Physics 2211M
Summer 2015
Test 2

Test form $\boxed{522}$

Name 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.

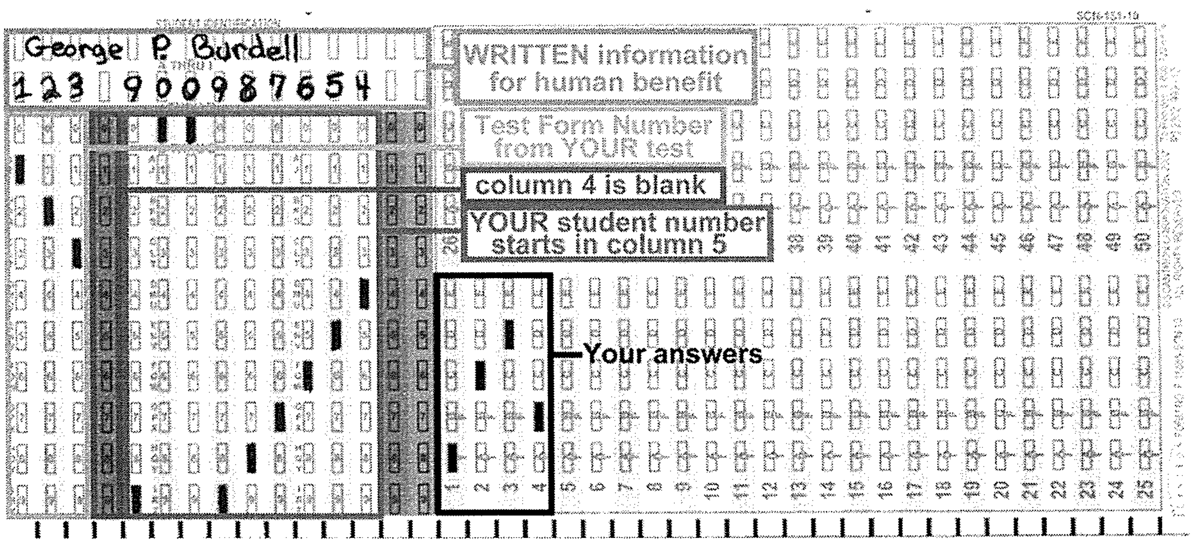
3) For each free-response question, show all relevant work supporting your answer. **Clearly box or underline your final answer.** "Correct" answers which are not supported by adequate calculations and/or reasoning will be counted wrong.

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.**

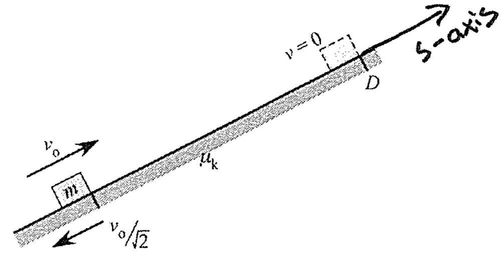
Your test form is: $\boxed{522}$



Our next test will be on Monday, July 13!

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)* A block is given a shove up a rough ramp that is inclined at an angle $\theta = 27.0°$ above the horizontal, with an initial speed v_o. It slides a distance D up the incline, stops momentarily, and then slides back down the ramp. It passes its starting point moving with a speed $v_o/\sqrt{2}$.



What is the coefficient of kinetic friction between the block and the ramp?

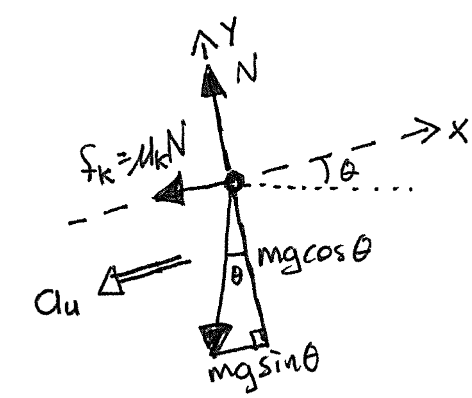
Hint: let a_u be the acceleration magnitude while sliding up the incline, and let a_d be the acceleration magnitude while sliding down the incline. Use kinematics to relate a_d to a_u, eliminating v_o and D. Then apply the 2nd Law to each trip.

"Speed equation" while ascending:

$V_f^2 = V_i^2 + 2\langle a\rangle\langle \Delta s\rangle \longrightarrow 0^2 = V_0^2 + 2\langle -a_u\rangle\langle +D\rangle \rightarrow \boxed{a_u = \frac{V_0^2}{2D}}$

while descending: $\left(\frac{V_0}{\sqrt{2}}\right)^2 = 0^2 + 2\langle -a_d\rangle\langle -D\rangle \rightarrow \boxed{a_d = \frac{V_0^2}{4D}} \rightarrow \boxed{a_d = \frac{1}{2}a_u}$

ascending: friction points downslope



$\Sigma \vec{F}_y = m\vec{a}_y = 0 \longrightarrow N = mg\cos\theta$

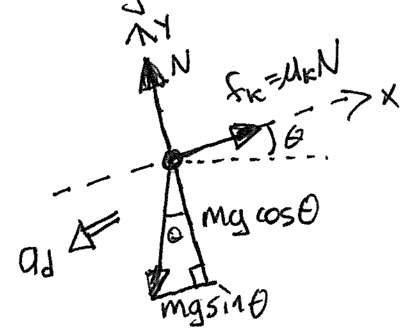
$\Sigma \vec{F}_x = m\vec{a}_x$

$\langle -\mu_k N\rangle + \langle -mg\sin\theta\rangle = m\langle -a_u\rangle$

$\cancel{m}a_u = \cancel{m}g\sin\theta + \mu_k \cancel{m}g\cos\theta$

$\boxed{a_u = g(\sin\theta + \mu_k\cos\theta)}$

descending: friction points upslope



again, $\Sigma \vec{F}_y = 0$ implies $N = mg\cos\theta$

so $\Sigma \vec{F}_x = m\vec{a}_x$ becomes:

$\langle +\mu_k mg\cos\theta\rangle + \langle -mg\sin\theta\rangle = m\langle -a_d\rangle$

$\rightarrow \boxed{a_d = g(\sin\theta - \mu_k\cos\theta)}$

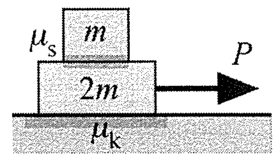
Now, invoke $a_u = 2a_d \rightarrow g(\sin\theta + \mu_k\cos\theta) = 2g(\sin\theta - \mu_k\cos\theta)$

$3\mu_k\cos\theta = \sin\theta$

$\boxed{\mu_k = \frac{1}{3}\tan\theta = 0.17}$

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.*

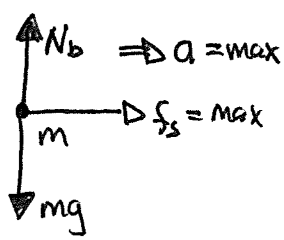
[II] *(20 points)* In the figure at right, a block of mass m rests upon a block of mass $2m$. The lower block is pulled along the ground by a horizontal force P, such that the two blocks accelerate *together* to the right. The coefficient of <u>static</u> friction between the two blocks is $\mu_s = 0.50$ and the coefficient of <u>kinetic</u> friction between the lower block and the ground is $\mu_k = 0.25$.



What is the maximum pulling force P for which block m will not slip off block $2m$ as they move? Express your answer as a multiple of mg.

① "Max pulling force" implies <u>maximum</u> possible acceleration for <u>both</u> blocks

⇒ max <u>rightward</u> accel for <u>m</u> can <u>only</u> be the result of <u>rightward</u> static friction (by 2m <u>on m</u>)



⇒ $a = \max$

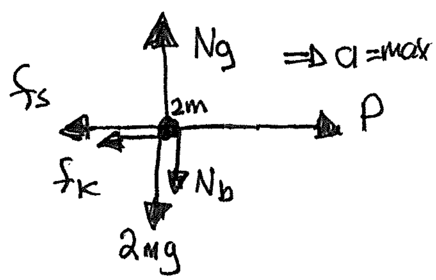
• N_b represents normal force <u>between</u> <u>blocks</u> (up on m, down on 2m)

• Max static friction means $f_s = \mu_s N_b$

$\langle +N_b \rangle + \langle -mg \rangle = 0 \rightarrow N_b = mg \rightarrow f_s = \mu_s mg$

$\langle +f_s \rangle = m\langle +a \rangle \rightarrow \mu_s mg = ma \rightarrow \boxed{a = \mu_s g = \frac{1}{2} g}$

② Apply 2nd law to 2m, to learn about P



⇒ $a = \max$

• 3rd Law: N_b pushes <u>down</u> on 2m, and static friction f_s with m pulls <u>left</u> on 2m

• N_g = normal force between 2m and ground → determines strength of kinetic friction f_k

$\Sigma F_y = 0 \rightarrow \langle +N_g \rangle + \langle -N_b \rangle + \langle -2mg \rangle = 0 \rightarrow N_g = N_b + 2mg = \underbrace{(mg)}_{\text{from above}} + 2mg$

$N_g = 3mg$, so $f_k = \mu_k N_g = \frac{1}{4}(3mg) = \frac{3}{4} mg$

$\Sigma \vec{F}_x = m\vec{a}_x \rightarrow \langle +P \rangle + \langle -f_k \rangle + \langle -f_s \rangle = (2m)\langle +a \rangle$

$P = 2ma + f_s + f_k = 2m\left(\frac{g}{2}\right) + \left(\frac{1}{2} mg\right) + \left(\frac{3}{4} mg\right)$

$= \frac{4}{4} mg + \frac{2}{4} mg + \frac{3}{4} mg$

$$\boxed{P = \frac{9}{4} mg}$$

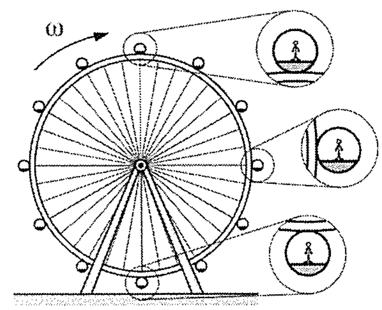
The following problem will be hand-graded. *Show all your work for this problem.* *Make no marks and leave no space on your answer card for it.*

0.026 rad/sec

[III] *(20 points)* The SkyView Atlanta ferris wheel has a radius $R = 30.5$ m. It typically rotates with an angular speed of about 0.25 rev/min ($\omega_0 =$ ~~0.262~~ rad /sec). One day, a passenger is riding the wheel when a deranged physics instructor sabotages the mechanism so that the wheel rotates at a much greater speed. The passenger—who conveniently has a metric bathroom scale in his backpack—measures his apparent weight a the top to be $W_T = 970$ N and his apparent weight at the bottom to be $W_B = 630$ N.

Construct free body diagrams for the passenger at both top and bottom, and use the Second Law to determine the true weight of the passenger (i.e. the gravitational force mg acting on him), and the new angular speed ω_f for the wheel.

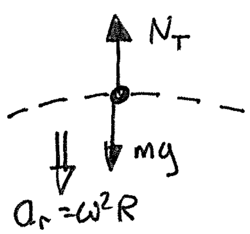
Remember—you're always rightside-up on a ferris wheel!



For circular motion using angular speed:

$$a_r = V^2/R \rightarrow a_r = \omega^2 R \quad (\text{because } \omega = V/R)$$

① At top: $\vec{N}_T$ is up, $\vec{a}_r$ is down and $|\vec{N}_T|$ generates sense of "weight" W_T

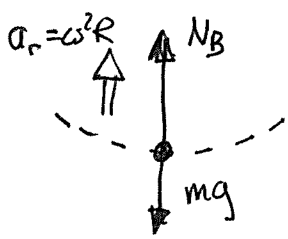


• letting down = positive

$$\langle -N_T \rangle + \langle +mg \rangle = m \langle +\omega^2 R \rangle$$

$$\rightarrow \boxed{W_T = N_T = mg - m\omega^2 R}$$

② at bottom: $\vec{N}_B$ is up, $\vec{a}_r$ is up, $|\vec{N}_B|$ is perceived as "weight" W_B



• letting up = positive

$$\langle +N_B \rangle + \langle -mg \rangle = m \langle +\omega^2 R \rangle$$

$$\boxed{W_B = N_B = mg + m\omega^2 R}$$

$$\boxed{W_T \quad = mg - m\omega^2 R} \quad (\text{from above})$$

③ Adding both equations: $W_B + W_T = 2mg \rightarrow \boxed{mg = \frac{W_B + W_T}{2} = 800\text{N}}$

④ Subtracting $\quad W_B - W_T = 2m\omega^2 R = 2mg\left(\frac{\omega^2 R}{g}\right)$

$$\omega^2 = \frac{g}{R} \cdot \frac{W_B - W_T}{2mg} = \frac{g}{R}\left(\frac{W_B - W_T}{W_B + W_T}\right)$$

$$\omega = \sqrt{\frac{g}{R}\left(\frac{W_B - W_T}{W_B + W_T}\right)} = \boxed{0.262 \text{ rad/sec}}$$

this is ≈ 10 times normal speed !!

Question value 4 points

(1) A passenger is riding a glass-walled elevator that is accelerating upward, when she passes an observer who is stationary on a nearby balcony. The passenger drops a golfball from her extended hand, and both passenger and observer record their observations. The stationary observer reports that the golf ball experienced a downward gravitational force *mg*, and an acceleration of magnitude *g*. What does the passenger report?

Her free body diagram

(a) She sees an acceleration *equal* to *g*, due to a perceived force *equal* to the ball s true weight.
(b) She sees an acceleration *less* than *g*, due to a perceived force *less* than the ball's true weight.
(c) She sees an acceleration *less* than *g*, due to a perceived force *greater* than the ball's true weight.
(d) She sees an acceleration *greater* than *g*, due to a perceived force *less* than the ball's true weight.
(e) She sees an acceleration *greater* than *g*, due to a perceived force *greater* than the ball's true weight.

If her acceleration relative to balcony is $\langle +a \rangle$, then ball's acceleration relative to her is $\vec{a}^* = \langle -g \rangle - \langle +a \rangle = \langle -(g+a) \rangle$

Question value 4 points

(2) A cannon fires a projectile *horizontally* from atop a cliff. The cannonball leaves the cannon traveling with a speed *v*, and immediately experiences a drag force of magnitude *D*. If a second cannonball is fired *vertically* from atop the cliff with a speed 2*v*, what will be the magnitude of the drag force it experiences as it leaves the cannon?

(a) D
(b) $D + mg$
(c) $4D$
(d) $D - mg$
(e) $2D$

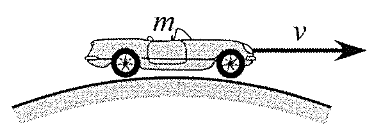
recall that drag forces are $\sim V^2$

if $V \to 2V$, $\boxed{D \to 4D}$

direction is irrelevant $\vec{D}$ is always opposite to $\vec{V}$, but direction relative to vertical does not matter

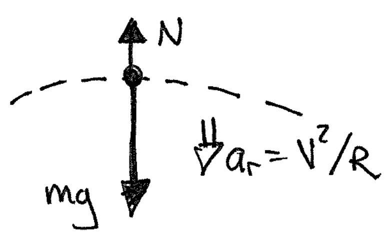
Question value 8 points

(3) When a car passes over the top of a hill at a speed of 16 m/s (36 mph or 58 kph), the 80-kg driver—who is not wearing his seatbelt—finds that he momentarily loses contact with his seat. What is the radius of curvature of the hill?



(a) 26 m
(b) 20 m
(c) 49 m
(d) 36 m
(e) 30 m

losing contact with seat: $N \to 0$



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

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

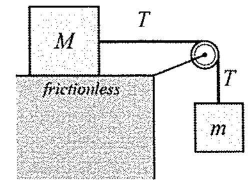
goes to zero

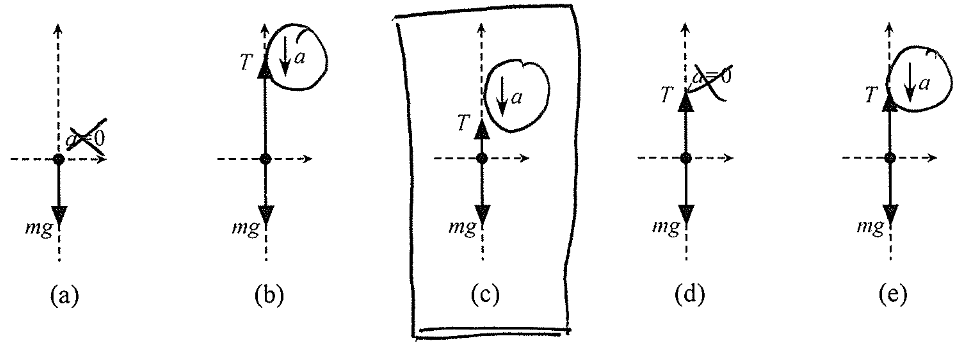
$\cancel{m}g = \frac{\cancel{m}V^2}{R}$ mass is irrelevant

$$\boxed{R = V^2/g = 26m}$$

Question value 4 points

(4) A block M is placed on a frictionless horizontal surface, and is attached via an ideal cord to a hanging mass m, where $m < M$. Which of the diagrams below *best* characterizes the free body diagram for the hanging block, when the larger block is released?





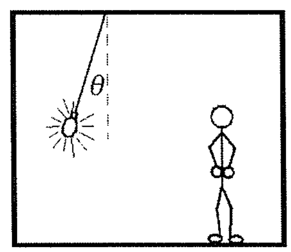
Since T pulls to the right on M, M must accelerate rightward, and hence $\boxed{\text{M must be accelerating downward}}$

by 2nd law, downward accel must be the result of net downward force

$\Rightarrow$ $\boxed{\text{upward tension must be less than downward grav. force}}$

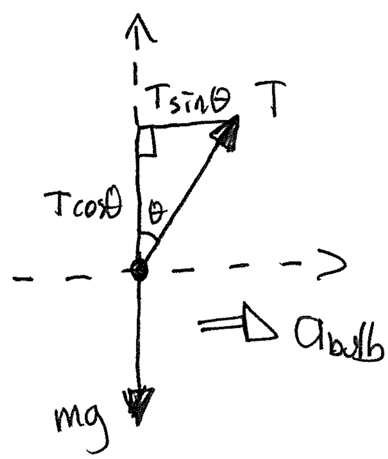
Question value 8 points

(5) You are in a closed boxcar, and cannot see your exterior surroundings. A single lighbulb hangs from the ceiling. You note that the cord, of length L = 1.25 m, is tilted at an angle of 17° to your left. What can you deduce about the state of motion of the boxcar?



(a) $\boxed{\text{The boxcar is accelerating to the right at 3.0 m/s}^2.}$
(b) The boxcar is rest.
(c) The boxcar is moving to the right at a constant speed of 1.9 m/s.
(d) The boxcar is accelerating to the left at 3.0 m/s^2.
(e) The boxcar is moving to the left at a constant speed of 1.9 m/s.

Free Body diagram for bulb:



Obviously, there is a net rightward force on bulb

$\rightarrow$ bulb accelerates to right

since bulb is not moving relative to car, $\boxed{\text{entire boxcar is accelerating to the right}}$

$\Sigma F_y = 0$

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

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

$\Sigma F_x = m\vec{a}_x$

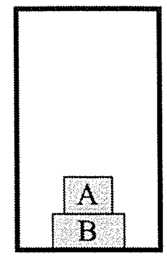
$\langle +T\sin\theta\rangle = m\langle +a\rangle$

$\dfrac{\cancel{m}g}{\cos\theta}\cdot\sin\theta = \cancel{m}a$

$\boxed{a = g\tan\theta = 2.996\ m/s^2}$ $\rightarrow$ call it $+3.0\ m/s^2$

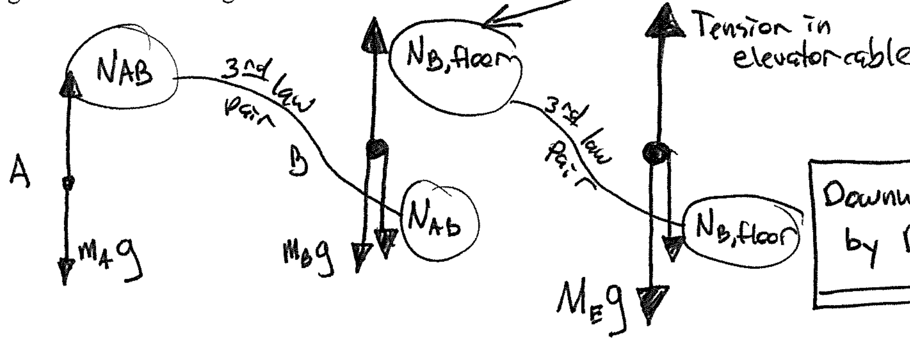
Question value 4 points

(6) Block A rest on block B, which in turn rests on the floor of an elevator that is moving downward at constant speed. What force is paired with the normal upward normal force by the floor on block B?



(a) The weight of *both* blocks A and B, acting downward on block B.
(b) The downward normal force by block B on the floor.
(c) The downward normal force by block A on block B
(d) The downward normal friction force of block A on block B.
(e) The weight of block A acting downward on block B.

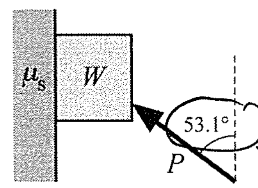
constant speed; $a=0$ for all



$\boxed{\text{Downward normal force by B on elevator floor}}$

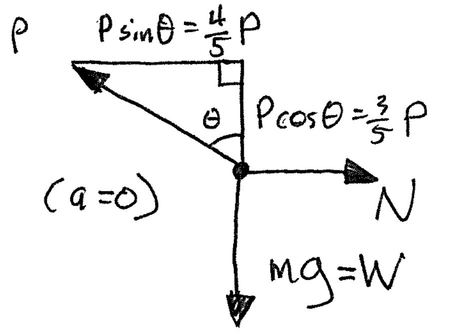
Question value 8 points

(7) A block of weight $W = 10$ N is held *stationary* against a vertical wall by a 15-N pushing force P, directed as shown at right. The coefficient of static friction between the block and wall is $\mu_s = 0.50$. What is the magnitude and direction of the friction force acting on the block?



Part of the 3-4-5 triangle!

(a) 8 N, downward
(b) 1 N, upward
(c) 4 N, upward
(d) 6 N, upward
(e) 2 N, downward



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

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

No vertical acceleration, so

$$\Sigma \vec{F}_y = 0 = \langle +P\cos\theta\rangle + \langle -mg\rangle + \vec{f}_s = 0$$

unknown magnitude and direction, at this stage

$$\Rightarrow \vec{f}_s = \langle +mg - P\cos\theta\rangle$$

$$= \langle +10N - 9N\rangle = \boxed{\langle +1N\rangle}$$

note well: f_s is not "$\mu_s N$" → we are not at upper limit of friction!