Name *Key* Seat Number ____________

PHYSICS 2110
Exam II – Spring 2010

INSTRUCTORS (Circle ONE): CLASS MEETING TIME
Shriner 8:00 AM
Ayik 10:10 AM
Murdock 11:15 AM

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.

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

PROBLEM	POINT VALUE	YOUR SCORE
1	14	
2	21	
3	10	
4	10	
5	12	
6	5	
7	8	
8	8	
9	12	
TOTAL	100	

1. A 3.0 kg particle starts from rest at x = 0.50 m and moves along the x-axis under the influence of two forces, the force of air resistance and an applied force given by $F_x = 6.0 + 4.0x - 2.0x^2$ (F_x is in newtons and x is in meters).

(a) What are the units of the quantity "-2.0"? (2 pts)

N/m^2

(b) Find the work done by this force as the particle moves from x = 0.50 m to x = 3.0 m. (6 pts)

$$W = \int \vec{F}\cdot d\vec{r} = \int_{0.5m}^{3.0m} F_x\,dx = \left[\int_{0.5}^{3}(6.0+4.0x-2.0x^2)\,dx\right] J$$

$$= \left[6x + 2x^2 - \tfrac{2}{3}x^3\right]_{0.5}^{3} J = 15\ J$$

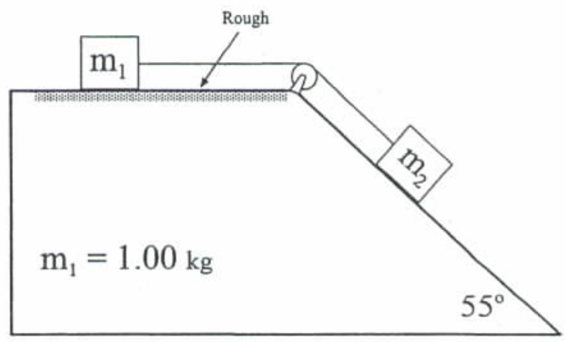
(c) If the particle reaches x = 3.0 m with a velocity $\vec{v} = 1.1\frac{m}{s}\hat{\imath}$, how much work was done by the force of air resistance during its journey? (6 pts)

$$W_{net} = \Delta K$$

$$W_{net} = W_{F_x} + W_{air} = 15\ J + W_{air} = \tfrac{1}{2}(3.0kg)(1.1 m/s)^2 - 0$$

$$\Rightarrow W_{air} = -13\ J$$

2. Two masses are joined by a massless string which runs over a massless, ideal pulley. One mass (1.00 kg) slides on a rough horizontal surface while the other slides on a frictionless 55.0° slope. The device is diagrammed at the right.



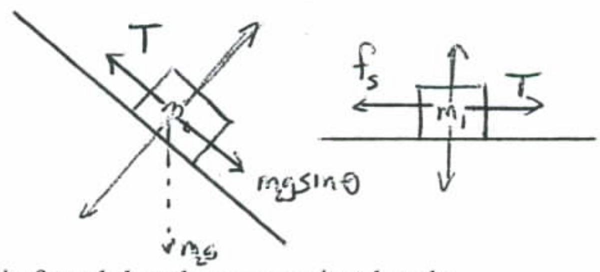
a) When m_2 is 0.200 kg and the masses are released, the masses remain at rest. In this situation, what is the magnitude of the friction force which acts on m_1? (5 pts)

Forces on masses all "cancel":

$T = m_2 g \sin\theta = 1.61\ N$

$T = f_s = 1.61\ N$

Friction force (static) on m_1 is $\boxed{1.61\ N}$



b) When m_2 is 0.300 kg and the masses are released, it is found that the masses just barely start to move. What is the coefficient of static friction for the horizontal surface and m_1? (6 pts)

When this occurs $T = m_2 g \sin\theta = 2.41\ N$ and f_s has its max. value, $f_s = \mu_s n = \mu_s mg = T$. Then

$$\mu_s = \frac{T}{mg} = \frac{2.41\ N}{(1.00\ kg)(9.80\ \frac{m}{s^2})} = \boxed{0.246}$$

c) When m_2 is 0.500 kg and the masses are released, it is found that the masses move with acceleration $0.700 \frac{m}{s^2}$. Find the tension in the string for this situation. (4)

Now N's 2nd law applied to m_2 (+ dir down slope) give

$m_2 g \sin\theta - T = m_2 a \implies T = m_2(g \sin\theta - a)$

$T = (0.500\ kg)(9.8\ \frac{m}{s^2} \sin 55° - 0.700\ \frac{m}{s^2}) = \boxed{3.66\ N}$

d) Find the coefficient of kinetic friction for the horizontal surface and m_1. (6)

Apply N's 2nd law to m_1; opposing force of kinetic friction is $f_k = \mu_k n = \mu_k m_1 g$, so

$T - \mu_k m_1 g = m_1 a$ Solve for μ_k:

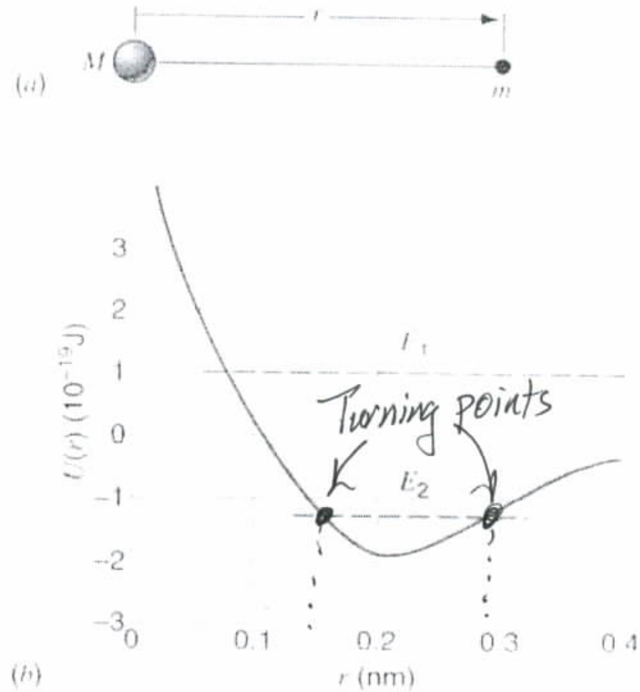
$$\mu_k = \frac{T - m_1 a}{m_1 g} = \frac{3.66\ N - (1\ kg)(0.700\ \frac{m}{s^2})}{(1\ kg)(9.8\ \frac{m}{s^2})} = \boxed{0.302}$$

[Mea Culpa: These answers are physically implausible because μ_k really has to be less than μ_s; I goofed when setting up the numbers! However parts (c) and (d) are independent of (a) and (b).]

3. As shown in figure (a), we have two atoms of masses M and m. Mass M is fixed so that it cannot move. The other atom can move, and it sees a force from mass M which has the potential energy function shown in figure (b).

(a) If mass m has mechanical energy E_2, mark on the graph any turning points that will occur as it moves. Describe its motion. (4 pts)

Particle will go back and forth between turning points



(b) Suppose instead that mass m has mechanical energy $E_1 = 1.0 \times 10^{-19}$ J and is located at r = 0.30 nm. Find the potential energy of this particle. (3 pts)

Read graph: $U(r = 0.30\,nm) \approx -1.1 \times 10^{-19}\,J$

(c) Find the kinetic energy of this particle. (3 pts)

$E_1 = K + U \Rightarrow K = E_1 - U = 1.0 \times 10^{-19}\,J - (-1.1 \times 10^{-19}\,J)$

$= 2.1 \times 10^{-19}\,J$

4. Indicate whether each part is true or false. (2 pts each)

F (a) Only conservative forces can do work.

F (b) If only conservative forces act on a particle, the kinetic energy of the particle cannot change.

F (c) The work done by a conservative force equals the change in the potential energy associated with that force.

F (d) If, for a particle constrained to move along only the x-axis, the potential energy associated with a conservative force decreases as the particle moves to the right, then the force points to the left.

T (e) If, for a particle constrained to move along only the x-axis, a conservative force points to the right, then the potential energy associated with that force increases as the particle moves to the left.

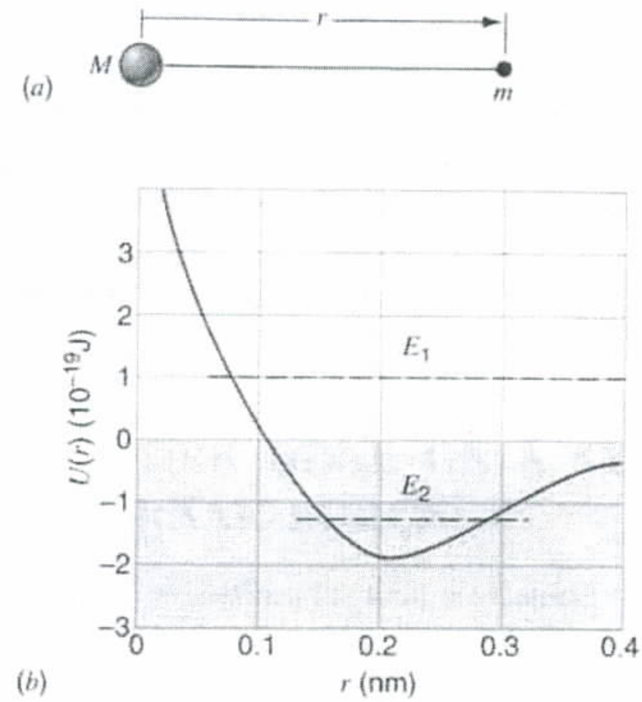
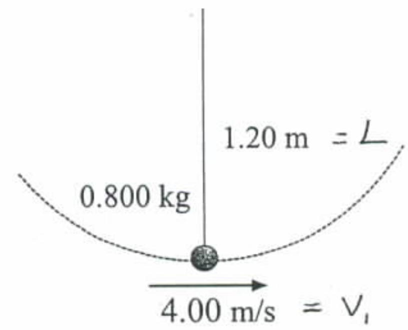


Figure for Problem 3

5. A small 0.800 kg mass hangs from a light string of length 1.20 m. It is given a rapid horizontal kick which gives it a speed of 4.00 m/s.



a) What is the speed of the mass when the string makes an angle of 60.0 degrees with the vertical? (6 pts)

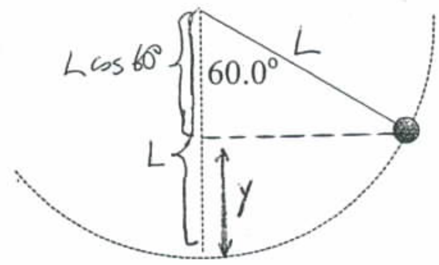
At this point its height above the starting point is

$y = L - L\cos 60^\circ = L - L\cdot\frac{1}{2} = L/2 = 0.600\ m$

If the speed at this point is v_2 then by energy conservation

$\frac{1}{2}mv_1^2 = \frac{1}{2}mv_2^2 + mgy \rightarrow v_1^2 = v_2^2 + 2gy$

$v_2^2 = v_1^2 - 2gy = 4.24\ \frac{m^2}{s^2}$ $\quad$ $\boxed{v_2 = 2.06\ \frac{m}{s}}$



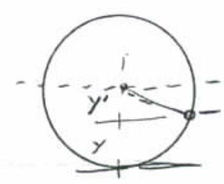
b) What is the maximum angle that the string will make with the vertical? (6 pts)

The mass swings upward until (presumably) its speed is zero at some point, a height y above the starting point then energy conservation gives

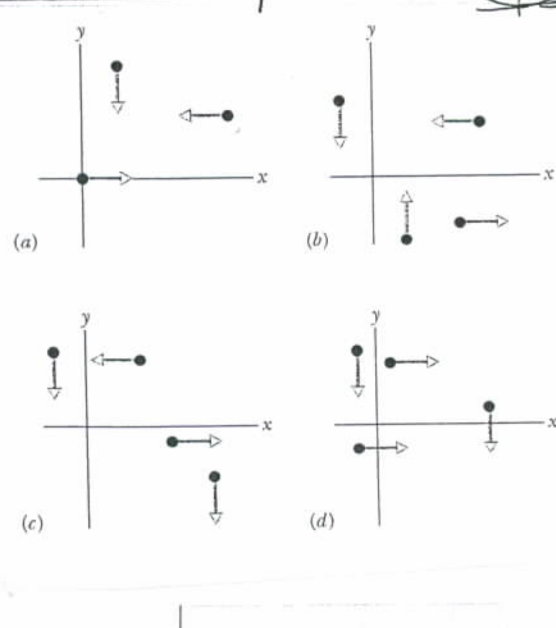
$\frac{1}{2}mv_1^2 = 0 + mgy \rightarrow y = \frac{v_1^2}{2g} = \frac{(4.00\frac{m}{s})^2}{2(9.8\frac{m}{s^2})} = 0.816\ m$

The vertical dist below the circle's center is then $y' = 1.2m - 0.816m = 0.384\ m$

which gives $\cos\theta = \frac{0.384\ m}{1.2\ m} \Rightarrow \boxed{\theta = 71.4^\circ}$

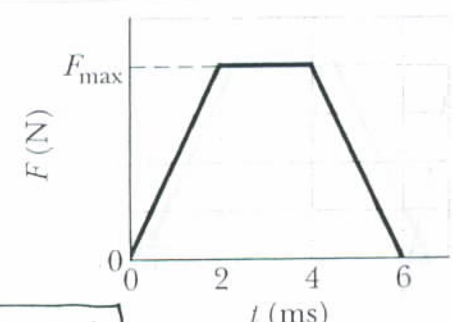


6. The figure shows four groups of three or four identical particles that move parallel to either the x-axis or the y-axis at identical speed. Rank the groups according to the center-of- mass speed, greatest first. (5 pts)



$\boxed{d, c, a, b}$

7. The figure shows a graph of the force F on a superball during a collision with a wall. The initial velocity of the ball is 25.0 m/s, and it is directed perpendicular to the wall. The ball rebounds directly back with approximately the same speed, also perpendicular to the wall. The mass of the ball is $m = 60.0$ g.



(a) What is the magnitude of the impulse exerted on the ball during the collision? (3 pts)

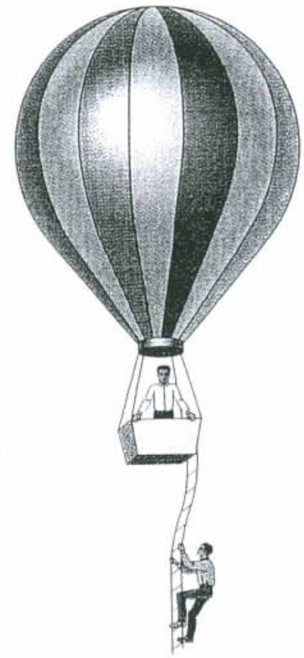
$J = |m\vec{v_f} - m\vec{v_i}| = 2mv = 2*0.06\times 25 = \boxed{3.0\ kg\cdot m/s}$

(b) What is the maximum magnitude F_{max} of the force on the ball during collision? (5 pts)

$J = \int F dt = \left(\frac{1}{2}*2*F_{max} + (4-2)F_{max} + \frac{1}{2}*2*F_{max}\right)*10^{-3}$

$3 = 4F_{max}*10^{-3} \rightarrow \boxed{F_{max} = 750\ N}$

8. The figure shows a 80.0 kg man on a ladder hanging from a balloon. Including the basket and the passenger, the balloon has a total mass of 320. kg. The balloon is initially stationary relative to the ground.



(a) If the man on the ladder begins to climb up at 2.00 m/s relative to the ground, determine the direction and magnitude of the velocity of the balloon relative to the ground. (5 pts)

$$0 = m\vec{v} + M\vec{u}$$

$$\vec{u} = -\frac{m}{M}\vec{v}$$

$$u = \frac{80}{320} * 2.0 = \boxed{0.5\ m/s\ \downarrow}$$

(b) If the man then stops climbing, what is the speed of the balloon? (3 pts)

$\boxed{\text{zero}}$

9. Two bodies, A and B with same mass $m_A = m_B = 2.0$ kg, collide on a frictionless horizontal floor. The velocities before the collision in unit vector notation are $v_A = 15.\hat{i} + 30.\hat{j}$ (m/s) and $v_B = -10.\hat{i} + 5.0\hat{j}$ (m/s). After the collision, the velocity of body A is $v'_A = -5.0\hat{i} + 20.\hat{j}$ (m/s).

(a) Determine the final velocity of body B in unit vector notation. (5 pts)

$$m\vec{V_A} + m\vec{V_B} = m\vec{V_A'} + m\vec{V_B'}$$

$$\vec{V_B'} = \vec{V_A} + \vec{V_B} - \vec{V_A'}$$

$$= 15\vec{i} + 30\vec{j} + (-10)\vec{i} + 5\vec{j} + 5\vec{i} - 20\vec{j}$$

$$\boxed{\vec{V_B'} = 10\vec{i} + 15\vec{j}\ (m/s)}$$

(b) Calculate, including the sign, the change in the total kinetic energy. (7 pts)

$$K_A = \tfrac{1}{2}mV_A^2 = (15)^2 + (30)^2 = 225 + 900 = 1125\ J$$

$$K_B = \tfrac{1}{2}mV_B^2 = (-10)^2 + (5)^2 = 100 + 25 = 125\ J$$

$$K_A' = \tfrac{1}{2}mV_A'^2 = (-5)^2 + (20)^2 = 25 + 400 = 425\ J$$

$$K_B' = \tfrac{1}{2}mV_B'^2 = (10)^2 + (15)^2 = 100 + 225 = 325\ J$$

$$K_i = K_A + K_B = 1125 + 125 = 1250\ J$$

$$K_f = K_A' + K_B' = 425 + 325 = 750\ J$$

$$\Delta K = K_f - K_i = 750 - 1250 = \boxed{-500\ J}$$