Name____________________________

Apr 3, 2001

Phys 121 — Spring 2001
Exam #2

1.	____________	(6)
2.	____________	(8)
3.	____________	(7)
4.	____________	(4)
5.	____________	(9)
6.	____________	(8)
7.	____________	(14)
8.	____________	(24)
MC	____________	(20)
Total	____________	(100)

You must show all your work and include the right units with your answers!

$$A_x = A\cos\theta \qquad A_y = A\sin\theta \qquad A = \sqrt{A_x^2 + A_y^2} \qquad \theta = \tan^{-1}\left(\frac{A_y}{A_x}\right)$$

$$1\,\mathrm{m} = 100\,\mathrm{cm} \qquad 1\,\mathrm{km} = 1000\,\mathrm{m} \qquad 1\,\mathrm{kg} = 10^3\,\mathrm{g} \qquad g = 9.80\,\tfrac{\mathrm{m}}{\mathrm{s}^2}$$

$$1\,\mathrm{N} = 1\,\tfrac{\mathrm{kg\cdot m}}{\mathrm{s}^2} \qquad 1\,\mathrm{N} = 0.2248\,\mathrm{lb} \qquad G = 6.67\times10^{-11}\,\tfrac{\mathrm{N\cdot m^2}}{\mathrm{kg}^2} = 6.67\times10^{-11}\,\tfrac{\mathrm{m}^3}{\mathrm{kg\cdot s^2}}$$

$$v_x = v_{0x} + a_x t \qquad x = v_{0x}t + \tfrac{1}{2}a_x t^2 \qquad v_x^2 = v_{0x}^2 + 2a_x x \qquad x = \tfrac{1}{2}(v_{0x} + v_x)t$$

$$v_y = v_{0y} + a_y t \qquad y = v_{0y}t + \tfrac{1}{2}a_y t^2 \qquad v_y^2 = v_{0y}^2 + 2a_y y \qquad y = \tfrac{1}{2}(v_{0y} + v_y)t$$

$$\mathbf{F}_{\mathrm{net}} = m\mathbf{a} \quad\Longrightarrow\quad F_{\mathrm{net},\,x} = ma_x \qquad F_{\mathrm{net},\,y} = ma_y$$

$$F_{\mathrm{grav}} = G\frac{m_1 m_2}{r^2} \qquad g_{\mathrm{planet}} = G\frac{M}{R^2} \qquad 1\,\mathrm{J} = 1\,\tfrac{\mathrm{kg\cdot m^2}}{\mathrm{s}^2}$$

$$a_c = \frac{v^2}{r} \qquad F_c = \frac{mv^2}{r} \qquad f_{\mathrm{stat}}^{\mathrm{Max}} = \mu_s F_N \qquad f_{\mathrm{kin}} = \mu_k F_N$$

$$W = Fs\cos\theta \qquad \mathrm{KE} = \tfrac{1}{2}mv^2 \qquad \mathrm{PE}_{\mathrm{grav}} = mgy \qquad \Delta E = \Delta\mathrm{PE} + \mathrm{KE} = W_{\mathrm{non-cons.}}$$

$$P = \frac{W}{t} \qquad \mathbf{p} = m\mathbf{v} \qquad \text{Isolated system: } \mathbf{P} \text{ is conserved.}$$

$$2\pi\,\mathrm{rad} = 1\,\mathrm{rev} = 360\,\mathrm{deg} \qquad s = r\theta \qquad v_T = \omega r \qquad a_T = \alpha r \qquad a_c = \omega^2 r$$

$$\omega = \omega_0 + \alpha t \qquad \theta = \omega_0 t + \tfrac{1}{2}\alpha t^2 \qquad \omega^2 = \omega_0^2 + 2\alpha\theta \qquad \theta = \tfrac{1}{2}(\omega_0 + \omega)t$$

$$\tau = Fr\sin\phi \qquad \tau_{\mathrm{net}} = I\alpha \qquad I = \sum_{\text{mass points } i} m_i r_i^2$$

$$I_{\text{solid sph.}} = \tfrac{2}{5}MR^2 \qquad I_{\text{rod, center}} = \tfrac{1}{12}MR^2 \qquad I_{\text{disk}} = \tfrac{1}{2}MR^2$$

Multiple Choice (2 each)

1. Two blocks, A and B are sliding across a horizontal surface which exerts a force of friction to slow them. The same coefficient of kinetic friction applies to both blocks. The mass of B is twice that of A. The acceleration of mass B is

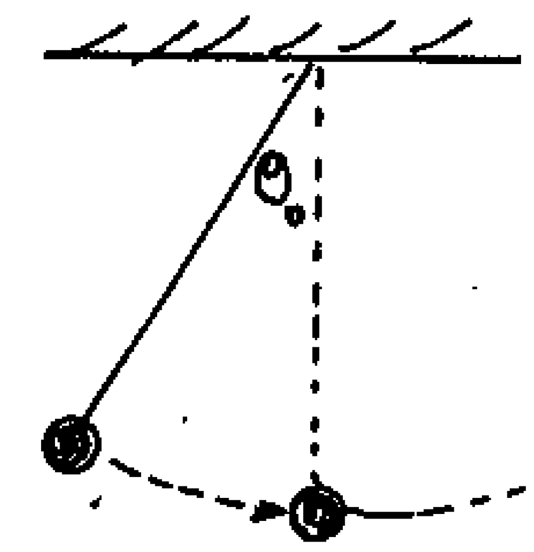
a) Half that of mass A.

b) The same as that of mass A.

c) Twice that of mass A.

d) Four times that of mass A.

2. The bob (mass m) of a simple pendulum is held back at an angle θ_0 and released. When the bob is at the bottom of its swing, the tension in the string is



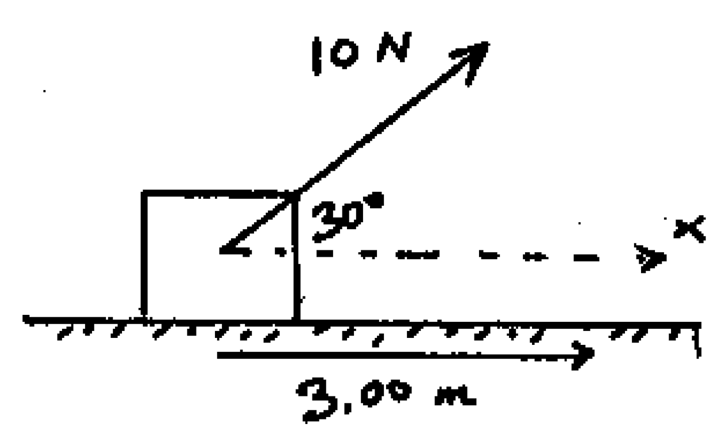
a) Less than mg.

b) Equal to mg.

c) Greater than mg.

d) One cannot say without knowing the value of θ_0.

3. A constant 10.0 N force directed at 30° above the $+x$ direction is applied to a mass as it moves 3.00 m over the surface in the $+x$ direction. The work done by this force is:



a) -15.0 J

b) 15.0 J

c) 26.0 J

d) 30.0 J

4. A *conservative force* is a force for which

a) The direction always opposes the direction of the instantaneous velocity.

b) The direction does not depend on position, though the magnitude might.

c) The kinetic energy of the object strictly *increases*.

d) The work done does not depend on the intermediate path taken.

5. An *isolated system* is one for which

a) Kinetic energy is conserved.

b) There are no friction–type forces between the particles.

c) There is no net external force.

d) Only electrical forces may act on the particles.

6. Object B has twice the mass of object A. When the two objects collide, the magnitude of the impulse received by B is

a) Half as large as the magnitude of the impulse delivered to A.

b) The same as the magnitude of the impulse delivered to A.

c) Twice as large as the magnitude of the impulse delivered to A.

d) Four times as large as the magnitude of the impulse delivered to A.

7. Object B has twice the speed of object A. The kinetic energy of B, as compared with that of A, is:

a) 2 times as large.

b) 4 times as large.

c) 8 times as large.

d) One cannot say with further information.

8. Of the following quantities, the one which is a *vector* is

a) Momentum

b) Kinetic energy.

c) Power.

d) Moment of inertia.

9. As a solid disk spins at a varying rate, all points on the disk have the same

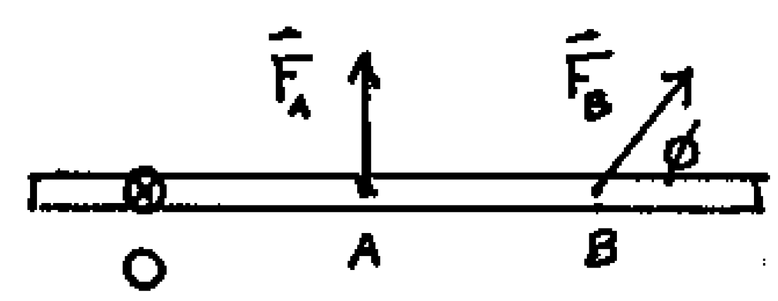
a) Tangential speed.

b) Angular acceleration.

c) Centripetal acceleration.

d) None of the above.

10. Two forces of equal magnitude are applied to a rod pivoted about point O. Force A is directed perpendicularly to the length of the rod. Force B is applied twice as far from the pivot as force A and is directed at an angle ϕ. Both forces produce the *same* torque individually.



What is the angle ϕ?

a) 0°

b) 30°

c) 45°

d) 60°

Problems

1. *Units? Units?* What are the appropriate MKS (SI, metric) units for the following quantities: (6)

a) Torque

$N \cdot m$

b) Angular Velocity

$\text{rad}/s = 1/s$

c) Potential Energy

$J = \frac{kg\, m^2}{s^2}$

d) Momentum

$kg \cdot m/s$

e) Moment of Inertia

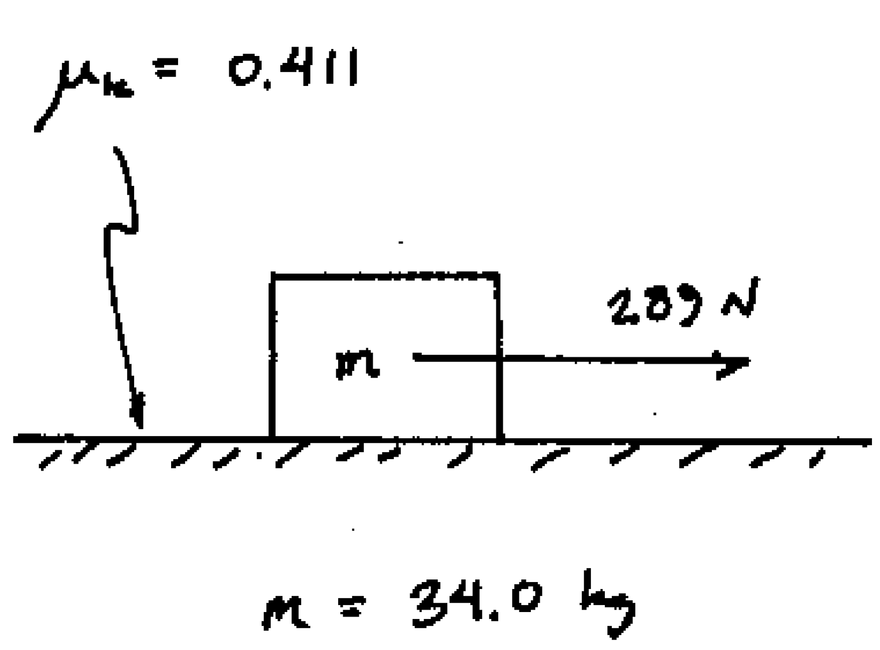
$kg \cdot m^2$

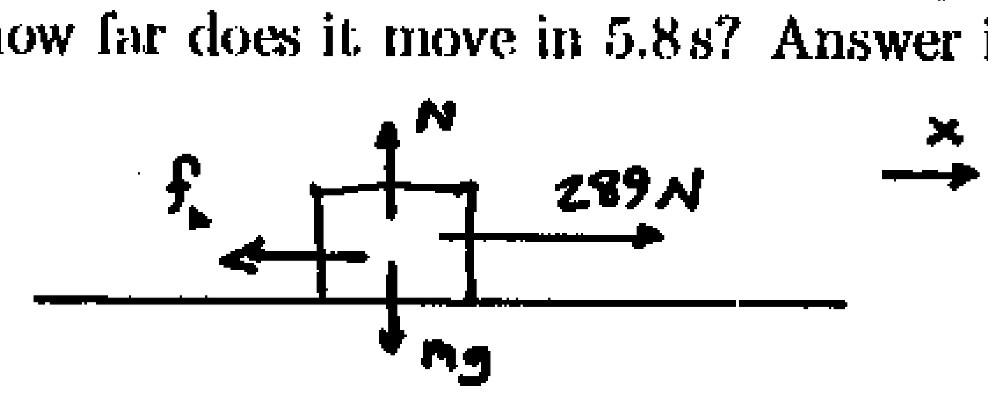
f) Power

$W = \frac{J}{s} = kg \cdot m^2/s^3$

2. A 34.0 kg crate is at rest on a level floor, and the coefficient of kinetic friction is 0.411.

If the crate is pushed horizontally with a force of 289 N, how far does it move in 5.8 s? Answer in units of m. (8)





Vertical forces cancel: $N = mg$

Friction force is $f_k = \mu_k mg = (0.411)(34.0\text{ kg})(9.80\frac{m}{s^2}) = 137\text{ N}$

In x-direction,

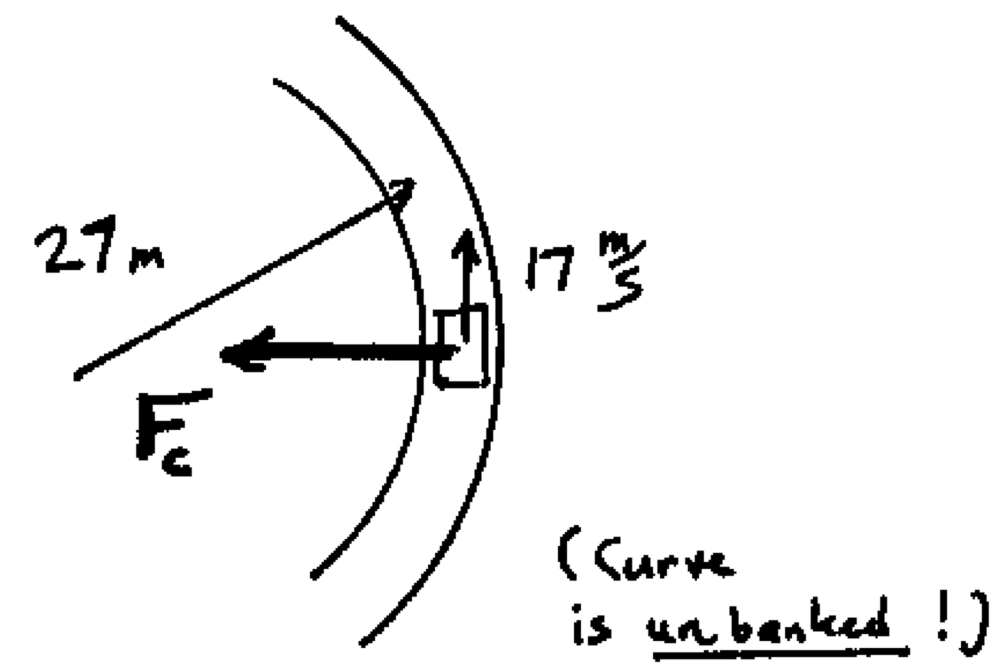
$\Sigma F_x = 289\text{ N} - 137\text{ N} = 152\text{ N} = m a_x \longrightarrow a_x = \frac{152\text{ N}}{34\text{ kg}} = 4.47\,m/s^2$

In 5.8 s it travels to:

$x = 0\cdot(5.8s) + \frac{1}{2}(4.47\frac{m}{s^2})(5.8s)^2 = 75.2\text{ m}$

3. A 2500 kg car goes around a circular curve of radius 27.0 m at a constant speed of 17.0 $\frac{m}{s}$.

a) What is the magnitude *and direction* of the acceleration of the car?(4)



Car accelerates toward the center of the circular bend, with magnitude

$$a_c = \frac{v^2}{r} = \frac{(17.0\,\frac{m}{s})^2}{(27.0\,m)} = 10.7\,\frac{m}{s^2}$$

b) What is the magnitude of the net force which acts on the car?(2)

Net force is $F_c = ma_c = (2500\,kg)(10.7\,\frac{m}{s^2}) = 2.68 \times 10^4\,N$

c) Identify (in words) the force in part (b). (1)

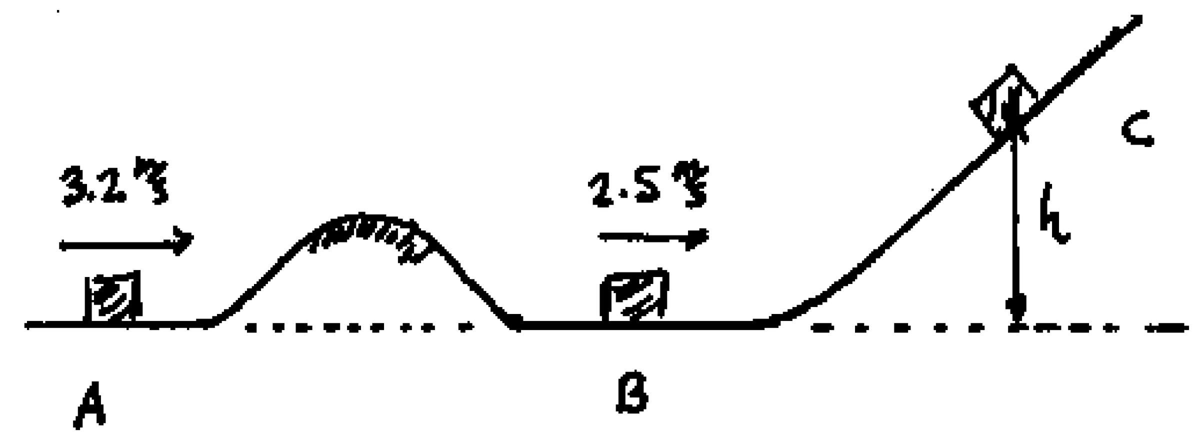
The force on the car is that of static friction (between car's tires & road.)

4. When we see TV pictures taken from inside the space shuttle, every loose object is floating around the cabin. For better or worse, this is called "weightlessness".

Briefly explain why we see this happening. (4)

Both the shuttle and its contents are in a state of free-fall. They are accelerating toward the earth with the same acceleration. As in a vertically falling elevator car, the walls exert no forces on the things inside.

5. A small 0.200–kg mass slides over a roller-coaster type track as shown. Except for a patch at the top of the bump, the track is frictionless. The mass begins its motion at A (the "ground level") with a speed of $3.2\,\frac{m}{s}$. When it gets back to the same vertical level at B its speed is $2.5\,\frac{m}{s}$.



a) What was the work done by friction on the mass between points A and B? (4)

$$W_{fric} = \Delta E = E_B - E_A$$

The mass has the same potential energy at A and B so this is just the change in kinetic energy:

$$W_{fric} = \Delta(KE) = \tfrac{1}{2}mv_B^2 - \tfrac{1}{2}mv_A^2 = \tfrac{1}{2}(0.20\,kg)(2.5\tfrac{m}{s})^2 - \tfrac{1}{2}(0.20\,kg)(3.2\tfrac{m}{s})^2$$

$$= -0.40\ J$$

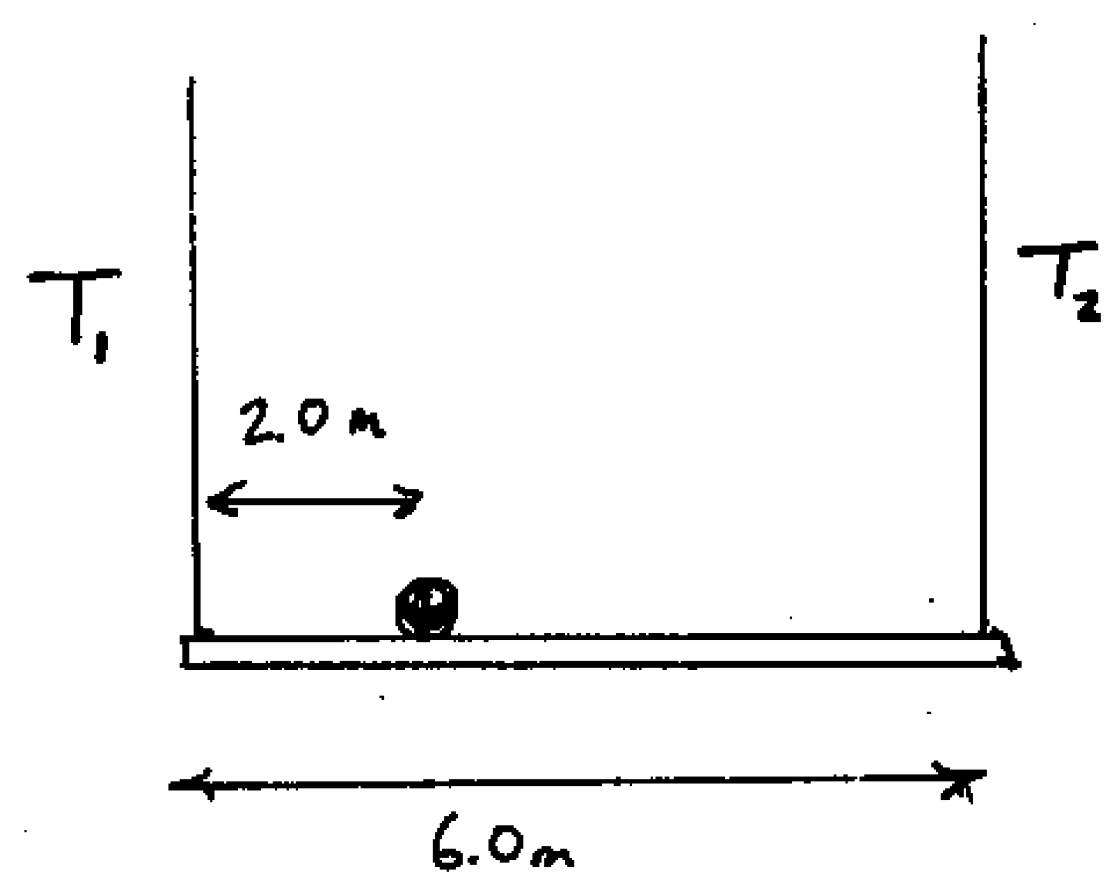
b) The mass continues up the track until it reaches maximum height at C. What is its height at point C? (5)

Between B and C energy is conserved, so

$$E_C = mgh + 0 = E_B = \tfrac{1}{2}mv_B^2 + 0$$

Can cancel m to get:

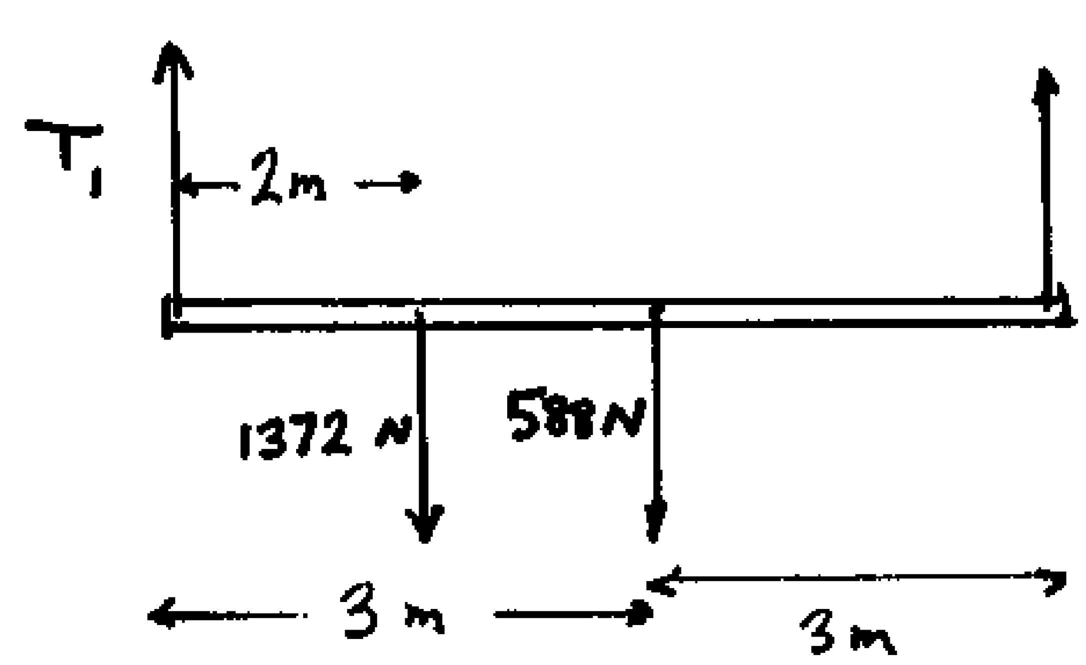
$$h = \frac{v_B^2}{2g} = 0.32\ m$$



6. A uniform 6.00–m board is supported at either end by a cable. The board has a mass of 60.0 kg. A 140 kg rock rests on the board 2.00 m from the left end.

Find the tension in the two cables. (8)

Finding the weights of the rock and board, the forces on the board are as shown.



Taking the right end of the board as the pivot point, the condition of zero net torque gives:

$$-T_1(6m) + (1372\,N)(4m) + (588\,N)(3m) = 0$$

Solve for T_1 and get:

$$T_1 = 1209\ N$$

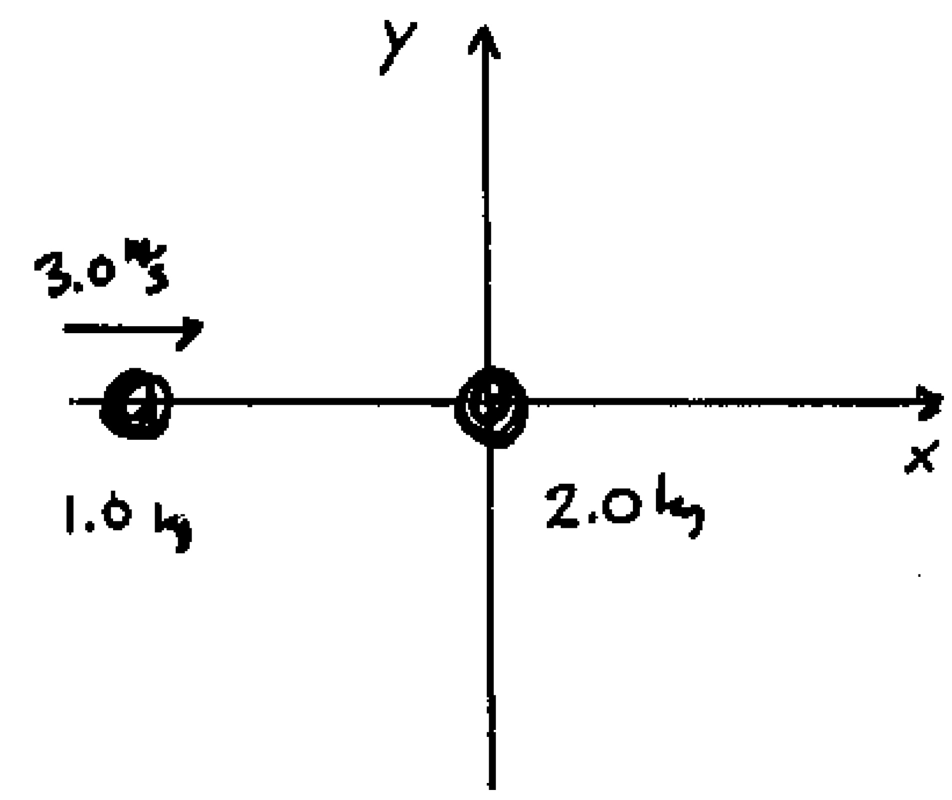
Take the left end of the board as the pivot and the condition of zero net torque gives:

$$-(1372\,N)(2m) - (588\,N)(3m) + T_2(6m) = 0$$

Solve for T_2 and get:

$$T_2 = 751\ N$$

7. Two pucks move on a frictionless surface. A 2.00 kg puck is initially at rest; a 1.00 kg puck moves in the $+x$ direction with speed 3.00 $\frac{m}{s}$ and collides with the other puck. After the collision, the 1.00 kg puck moves in a direction that is at $+30.0°$ from the $+x$ axis with speed 2.50 $\frac{m}{s}$.



a) Use the principle of conservation of momentum for this system to find the x and y components of the velocity of the 2.00 kg puck after the collision. (8)

x-momentum is conserved. This gives:

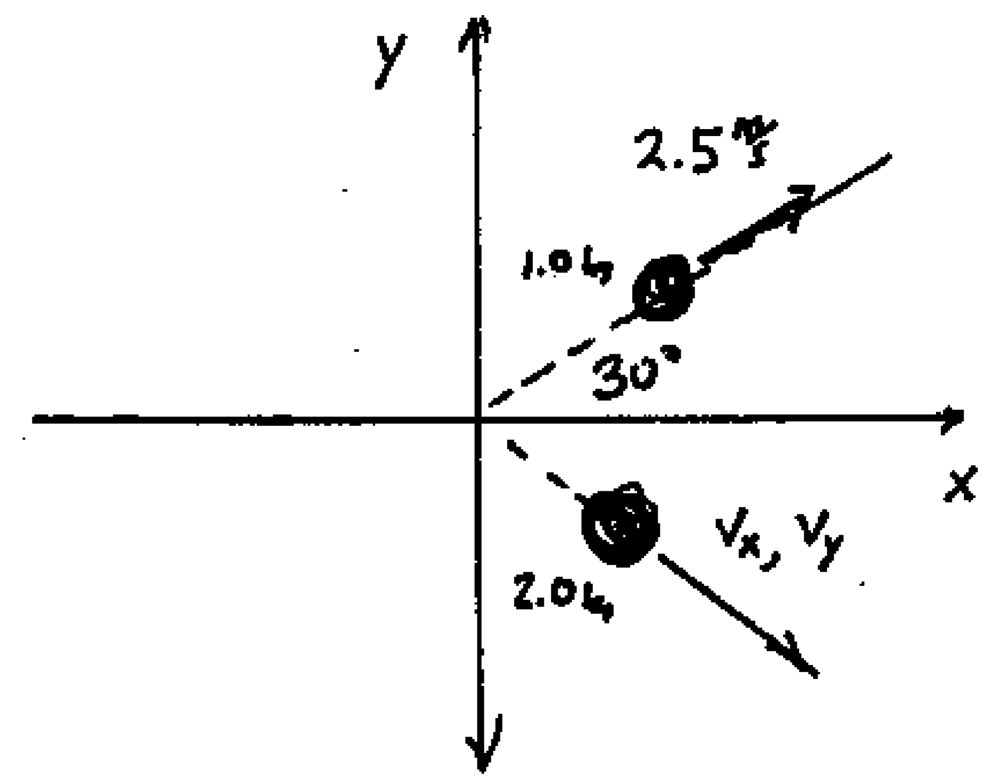
$$(1.0\,kg)(3.0\,\tfrac{m}{s}) = (1.0\,kg)(2.5\,\tfrac{m}{s})\cos 30° + (2.0\,kg)\,V_x$$

Solve for V_x, get: $V_x = 0.417\,\frac{m}{s}$

y-momentum is conserved. This gives:

$$0 = (1.0\,kg)(2.5\,\tfrac{m}{s})(\sin 30°) + (2.0\,kg)\,V_y$$

Solve for V_y, get: $V_y = -0.625\,\frac{m}{s}$



b) What is the speed of the 2.00 kg puck after the collision? (2)

Speed is (use components from (a)):

$$V = \sqrt{V_x^2 + V_y^2} = \sqrt{(0.417\,\tfrac{m}{s})^2 + (-0.625\,\tfrac{m}{s})^2} = 0.752\,\tfrac{m}{s}$$

(Direction of final $\vec{v}$ of 2.0 kg mass is $-56.3°$)

c) What is the total kinetic energy of the pucks after the collision? (2)

After,

$$\Sigma (KE)_f = \tfrac{1}{2}(1.0\,kg)(2.5\,\tfrac{m}{s})^2 + \tfrac{1}{2}(2.0\,kg)(0.752\,\tfrac{m}{s})^2$$

$$= 3.69\,J$$

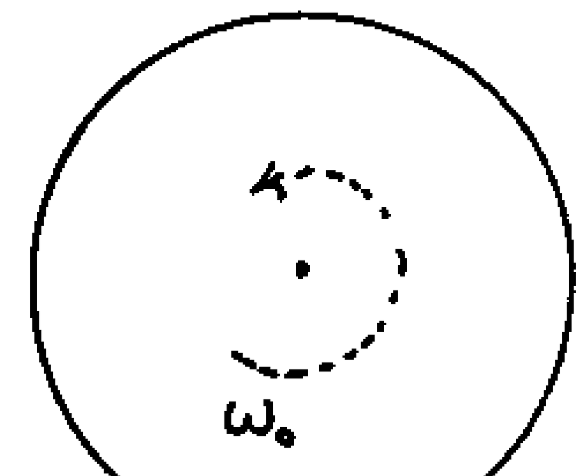
d) How much kinetic energy was lost in this collision? (2)

Since $(KE)_0 = \frac{1}{2}(1.0\,kg)(3.0\,\frac{m}{s})^2 = 4.50\,J$,

Then $4.50\,J - 3.69\,J = 0.81\,J$

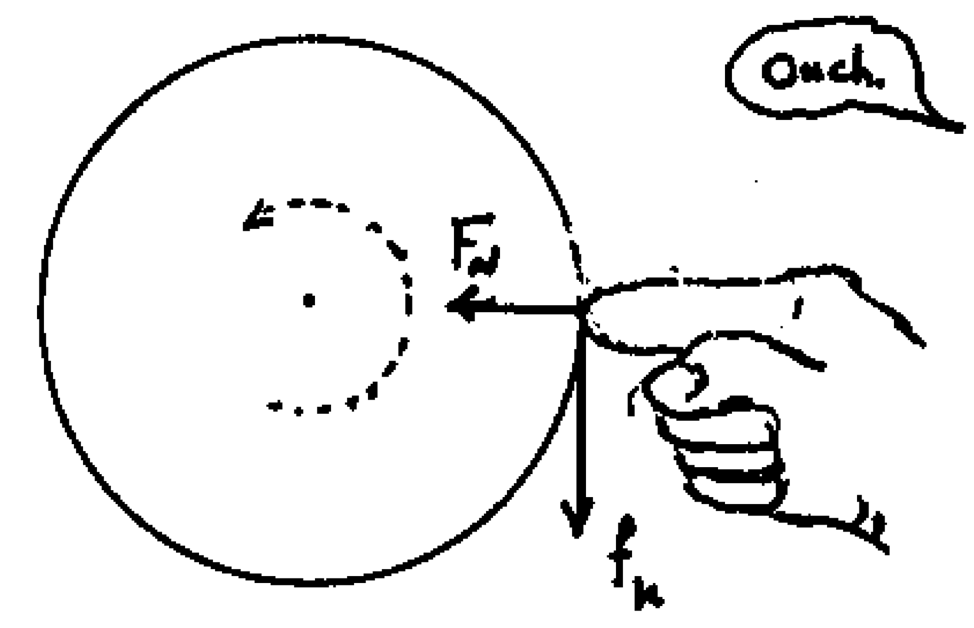
of kinetic energy was lost.

8. A uniform disk of radius 15.0 cm and mass 150 kg spins at a rate of 12.0 rev/s. We will slow it down by pushing on the edge with a finger and letting friction slow it down via a (tangential) kinetic friction force!



a) What is the initial angular velocity of the disk? (1)

$$\omega_0 = 12.0\,\frac{\text{rev}}{\text{s}} \cdot \left(\frac{2\pi\ \text{rad}}{1\ \text{rev}}\right) = 75.4\ \frac{\text{rad}}{\text{s}}$$



b) If the disk takes 10 seconds to come to rest, what was the angular acceleration of the disk? (3)

$\omega_f = 0$

$$\alpha = \frac{\omega_f - \omega_0}{t} = \frac{0 - 75.4\ \frac{\text{rad}}{\text{s}}}{10\ \text{s}} = -7.54\ \frac{\text{rad}}{\text{s}^2}$$

c) How many revolutions did the disk make in coming to rest? (6)

Can use $\omega^2 = \omega_0^2 + 2\alpha\Theta$

Then $$\Theta = \frac{\omega^2 - \omega_0^2}{2\alpha} = \frac{0 - (75.4\ \frac{\text{rad}}{\text{s}})^2}{2(-7.54\ \frac{\text{rad}}{\text{s}^2})} = 377\ \text{rad}$$

$$\#\ \text{rev's} = 377\ \text{rad}\left(\frac{1\ \text{rev}}{2\pi\ \text{rad}}\right) = 60.0\ \text{rev}$$

d) What is the moment of inertia of the disk? (3)

$$I_{\text{disk, w-t}} = \tfrac{1}{2}m(R^2) = \tfrac{1}{2}(150\ \text{kg})(0.150\ \text{m})^2 = 1.69\ \text{kg m}^2$$

e) What was the magnitude of the torque on the disk? (3)

$$|\tau| = I|\alpha| = (1.69\ \text{kg m}^2)(7.54\ \tfrac{\text{rad}}{\text{s}^2}) = 12.7\ \text{N}\cdot\text{m}$$

f) What was the magnitude of the force of friction on the disk? (4)

$$|\tau| = f \cdot R \cdot \underbrace{1}_{\sin\phi = 1,\ \text{tangential force}} \quad \text{So} \quad f_k = \frac{|\tau|}{R} = \frac{12.7\ \text{N}\cdot\text{m}}{0.150\ \text{m}} = 85.7\ \text{N}$$

g) If the coefficient of friction between finger and disk is 0.30, what was the magnitude of the *normal* force between finger and disk? (4)

$$f_k = \mu_k F_N, \quad \text{so} \quad F_N = \frac{f_k}{\mu_k} = \frac{85.7\ \text{N}}{0.30} = 282\ \text{N}$$