^2} = \boxed{8.2\,m/s}$

#9 (5.45) Given: $m = 1.6\,\text{kg}$, $v = 12\,\text{m/s}$, $R = 5\,\text{m}$



Apply $\sum F = m a_{rad}$ where $a_{rad} = \dfrac{v^2}{R}$

(a) at bottom of track ...

$$F_A - mg = m a_{rad}$$

$$\Rightarrow F_A = mg + m a_{rad}$$

$$= m\left(g + \frac{v^2}{R}\right)$$

$$= (1.6\,\text{kg})\left(9.8\,\text{m/s}^2 + \frac{(12\,\text{m/s})^2}{(5\,\text{m})}\right)$$

$$= \boxed{61.8\,\text{N}}$$

(b) at top of track ...

$$\sum_i F = m a_{rad} \implies F_B + mg = m a_{rad}$$

$$F_B = m a_{rad} - mg$$

$$= m\left(\frac{v^2}{R} - g\right)$$

$$= (1.6\,\text{kg})\left(\frac{(12\,\text{m/s})^2}{(5\,\text{m})} - 9.8\,\text{m/s}^2\right)$$

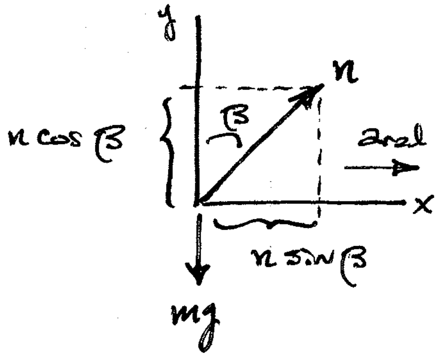
$$= \boxed{30.4\,\text{N}}$$

<u>EVALUATE:</u> $F_A > F_B$

$$F_A - 2mg = F_B$$

#10 (5.49) <u>Given:</u> $m_c = 1125\ \text{kg}$, $R = 225\ \text{m}$
$m_t = 2250\ \text{kg}$

(a) $v_0 = 65\ \text{mph} = 28.7\ \text{m/s}$ ... at what angle β should we bank the curve?



<u>recall:</u> from LECTURE ...

- $\sum F_x = m a_{rad} = m \frac{v^2}{R}$

(1:) $\Rightarrow \quad n \sin\beta = m a_{rad}$

- $\sum F_y = 0$

$\Rightarrow \quad n\cos\beta - mg = 0$

(2:) $\Rightarrow \quad n = \frac{mg}{\cos\beta}$

Substitute (2:) into (1:) ...

$$\Rightarrow \left(\frac{\cancel{m}g}{\cos\beta}\right)\sin\beta = \cancel{m} a_{rad}$$

$$\tan\beta = \frac{a_{rad}}{g} = \frac{v^2}{gR}$$

$$\therefore \quad \beta = \tan^{-1}\left(\frac{v^2}{gR}\right) = \tan^{-1}\left(\frac{(28.7\ \text{m/s})^2}{(9.8\ \text{m/s}^2)(225\ \text{m})}\right) = \boxed{20.5^\circ}$$

<u>Noted</u> above expression does not involve the mass of vehicles, so both car and truck should travel at same speed.

(b) As both car and truck round curve, what are the normal forces on each one due to the surface of the highway?

<u>Eqn</u> (2:) $\quad n = \frac{mg}{\cos\beta}$

$$n_{car} = \frac{(1125\ \text{kg})(9.8\ \text{m/s}^2)}{\cos(20.5^\circ)} = \boxed{1.18 \cdot 10^4\ \text{N}}$$

$$n_{truck} = \frac{(2250\ \text{kg})(9.8\ \text{m/s}^2)}{\cos(20.5^\circ)} = \boxed{2.35 \cdot 10^4\ \text{N}}$$

#11 (5.53) Given: $R = \overset{\text{diameter}}{\overset{\downarrow}{(800\,m)}}\frac{1}{2} = 400\,m$

(a) What is period of rotation (T) for $a_{rad} = 9.8\,m/s^2$?

recall: $a_{rad} = \frac{v^2}{R} = \frac{(2\pi R/T)^2}{R} = \frac{4\pi^2 R}{T^2}$

Set $a_{rad} = g$: $\Rightarrow T^2 = \frac{4\pi^2 R}{g}$

$$\Rightarrow T = 2\pi\sqrt{\frac{R}{g}} = 2\pi\sqrt{\frac{(400\,m)}{(9.8\,m/s^2)}} = \boxed{40.1\,s}$$

(b) Let $g_m = 3.7\,m/s^2$

So number of revolutions per minute

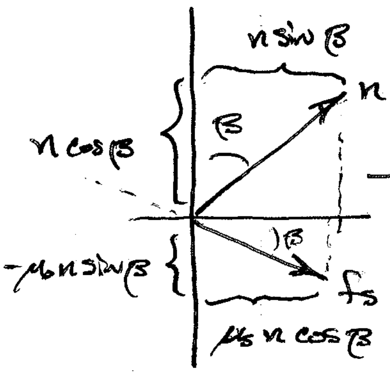
$$= \left[(40.1\,s) \times \left(\frac{1\,min}{60\,s}\right)\right]^{-1} = \boxed{1.5\,rev/min}$$

$$T = 2\pi\sqrt{\frac{R}{g_m}}$$

$$= 2\pi\sqrt{\frac{400\,m}{(3.7\,m/s^2)}} = \underline{\underline{65.3\,s}}$$

# of rev/min $\Rightarrow \left[(65.3\,s) \times \left(\frac{1\,min}{60\,sec}\right)\right]^{-1} = \boxed{0.92\,rev/min}$

#12 (5.100) Given: $\beta = 25°$, $R = 50$, $\mu_s = 0.3$



$$\bullet \sum F_x = m a_{rad}$$

Solve for a_{rad} such that vehicle breaks coefficient of friction...

$$\Rightarrow n \sin\beta + f_s \cos\beta = m a_{rad}$$

$$\Rightarrow n \sin\beta + \mu_s n \cos\beta = m a_{rad}$$

$$\Rightarrow n(\sin\beta + \mu_s \cos(\beta)) = m a_{rad} \quad : \underline{\text{Eqn } ①}$$

$$\begin{cases} f_{s_x} = \mu_s n \cos\beta \\ f_{s_y} = -\mu_s n \sin\beta \end{cases}$$

$$\bullet \sum F_y = 0$$

$$\Rightarrow n \cos\beta - f_s \sin\beta - mg = 0$$

$$\Rightarrow n \cos\beta - \mu_s n \sin\beta - mg = 0$$

- Solve for n:

$$n(\cos\beta - \mu_s \sin\beta) = mg$$

Eqn ②: $$n = \frac{mg}{(\cos\beta - \mu_s \sin(\beta))}$$

Substitute into equation ①:

$$\frac{\cancel{m}g}{(\cos\beta - \mu_s \sin(\beta))} \cdot (\sin\beta + \mu_s \cos\beta) = \cancel{m} a_{rad}$$

$$\Rightarrow a_{rad} = g\,\frac{\sin\beta + \mu_s \cos\beta}{\cos\beta - \mu_s \sin\beta} = (9.8\,m/s^2)\cdot\frac{(0.695)}{(0.779)} = 8.73\ m/s^2$$

recall:

$$a_{rad} = \frac{v^2}{R} \Rightarrow v = \sqrt{a_{rad}\cdot R} = \sqrt{(8.73\,m/s^2)(50\,m)}$$

$$\therefore\ v = \boxed{20.9\ m/s}$$

(b) To avoid slipping... (assuming no friction)

$$a_{rad} = \frac{v^2}{R} = g\tan\beta$$

$$\Rightarrow v = \sqrt{Rg\tan\beta} = \sqrt{(50\,m)(9.8\,m/s^2)\tan(25°)}$$

$$= 15.1\ m/s$$