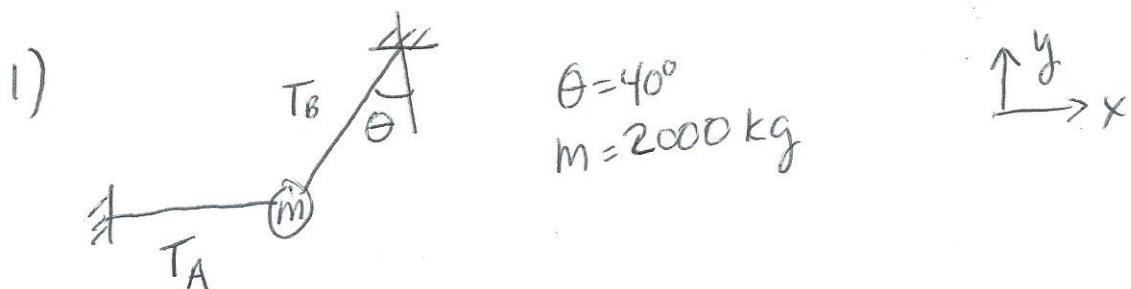


Wentworth Institute of Technology
 Engineering Physics I
 Problem Set 5 - SOLUTIONS



a) My intuition says that the tension in cable A will increase if the mass increases. I also expect that θ would decrease.

b) $T_A = ?$

$$\sum F_x = 0 = T_B \sin \theta - T_A$$

$$T_A = T_B \sin \theta = 2.5 \times 10^4 \text{ N} \sin 40^\circ$$

$$\boxed{T_A = 1.6 \times 10^4 \text{ N}}$$

c) $T_B = ?$

$$\sum F_y = 0 = T_B \cos \theta - mg$$

$$T_B \cos \theta = mg \rightarrow T_B = \frac{mg}{\cos \theta}$$

$$T_B = \frac{(2000 \text{ kg})(9.81 \text{ m/s}^2)}{\cos 40^\circ}$$

$$= \boxed{2.5 \times 10^4 \text{ N} = T_B}$$

$$1d) T_A = T_B \sin \theta$$

$$T_A = \left(\frac{mg}{\cos \theta} \right) \sin \theta = mg \tan \theta$$

so if mass increases to 3000kg, $T_A = (3000)^{\frac{kg}{9.81m}} \tan 40^\circ$

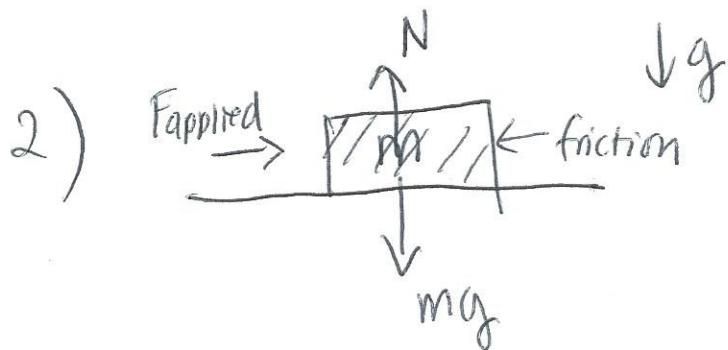
$$\boxed{T_A = 2.4 \times 10^4 N}$$

I predicted that $T_A \uparrow$ if $m \uparrow$ and that agrees w/
what I calculated

Also, if T_A stays the same but m increases

then $\tan \theta$ must decrease, meaning θ gets
smaller

(as predicted)



$$m = 10 \text{ kg}$$

$$\mu_k \text{ (kinetic friction)} = 0.21$$

$$\mu_s \text{ (static friction)} = 0.32$$

a) if I apply a force of 15N:

the maximum static friction force is $\mu_s N = \mu_s mg$
 $= 0.32(10 \text{ kg})(9.81 \text{ m/s}^2)$

$$f_{s\max} = 31.4 \text{ N}$$

2a) since the maximum static friction force is $31.4 \text{ N} > 15 \text{ N}$ (applied force), the box does not move or accelerate.

Therefore $\sum F_x = 0 = F_{\text{applied}} - f_s$

so the static friction force must be equal "in magnitude and opposite" to the force applied, $\boxed{15 \text{ N}}$

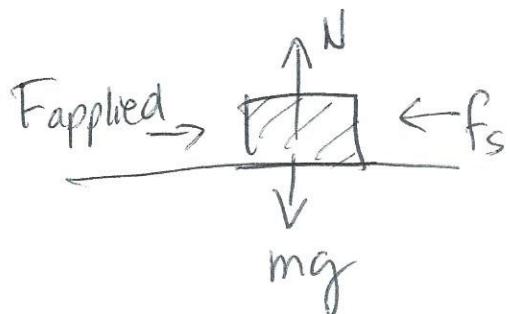
b) min. horizontal force required to overcome static friction is $\mu_s N = 31.4 \text{ N}$ (see part a)

c) min. force required to keep box moving (to overcome kinetic friction) is $\mu_k N = \mu_k mg$

$$\begin{aligned} &= 0.21 (10 \text{ kg}) (9.81 \frac{\text{m}}{\text{s}^2}) \\ &= 20.4 \text{ N} \end{aligned}$$

2d) if I apply a force of 30N to the box I do not overcome static friction so the box has zero acceleration

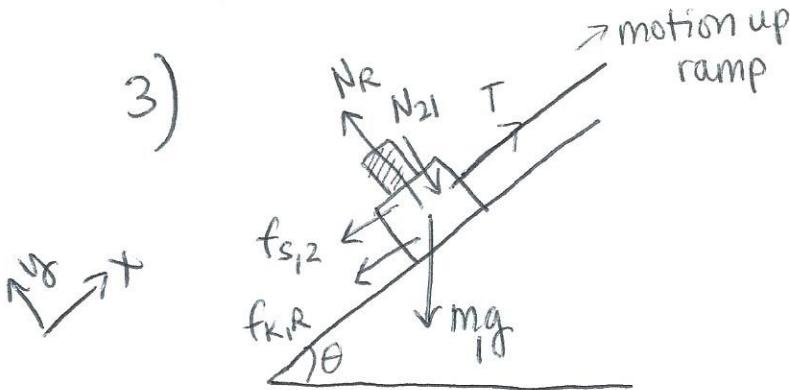
and the magnitude of the friction force is 30N



$$\sum F_x : F_{\text{Applied}} - f_s = 0$$

↑
30 N

3)



free body diagram for
lower box

$f_{k,R}$: kinetic friction
between lower box + ramp

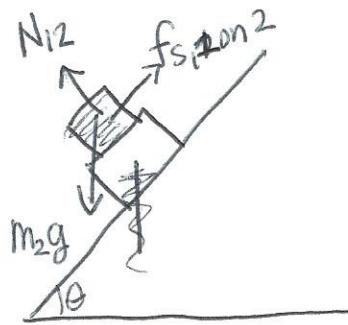
N_R : normal force of ramp on
lower box

N_{21} : normal force of ^{upper} box 2
on lower box

$f_{s,2}$: friction force between
upper + lower boxes

m_1g : weight

T: Force ^{tension} apply



free body diagram
for upper box

N_{12} : magnitude ^{direction}
equal "and opposite"
to N_{21}

m_2g : weight

$f_{s,1on2}$: equal + opposite
to $f_{s,2}$

Box 1

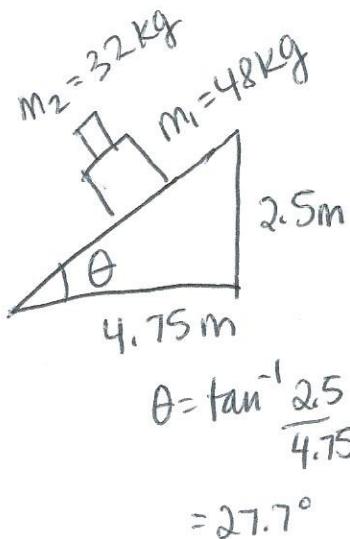
$$\sum F_x = 0 = T - f_{KR} - f_{S2} - m_1 g \sin \theta$$

$$\sum F_y = 0 = N_R - N_{21} - m_1 g \cos \theta$$

Box 2

$$\sum F_x = 0 = f_{S2} - m_2 g \sin \theta$$

$$\sum F_y = 0 = N_{12} - m_2 g \cos \theta$$



a) is looking for T

$$M_K = 0.2$$

$$M_S = 0.6$$

$$\text{from } \sum F_{x1} \quad T = f_{KR} + f_{S2} + m_1 g \sin \theta$$

$$f_{KR} = N_R M_K, \text{ from } \sum F_{y1}: N_R = N_{21} + m_1 g \cos \theta$$

$$N_{21} = +m_2 g \cos \theta \text{ from } \sum F_{y2}$$

$$N_R = m_2 g \cos \theta + m_1 g \cos \theta$$
$$= (m_1 + m_2) g \cos \theta$$

$$f_{KR} = (m_1 + m_2) g \cos \theta M_K$$

$$f_{S2} = m_2 g \sin \theta \text{ from } \sum F_{x2}$$

so $T = (m_1 + m_2) g \cos \theta M_K + m_2 g \sin \theta + m_1 g \sin \theta$

$(m_1 + m_2) g \sin \theta$

$$T = 48\cancel{kg} 32\cancel{kg} 80\text{kg} (9.81\text{m/s}^2) \cos 27.7^\circ (0.2) + 80\text{kg} (9.81)$$

$\sin 27^\circ$

~~Not taken~~ | $T = 503.7 \text{ N}$

b) What is the max force I can apply without the upper box slipping?

If I apply more force then both boxes will have a net accel.

$$\sum F_{x1} = m_1 a_x = T - f_{kR} - f_{s2} - m_1 g \sin \theta$$

$$\sum F_{x2} = m_2 a_x = f_{s2} - m_2 g \sin \theta$$

$$\begin{aligned} \text{max } f_{s2} &= \mu_s N_{21} = \mu_s m_2 g \cos \theta = 0.6(32\text{kg})(9.81\frac{\text{m}}{\text{s}^2})(\cos 27.7^\circ) \\ &= 166.7 \text{ N} \end{aligned}$$

which means that $a_x = \frac{1}{32\text{kg}} (166.7 \text{ N} - (32\text{kg})(9.81\frac{\text{m}}{\text{s}^2}) \sin 27.7^\circ)$

$$a_x = 0.64 \text{ m/s}^2$$

$$m_1 a_x = T - f_{kR} - f_{s2} - m_1 g \sin \theta$$

$$T = m_1 a_x + f_{kR} + f_{s2} + m_1 g \sin \theta$$

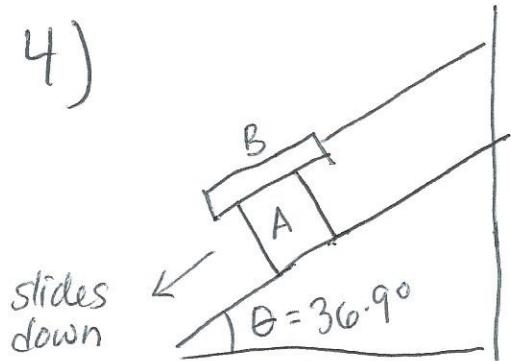
$$= 40\text{kg}(0.64 \text{ m/s}^2) + (m_1 + m_2)g \cos \theta \mu_k + 166.7 \text{ N} + m_1 g \sin \theta$$

$$138.9 \text{ N}$$

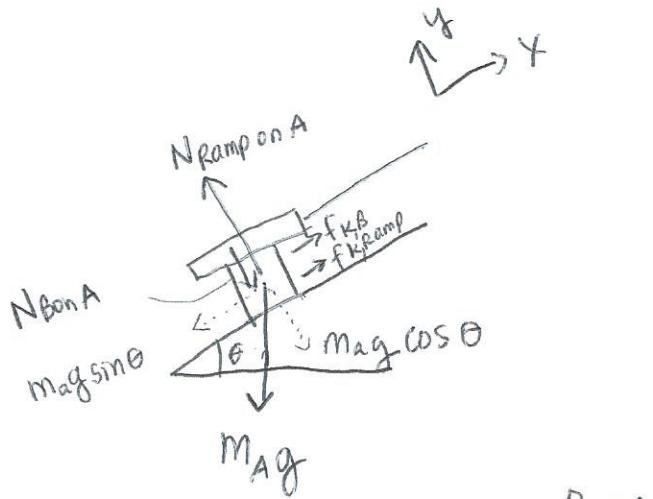
$$T = 522.7 \text{ N}$$

~~149.7 N~~
~~191.5 N~~

4)

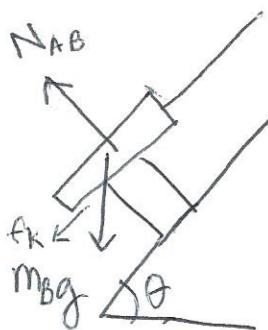
 m_A

$$m_B = 3m_A$$



a) Normal force between blocks $B+A \Rightarrow m_B g \cos \theta = N_{BA}$

forces on B:



Normal force between
block A + ramp:

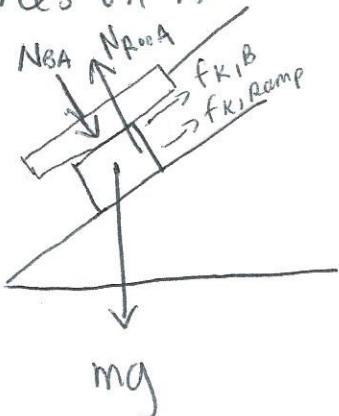
$$\sum F_y = 0 = N_{R_{on}A} - m_A g \cos \theta - N_{B_{on}A}$$

$$N_{R_{on}A} = m_A g \cos \theta + m_B g \cos \theta$$

\sim
 $3m_A$

$$N_{R_{on}A} = 4m_A g \cos \theta$$

forces on A:



b) see diagrams

c) coefficient of kinetic friction?

A:

$$\sum F_x = 0 = f_{k,B} + f_{k,ramp} - m_A g \sin \theta$$

\sim
Kinetic
friction
w/ block
||

\sim
Kinetic
friction
w/ ramp
||

$$\mu_K N_{BA}$$

$$\mu_K N_{RA}$$

$$\begin{aligned}
 4c) \quad \sum F_x = 0 &= f_{k,B} + f_{k,ramp} - mag \sin \theta \\
 &= \mu_k N_{BA} + \mu_k N_{RA} - mag \sin \theta \\
 &= \mu_k (m_B g \cos \theta) + \mu_k (4m_a g \cos \theta) - mag \sin \theta \\
 0 &= \mu_k (3m_a g \cos \theta) + \mu_k (4m_a g \cos \theta) - mag \sin \theta
 \end{aligned}$$

$$mag \sin \theta = \mu_k 7 m_a g \cos \theta$$

$$\frac{1}{7} \tan \theta = \mu_k = \frac{1}{7} \tan 36.9^\circ$$

$$\boxed{\mu_k = 0.10}$$

We can also
check $\sum F_x$ if $m_B = 0$:

$$\begin{aligned}
 \sum F_x = 0 &= f_{k,B} + f_{k,Ramp} - mag \sin \theta \\
 0 &= f_{k,R} - mag \cos \theta
 \end{aligned}$$

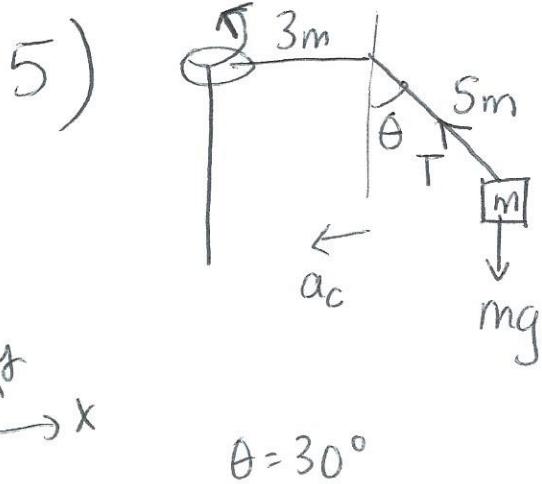
$$f_{k,R} = \mu_k N_{RA} = \mu_k (\underbrace{m_a}_{4m_a} m_B) g \cos \theta$$

from prev. page

if $m_B = 0$ then $f_{k,R} = \mu_k mag \cos \theta$ so

$$0 = \mu_k mag \cos \theta - mag \sin \theta$$

$$\tan \theta = \mu_k \checkmark \text{ as expected}$$



$$\theta = 30^\circ$$

a)

free body diagram

Includes tension from ride
and mg - does not include
 a_c , the centripetal acceleration,
because it is not a force, but
we can add it to the drawing so
long as it is clear that a_c is not
a force acting on the person.

The net force will be equal to a_c

$$\sum F_x = -ma_c = -T \sin \theta \quad , \quad \sum F_y = 0 = T \cos \theta - mg$$

$$T = \frac{mg}{\cos \theta}$$

so the net force
is $-mg \tan \theta \hat{x}$

b) $a_c = \frac{V^2}{R}$ $R = 3m + 5m \sin \theta$ $\sin 30^\circ = \frac{1}{2}$
 $= 3m + 2.5m = 5.5m$

$$V = \sqrt{a_c(5.5m)} \quad , \quad a_c = g \tan \theta$$

$$= \sqrt{9.81 \text{ m/s}^2 (\tan 30^\circ) 5.5 \text{ m}} = \boxed{V = 5.5 \text{ m/s}}$$

b) period $T = \frac{2\pi R}{v} = \frac{2\pi(5.5\text{ m})}{(5.5\text{ m/s})} = 6.28\text{ s}$

c) For a given rotation rate, $a_c = g \tan \theta$

no mass involved ($m a_c = m g \tan \theta \rightarrow \cancel{m}$ mass cancels)

so the person's mass does not affect ~~θ~~ θ if given a_c or v
(However, for the same tension $T = \frac{mg}{\cos \theta}$)

so m does affect θ , so it would affect
the angle - but then a_c and the
rotation rate would also have to change.)