Name ______________________________ Seat Number ______________

PHYSICS 2110
Exam II – Fall 2008

INSTRUCTORS (Circle ONE):	CLASS MEETING TIME
Shriner	8:00 AM
Engelhardt	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	5	
2	12	
3	8	
4	16	
5	9	
6	10	
7	10	
8	15	
9	15	
TOTAL	100	

1. A force $\vec{F} = 12\hat{i} - 10\hat{j}$ N acts on an object. How much work does this force do as the object moves from the origin to the point $\vec{r} = 13\hat{i} + 11\hat{j}$ m? (5 pts)

$W = \vec{F} \cdot \Delta\vec{r}$

If the object moves from the origin $\vec{r}_0 = 0$ to $\vec{r} = 13\hat{i} + 11\hat{j}$ m, then the work done by a constant force $\vec{F} = 12\hat{i} - 10\hat{j}$ N is

$W = (12\hat{i} - 10\hat{j}\ N) \cdot (13\hat{i} + 11\hat{j})m$

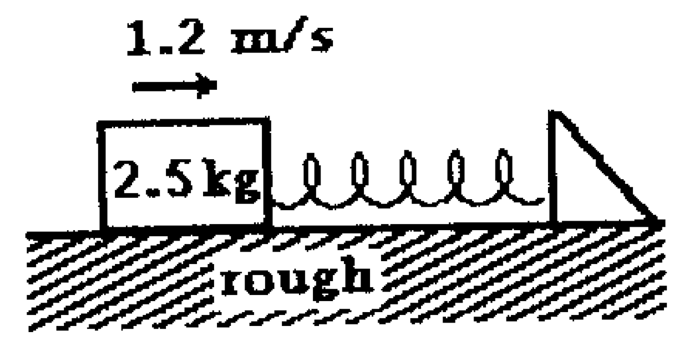
$W = (12)(13)\,\hat{i}\cdot\hat{i} - (10)(11)\,\hat{j}\cdot\hat{j}$ N.m

$\hat{i}\cdot\hat{i} = 1$
$\hat{j}\cdot\hat{j} = 1$
$\hat{i}\cdot\hat{j} = 0$
$\hat{j}\cdot\hat{i} = 0$

$W = 156 - 110$ N.m

$W = 46\ J$ (1 J = 1 N.m)

2. A 2.5-kg block, sliding on a rough surface, has a speed of 1.2 m/s when it makes contact with a spring. The block comes to a momentary halt when the compression of the spring is 5.0 cm. The work done by the friction, from the instant the block makes contact with the spring until it comes to a momentary halt, is -0.50 J.



(a) Find the force constant of the spring. (4 pts)

Work done by friction is $W_f = -0.50\ J$

Use $\Delta K + \Delta U = W_f = (K_f - K_i) + (U_f - U_i)$

Here $U_i = 0$ $K_f = 0$ $K_i = \frac{1}{2}mv_i^2 = 1.80\ J$ and $U_f = \frac{1}{2}k(\Delta x)^2$ w/ $\Delta x = 5.0\ cm = 0.050\ m$

This gives $U_f = 1.30\ J = \frac{1}{2}k(\Delta x)^2$ So then $k = \frac{2U_f}{(\Delta x)^2} = \boxed{1040\ \frac{N}{m}}$

(b) Determine the coefficient of friction. (4 pts)

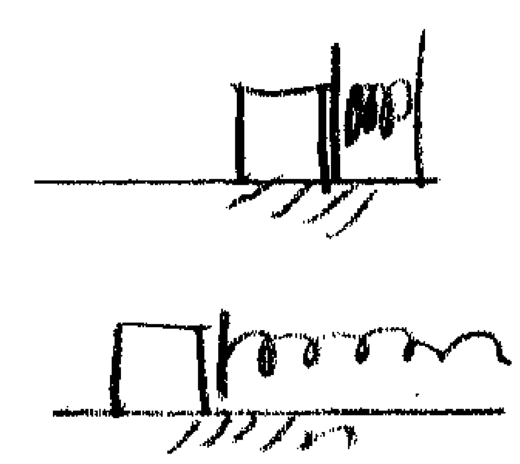
Magnitude of friction force is $f_k = \mu_k mg$ so work done by friction in stopping block is

$W_f = -\mu_k mg\Delta x = -0.50\ J$ With $m = 2.5\ kg$, $\Delta x = 0.050\ m$, get

$\mu_k = \frac{(0.50\ J)}{(2.5\ kg)(9.8\frac{m}{s^2})(0.050\ m)} = \boxed{0.41}$

(c) After compressing the spring, the block moves away from it. Calculate the speed of the block, upon separation from the spring. (4 pts)

As block moves away from spring it travels 0.050 to separation and again friction does -0.50 J of work on the block.



Use $\Delta K + \Delta U = W_f = (K_f - K_i) + (U_f - U_i) = -0.50\ J$

Here $U_i = \frac{1}{2}k\Delta x^2 = 1.30\ J$ and $K_i = 0$ and $U_f = 0$

Gives: $K_f = 0.80\ J = \frac{1}{2}mv_f^2$ Gives $v_f = \boxed{0.80\ \frac{m}{s}}$

3. A grinding stone is spinning at 1100. rpm when its power is shut off. It slows with uniform angular acceleration until it stops 45 s later. (8 pts)

(a) What is the angular acceleration during this time?

$\omega = \omega_0 + \alpha t$

$\Rightarrow \alpha = \frac{\omega - \omega_0}{t} = \frac{0\ rpm - 1100\ rpm}{0.75\ min} = -1500\ rev/min^2 = -0.41\ \frac{rev}{s^2}$

$= -2.6/s^2$

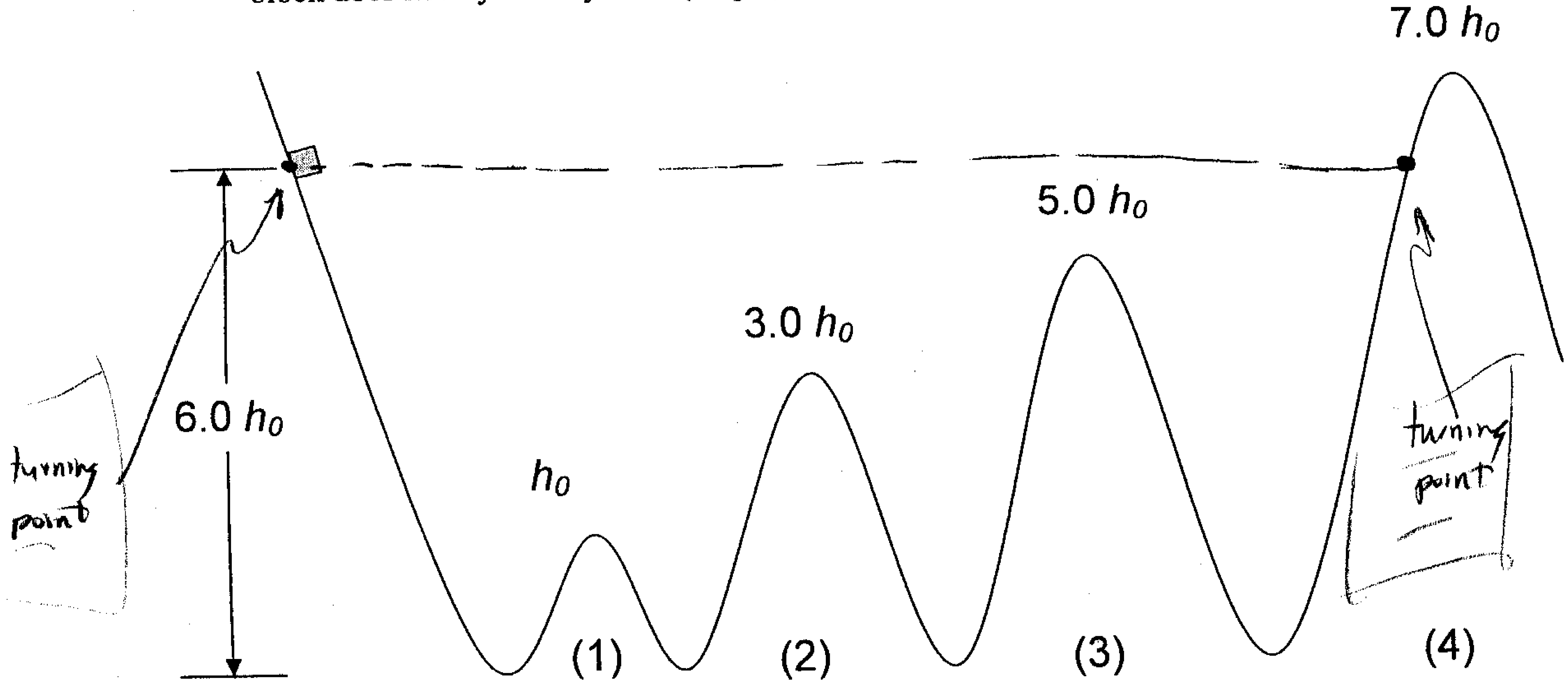
(b) How many revolutions does the stone make while slowing down?

$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$

$\Rightarrow \Delta\theta = (1100\ rpm)(0.75\ min) + \frac{1}{2}(-1500\ rev/min^2)(0.75\ min)^2$

$= 410\ rev$

4. In the figure, a small, initially stationary block of mass m is released on a frictionless ramp at a height of $6.0h_0$, where h_0 is the height of the first hill and other hill heights to the right of the ramp are as shown. The hills all have identical circular tops, and the block does not fly off any hill. (16 pts)



(a) On the figure, identify the turning points of the motion.

(b) (1),(2),(3), or (4), is the first hill that the block cannot cross?

(4)

(c) What does the block do after failing to cross that hill?

Reverses direction, crossing hills (3), (2), (1) and returning to height 6.0 h_0 (starting point) then continuing forward and back forever.

(d) In terms of g, m and h_0, what is the total energy of the block when it is at the top of hill (1)?

$E = mg\,h_0\,(6.0)$

(e) In terms of g, m and h_0, what is the kinetic energy of the block at the top of hill (1)?

$E = U + K$

$K = E - U = 6.0(mgh_0) - mgh_0 = 5.0\,mgh_0$

(f) Assuming the block could reach the top of hill (3), how much work would be done on the block by gravity in moving from its initial position to the top of hill (3)?

$W_{grav} = -\Delta U_{grav} = -U_f + U_i = -5.0mgh_0 + 6.0mgh_0 = mgh_0$

(g) On which hilltop is the centripetal acceleration of the block greatest

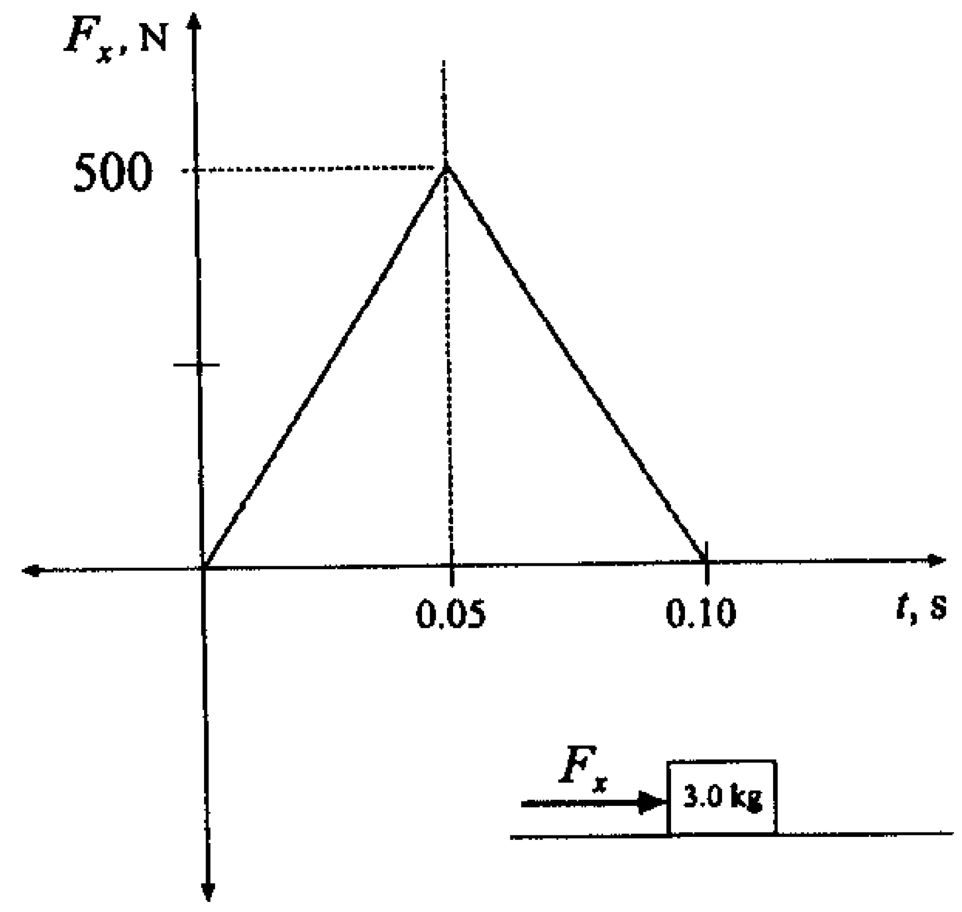
$a_c = \frac{v^2}{r}$ KE is greatest on hill (1), $\therefore$ hill (1)

$K = \frac{1}{2}mv^2$

(h) On which hilltop is the normal force on the block least?

hill (1)

5. A force along the along the x axis acts on a 3.0 kg mass. (It is the only x-force on the mass.) The force varies with time as shown in the graph here.



(a) What was the average force acting on the mass from 0.0s to 0.10 s? (3 pts)

$F_{av} = \frac{1}{\Delta t}\int_0^{\Delta t} F\,dt = \frac{1}{\Delta t}\left(\frac{1}{2}(500N)\,\Delta t\right)$

$= \boxed{250\ N}$, w/ $\Delta t = 0.10$ s

(This is clear since there are only linear functions here.)

(b) What was the change in momentum of the mass? (3 pts)

$\Delta p_x = F_x \Delta t = (250\ N)(0.10\ s) = \boxed{25\ \frac{kg\,m}{s}}$

(c) What is the final speed of the mass if it starts from rest? (3 pts)

$mV_x - 0 = 25\ \frac{kg\cdot m}{s} = \Delta p_x$ Since $m = 3.0$ kg,

$\boxed{V_x = 8.33\ \frac{m}{s}}$

6. This problem describes three rotational situations. In each case, take the clockwise direction to be positive. (10 pts)

(a) A fan is rotating clockwise and slowing down. What are the appropriate signs for its angular velocity and angular acceleration?

ω is $+$

α is opposite ω, so α is $-$

(b) A fan is rotating counterclockwise and speeding up. What are the appropriate signs for its angular velocity and angular acceleration?

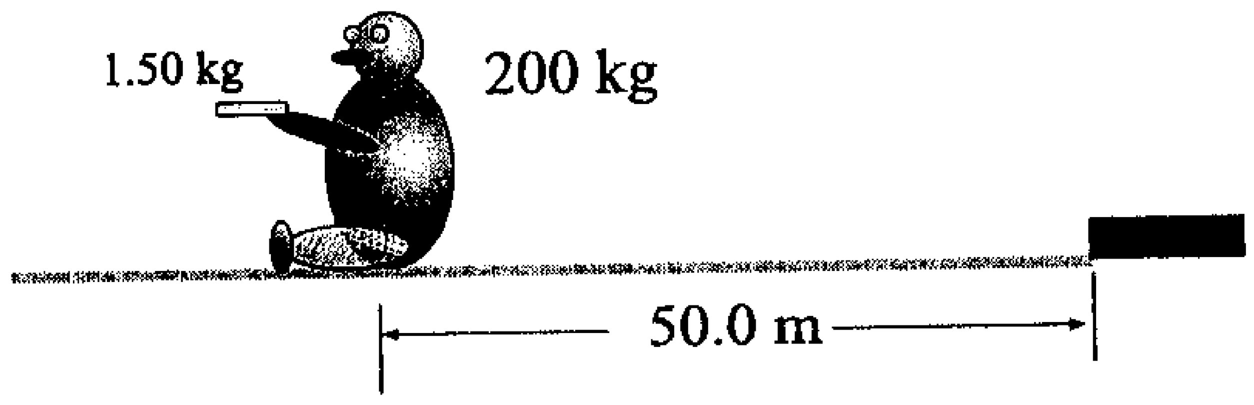
ω is $-$

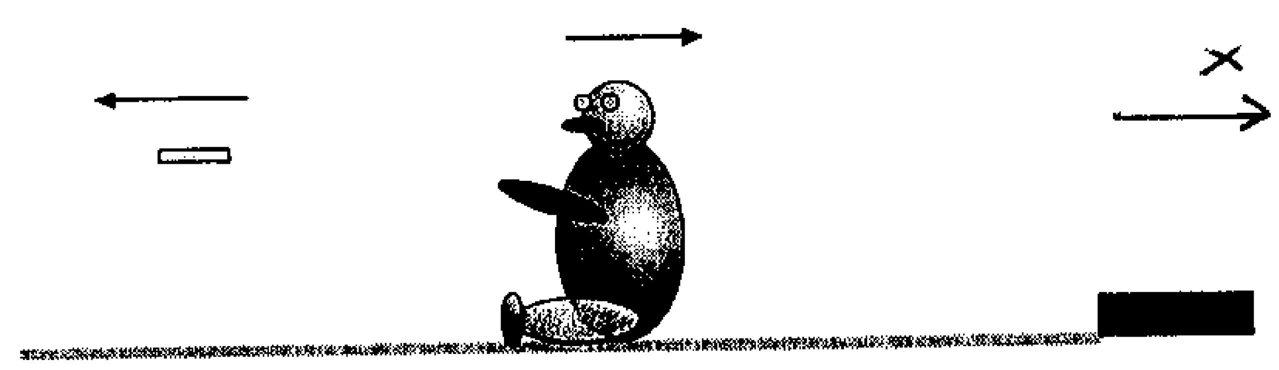
α is same as ω, so α is $-$

(c) A cylinder is free to rotate about a fixed axis through its center. The object is initially rotating in a counterclockwise direction at constant angular speed. Then a torque is applied which has a positive but decreasing magnitude. Describe the subsequent rotational motion of the cylinder.

Positive $T \Rightarrow$ Positive α. Positive α combined with negative $\omega \Rightarrow$ slowing down. Depending on magnitudes of T and ω and rate at which $|T|$ decreases, the object may or may not eventually reverse direction and rotate clockwise.

7. A big fat guy of mass of 200 kg has found himself stranded on a frictionless surface, 50 m from its edge; he has a 1.50-kg physics book. He throws the book such that he recoils in the opposite direction. He takes 6.00 minutes to reach the edge.





What was the speed of the physics book after he threw it? (10 pts)

Speed of BFG after tossing was $\frac{50.0\text{ m}}{(6.0)(60\text{ s})} = 0.139\ \frac{m}{s}$

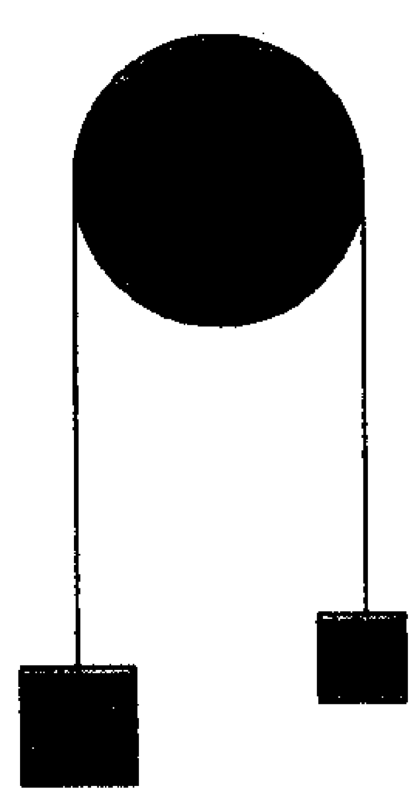
Momentum conserved in the toss, so if vel of book is V_x, then

$$(1.50\text{ kg})(V_x) + (200\text{ kg})(0.139\ \tfrac{m}{s}) = 0$$

Solve for V_x:

$V_x = -18.5\ \frac{m}{s}$ Book's speed: $\boxed{18.5\ \frac{m}{s}}$

8. An Atwood's machine consists of two blocks connected by a string over a pulley as shown. The left block has mass 0.65 kg, and the right block has mass 1.35 kg. The pulley has a moment of inertia of 5.0×10^{-3} kg-m^2 and a radius of 10.0 cm. The string may be treated as massless. There is friction where the pulley pivots. The mass on the right is observed to have a constant downward acceleration of 3.30 m/s^2. (15 pts)



(a) Find the tension in the rope hanging from the right side of the pulley.

$y\uparrow$ T_R, $M_R g$

$$T_R - M_R g = M_R a_R \quad (a_R < 0)$$

$$T_R = M_R(g + a_R) = 1.35\text{ kg}\,[9.80\text{ m/s}^2 - 3.30\text{ m/s}^2] = 8.78\text{ N}$$

(b) Find the tension in the rope hanging from the left side of the pulley.

$\uparrow y$ T_L, $M_L g$

$$T_L - M_L g = M_L a_L \quad (a_L > 0)$$

$$T_L = M_L(g + a_L) = 0.65\text{ kg}\,[9.80\text{ m/s}^2 + 3.30\text{ m/s}^2] = 8.5\text{ N}$$

(c) Find the angular acceleration of the pulley.

$$\alpha = \frac{a_T}{R} = \frac{3.30\text{ m/s}^2}{.100\text{ m}} = 33.0/s^2$$

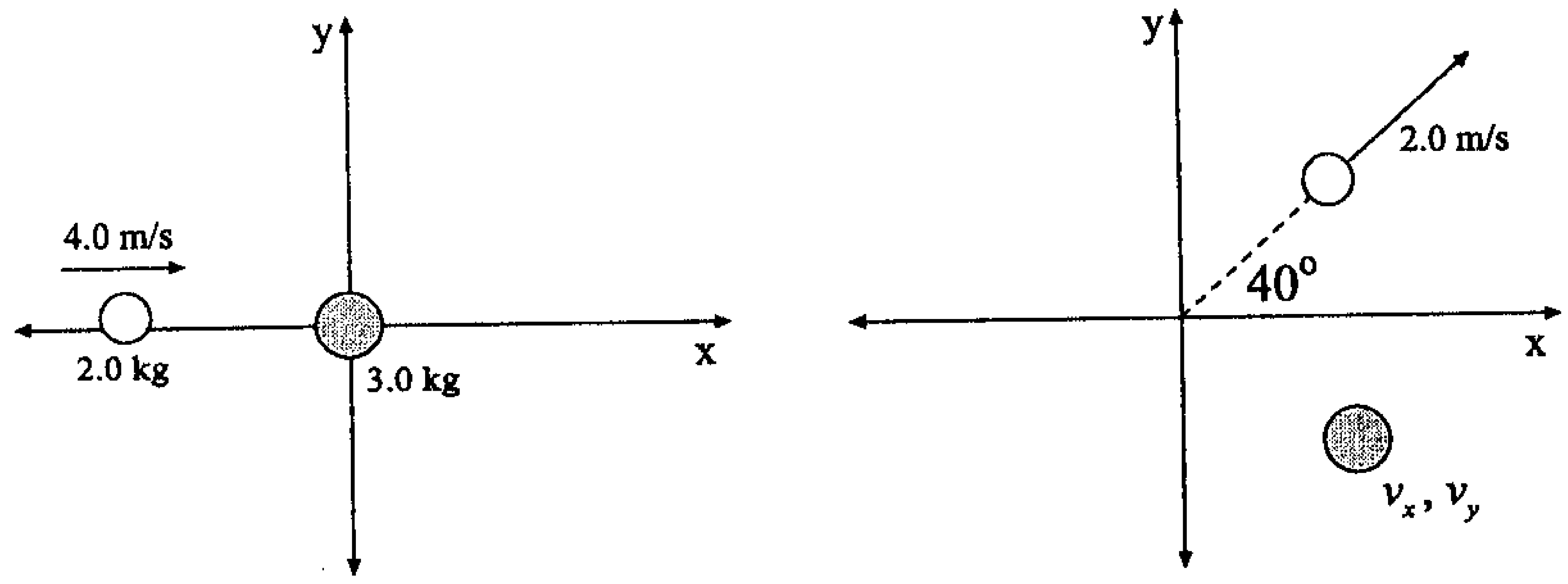
(d) Find the magnitude of the torque exerted by the frictional force between the pulley and its axle.

$$\tau_{net} = I\alpha = (.0050\text{ kg-m}^2)(33.0/s^2) = 0.165\text{ N-m}$$

$$\tau_{net} = \tau_R - \tau_L + \tau_{fric} = (8.78\text{ N} - 8.5\text{ N})(.100\text{ m}) + \tau_{fric} = 0.165\text{ N-m}$$

$$\Rightarrow |\tau_{fric}| = .14\text{ N-m}$$

9. A collision between a 2.0 kg mass and a 3.0 kg mass takes place on a horizontal frictionless table. Before the collision, the 2.0 kg mass moves along the +x axis at 4.0 m/s and the 3.0 kg mass is at rest. After the collision, the 2.0 kg mass moves at 40 deg from the +x axis at a speed of 2.0 m/s



(a) Find the velocity components v_x and v_y of the 3.0 kg mass after the collision. (8 pts)

x-momentum is conserved:

$$(2.0\,\text{kg})(4.0\,\tfrac{m}{s}) = (2.0\,\text{kg})(2.0\,\tfrac{m}{s})\cos 40^\circ + (3\,\text{kg})\,V_x$$

$$\Rightarrow \boxed{V_x = 1.64\,\tfrac{m}{s}}$$

y-momentum is conserved:

$$0 = (2.0\,\text{kg})(2.0\,\tfrac{m}{s})\sin 40^\circ + (3\,\text{kg})\,V_y \quad \rightarrow \boxed{V_y = -0.857\,\tfrac{m}{s}}$$

(b) What is the speed and direction of motion of the 3.0 kg mass after the collision? (3 pts)

$$\text{Speed} = v = \sqrt{V_x^2 + V_y^2} = \sqrt{(1.64\,\tfrac{m}{s})^2 + (0.857\,\tfrac{m}{s})^2} = \boxed{1.85\,\tfrac{m}{s}}$$

Direction:

$$\tan\theta = \frac{V_y}{V_x} = -0.522 \quad \rightarrow \boxed{\theta = -27.6^\circ}$$

(c) How much energy was lost in the collision? (4 pts)

Initial KE:

$$K_i = \tfrac{1}{2}(2.0\,\text{kg})(4.0\,\tfrac{m}{s})^2 = 16.0\,\text{J}$$

Final KE:

$$K_f = \tfrac{1}{2}(2.0\,\text{kg})(2.0\,\tfrac{m}{s})^2 + \tfrac{1}{2}(3.0\,\text{kg})(1.85\,\tfrac{m}{s})^2 = 9.13\,\text{J}$$

Then $16.0\,\text{J} - 9.13\,\text{J} = \boxed{6.9\,\text{J}}$ of energy was lost (to thermal energy)