Physics 2211 B/C
Spring 2016
Exam 2

Test form **261**

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.

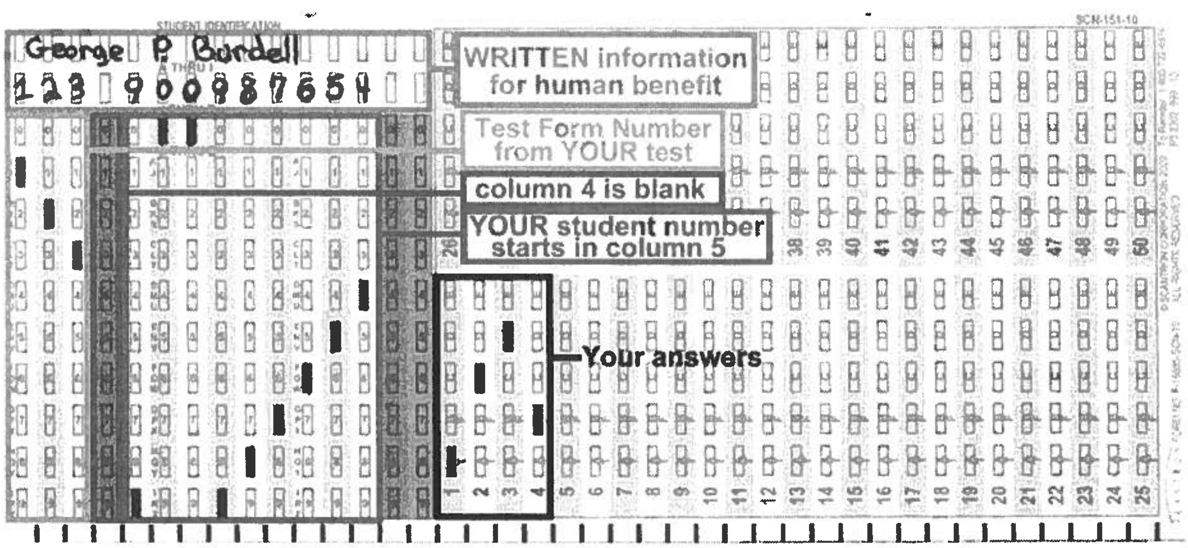
3) For each free-response question, show all relevant work supporting your answer. **Clearly box or underline your final answer.** "Correct" answers which are not supported by adequate calculations and/or reasoning will be counted wrong.

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: 262

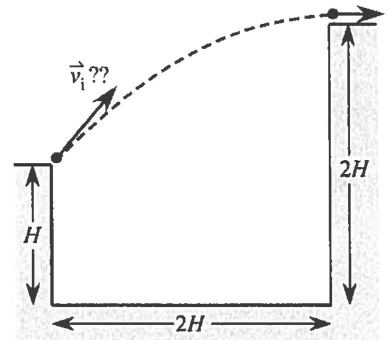


Our next test will be on Monday, March 14!

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.*

[I] *(20 points)* Lou is standing atop a cliff of height H, when he sees Hank across the canyon, atop a cliff of height $2H$. The width of the canyon is $W = 2H$, as well. Lou throws a rock at Hank, to get his attention. When the stone strikes Hank, its velocity vector is exactly <u>horizontal</u>.

What was the initial velocity vector of the thrown stone? Express the initial speed in terms of the paramenters H and g, and the initial direction as an angle above the horizontal.



① Vertical motion: Free fall

$\vec{V}_{yf} - \vec{V}_{yi} = \langle -g \rangle \Delta t$ (velocity eqn.)

$V_{yf}^2 = V_{yi}^2 + 2\langle -g \rangle \overrightarrow{\Delta y}$ (speed eqn)

ⓐ with $\vec{V}_{yf} = 0$ at apex, speed equation gives $0 = V_{yi}^2 + 2\langle -g \rangle \langle +H \rangle$

$\rightarrow V_{yi} = \sqrt{2gH}$ $\boxed{\vec{V}_{yi} = \langle +\sqrt{2gH} \rangle}$

ⓑ Knowing $\vec{V}_{yf}$ and now $\vec{V}_{yi}$, velocity equation gives time of flight

$\langle 0 \rangle - \langle +\sqrt{2gH} \rangle = \langle -g \rangle \Delta t_{TOT}$

$\hookrightarrow \boxed{\Delta t_{TOT} = \sqrt{\frac{2H}{g}}}$

② Horizontal motion: Constant velocity $\vec{V}_x$

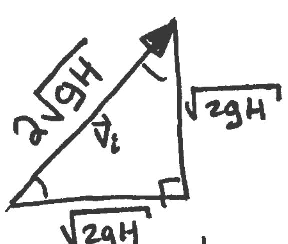
$\overrightarrow{\Delta X} = \vec{V}_x \Delta t$ (displacement eqn)

using full time of flight, we have: $\langle +2H \rangle = \vec{V}_x \Delta t_{TOT} = \vec{V}_x \sqrt{\frac{2H}{g}}$

$\rightarrow \boxed{\vec{V}_x = \langle +\sqrt{2gH} \rangle}$

③ Noting that $\vec{V}_{yi} = \vec{V}_{xi}$, it is straightforward to reconstruct $\vec{V}_i$

$\vec{V}_i = \langle +\sqrt{2gH} \rangle \hat{i} + \langle +\sqrt{2gH} \rangle \hat{j}$



$\boxed{\vec{V}_i = 2\sqrt{gH} \text{ at angle } \theta = 45^\circ \text{ above horizontal}}$

$\hookrightarrow$ 45-45-90 triangle: hypotenuse $= \sqrt{2} \times$ side

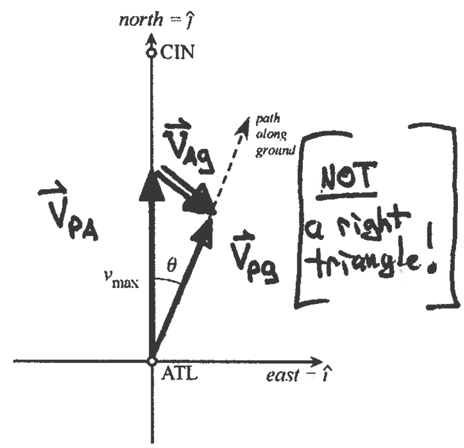
The following problem will be hand-graded. <u>*Show all your work for this problem*</u>. *Make no marks and leave no space on your answer card for it.*

[II] *(20 points)* You are the pilot of a private jet, flying due north from Atlanta to Cincinnati. You aim the nose of the plane due north and fly at full throttle, with a resulting <u>airspeed</u> v_{max}. However, your GPS receiver indicates that relative to the ground, you are actually travelling in a direction $\theta = 22°$ east of north, with a speed $0.80\, v_{max}$. You quickly deduce that you are flying through a moving airmass, and decide to correct for this crosswind by aiming a little bit to the *west* of your destination (still at maximum throttle).

Two-digit precision!

In what direction ϕ, measured west of north, should you point the plane? What will be your speed relative to the ground, expressed as a fraction of v_{max}, after you make this course correction?

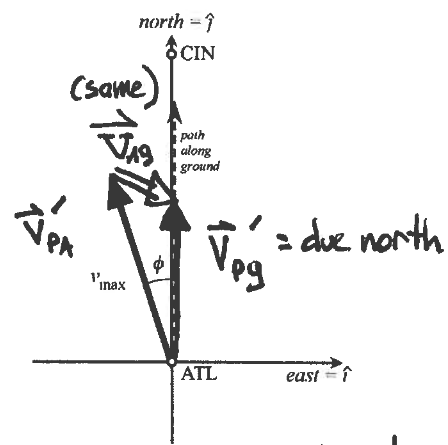
initial flight plan



note $|\vec{V}_{Pg}| < |\vec{V}_{PA}|$ → this tells us that there is a <u>headwind</u>, in addition to the crosswind

⇒ $\vec{V}_{Ag}$ has eastward <u>AND</u> southward components (<u>basic</u> vector math will confirm this)

revised flight plan



① $\vec{V}_{PA}$ = given = $\langle 0\rangle\hat{i} + \langle +V_m\rangle\hat{j}$

② $\vec{V}_{Pg}$ = given = $\langle +0.8V_m \sin 22°\rangle\hat{i} + \langle +0.8V_m \cos 22°\rangle\hat{j}$

$= \langle +0.300V_m\rangle\hat{i} + \langle +0.742V_m\rangle\hat{j}$

since $\vec{V}_{Pg} = \vec{V}_{PA} + \vec{V}_{Ag}$, we want $\vec{V}_{Ag} = \vec{V}_{Pg} - \vec{V}_{PA}$

③ $\vec{V}_{Ag} = \left[\langle +0.300V_m\rangle\hat{i} + \langle 0.742V_m\rangle\hat{j}\right] - \left[\langle +V_m\rangle\hat{j}\right]$

$\boxed{\vec{V}_{Ag} = \langle +0.300V_m\rangle\hat{i} + \langle -0.258V_m\rangle\hat{j}}$ → see? <u>Headwind</u> gusting southward

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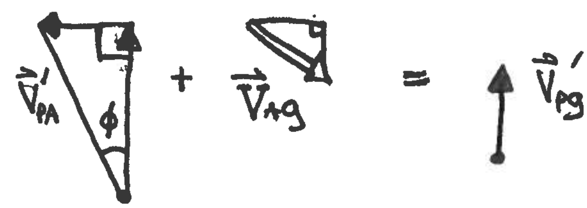
Aim <u>west</u> by angle ϕ

$\vec{V}_{PA}' = \langle -V_m \sin\phi\rangle\hat{i} + \langle +V_m \cos\phi\rangle\hat{j}$

$+\ \vec{V}_{Ag} = \langle +0.300V_m\rangle\hat{i} + \langle -0.258V_m\rangle\hat{j}$

$= \vec{V}_{Pg}' = \langle 0\rangle\hat{i} + \langle V_{ground}\rangle\hat{j}$



desired V_x to be travelling <u>due</u> north

$-V_m \sin\phi + 0.300V_m = 0$

$\sin\phi = 0.300 \rightarrow \phi = 17.44°$

rounds to $\boxed{\phi = 17°}$ (two digit precision)

↳ Speed along ground is

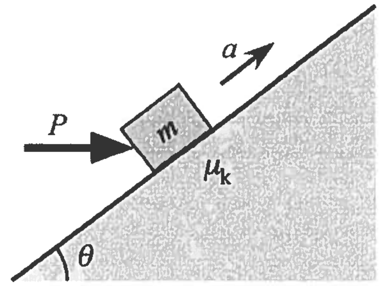
$V_{ground} = V_m \cos\phi - 0.258V_m$

$= 0.954V_m - 0.258V_m = 0.6958V_m$

rounds to $\boxed{V_{ground} = 0.70V_m}$

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 <u>horizontal</u> applied force P pushes a block of mass m up a ramp that is inclined at an angle $\theta = 36.9°$ above the horizontal. The coefficient of kinetic friction between the block and the ramp is $\mu_k = 0.40$. The block is observed to experience an upslope acceleration of magnitude $a = 0.20g$.



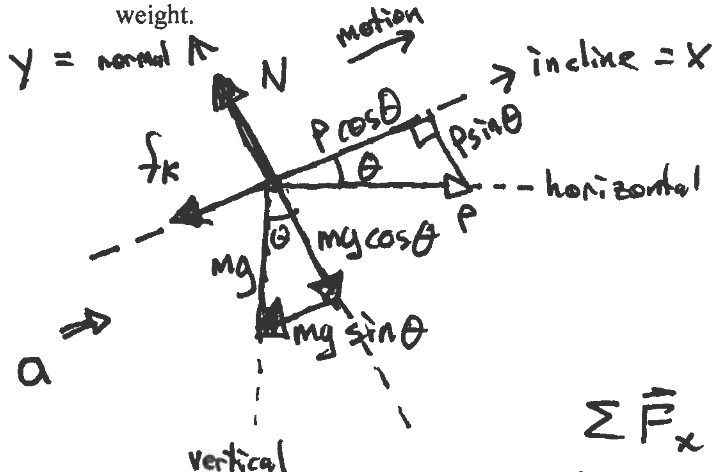
Sketch a free body diagram for the block, and identify appropriate coordinate axes. Decompose all force vectors into components and draw them. Write out Second Law equations for each component direction. (The quality of this diagram <u>will</u> be graded!)

Use your equations to find an expression for the magnitude of the pushing force P. Express your answer as a multiple of mg, the block's actual weight.

Helpful math:

$\sin(36.9°) = \frac{3}{5}$ $\quad$ $\cos(36.9°) = \frac{4}{5}$

$\mu_k = 0.40 = \frac{2}{5}$ $\quad$ $a = 0.20g = \frac{1}{5}g$



$$\Sigma \vec{F}_y = m\vec{a}_y \quad \text{(normal to surface)}$$

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

$$\boxed{N - \tfrac{3}{5}P - \tfrac{4}{5}mg = 0}$$

$$\Sigma \vec{F}_x = m\vec{a}_x \quad \text{(along ramp)}$$

$$\langle +P\cos\theta \rangle + \langle -mg\sin\theta \rangle + \langle -f_k \rangle = m\langle +a \rangle$$

$$\boxed{\tfrac{4}{5}P - \tfrac{3}{5}mg - f_k = ma}$$

① solve y-equation for N: $N = \frac{4}{5}mg + \frac{3}{5}P$

② magnitude of friction force is then $f_k = \mu_k N = \mu_k\left(\frac{4}{5}mg + \frac{3}{5}P\right)$

$$= \tfrac{8}{25}mg + \tfrac{6}{25}P \quad \left(\mu_k = \tfrac{2}{5}\right)$$

③ Plug f_k into x-equation:

$$\tfrac{4}{5}P - \tfrac{3}{5}mg - \left[\tfrac{8}{25}mg + \tfrac{6}{25}P\right] = m\left(\tfrac{1}{5}g\right)$$

$$4P - 3mg - \tfrac{8}{5}mg - \tfrac{6}{5}P = mg$$

$$\tfrac{14}{5}P = \tfrac{5}{5}mg + \tfrac{15}{5}mg + \tfrac{8}{5}mg = \tfrac{28}{5}mg$$

$$P = \tfrac{28}{14}mg = \boxed{2mg}$$

Question value 5 points

(1) A passenger is standing on a scale that has been placed on the floor of an elevator. When standing on a similar scale on the ground, the passenger reads his actual (true) weight as W. If, while on the elevator, the scale indicates that the passenger's apparent (perceived) weight is a steady 1.2W, what possible state of motion is the passenger (and elevator) experiencing?

(a) Ascending with an upward acceleration that is steadily ~~increasing in magnitude~~.
(b) Acsending while losing speed at a constant rate (downward accel)
(c) Descending with an ~~downward acceleratio~~n that is steadily ~~increasing in magnitude~~.
(d) Descending while losing speed at a constant rate.
(e) Descending while gaining speed at a ~~constant rate~~. (no accel)

N gives perception of weight, $W^* = 1.2W$

$\Uparrow a$

$W^* = 1.2W = \text{constant}$: $N = 1.2W = \text{constant}$

↳ $\Sigma\vec{F} = \text{constant}$: $\boxed{\vec{a} = \text{constant}}$

$N > W$: $\boxed{\text{upward accel}}$

↳ $\vec{V}$ = down, speed decreasing is consistent with $\vec{a}$ = upward

Question value 5 points

(2) A block is placed on the floor of a stationary elevator, and given a shove. It slides a distance *D* before stopping due to kinetic friction forces. In what way could the elevator be moving that would cause the block, given the exact same shove as before, to slide a distance greater than *D* along the elevator floor?

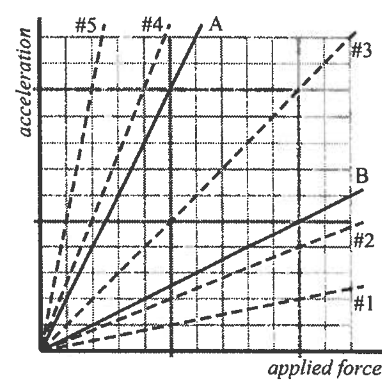
(a) Descending with an increasing speed. $\vec{a}$ = down
(b) Ascending with an increasing speed. $\vec{a}$ = up
(c) Descending with a constant speed. $\vec{a} = 0$
(d) The block will always slide the same distance *D*, regardless of the elevator's vertical motion. [Nope!]
(e) Ascending at a constant speed. $\vec{a} = 0$

greater distance → less horizontal accel
→ less kinetic friction
→ less normal force
That is, $N < mg$

→ Free-Body Diagram says:
$\boxed{\text{vertical accel must be downward}}$

Question value 5 points

(3) Blocks A and B are placed on a frictionless surface, and are subjected to horizontal applied forces of varying strength. The resulting accelerations for each block are plotted as a function of the applied force in the graph at right. If the blocks were glued together, and subjected to the same series of applied forces, what would a plot of "acceleration-vs-force" look like? [*Hint: use the grid.*]



it HAS to be one of these two

(a) Plot #5
(b) Plot #2
(c) Plot #3
(d) Plot #1
(e) Plot #4

$\vec{a} = \frac{\Sigma\vec{F}}{m}$ ⇒ acceleration graph has slope $\sim \frac{1}{m}$

From graph: Slope(B) = $\frac{1}{2}$, Slope(A) = 2

So: slope(B) = $\frac{1}{4}$ slope(A) ⟶ mass(B) = 4 mass(A)

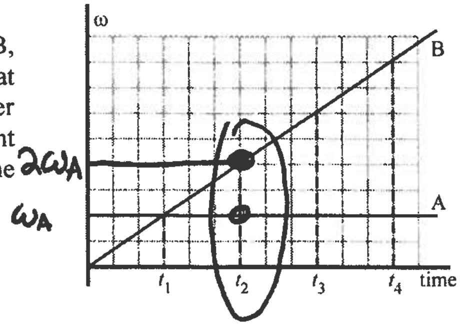
mass(B+A) = 5 mass(A)

slope(B+A) = $\frac{1}{5}$ slope(A) = $\frac{1}{5}(2)$

$\boxed{\text{slope}(B+A) = \frac{2}{5} = 0.4 \text{ — plot \#2}}$

Question value 5 points

(4) Bicycle wheel A rotates with a constant angular speed ω_A. Bicycle wheel B, beginning from rest, experiences a constant angular acceleration α_B that allows it to catch up to the first wheel after one full revolution (that is, after both have rotated through an angle $\Delta\theta_A = \Delta\theta_B = 2\pi$). The graph at right displays angular velocity versus time for both wheels. Which of the indicated times represents <u>one full revolution</u> for each wheel?



(a) At time t_4.
(b) At none of the indicated times.
$\boxed{\text{(c) At time } t_2.}$
(d) At time t_1.
(e) At time t_3.

same total

⇒ same area under each graph

A: rectangle: area = base × height(A)

B: triangle: area = $\frac{1}{2}$ base × height(B)

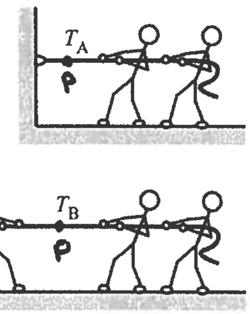
] same base, Δt

→ find time when height(A) = $\frac{1}{2}$ height(B)

$\boxed{\text{true at time } t_2}$

Question value 5 points

(5) Two American football players are in a tug-o-war competition. In case A, they pull (with all their strength) on a rope that is tied to an iron ring in a fixed wall, resulting in a tension T_A in the rope. In case B they pull (with the <u>same</u> strength) against three World football (i.e. soccer) players, who pull back, and the result is a stalemate—with neither side gaining or losing ground. What is the tension T_B in the rope in this situation, in comparison to the tension T_A?

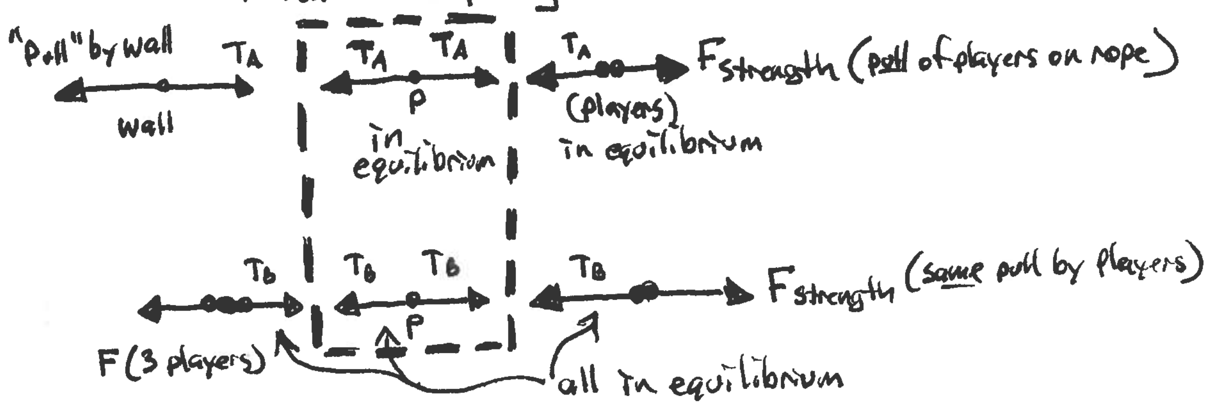


(a) $T_B = 0$
$\boxed{\text{(b) } T_B = T_A}$
(c) $T_B = \frac{5}{2} T_A$
(d) $T_B = 2\,T_A$
(e) $T_B = \frac{1}{2} T_A$

consider a point P on rope

→ in <u>both</u> cases, P is in equilibrium

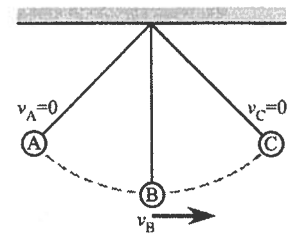
→ tension is <u>pulling</u> on P in <u>both</u> directions



As far as the <u>rope</u> is concerned, both situations are the same

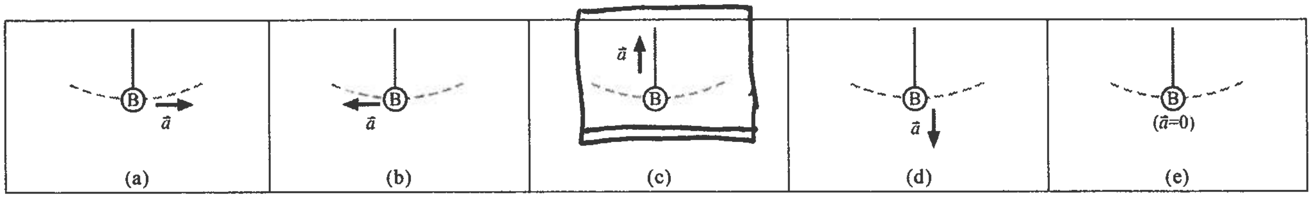
so $\boxed{T_B = T_A}$

The next two questions involve the following situation:
A pendulum swings in a vertical semicircular arc—from A, through B, to C—and then back again, in a continuous cycle. The pendulum bob is momentarily stationary at A and C, and moves with maximum speed through postion B.



Question value 5 points

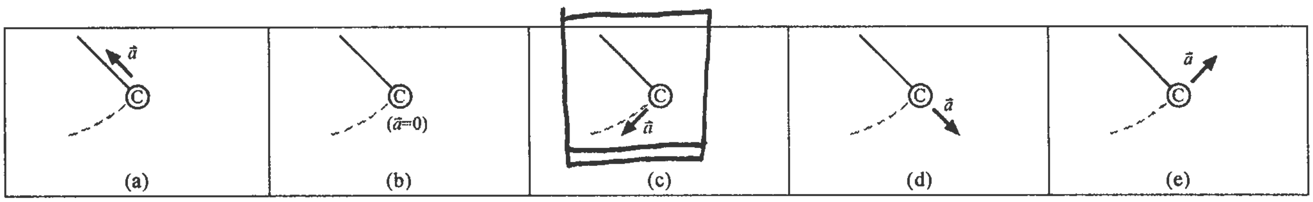
(6) Which of the figures below best characterizes the acceleration vector for the pendulum bob at position B?



V_B = horizontal = max, so no tangential/horizontal accel
but "circular (tangential) motion implies radial acceleration

Question value 5 points

(7) Which of the figures below best characterizes the acceleration vector for the pendulum bob at position C?



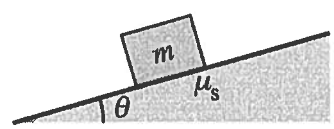
$V_c = 0 \rightarrow$ no motion means no radial accel

C is a turning point: before, $\vec{V}=$ ↗ after, $\vec{V}$ will be ↙ (down and left)

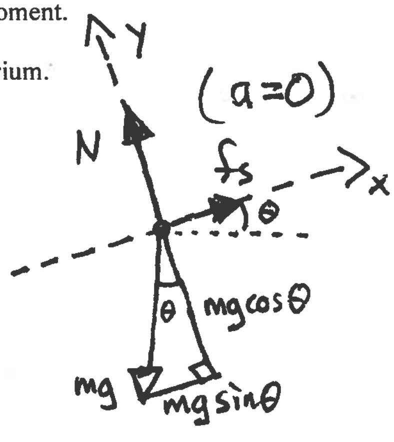
so $\vec{\Delta V} = \vec{V}_f - \vec{V}_i = (↙) - (↗) =$ ↙ so there is tangential accel

Question value 5 points

(8) A block of mass m is placed on a rough ramp that is inclined at an angle θ relative to the horizontal. The block remains at rest. What is the magntiude of the (static) friction force acting on the block at this moment.



(a) Zero, because the block is in equilibrium.
(b) $\mu_s mg \cos\theta$
(c) $mg \cos\theta$
(d) $\mu_s mg \sin\theta$
(e) $\boxed{mg \sin\theta}$



$\sum F_y = 0$ not really needed

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

$\langle +f_s \rangle + \langle -mg\sin\theta \rangle = 0$

$$\boxed{f_s = mg\sin\theta}$$

You should NOT simply assume that static friction is at its upper limit $\rightarrow f_s \leq \mu_s N$

[This is one of those situations where you don't use the equal sign!]