KEY

PHYSICS 2110 – EXAM #2
November 10, 2011

SEAT NO.______________ **NAME (PRINT)**__________________________

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.

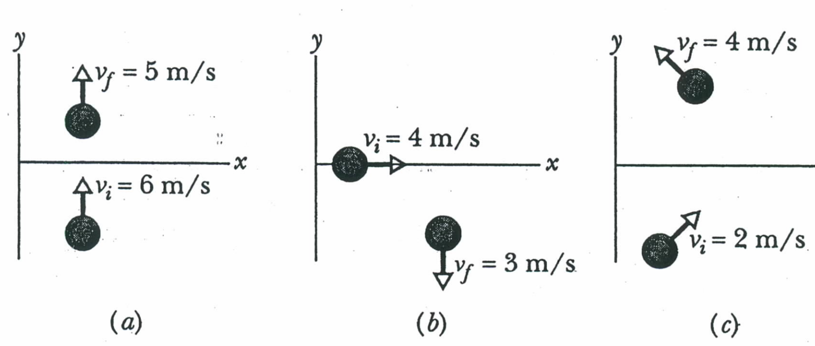
Free-body diagrams are ***required*** for problems involving forces.

INSTRUCTORS (Circle ONE):	CLASS MEETING TIME
Shriner	8:00 AM
Kozub	9:05 AM
Ayik	10:10 AM
Murdock	1:15 PM

PROBLEM	POINT VALUE	YOUR SCORE
1	6	
2	10	
3	9	
4	7	
5	8	
6	10	
7	6	
8	25	
9	6	
10	13	
TOTAL	100	

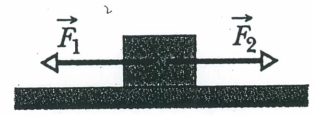
1.

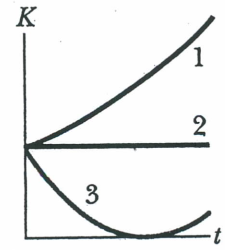
(a) In three situations, a briefly applied horizontal force changes the velocity of a hockey puck that slides over frictionless ice. The overhead views indicate, for each situation, the puck's initial speed v_i, its final speed v_f and the directions of the corresponding velocity vectors. Rank the situations according to the work done on the puck by the applied force, from most positive to most negative. (3 pts)



c, b, a

(b) The upper figure to the right shows two horizontal forces that act on a block that is sliding to the right across a frictionless floor. The lower figure shows three plots of the block's kinetic energy K versus time t. Which of the plots best corresponds to the following three situations? (3 pts)



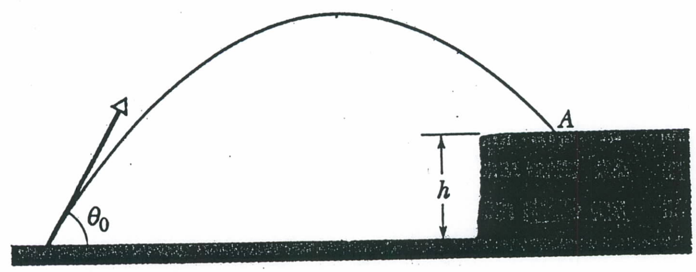


(i) $F_1 = F_2$ 2

(ii) $F_1 > F_2$ 3

(iii) $F_1 < F_2$ 1

2. A ball of mass m = 2.00 kg is thrown into the air with an initial speed $v_0 = 20.0$ m/s. The speed of the ball just before it lands at a point A on the roof of a building is v = 15.0 m/s. The height of the roof from the ground is h = 5.00 m. The influence of air drag on the motion of ball is not negligible.



(a) How much work is done by gravity on the ball during the flight? (4 pts)

$$W_g = m\vec{g}\cdot\vec{d}$$
$$= -(2)(9.8)(5) = \boxed{-98.0\,J}$$

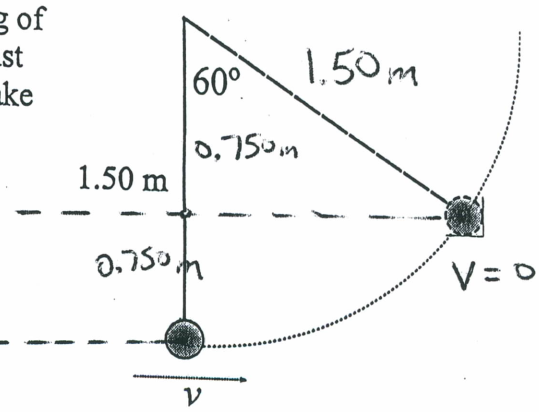
(b) How much work is done by air drag on the ball during the flight? (6 pts)

$$W_{net} = W_g + W_a = K_f - K_i$$
$$W_a = -W_g + K_f - K_i$$
$$W_a = 98 + \tfrac{1}{2}(2)(225) - \tfrac{1}{2}(2)(400) = \boxed{-77.0\,J}$$

3. A machine carries an m = 4.0 kg load from an initial position of $\vec{d}_i = (0.5\hat{\imath} + 1.5\hat{\jmath} + 0.2\hat{k})\ m$ to a final position of $\vec{d}_f = (7.5\hat{\imath} + 6.5\hat{\jmath} + 7.2\hat{k})\ m$ over a time interval of $t = 10.$ seconds. The constant force applied by the machine on the load is $\vec{F} = (0.5\hat{\imath} + 1.5\hat{\jmath} + 0.2\hat{k})\ N$. Calculate the average power supplied by the machine on the load during the time interval. (9 pts)

$$\vec{d} = \vec{d}_f - \vec{d}_i = 7.0\vec{i} + 5.0\vec{j} + 7.0\vec{k}$$
$$W = \vec{F}\cdot\vec{d} = (0.5\vec{i} + 1.5\vec{j} + 0.2\vec{k})\cdot$$
$$(7.0\vec{i} + 5.0\vec{j} + 7.0\vec{k})$$
$$W = 3.5 + 7.5 + 1.4 = 12.4\ J$$
$$P = \frac{W}{t} = \frac{12.4}{10} = \boxed{1.2\ W}$$

4. A small 0.600 kg mass swings on the end of a light string of length 1.50 m. What is the minimum speed the mass must have at the bottom of the swing so that the string will make a maximum angle of 60.0° with the vertical? (7 pts)



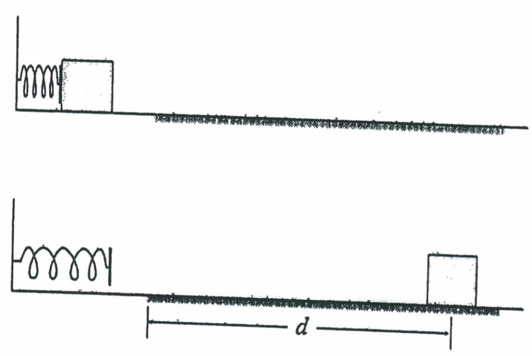
From geometry the mass in the final position has height 0.750 m above the starting position. No friction forces here; mechanical energy is conserved. This gives

$$\frac{1}{2}mv^2 = mgh \Longrightarrow v^2 = 2gh = 2(9.80\,\tfrac{m}{s^2})(0.750\,m)$$

$$= 14.7\,\tfrac{m^2}{s^2}$$

$$\longrightarrow \boxed{v = 3.83\,\tfrac{m}{s}}$$

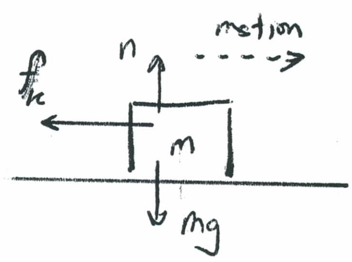
5. A spring of constant 3500 N/m is used to launch a 2.00 kg mass along a smooth horizontal table which has a long rough part whose coefficient of sliding friction is 0.300. If the block slides 2.30 m along the rough surface, by how much was the spring compressed? (8 pts)



Magnitude of force of kinetic friction is

$$f_k = \mu n = \mu mg$$

and it opposes the motion; the work done by friction is



$$W_{fric} = (\mu mg)(d)(-1) = -\mu mgd$$

The change in mechanical energy is

$$\Delta E = 0 - \frac{1}{2}kx^2 = W_{fric} = -\mu mgd$$

Then

$$x^2 = \frac{2\mu mgd}{k} = \frac{2(0.300)(2.00\,kg)(9.80\,\tfrac{m}{s^2})(2.30\,m)}{(3500\,\tfrac{N}{m})}$$

$$= 7.72 \times 10^{-3}\,m^2$$

$$\longrightarrow x = 8.8 \times 10^{-2}\,m = \boxed{8.8\,cm}$$

6. A particle moving in one dimension with total energy 13.00 J is trapped in a potential well described by

$$U(x) = (4.00\,\frac{\text{J}}{\text{m}^2})\,x^2 - 3.00\text{ J}$$

a) What is the kinetic energy of the particle when it is at x = 0.0 m ? (3 pts)

At $x = 0.0\,m$, $U = -3.00\,J$ and $U + K = E = 13.0\,J$

so $K = E - U = 13\,J - (-3\,J) = \boxed{16.0\,J}$

b) What is the force on the particle at x= +1.00 m? (4 pts)

$F_x = -\frac{dU}{dx} = -2\,(4.00\,\frac{J}{m^2})\,x = (-8.00\,\frac{J}{m^2})(x)$

t $x = 1.00\,m$; $F_x = (-8.00\,\frac{J}{m^2})(1.00\,m) = \boxed{-8.00\,N}$

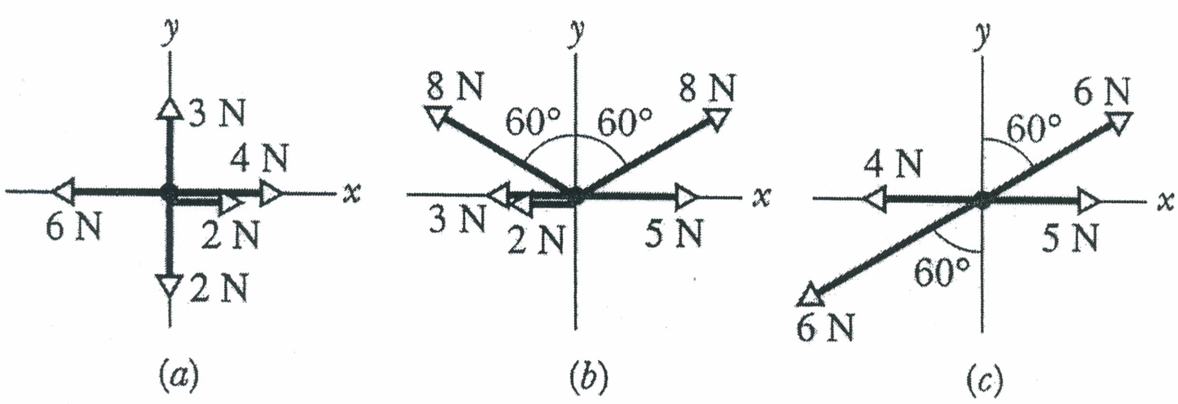
c) At what points does the particle reverse direction, i.e. what are its "turning points"? (3 pts)

This is where $K = 0$ or $U = E = 13.0\,J$, or

$13.0\,J = 4x^2 - 3.00\,J \rightarrow (4.00\,\frac{J}{m^2})\,x^2 = 16.0\,J$

$\rightarrow x^2 = 4.00\,m^2 \Rightarrow \boxed{x = \pm 2.00\,m}$

7. The free-body diagrams in the figure below show (from an overhead view) the horizontal forces acting on three boxes of chocolate as the boxes move over a frictionless counter. For each box, determine whether its momentum is conserved or not conserved. An explanation of your reasoning is required. (6 pts)



Momentum is conserved when $\Sigma\vec{F}_{ext} = 0$. So is $\Sigma\vec{F}_{ext} = 0$ in each case?

a) no

b) no

c) no

8. Pickup truck A (M_A=2500. kg, including driver) is traveling in an easterly (+x) direction at a speed of 20.0 m/s along a country road. Pickup truck B (M_B=1800. kg, including driver) is traveling in a westerly (-x) direction with a speed of 12.0 m/s. Since both are straddling the centerline of the road, they collide head-on at the top of a hill. Truck A has a velocity of 5.00 m/s east immediately after the collision.

(a) Calculate the velocity of the center of mass of the two-truck system before the collision. (5 pts)

$$\vec{v}_{CM} = \frac{m_A\vec{v}_A + m_B\vec{v}_B}{m_A+m_B} = \frac{(2500\,kg)(20\hat{i}\,\frac{m}{s}) - (1800\,kg)(12\hat{i}\,\frac{m}{s})}{4300\,kg}$$

$$\vec{v}_{CM} = 6.60\,m/s\,\hat{i}\ (East)$$

(b) Calculate the velocity of truck B immediately after the collision. (5 pts)

$$\vec{P}_i = \vec{P}_f$$

$$m_A\vec{v}_A + m_B\vec{v}_B = m_A\vec{v}_A{}' + m_B\vec{v}_B{}'$$

$$[2500(20\hat{i}) + (1800)(-12\hat{i})]\frac{kg\,m}{s} = 2500\,kg(5\hat{i}\,\frac{m}{s}) + 1800\,kg\,\vec{v}_B{}'$$

$$\vec{v}_B{}' = \frac{2500(20) - 1800(12) - 2500(5)}{1800}\hat{i}\,\frac{m}{s} = 8.83\frac{m}{s}\hat{i}\ (East)$$

(c) Determine the velocity of the center of mass of the two-truck system immediately *after* the collision. You must explain your answer! (3 pts)

$$\vec{F}_{net} \simeq 0,\ so\ \vec{a}_{CM} \simeq 0,\ so\ \vec{v}_{CM} \simeq const. \Rightarrow \vec{v}_{CM}{}' = \vec{v}_{CM} = 6.60\,m/s\,\hat{i}\ (East)$$

check: $\vec{v}_{CM}{}' = \frac{M_A\vec{v}_A{}' + M_B\vec{v}_B{}'}{M_A+M_B} = \frac{2500(5\hat{i}) + 1800(8.83\hat{i})}{4300}\frac{m}{s} = 6.60\frac{m}{s}\hat{i}$ ✓

(d) The driver of truck A has a mass of 85.0 kg. If the duration of the collision is 0.100 s, what is the magnitude of the average force on this driver during the collision, assuming he stays inside the truck? Compare this force to the weight of his vehicle (truck A). (5 pts)

$$\vec{F}_{Ave}\Delta t = \vec{J} = \Delta\vec{p} = \vec{P}_f - \vec{P}_i = m(\vec{v}_A{}' - \vec{v}_A)$$

$$|\vec{F}_{Ave}| = \left|\frac{85.0\,kg(5\,m/s\,\hat{i} - 20\frac{m}{s}\hat{i})}{0.100\,s}\right| = 12{,}800\,N$$

Weight of truck: $M_A g = (2415\,kg)(9.80\frac{m}{s^2}) = 23{,}700\,N$, so $|\vec{F}_{ave}| \sim \frac{M_A g}{2}$ (even worse for driver B)

(e) Define what is meant by an elastic collision, and determine (or show/explain how you could determine) whether or not this collision was elastic. (7 pts)

An elastic collision is one in which the total kinetic energy is conserved.

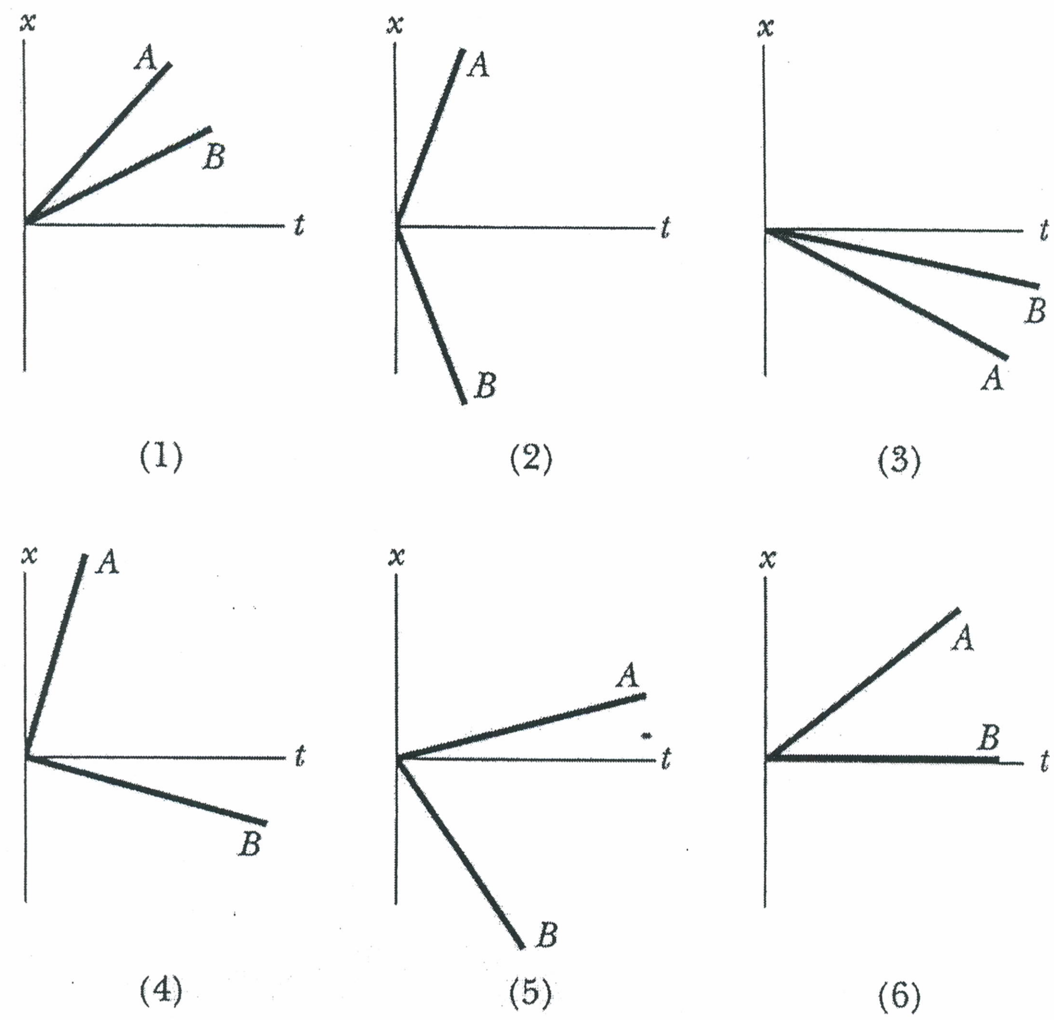
Here, $K_i = \frac{1}{2}m_A v_A^2 + \frac{1}{2}m_B v_B^2 = \frac{1}{2}[2500(20)^2 + 1800(12)^2]\,J$

$K_i = 630{,}000\,J$

$K_f = \frac{1}{2}m_A v_A'^2 + \frac{1}{2}m_B v_B'^2 = \frac{1}{2}[2500(5)^2 + 1800(8.83)^2]\,J$

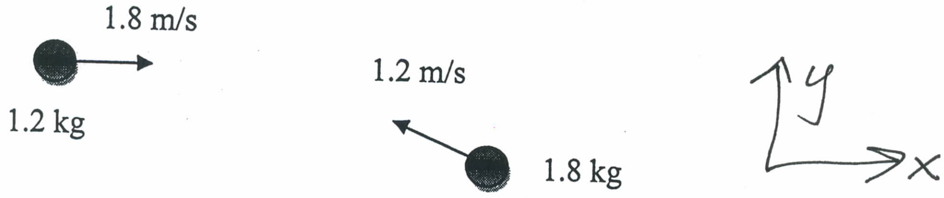
$K_f = 101{,}000\,J \neq K_i$, so it's inelastic.

9. An initially stationary object on a frictionless horizontal floor explodes into two pieces A and B with masses m_A and m_B, respectively. Suggested graphs of **position** vs. **time** for the two pieces are given in the figure below. For each graph, identify whether it describes a physically possible explosion or not. An explanation of your reasoning is required. (6 pts)



Momentum conserved in collision. $\vec{P}_{before} = 0$ so $\vec{P}_{after} = 0$. That can ~~be~~ only true if the objects go in opposite directions. Graphs that show the objects going in opposite directions are (2), (4), (5).

10. Two objects of masses 1.2 kg and 1.8 kg move toward each other on a frictionless horizontal surface as shown with speeds 1.8 m/s and 1.2 m/s, respectively. The 1.8 kg object travels at an angle that is 32° above horizontal.



The two objects collide. After the collision the 1.2 kg object is traveling with a speed of 1.5 m/s at an angle of 41° above horizontal to the right. Find the velocity of the 1.8 kg object after the collision. (13 pts)

Momentum is conserved during collision

So $(1.2\,kg)(1.8\,m/s)\hat{i} + (1.8\,kg)(-1.2\,m/s \cos 32^\circ \hat{i} + 1.2\,m/s \sin 32^\circ \hat{j})$

$= (1.2\,kg)(1.5\,m/s \cos 41^\circ \hat{i} + 1.5\,m/s \sin 41^\circ \hat{j}) + (1.8\,kg)\vec{v}_f$

$\Rightarrow \vec{v}_f = [-0.57\hat{i} - 0.020\hat{j}]\ m/s$