Physics 2211M
Summer 2018
Test 2

form A

First name (please write as legibly as possible within the boxes)

S	O	L	U	T	I	O	N		S	E	T					

Last name

nine-digit GTID

Instructions:

1) Please use **dark-colored ink** or **heavy pencil strokes**; this test will be scanned and graded electronically, and it is important for your work to be legible on the scanned page.

2) **DO NOT ERASE** any of your work and overwrite it with new work—this will interfere with the legibility of your scanned test. Please draw a line through invalid work that you wish us to disregard.

3) No not include any loose scratch work on a separate page along with your test—extra pages are not scanable. If you need additional workspace, please use the provided blank space on pages 2 or 9. Be sure to point out, on the main problem, when you have additional work on the scratch page(s).

4) For each free response question, show all work necessary to support your answer. Clearly indicate your final answer by underlining it, or boxing it in.

5) For each multiple-choice question, select the answer most nearly correct, **circle this answer on your test**, and bubble it in on your answer card. **Show all relevant work on your quiz.**

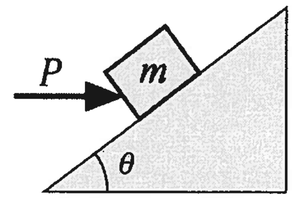
6) You may use a simple scientific calculator capable of logarithms, exponentials, and trigonometric functions. **Programmable engineering calculators with text or graphical capabilities are not allowed. Wireless devices are prohibited.**

Form A

Please do not write above this line

The following problem will be hand-graded. *Show all supporting work for this problem.*

[I] *(20 points)* A crate of mass m is pushed up a ramp that is inclined at an angle $\theta = 36.9°$ above the horizontal, by an applied pushing force P that is exactly horizontal. When the push is equal to twice the weight of the crate (i.e. when $P = 2mg$), the crate moves up the ramp at constant speed.

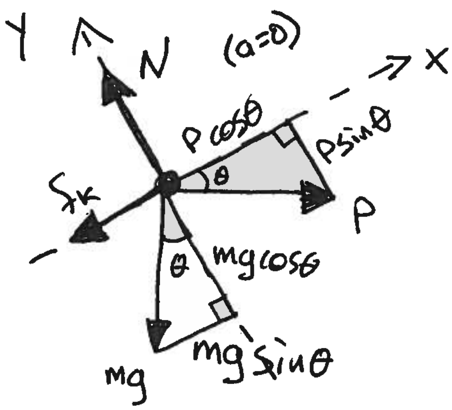


Draw a free body diagram for the crate, and then use the 2nd Law to determine the coefficient of friction between the crate and the ramp. Express your answer as a decimal value.

$\cos(36.9°) = \frac{4}{5}$

The quality of your free body diagram ***WILL*** *be graded along with your work!*

$\sin(36.9°) = \frac{3}{5}$



Motion upslope $\Rightarrow$ Kinetic friction downslope with $f_K = \mu_K N$

Constant speed $\Rightarrow \vec{a} = 0$ (this is an equilibrium problem)

$$\Sigma \vec{F}_x = m\cancel{\vec{a}_x}^{0} = 0$$

$$\langle + P\cos\theta \rangle + \langle -mg\sin\theta \rangle + \langle -f_K \rangle = 0$$

$$P\cos\theta - mg\sin\theta = f_K$$

$$P\cos\theta - mg\sin\theta = \mu_K (P\sin\theta + mg\cos\theta)$$

$$\Sigma \vec{F}_y = m\cancel{\vec{a}_y}^{0} = 0$$

$$\langle +N \rangle + \langle -P\sin\theta \rangle + \langle -mg\cos\theta \rangle = 0$$

$\rightarrow$ Note that $N \neq$ "$mg\cos\theta$" $\boxed{!!}$

$$\boxed{N = P\sin\theta + mg\cos\theta}$$

so $f_K = \mu_K N = \mu_K (P\sin\theta + mg\cos\theta)$

use this in equation for X-direction

$$\mu_K = \frac{P\cos\theta - mg\sin\theta}{P\sin\theta + mg\cos\theta} = \frac{(2\cancel{m}g)\cos\theta - \cancel{mg}\sin\theta}{(2\cancel{mg})\sin\theta + \cancel{mg}\cos\theta}$$

$$\boxed{\mu_K = 0.50}$$

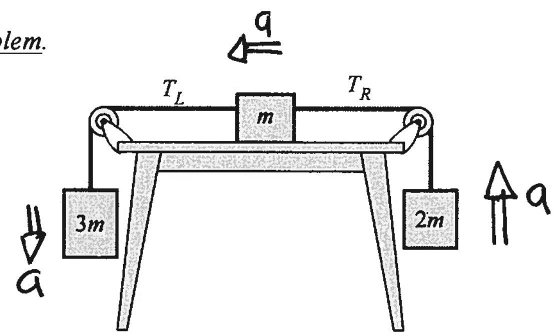
$$\mu_K = \frac{2\cos\theta - \sin\theta}{2\sin\theta + \cos\theta} = \frac{2(\frac{4}{5}) - (\frac{3}{5})}{2(\frac{3}{5}) + (\frac{4}{5})} = \frac{\frac{5}{\cancel{5}}}{\frac{10}{\cancel{5}}} = \frac{5}{10}$$

Form A

Please do not write above this line

The following problem will be hand-graded. *Show all supporting work for this problem.*

[II] *(20 points)* A block of mass m is placed on a horizontal surface having negligible friction. Cords attached to the left and right sides of the block pass over frictionless pullies, suspending blocks of mass $3m$ (on the left) and $2m$ (on the right).



Draw free body diagrams for each block, and then use the 2nd and 3rd laws to determine the tensions T_L and T_R in the two cords. (You may assume the cords are *ideal*.) Express each answer as a multiple of mg.

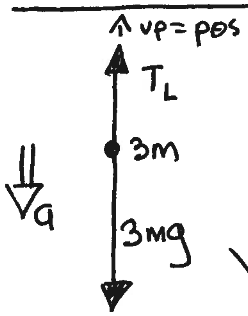
The quality of your free body diagrams ***WILL*** *be graded along with your work!*

→ You cannot assume "equilibrium" here!

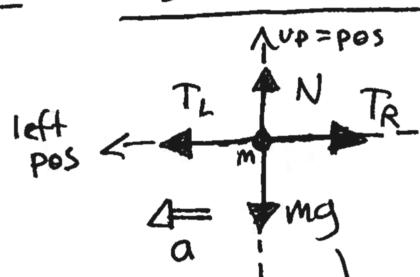
"More weight" pulls down on left than on right

→ reasonable to infer acceleration is (ccw-ish)

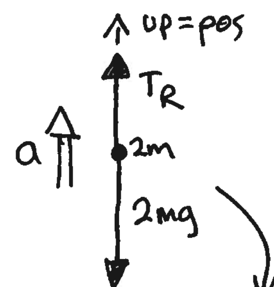
block on left



block on table



block on right



$$\sum \vec{F}_y = m\vec{a}_y$$

$$\langle +T_L \rangle + \langle -3mg \rangle = (3m)\langle -a \rangle$$

$$\sum \vec{F}_x = m\vec{a}_x$$

$$\langle +T_L \rangle + \langle -T_R \rangle = (m)\langle +a \rangle$$

$$\sum \vec{F}_y = m\vec{a}_y$$

$$\langle +T_R \rangle + \langle -2mg \rangle = (2m)\langle +a \rangle$$

→ We now have three equations in unknowns a, T_L, T_R

$3mg - T_L = 3ma \longrightarrow 3mg - T_L = 3(T_L - T_R) \longrightarrow 3mg + 3T_R = 4T_L$

$T_R - 2mg = 2ma \longrightarrow T_R - 2mg = 2(T_L - T_R) \longrightarrow -2mg + 3T_R = 2T_L$

$\boxed{T_L - T_R = ma}$

sub this into the other two, to eliminate a in favor of T_L, T_R

subtract: $5mg = 2T_L$

$\boxed{T_L = \frac{5}{2}mg}$

sub into 2nd equation

$-2mg + 3T_R = 2(\frac{5}{2}mg)$

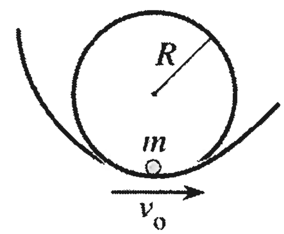
$3T_R = 7mg$

$\boxed{T_R = 7/3\, mg}$

Please do not write above this line

The following problem will be hand-graded. *Show all supporting work for this problem.*

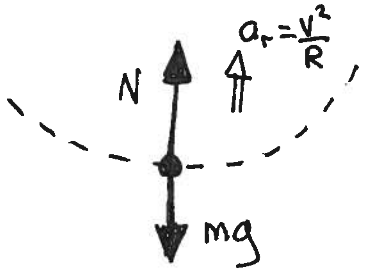
[III] *(20 points)* A roller-coaster has a loop-the-loop of radius R. The track is designed in such a way that cars ordinarily pass through the very bottom of the loop with a speed v_0. When this happens, each passenger feels an *apparent weight* that is 25% larger than normal. (In other words, a passenger of mass m would feel as if she "weighed 1.25 mg", at the bottom of the loop.)



On a rainy day, when the track is more slippery than usual, the car passes through the bottom of the loop with a speed $2v_0$. What will a passenger feel as his *apparent weight*, at the bottom of the loop? Express your answer as a multiple of the passenger's normal weight, mg.

Include a free body diagram for the passenger! The quality of that diagram ***WILL*** *be graded along with your work!*

FBD at either speed:



"perceived weight" comes from $\boxed{\text{magnitude of normal force}}$

$\boxed{\text{Case 1:}}$ normal day : $V = V_0$

$$N_1 = 1.25mg = \frac{5}{4}mg$$

$$\langle +N_1 \rangle + \langle -mg \rangle = m \langle +V^2/R \rangle$$

$$\frac{5}{4}mg - mg = m\frac{V_0^2}{R} \quad \rightarrow m \text{ drops out!}$$

$$\boxed{\frac{V_0^2}{R} = \frac{1}{4}g}$$ no need to simplify further

$\boxed{\text{Case 2:}}$ rainy day, $V = 2V_0$

→ what is N_2? That is new "perceived weight" for passenger

again, 2nd Law gives

$$\langle +N_2 \rangle + \langle -mg \rangle = m \left\langle + \frac{(2V_0)^2}{R} \right\rangle$$

(just use current speed an current normal force

$$N_2 = mg + 4m\frac{V_0^2}{R} = mg + 4m\left(\frac{1}{4}g\right) \text{ from above}$$

$$= mg + mg \qquad \boxed{N_2 = 2mg}$$

Perceived weight is Twice the normal value

Form A

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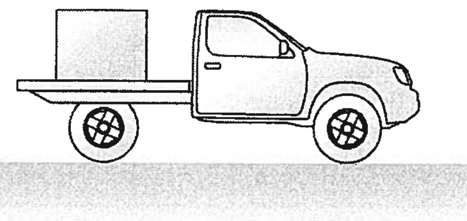
The next two questions involve the following situation:
A flatbed truck transporting a crate of fragile artwork is traveling to the east at high speed, when the driver sees an accident blocking the road ahead of him. He slams on the brakes to bring the truck to a rapid stop, causing the crate to break loose and slide forward along the truckbed.



Question value 4 points
(1) According to the driver…

NOT consistent with 2nd Law

(a) …the crate experienced a forward-directed acceleration and a backward-directed friction force.

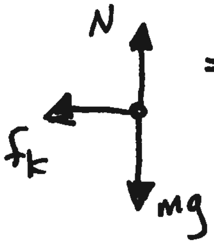
(b) …the crate experienced a backward-directed acceleration and a backward-directed friction force.

(c) …the crate experienced a backward-directed acceleration and a forward-directed friction force.

(d) …the crate experienced a forward-directed acceleration and a forward-directed friction force.

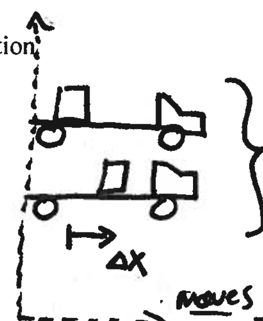
Note that driver's fram of reference is accelerating

⇒ Driver will not see "Valid 2nd Law" relationships, due to truck's accel



a (crate to truck) ⟹

$\boxed{\sum \vec{F} = m\vec{a}, \text{ from driver's POV}}$



crate $\boxed{\text{accelerates forward along truck bed}}$

moves forward relative to bed, so $\boxed{\text{kinetic friction is directed backward}}$

Question value 4 points
(2) According to a bystander on the roadside…

(a) …the crate experienced a forward-directed acceleration and a backward-directed friction force.

(b) …the crate experienced a backward-directed acceleration and a forward-directed friction force.

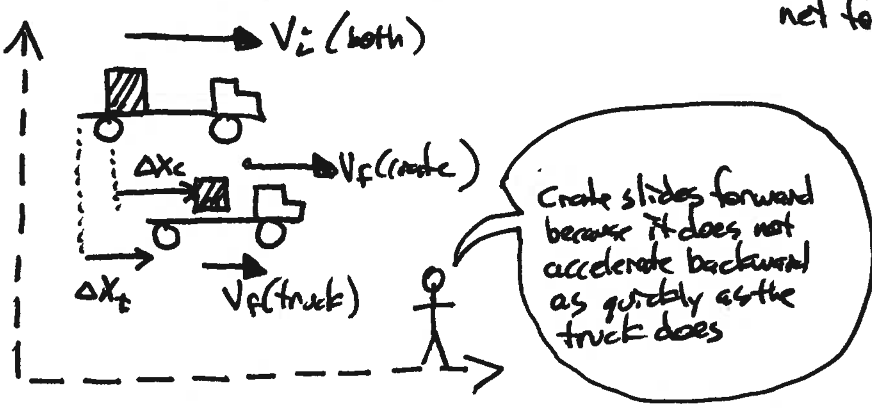
(c) …the crate experienced a forward-directed acceleration and a forward-directed friction force.

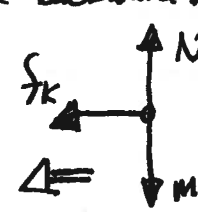
Consistent with 2nd Law

(d) …the crate experienced a backward-directed acceleration and a backward-directed friction force.

① Crate slides forward along bed, so $\boxed{\text{Kinetic friction force is backward}}$

② Observer is not accelerating, so 2nd Law must be obeyed: net force backward: $\boxed{\text{accel backward}}$





Interaction Diagram

Form A

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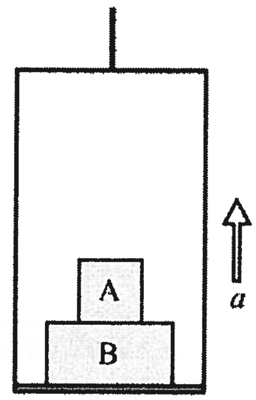
Question value 8 points

(3) Block A rests on Block B, which rests on the floor of an elevator that is accelerating upward. According to the Third Law, what force is paired with the $\boxed{\text{upward}}$ $\boxed{\text{normal}}$ force $\boxed{\text{on block B}}$ $\boxed{\text{by the floor}}$ of the elevator?



(a) ~~The weight of block B down on the floor.~~

(b) ~~The weight of block A down on block B.~~

(c) Since the elevator is *accelerating*, this force has no equal partner. (oh, Gosh No!)

(d) The $\boxed{\text{downward}}$ $\boxed{\text{normal}}$ force $\boxed{\text{by block B}}$ $\boxed{\text{on the floor.}}$

(e) ~~The weight of *both* blocks down on the floor.~~

3rd Law: equal magnitudes / opposite directions

AND agent/object relationships "reciprocate"

(A exerts force on B ⟺ B exerts force on A)

AND: force pairs are one interaction, and are the same force type

(4) An American astronaut of mass m is aboard a Russian Soyuz rocket at rest on the launch pad. As she bemoans NASA's lack of a manned launch vehicle, the main engines ignite and the rocket lifts off with an upward-directed acceleration of magnitude $3g$. What does the astronaut perceive as her apparent weight?

(a) Her weight seems to push upward, with a magnitude $2mg$.

(b) Her weight seems to pull downward, with a magnitude $4mg$.

(c) Her weight seems to pull downward, with a magnitude mg.

(d) Her weight seems to push upward, with a magnitude $3mg$.

(e) Her weight seems to pull downward, with a magnitude $3mg$.

N = force by seat, upward on astronaut

$\Uparrow \vec{a} = \langle +3g \rangle$

mg = true grav force pulling down on astronaut

2nd Law:

$$\Sigma \vec{F}_y = m\vec{a}_y$$

$$\langle +N \rangle + \langle -mg \rangle = m\langle +3g \rangle$$

$$\rightarrow \boxed{N = 4mg}$$

This is the only force that astronaut can "feel", because gravity acts equally over her entire body

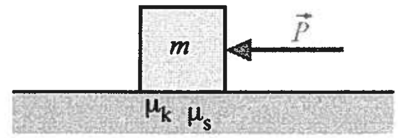
upward push by seat is felt as a greater tendence for other thing to be pulled down, so "weight" is an enhanced $\boxed{\text{downward}}$ pull

Form A

Please do not write above this line

Question value 8 points

(5) A block of mass m lies on a rough surface. It is pushed by a force P, but does not move. The frictional force exerted by the surface on the block is:



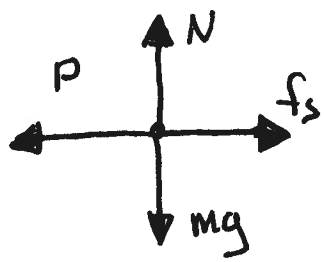
(a) mg / μ_k

(b) $\mu_s mg$

(c) $\mu_k mg$

$\boxed{\text{(d) } P}$

(e) mg / μ_s



Since block does not move, static friction must oppose the push

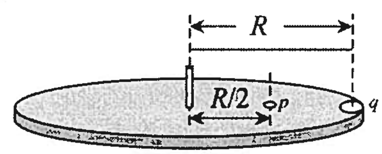
$$\Sigma \vec{F}_x = 0$$

$$\langle +P \rangle + \langle -f_s \rangle = 0$$

$$\boxed{f_s = P}$$

Question value 8 points

(6) Two coins are on a record turntable of radius R: a penny of mass m at a distance $R/2$ from the center, and quarter of mass $4m$ at the very rim. The turntable is initially at rest, but experiences an angular acceleration that causes its rotational speed to steadily increase. At speed ω the quarter is "flung off" the turntable, and at speed 2ω the penny is "flung off". Compare the coefficients of static friction between the two coins and the turntable.



(a) $\mu_P = \mu_Q$

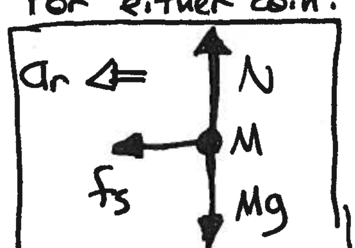
$\boxed{\text{(b) } \mu_P = 2\,\mu_Q}$

(c) $\mu_P = \mu_Q / 4$

(d) $\mu_P = 4\,\mu_Q$

(e) $\mu_P = \mu_Q / 2$

For either coin:



$$\Sigma \vec{F}_r = M\vec{a}_r$$

- $a_r = \omega^2 r$
- "about to slip" $f_s = \max = \mu_s N$
- $\Sigma \vec{F}_y = 0$

$$\langle +N \rangle + \langle -Mg \rangle = 0$$

$$N = Mg$$

so $f_s = \mu_s Mg$

radial equation:

$$\langle +f_s \rangle = M \langle +\omega^2 r \rangle$$

$$\mu_s \cancel{M} g = \cancel{M} \omega^2 r$$

$\boxed{\text{mass does not matter!}}$

$$\mu = \frac{\omega^2 r}{g}$$

so $\mu_Q = \dfrac{\omega^2 R}{g}$

$$\mu_P = \frac{(2\omega)^2 (R/2)}{g}$$

$$\mu_P = 2\,\frac{\omega^2 R}{g} = 2\mu_Q \Rightarrow \boxed{\mu_P = 2\mu_Q}$$