PHYSICS 2110 – EXAM #1

October 4, 2012

SEAT NO.____________ **NAME (PRINT)**__Key__

YOU MUST SHOW YOUR WORK AND EXPLAIN YOUR REASONING TO RECEIVE CREDIT. ALL CELL PHONES AND OTHER COMMUNICATION DEVICES MUST BE TURNED OFF AND STORED OUT OF SIGHT. NO EXTRA PAPERS ARE ALLOWED OTHER THAN THE PROVIDED FORMULA SHEET. STANDARD SCIENTIFIC CALCULATORS MAY BE USED.

You may ignore air resistance unless told otherwise.
Free-body diagrams are ***required*** for problems involving forces.

INSTRUCTORS (Circle ONE):	CLASS MEETING TIME
Shriner	8:00 AM
Kozub	9:05 AM
Kidd	10:10 AM
Kidd	11:15 AM
Murdock	12:20 PM

PROBLEM	POINT VALUE	YOUR SCORE
1	10	
2	10	
3	3	
4	2	
5	15	
6	15	
7	5	
8	10	
9	5	
10	15	
11	10	
TOTAL	100	

1. An object is observed to move along a horizontal line with position vector $\vec{r} = \left[1.0\text{ m} - 2.0\frac{\text{m}}{\text{s}}\,t + 1.2\text{ m}\,\sin\left(5\frac{1}{\text{s}}\,t\right)\right]\hat{\imath}$.

(a) Find the first time after t = 0 at which the object reverses direction. (5 pts)

Need to find t when $\vec{v} = 0$

$$\vec{v} = \frac{d\vec{r}}{dt} = \left[-2.0\,\text{m/s} + 6.0\,\text{m/s}\,\cos\left(5\tfrac{1}{s}t\right)\right]\hat{\imath} = 0 \Rightarrow$$

$$\cos\left(\tfrac{5}{s}t\right) = \frac{1.0}{3.0} \Rightarrow \tfrac{5}{s}t = 1.2 \Rightarrow t = 0.25\,s$$

(b) What is the acceleration of the object at this time? (5 pts)

$$\vec{a} = \frac{d\vec{v}}{dt} = -30\,\text{m/s}^2 \sin\left(\tfrac{5}{s}t\right)\hat{\imath}$$

$$\vec{a}(t = 0.25s) = -30\,\text{m/s}^2 \sin(5 \times 0.25)\hat{\imath} = -28\,\text{m/s}^2\,\hat{\imath}$$

2. A ball is thrown vertically into the air from the surface of the earth. The ball leaves the thrower's hand 1.90 m above the ground with a speed of 15.0 m/s. Define the positive y-direction to be upward.

(a) Determine the acceleration of the ball immediately after leaving the hand. (2 pts)

$9.80\ m/s^2$ downward (free-fall)

(b) Determine the acceleration of the ball at its highest point. (2 pts)

$9.80\ m/s^2$ downward (free-fall)

(c) The thrower is 1.74 m tall. How much time is there after the ball is released before the ball returns to the height of the top of her head? (6 pts)

$a_y = -9.80\ m/s^2$

$v_{0y} = 15.0\ m/s$

$y_0 = 1.90\ m$

When does ball reach $y = 1.74\ m$

$$y = y_0 + v_{0y}t + \frac{1}{2}a_y t^2$$

$$1.74\,m\ \cancel{1.90\,m} = 1.90\,m + 15.0\ m/s\ t + \frac{1}{2}(-9.80\ m/s^2)\,t^2$$

$$\Rightarrow -4.90t^2 + 15.0t + 0.16 = 0$$

Apply quadratic formula and choose positive root

$$t = 3.07\ s$$

3. Circle the situations in which your acceleration is not zero. (3 pts)

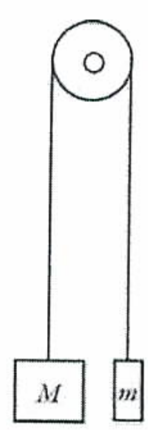
(a) you are on a merry-go-round

(b) you are in your car using cruise control on a straight and level road

(c) you are in an elevator as it is coming to a stop

(d) you are on an airplane as it is taking off

4. Two unequal masses, M and m (M>m) are connected by a light cord passing over a pulley of negligible mass, as shown in the figure. When released, the system accelerates. Friction is negligible. Circle the figure below which gives the correct free-body diagrams for the two masses in the moving system. (2 points)



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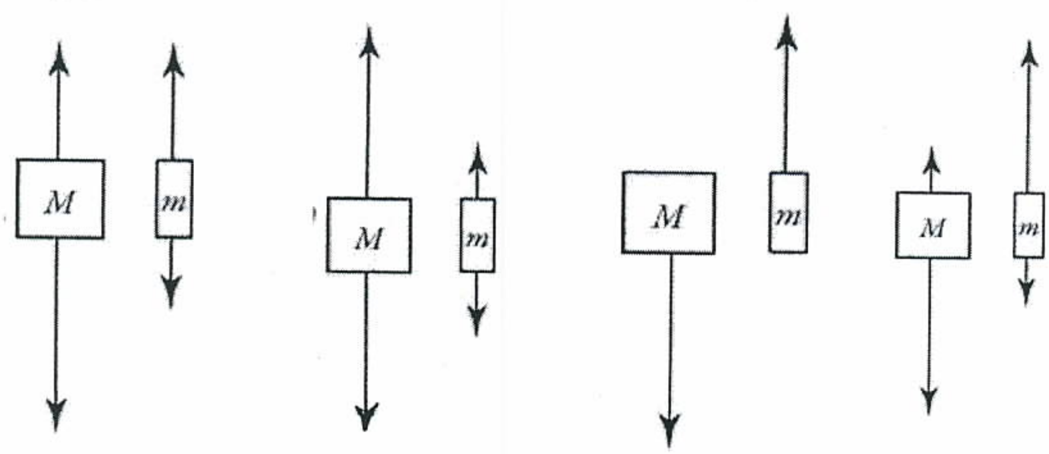


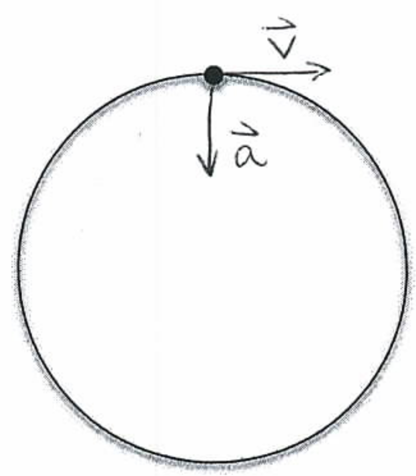
5. In each of the following situations, a dot represents the location of the object in question. Draw arrows indicating the directions of the velocity and acceleration vectors. Label clearly which arrow represents which quantity. If a vector quantity is zero, indicate that by writing $\vec{v}=\vec{0}$, for example. (3 pts each)

(a) An object is moving parallel to the horizontal direction. At this particular instant in time, it is traveling to the right and slowing down.

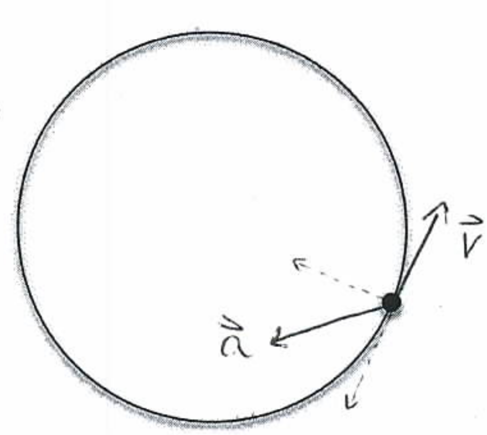
(b) An object is moving parallel to the horizontal direction. At this particular instant in time, it is traveling to the left and speeding up.

(c) An object is moving parallel to the horizontal direction. At this particular instant in time, it has reached the point where it is changing directions from moving right before this time to moving left after this time.

(d) An object is moving clockwise around the circular path shown at constant speed.

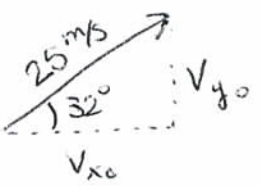


(e) An object is moving counterclockwise around the circular path shown and is slowing down.



6. An angry bird is launched from a 4.2-meter high slingshot. Its initial velocity always has a magnitude of 25 m/s, independent of the launch angle θ. The pig king is on a platform 42 m away from the slingshot and 7.3 m high.

(a) The player chooses a launch angle of 32 degrees. What are the x- and y-components of the initial velocity? (5 pts)



$V_{xo} = V_o \cos\theta$

$V_{xo} = (25\,m/s)\cos(32°)$

$= 21.2\,m/s \approx 21\,m/s$

$V_{yo} = V_o \sin\theta$

$V_{yo} = (25\,m/s)\sin(32°)$

$= 13.2\,m/s \approx 13\,m/s$

(b) Does the bird hit the pig? You may neglect air resistance. (10 points)

find the time it takes to travel 42 m.

there are multiple ways to do this!

$X_o = 0\,m$

$X_f = 42\,m$

$a_x = 0\,m/s^2$ (neglect air resistance)

$V_{ox} = 21\,m/s$

$x = x_o + V_{ox}t + \frac{1}{2}a_x t^2$

$42\,m = 0\,m + (21\,m/s)t$

$t = \frac{42\,m}{21\,m/s} = 1.98\,s \approx 2.0\,s$

find height (or y) of bird when it has reached 42 m in x.

$y_o = 4.2\,m$

$y_f = ?$

$a_y = -9.8\,m/s^2$

$V_{oy} = 13\,m/s$

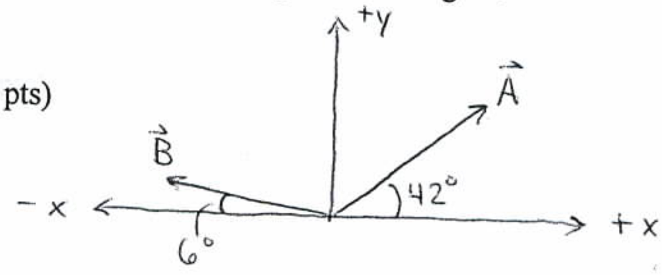
$y = y_o + V_{oy}t + \frac{1}{2}a_y t^2$

$= 4.2\,m + (13\,m/s)(2.0\,s) + \frac{1}{2}(-9.8\,m/s^2)(2.0\,s)^2$

$= \cancel{10.4\,m}$ $10.6\,m$

for the bird to hit pig, y would need to be 7.3 m, so the bird misses the pig.

7. Vector $\vec{A}$ has magnitude of 4.5 m at an angle of 42 degrees measured counterclockwise from the +x-axis. Vector $\vec{B}$ has a magnitude of 5.2 m at an angle of 6.0 degrees measured clockwise from the –x-axis.



(a) Write $\vec{A}$ and $\vec{B}$ in unit vector notation. (3 pts)

$A_x = A\cos\theta$
$= (4.5\,m)\cos(42°)$
$= 3.3\,m$

$A_y = A\sin\theta$
$= (4.5\,m)\sin(42°)$
$= 3.0\,m$

$\vec{A} = (3.3\,m)\hat{i} + (3.0\,m)\hat{j}$

$B_x = B\cos\theta$
$= (5.2\,m)\cos(174°)$
$= -5.2\,m$

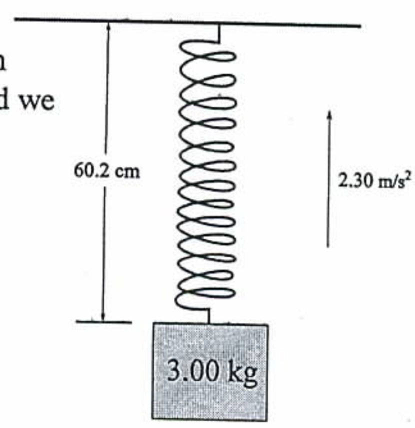
$B_y = B\sin\theta$
$= (5.2\,m)\sin(174°)$
$= 0.54\,m$

$\vec{B} = (-5.2\,m)\hat{i} + (0.54\,m)\hat{j}$

(b) What is $\vec{A} + \vec{B}$ in unit vector notation? (Show your work!) (2 pts)

$\vec{A} + \vec{B} = (3.3\,m + (-5.2\,m))\hat{i} + (3.0\,m + 0.54\,m)\hat{j}$
$= (-1.9\,m)\hat{i} + (3.5\,m)\hat{j}$

8. A 3.00 kg mass hangs from an ideal spring inside an elevator car. The spring has a normal (non-deformed) length of 55.0 cm but when the car is accelerating at 2.30 $\frac{m}{s^2}$ upward we observe that it has a length of 60.2 cm.

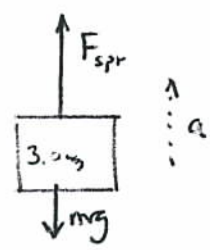


(a) What is the force constant k of the spring? (6 pts)

From force diagram,

$F_{spr} - mg = ma$ w/ $a = +2.30\,\frac{m}{s^2}$

$F_{spr} = mg + ma = m(g+a) = (3.00\,kg)(12.1\,\frac{m}{s^2})$
$= 36.3\,N$



$|F_{spr}| = k|x| \rightarrow k(60.2\,cm - 55.0\,cm) = k(5.2\,cm)$

$\Rightarrow k = \frac{36.3\,N}{0.052\,m} = \boxed{7.0\times10^2\,\frac{N}{m}}$

(b) When the elevator car is accelerating at 3.00 $\frac{m}{s^2}$ downward, what is the (total) length of the spring? (4 pts)

Then $a = -3.00\,\frac{m}{s^2}$, so

$F_{spr} = m(g+a) = (3.00\,kg)(9.80\,\frac{m}{s^2} - 3.00\,\frac{m}{s^2}) = 20.4\,N$

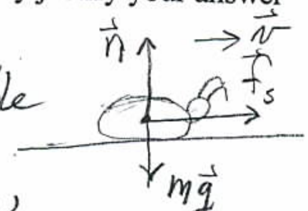
From $|F_{spr}| = k|x|$ the springs extension (it still pulls up) is

$|x| = F_{spr}/k = \frac{20.4\,N}{7.0\times10^2\,\frac{N}{m}} = 2.9\times10^{-2}\,m$

so the total length of the spring is

$L = 55.0\,cm + 2.9\,cm = \boxed{57.9\,cm}$

9. Insain Nut, the racing cockroach, is training for the Insect Olympics. The coefficients of static and kinetic friction between his feet and the racing surface are 0.75 and 0.50, respectively. His trainers are told by a breakfast food salesman that if Insain eats Wheaties for a week, he will be able to run 1.00-m, starting from rest, in less than 0.50 s. Can the salesman be trusted? Why or why not? You must fully justify your answer using physics. (5 pts) $a_y = 0 \Rightarrow n = mg$

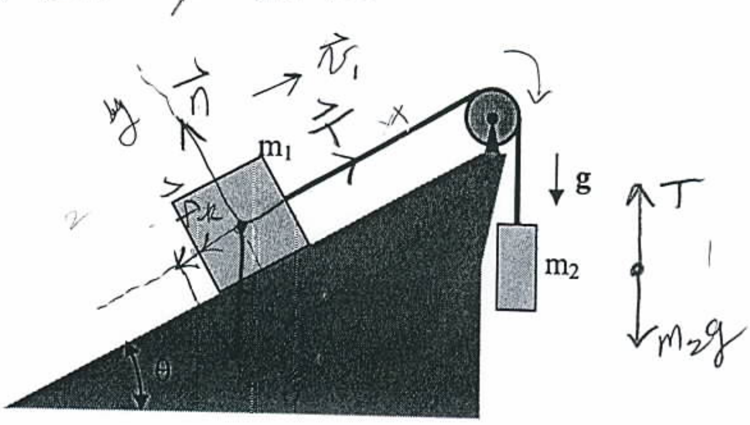


The maximum acceleration possible is $a = \frac{f_{s\,max}}{m} = \frac{\mu_s n}{m} = \frac{\mu_s mg}{m} = \mu_s g$,

so if this acceleration is sustained for the entire distance, $x = \frac{1}{2}at^2$ (starting from rest), and

$t = \sqrt{\frac{2x}{\mu_s g}} = \sqrt{\frac{2(1.00\,m)}{0.75(9.8\,\frac{m}{s^2})}} = 0.52\,s > 0.50\,s$, so the salesman cannot be trusted. Insain's strength is not the issue.

10. In the system shown, m_1=10.0 kg, m_2=3.00 kg, and θ=35.0°. The coefficients of friction between m_1 and the incline are μ_s=0.400 and μ_k=0.250. Assume the rope is massless and the pulley has neither mass nor friction.



(a) Calculate the tension in the rope, assuming m_1 is moving up the incline initially. (10 pts)

1 m_1: $\Sigma F_y = 0 \Rightarrow n = m_1 g\cos\theta$

$\Sigma F_x = T - m_1 g\sin\theta - f_k = m_1 a_x$; $f_k = \mu_k n = \mu_k m g\cos\theta$ 1

2 ① $m_1 g\sin\theta + \mu_k m_1 g\cos\theta = T - m_1 a_x$

2 m_2: $m_2 g - T = m_2 a_x \Rightarrow a_x = \frac{m_2 g - T}{m_2} \Rightarrow$ ① becomes

$m_1 g\sin\theta + \mu_k m_1 g\cos\theta = T - \frac{m_1(m_2 g - T)}{m_2} = T\left(1 + \frac{m_1}{m_2}\right) - m_1 g$

$T = \frac{m_1 g(\sin\theta + \mu_k\cos\theta + 1)}{1 + \frac{m_1}{m_2}} = \frac{10\,kg(9.8\,\frac{m}{s^2})(\sin 35° + 0.25\cos 35° + 1)}{1 + \frac{10}{3}}$

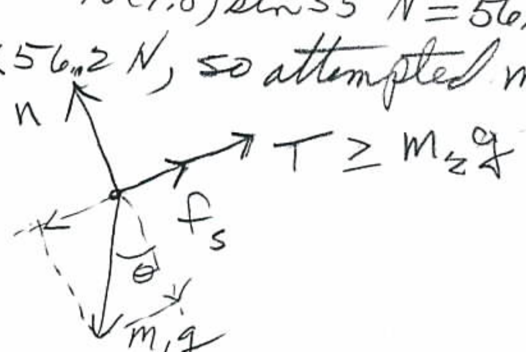
$T = 40.2\,N$

(b) Calculate the acceleration, assuming m_1 is initially at rest. (5 pts)

At rest ⇒ friction force is initially f_s, but which way? $m_1 g\sin\theta = 10(9.8)\sin 35°\,N = 56.2\,N$

$m_2 g = 3(9.8) = 29.4\,N < 56.2\,N$, so attempted motion is down the incline.

Can f_s hold it?



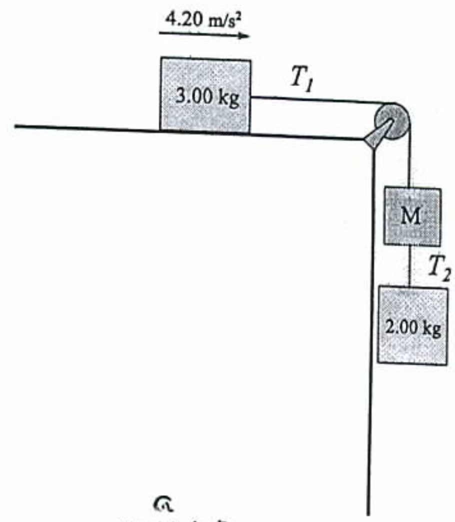
$T + f_{s\,max} = T + \mu_s m_1 g\cos\theta$

$= 29.4\,N + 0.4(10)(9.8)\cos 35°\,N = 61.5\,N > m_1 g\sin\theta = 56.2\,N$

so yes f_s holds, and $a = 0$ (it will not move).

11. Three masses are connected by two strings as shown: A 3.00-kg mass sliding on a frictionless table is connected by a string which runs over an ideal pulley to a mass M, from which is suspended a 2.00 kg mass as shown. All strings can be treated as massless.

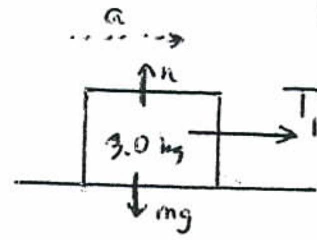
When the masses are released, their accelerations have magnitude $4.20\frac{m}{s^2}$.



(a) What is the tension in the first (topmost) string? (3 pts)

Newton's 2nd law gives

$$T_1 = (3.00\text{ kg})\,a = (3.00\text{ kg})(4.20\tfrac{m}{s^2})$$
$$= \boxed{12.6\text{ N}}$$

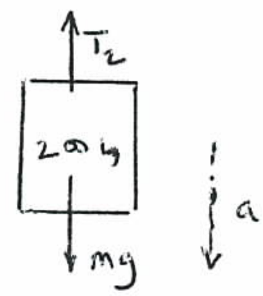


(b) What is the tension in the string which connects the hanging masses? (4 pts)

Look at downward forces acting on 2.00 kg mass:

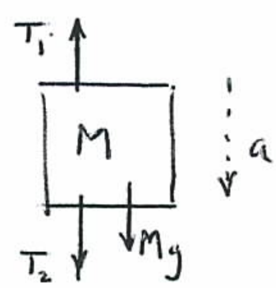
$$mg - T_2 = ma, \quad \text{w/} \quad a = +4.20\,m/s^2$$

$$T_2 = mg - ma = m(g-a)$$
$$= (2.00\text{ kg})(9.80\tfrac{m}{s^2} - 4.20\tfrac{m}{s^2}) = \boxed{11.2\text{ N}}$$



(c) What is the value of M? (3 pts)

Force diagram for M; adding up the downward forces on M gives



$$T_2 + Mg - T_1 = Ma$$

$$M(g-a) = T_1 - T_2$$

$$M = \frac{T_1 - T_2}{(g-a)} = \frac{(12.6\text{ N} - 11.2\text{ N})}{(9.8\frac{m}{s^2} - 4.2\frac{m}{s^2})} = \boxed{0.25\text{ kg}}$$