Physics 2211 A/B
Fall 2015
Exam 2

Test form **624**

Name Official Solutions

Recitation Section (see back of test):__________

A

1) Print your name, test form number (above), and nine-digit student number in the section of the answer card labeled "STUDENT IDENTIFICATION".

2) Bubble your test form number (**ABOVE**) in columns 1-3, skip column 4, then bubble in your student number in columns 5-13.

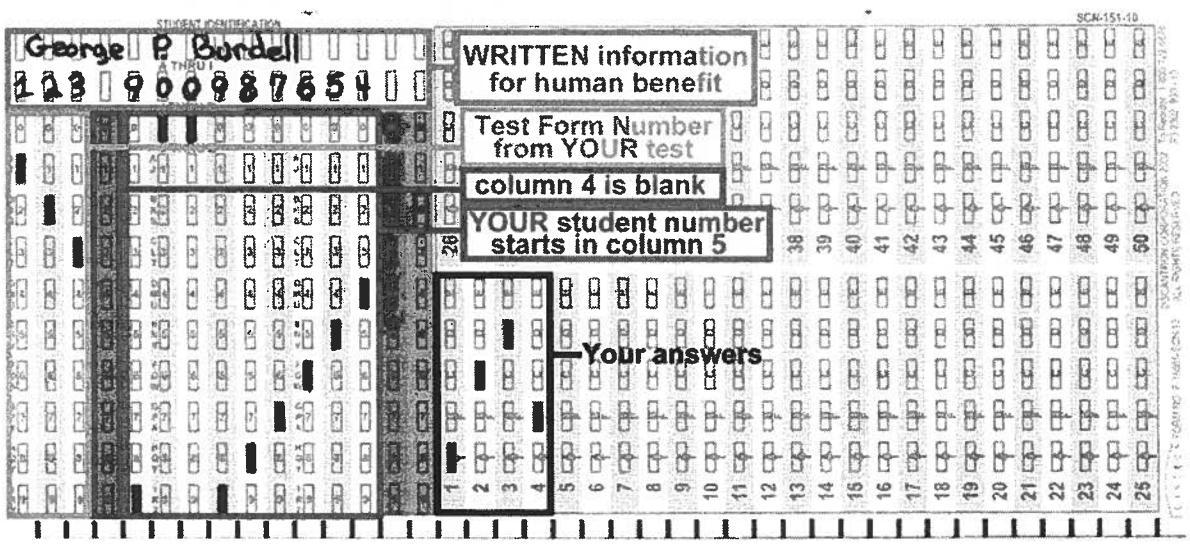
3) For each free-response question, show all relevant work supporting your answer. **Clearly box or underline your final answer.** "Correct" answers which are not supported by adequate calculations and/or reasoning will be counted wrong.

4) 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.**

5) Be prepared to present your Buzzcard as you turn in your test. Scores will be posted to WebAssign after they have been been graded. **Quiz grades become final when the next quiz is given.**

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.**

Your test form is: 624

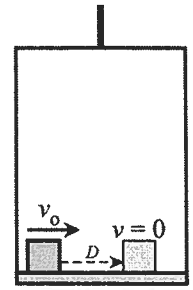


Our next test will be on Monday, November 02!

The following problem will be hand-graded. *Show all your work for this problem.* *Make no marks and leave no space on your answer card for it.*

[I] *(20 points)* You are in an elevator that is at rest. You give a wooden block a shove across the rough elevator floor. Starting from an initial speed v_0, the block slides a distance D before coming to a stop. You then feel the elevator start to move, and perform the same experiment, giving the block the same initial speed v_0. You observe that this time, the block slides a distance $1.25\,D$ before coming to a stop.

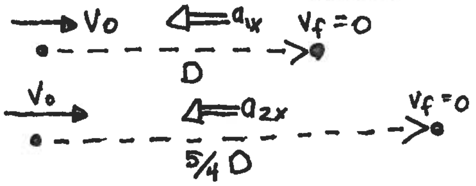
What acceleration (magnitude and direction) is the elevator experiencing, during your second experiment? Express your answer as a multiple of g.



[Hint: think about the block's horizontal motion along the floor *separate* from the vertical motion of the whole elevator…]

The quality and clarity of your free body diagrams will graded, as part of your work on this problem!

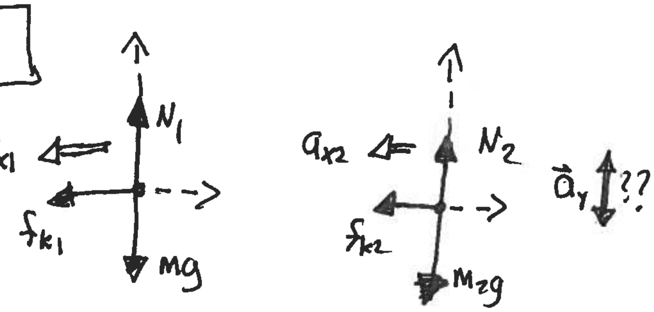
① Kinematics: for motion along floor, use $v_f^2 = v_i^2 + 2\vec{a}_x \vec{\Delta x}$



1: $0 = V_0^2 + 2\langle -a_{1x}\rangle\langle +D\rangle \rightarrow 2a_{1x}D = V_0^2$

2: $0 = V_0^2 + 2\langle -a_{2x}\rangle\langle +\tfrac{5}{4}D\rangle \rightarrow 2a_{2x}(\tfrac{5}{4}D) = V_0^2$

So: $a_{1x}D = a_{2x}(\tfrac{5}{4}D) \longrightarrow \boxed{a_{2x} = \tfrac{4}{5}a_{1x}}$



② 2nd Law for motion along floor:

$\Sigma F_x = m\hat{a}_x$ leads to:

1: $\langle -f_{k1}\rangle = m\langle -a_{x1}\rangle$

2: $\langle -f_{k2}\rangle = m\langle -a_{x2}\rangle$

$\rightarrow a_{2x} = \tfrac{4}{5}a_{1x}$ implies $\boxed{f_{k2} = \tfrac{4}{5}f_{k1}}$

③ Relation between friction and normal force

$f_k = \mu_k N$ leads to:

1: $f_{k1} = \mu_k N_1$

2: $f_{k2} = \mu_k N_2$

$\rightarrow f_{k2} = \tfrac{4}{5}f_{k1}$ implies $\boxed{N_2 = \tfrac{4}{5}N_1}$

④ 2nd Law for vertical motion of block

$\Sigma \vec{F}_y = m\vec{a}_y \rightarrow \langle +N_1\rangle + \langle -mg\rangle = 0 \rightarrow N_1 = mg \rightarrow N_2 = \tfrac{4}{5}mg$

$\rightarrow \langle +N_2\rangle + \langle -mg\rangle = m\vec{a}_y \rightarrow m\vec{a}_y = \langle +\tfrac{4}{5}mg\rangle + \langle -mg\rangle = \langle -\tfrac{1}{5}mg\rangle$

so $\boxed{\vec{a}_y = \langle -\tfrac{1}{5}g\rangle}$

Since block and elevator move vertically together this is also the elevator's acceleration…

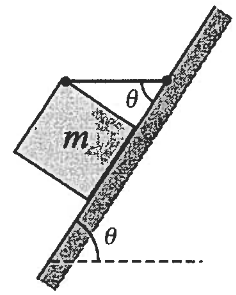
negative sign: downward accel

The following problem will be hand-graded. *Show all your work for this problem.* *Make no marks and leave no space on your answer card for it.*

[II] *(20 points)* In the figure at right, a crate rests on a steep frictionless ramp inclined at an angle $\theta = 56.5°$ above the horizontal. The block is held in equilibrium by a cord that is attached to the ramp in such a way that the cord is exactly horizontal.

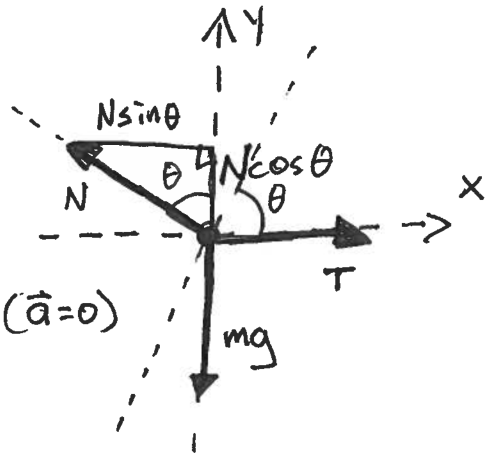
Determine the tension in the cord and the normal force exerted by the ramp on the block. Express each force as some multiple of mg.

The quality and clarity of your free body diagrams will graded, as part of your work on this problem!



Equilibrium Problem — any choice of coord systems is allowed

→ since two forces are vertical or horizontal, choose conventional xy axes



$\Sigma \vec{F}_y = m\vec{a}_y$ → zero in equilibrium

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

$$\boxed{N = \frac{mg}{\cos\theta} = 1.81\,mg}$$

$\Sigma \vec{F}_x = m\vec{a}_x$ → zero

$\langle +T \rangle + \langle -N\sin\theta \rangle = 0$

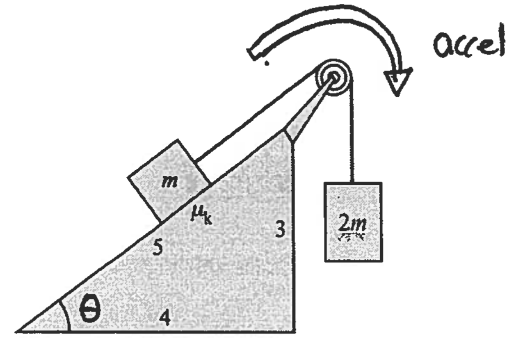
$T = N\sin\theta = \left(\frac{mg}{\cos\theta}\right)\sin\theta$

$$\boxed{T = mg\tan\theta = 1.51\,mg}$$

The following problem will be hand-graded. *<u>Show all your work for this problem</u>.* *Make no marks and leave no space on your answer card for it.*

[III] *(20 points)* A block of mass m lies on a triangular wedge having the 3-4-5 geometry, as shown. The coefficient of friction between the block and wedge is $\mu_k = 0.25$. Block m is attached to an ideal cord that passes over a massless and frictionless pulley, suspending a second block of mass $2m$.

Determine the tension in the cord and the magnitude of the two blocks' acceleration. Express the tension as some multiple of mg, and the acceleration as some multiple of g.



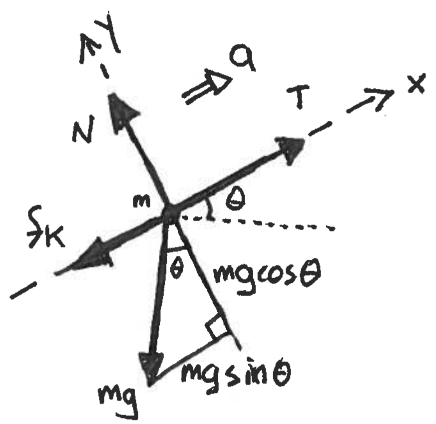
3-4-5 triangle: $\theta = 36.9^\circ$

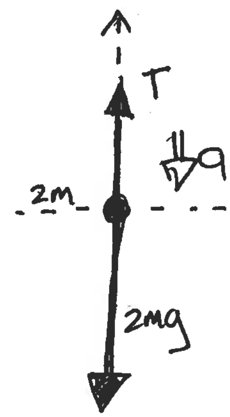
The quality and clarity of your free body diagrams will graded, as part of your work on this problem!

$\sin\theta = \frac{3}{5}$

$\cos\theta = \frac{4}{5}$

$\tan\theta = \frac{3}{4}$





Note: $mg\sin\theta = \frac{3}{5}mg$ pulls "downslope" while $2mg$ pulls on right → overall motion will be in "clockwise" sense

⇒ Since m slips up slope, kinetic friction points downslope

- $\Sigma \vec{F}_y = m\vec{a}_y$ (→ 0)

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

$N = mg\cos\theta$

$f_K = \mu_k N = \mu_k mg\cos\theta$

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

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

$T + 2ma = 2mg$ [A]

- $\Sigma \vec{F}_x = m\vec{a}_x$

$\langle +T\rangle + \langle -mg\sin\theta\rangle + \langle -f_k\rangle = m\langle +a\rangle \rightarrow T - ma = mg\sin\theta + \mu_k mg\cos\theta$

$= mg(3/5) + (\frac{1}{4})mg(\frac{4}{5})$

$T - ma = \frac{4}{5}mg$ [B]

Equations [A] and [B] give us two equations in unknowns T, a

[A] + 2[B]: $(T+2ma) + 2(T-ma) = 2mg + \frac{8}{5}mg \rightarrow 3T = \frac{18}{5}mg$

$T = \frac{6}{5}mg$

[A] − [B]: $(T+2ma) - (T-ma) = 2mg - \frac{4}{5}mg$

$3ma = \frac{6}{5}mg \rightarrow a = \frac{2}{5}g$

Question value 5 points

(1) A non-inertial reference frame is defined as:

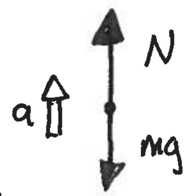
(a) a reference frame attached to an object of zero mass, and therefore having zero inertia.
(b) a reference frame moving at constant velocity relative to some stationary reference frame.
(c) any reference frame that is not stationary.
(d) a reference frame in which Newton's laws of motion do not appear to be valid.
(e) a reference frame that does not use conventional x- and y axes, such as a tilted coordinate system.

"non-inertial" implies the reference frame is accelerating: Newton's laws – 1st, 2nd particularly – are not valid

Question value 5 points

(2) A passenger riding in an elevetor has a true weight $W = mg$. At a particular moment when the elevator is in motion, the passenger feels an apparent weight W^* that is greater than W. Which of the statements below provide a possible description of the elevator's motion?

(a) The elevator is moving upward at ~~constant speed~~.
(b) The elevator is moving upward at decreasing speed.
(c) The elevator is moving downward at ~~constant speed~~.
(d) The elevator is moving downward at increasing speed.
(e) The elevator is moving downward at decreasing speed.

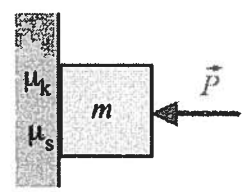


N = perception of weight, $= W^*$
$W^* > mg$
$N > mg$
⇒ upward acceleration

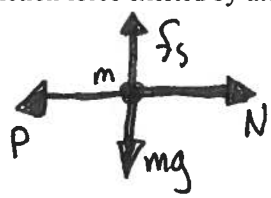
upward accel can mean: → ascending and gaining speed (not an option)
→ descending and losing speed

Question value 5 points

(3) A block of mass m is pressed against a vertical wall by a force P. The coefficients of friction between the block and the wall are μ_s and μ_k. The block does not move. The magnitude of the friction force exerted by the surface on the block is:



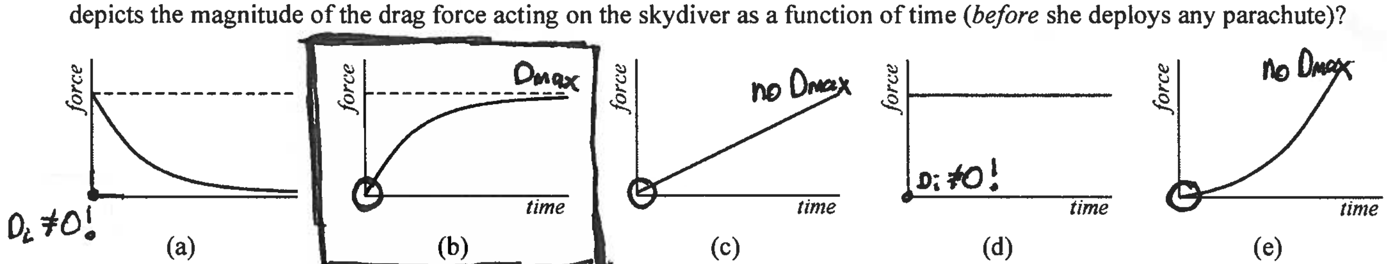
(a) $\mu_s P$
(b) mg
(c) P
(d) $\mu_s mg$
(e) P/μ_s



$\Sigma \vec{F}_y = m\vec{a}_y$ → zero
$\langle +f_s \rangle + \langle -mg \rangle = 0$
$f_s = mg$

Question value 5 points

(4) A skydiver steps out of a hot-air balloon that is floating stationary, 3km above the ground. Which of the graphs below best depicts the magnitude of the drag force acting on the skydiver as a function of time (*before* she deploys any parachute)?

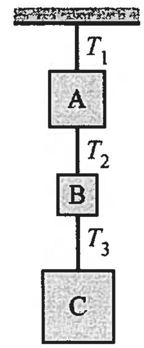


(a) (b) (c) (d) (e)

① Drag forces: $D \sim v^2$ → skydiver begins at rest, so $D_i \equiv 0$

② As time passes: $v\uparrow$, so $D\uparrow$ But: eventually reach terminal speed as $t \to$ large as $v \to v_{terminal}$ = constant, $D \to D_\infty$ = constant (or call it D_{max})

The next two questions involve the following situation:
Three blocks hang from the ceiling as shown in the figure at right, with $M_A = 2m$, $M_B = m$, and $M_C = 3m$. The blocks are attached to each other via ideal cords (massless and unstretchable), having tensions T_1, T_2, and T_3 as shown.



Question value 5 points

(5) According to the 3rd Law, what force is paired with the tension T_2 pulling up on block B?

(a) Tension T_3 pulling ~~down on block~~ B.
(b) Weight mg pulling ~~down on block~~ B.
(c) Tension T_3 pulling up on block C.
(d) Tension T_2 pulling down on block A.
(e) Weights mg and $3mg$ pulling down ~~on block B.~~

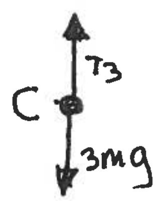
① 3rd Law Partner is not Block B

② 3rd Law Partner is the object interacting with B via tension T_2
→ That's Block A not C

Question value 5 points

(6) Rank, from greatest to least, the tensions in the three cords.

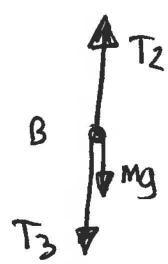
(a) $T_3 > T_1 > T_2$
(b) $T_1 = T_3 > T_2$
(c) $T_3 > T_2 > T_1$
(d) $T_2 > T_1 > T_3$
(e) $T_1 > T_2 > T_3$



Tension T_3 supports only weight of C

$\Sigma \vec{F}_y = 0 = \langle +T_3 \rangle + \langle -3mg \rangle$

$T_3 = 3mg$

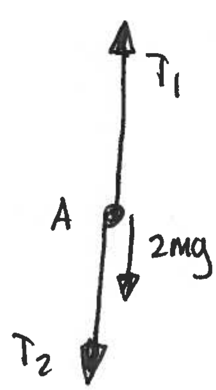


Tension T_2 supports weight of B AND cancels pull of T_3

$T_2 > T_3$

$\Sigma \vec{F}_y = 0 = \langle +T_2 \rangle + \langle -T_3 \rangle + \langle -mg \rangle$

$T_2 = T_3 + mg = 4mg$



T_1 supports weight of A AND cancels pull of T_2

$T_1 > T_2$

$\Sigma \vec{F}_y = 0 = \langle +T_1 \rangle + \langle -T_2 \rangle + \langle -2mg \rangle$

$T_1 = T_2 + 2mg = 6mg$

The next two questions involve the following situation:

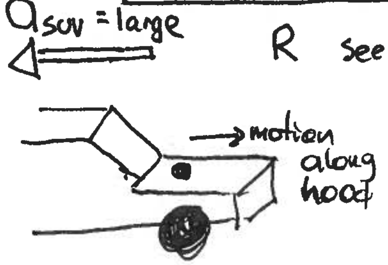
The Zombie Apocalype has arrived! Rick is driving an SUV along a straight stretch of highway, when a zombie drops onto the hood of his vehicle from an overpass. Glen is standing stationary on the shoulder of the highway at the moment this happens. After a few moments freaking out, Rick slams on the brakes and the zombie tumbles off the front of the hood.

Consider motion as zombie is slipping off the hood, just after brakes are applied

Question value 5 points

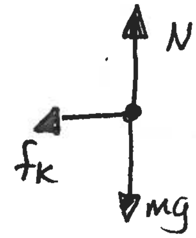
(7) From Rick's perspective (i.e *frame of reference*) in the truck…

(a) …the zombie experiences a friction force directed *forward*, while accelerating *backward* relative to the hood.
(b) …the zombie experiences a friction force directed *forward*, while accelerating *forward* relative to the hood.
(c) …the zombie experiences a friction force directed *backward*, while accelerating *backward* relative to the hood.
(d) …the zombie experiences a friction force directed *backward*, while accelerating *forward* relative to the hood.



R sees zombie slide forward relative to hood

$\Rightarrow \vec{a}_z$ is forward
$\vec{f}_K$ is opposite to relative motion = backward



Note how this diagram appears to violate 2nd Law

Question value 5 points

(8) From Glen's perspective (i.e *frame of reference*) on the ground…

(a) …the zombie experiences a friction force directed *forward*, while accelerating *backward* relative to the ground.
(b) …the zombie experiences a friction force directed *backward*, while accelerating *forward* relative to the ground.
(c) …the zombie experiences a friction force directed *forward*, while accelerating *forward* relative to the ground.
(d) …the zombie experiences a friction force directed *backward*, while accelerating *backward* relative to the ground.

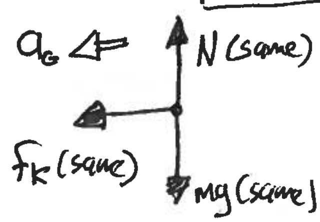
G also sees zombie slide forward relative to hood

So: Glen sees a backward-directed friction force

But: Glen is in a non-accelerating reference frame

$\Rightarrow$ he sees 2nd law as valid:

backward friction $\rightarrow$ backward accel relative to ground



$\vec{a}_{SUV\ to\ ground} = \langle -a_{SUV} \rangle$

$\vec{a}_{Z\ to\ SUV} = \langle +a_{rel} \rangle$

$\vec{a}_{Z\ to\ ground} = \langle -a_G \rangle$

$\vec{a}_{Z\,to\,G} = \vec{a}_{Z\,to\,S} + \vec{a}_{S\,to\,G}$