Nov. 9, 1999 **Name**____________________________

Seat No. 801 **Instructor** (circle only one): Semmes MURDOCK

Physics 121, Exam #2

1. ________________ (15)

2. ________________ (17)

3. ________________ (10)

4. ________________ (22)

5. ________________ (16)

Mult Choice ________________ (20)

Total ________________ (100)

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

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

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

$\sum \mathbf{F} = \mathbf{F}_{\text{net}} = m\mathbf{a} \quad \Rightarrow \quad \sum F_x = ma_x \quad \sum F_y = ma_y \quad F = G\frac{m_1 m_2}{r^2}$

$g = 9.80\,\frac{\text{m}}{\text{s}^2} \quad G = 6.67\times10^{-11}\,\frac{\text{N}\cdot\text{m}^2}{\text{kg}^2} = 6.67\times10^{-11}\,\frac{\text{m}^3}{\text{kg}\cdot\text{s}^2} \quad \text{Weight} = mg$

$f_s^{\text{MAX}} = \mu_s F_N \quad f_k = \mu_k F_N \quad a_c = \frac{v^2}{r} \quad F_c = \frac{mv^2}{r} \quad C = 2\pi R \quad v = \frac{2\pi R}{T}$

$W = Fs\cos\theta \quad W_{\text{net}} = \Delta\text{KE} \quad \text{KE} = \frac{1}{2}mv^2 \quad \text{PE}_{\text{grav}} = mgy \quad \Delta E = \Delta\text{KE} + \Delta\text{PE} = W_{\text{non-cons}}$

$P = \frac{W}{t} \quad \mathbf{p} = m\mathbf{v} \quad \mathbf{I} = \Delta\mathbf{p} \quad \overline{\mathbf{F}} = \frac{\Delta\mathbf{p}}{\Delta t} = \frac{\mathbf{I}}{\Delta t} \quad x_{\text{CM}} = \frac{m_1 x_1 + m_2 x_2}{m_1 + m_2} \quad v_{\text{CM},x} = \frac{m_1 v_{1,x} + m_2 v_{2,x}}{m_1 + m_2}$

$1\text{ rev} = 360\text{ deg} = 2\pi\text{ rad} \quad s = \theta r \quad \overline{\omega} = \frac{\Delta\theta}{\Delta t} \quad \overline{\alpha} = \frac{\Delta\omega}{\Delta t}$

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

$v_T = r\omega \quad a_T = r\alpha \quad a_c = \frac{v_T^2}{r} = r\omega^2$

For all projectile problems, neglect air resistance.

Multiple Choice (2 pts each)

1. In terms of the basic units, the SI unit for energy is

(A) $\frac{kg^2 \cdot m}{s}$

(B) $\frac{kg \cdot m^2}{s^3}$

(C) $\frac{kg \cdot m^2}{s^2}$

(D) $\frac{kg \cdot m}{s^2}$

2. Projectiles A and B are fired straight up from ground level; the maximum height of B is 5 times that of A. The initial speed of B was

(A) $\sqrt{5}$ times that of A

(B) 5 times that of A

(C) $5\sqrt{5}$ times that of A

(D) 25 times that of A

3. A certain string breaks when it under 400 N of tension. A boy uses this string to whirl a 10 kg stone in a horizontal circle of radius 10 m. The boy continuously increases the speed of the stone. At approximately what speed will the string break?

(A) 10 m/s

(B) 20 m/s

(C) 80 m/s

(D) 100 m/s

4. A ball with a mass of 0.20 kg falls straight down and hits the floor with a speed of $1.2\,\frac{m}{s}$; it rebounds (straight up) with a speed of $0.80\,\frac{m}{s}$. The magnitude of the impulse imparted to the ball is

(A) $0.08\,\frac{kg \cdot m}{s}$

(B) $0.10\,\frac{kg \cdot m}{s}$

(C) $0.20\,\frac{kg \cdot m}{s}$

(D) $0.40\,\frac{kg \cdot m}{s}$

5. Mass B has twice the mass of mass A and is moving at twice the speed of A. Its kinetic energy is

(A) The same as that of A.

(B) Twice that of A.

(C) Four times that of A.

(D) Eight times that of A.

6. A car with kinetic energy 8×10^6 J travels along a horizontal road. How much power is required to stop the car in 10 s?

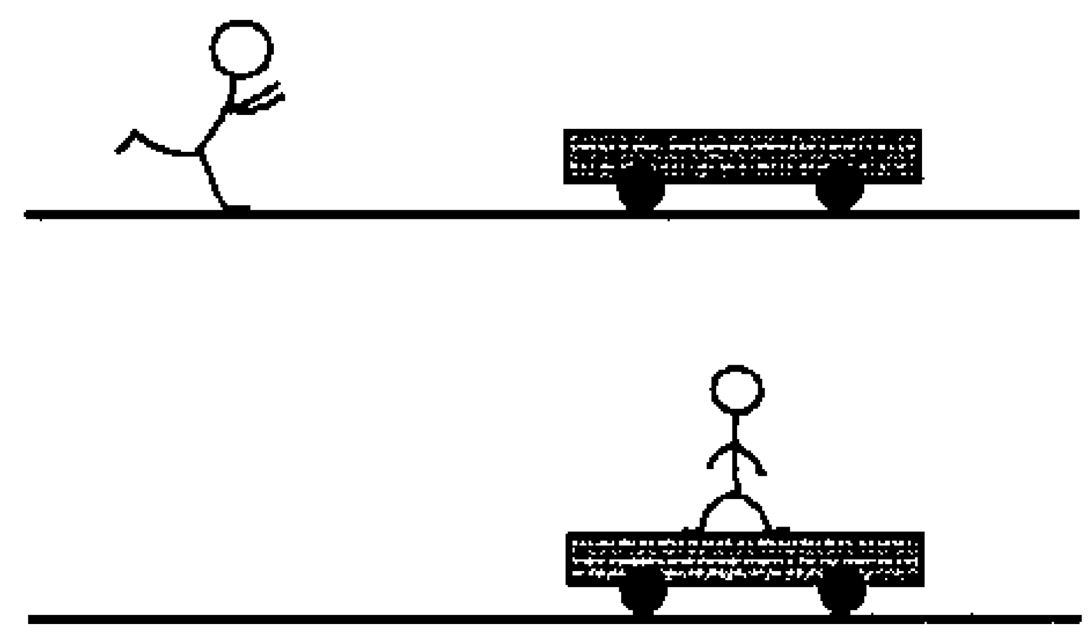
(A) Zero.

(B) 8×10^4 W

(C) 8×10^5 W

(D) 8×10^6 W

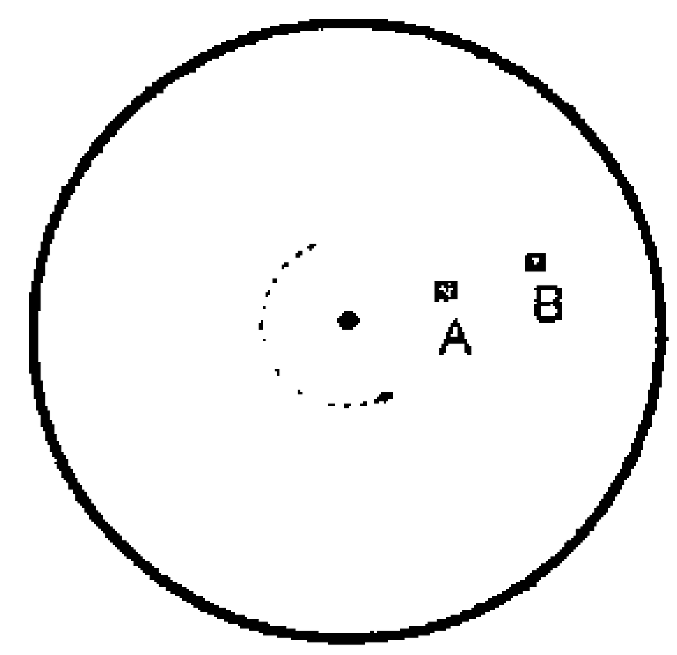
7. A 100-kg man runs at a speed of $10.0\frac{m}{s}$ and jumps onto a cart as shown in the figure. The cart is initially at rest. If the speed of the cart with the boy on it is $2.50\frac{m}{s}$, what is the mass of the cart?



(A) 300 kg
(B) 400 kg
(C) 600 kg
(D) 800 kg

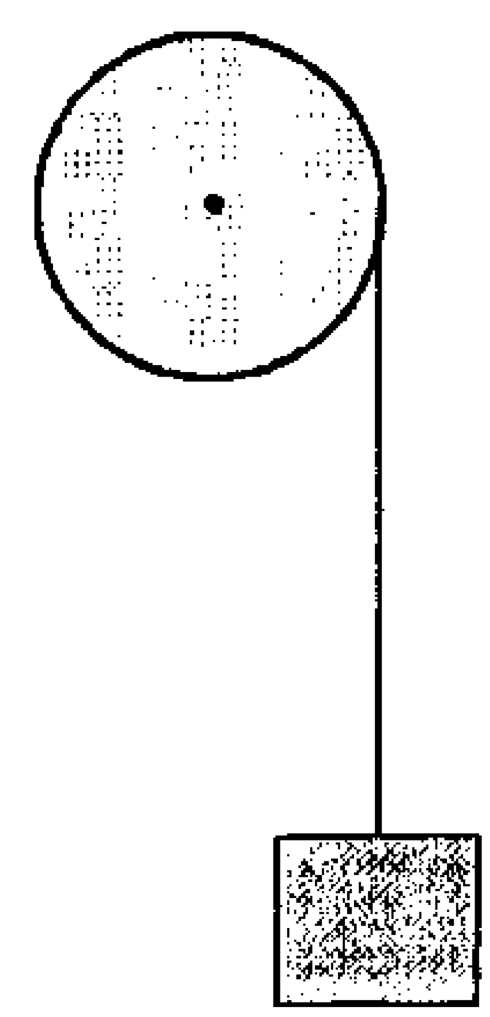
8. Which of the following quantities have the same units?
(A) Momentum and impulse.
(B) Momentum and average force.
(C) Impulse and potential energy.
(D) Kinetic energy and angular momentum.

9. Two points are located on a rigid wheel that is rotating with a constant angular acceleration. Point B is twice as far from the axis as point A. Which of the following is true concerning this situation?



(A) Both points have the same centripetal acceleration.
(B) Both point have the same tangential acceleration.
(C) The angular velocity of B is greater than that of A
(D) Both points have the same instantaneous angular velocity.

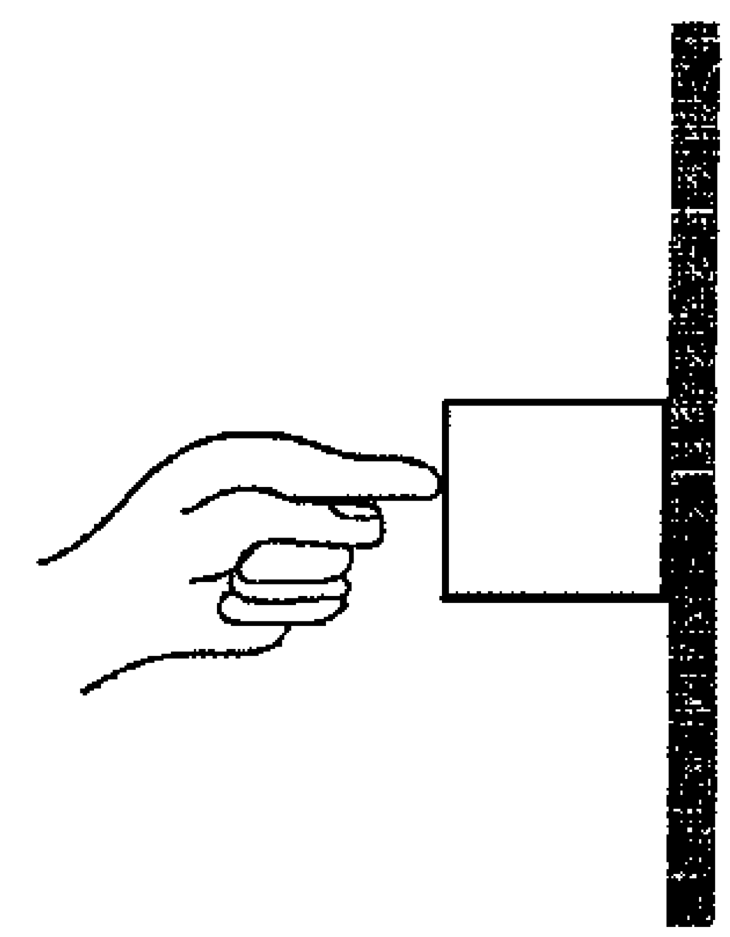
10. A mass hangs from a string which is wrapped around the outer edge of a disk of radius 0.20 m. The mass is descending at a rate of $1.0\frac{m}{s}$. What is the angular speed of the wheel?



(A) $0.040\frac{rad}{s}$
(B) $0.20\frac{rad}{s}$
(C) $5.0\frac{rad}{s}$
(D) $25.0\frac{rad}{s}$

Problems. (Show your work)

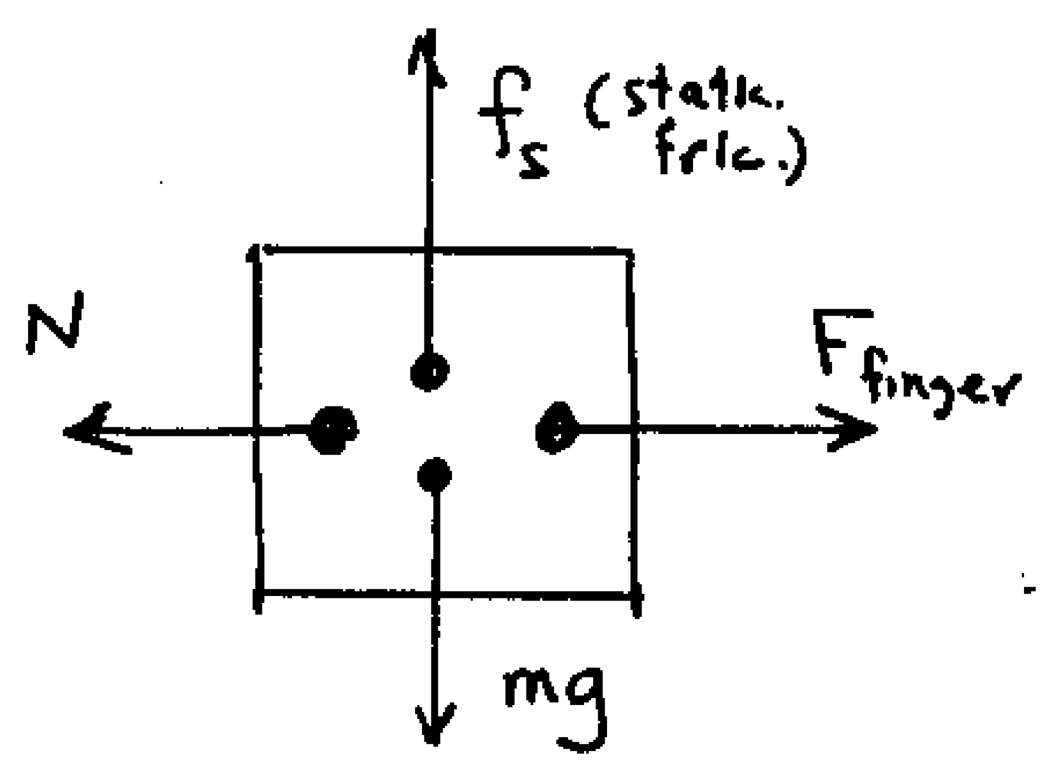
1. A physics student mystifies his friends by keeping a 450 g block from falling by pushing it against a rough (vertical) wall with his finger! His push is directed horizontally. See figure.



a) What is the force that keeps the block from falling? (2)

The force of $\boxed{\text{static friction}}$ (between wall and block).

b) Draw a Free-Body-Diagram[1] for the block. Clearly show what forces are acting and their direction. (6)



N = normal force of wall

$M = 0.450$ kg

c) The student finds that if he pushes with a force of 1.1 N, he will just barely be able to keep the block from falling. For this case, find the magnitudes of all the forces you diagrammed in part (b). (4)

Horiz. forces sum to zero: Gives $\boxed{F_{finger} = N = 1.1\ N}$

Vert. forces sum to zero: Gives $\boxed{f_s = mg} = (0.450\ kg)(9.80\ m/s^2) = \boxed{4.41\ N}$

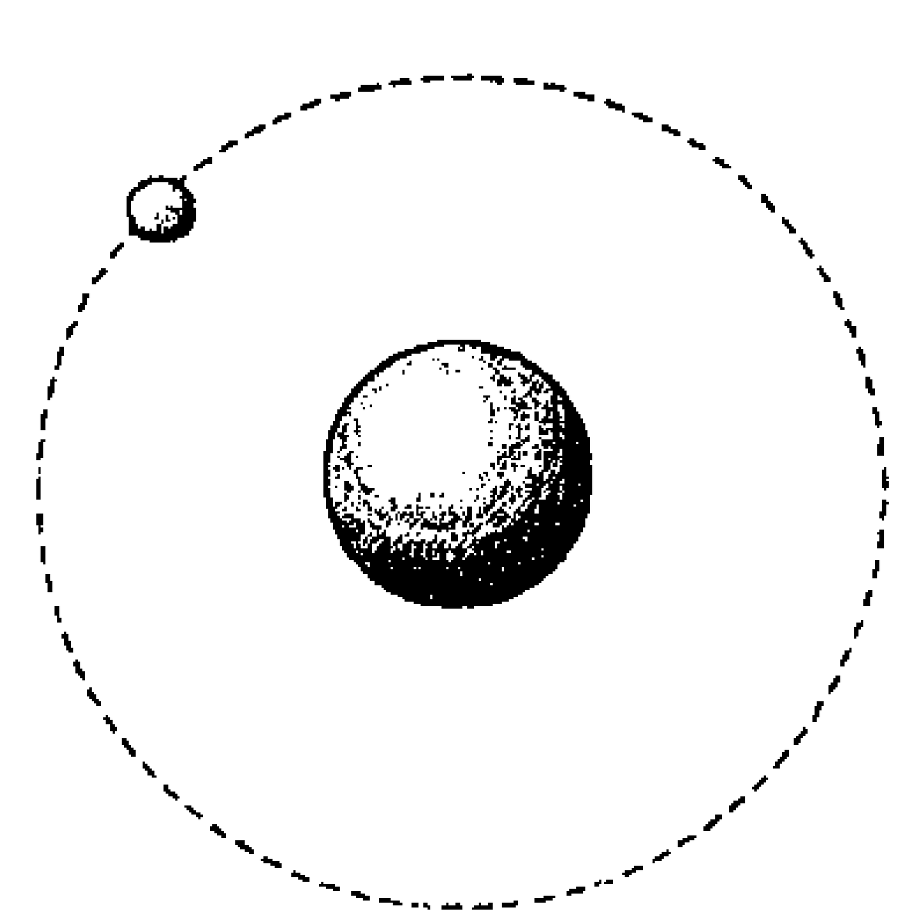
d) Recall that in part (c) the block was just about to slip when the 1.1 N force was applied. Find μ_s for the block and wall. *Hint: Under these conditions, one of those forces takes on its maximum value...* (3)

f_s (static friction) has its maximum value at the "just slipping" condition. Since $f_s^{MAX} = \mu_s N$, we get

$$\mu_s = f_s^{max} / N = \frac{4.41\ N}{1.1\ N} = \boxed{4.0}\ !$$

OK, unrealistically big. I made a poor choice of numbers! Normally, $0 \le \mu_s \le 1$

2. The planet Jupiter has a very interesting moon called Europa which orbits Jupiter at a radius of 6.70×10^8 m. The mass of Jupiter is 1.90×10^{27} kg and the mass of Europa is 4.75×10^{22} kg.



a) Identify the (physical) force acting on Europa which provides the centripetal force for its orbital motion. (2)

The force of $\boxed{\text{gravity}}$ (attractive force from planet Jupiter).

b) What is the magnitude of the force on Europa? (4)

From law of gravity,

$$F = G\frac{m_{Jup} m_{Eur}}{r^2} = \left(6.67\times10^{-11}\ \frac{Nm^2}{kg^2}\right)\frac{(1.90\times10^{27}\ kg)(4.75\times10^{22}\ kg)}{(6.70\times10^8\ m)^2}$$

$$= \boxed{1.34\times10^{22}\ N}$$

c) What is magnitude of the acceleration of Europa? (3)

Mag. of a is $a = F/m$:

$$a = \frac{1.34\times10^{22}\ N}{4.75\times10^{22}\ kg} = \boxed{2.82\times10^{-1}\ m/s^2}$$

d) What is the speed of Europa? (3)

The value found in (c) is the centripetal acceleration, $a_c = v^2/r$. So

$$v^2 = r a_c = (6.70\times10^8\ m)(0.282\ m/s^2) = 1.89\times10^8\ m^2/s^2$$

$$\longrightarrow \boxed{v = 1.37\times10^4\ m/s}$$

e) How long does it take Europa to orbit Jupiter? (5)

With T being the period of the motion,

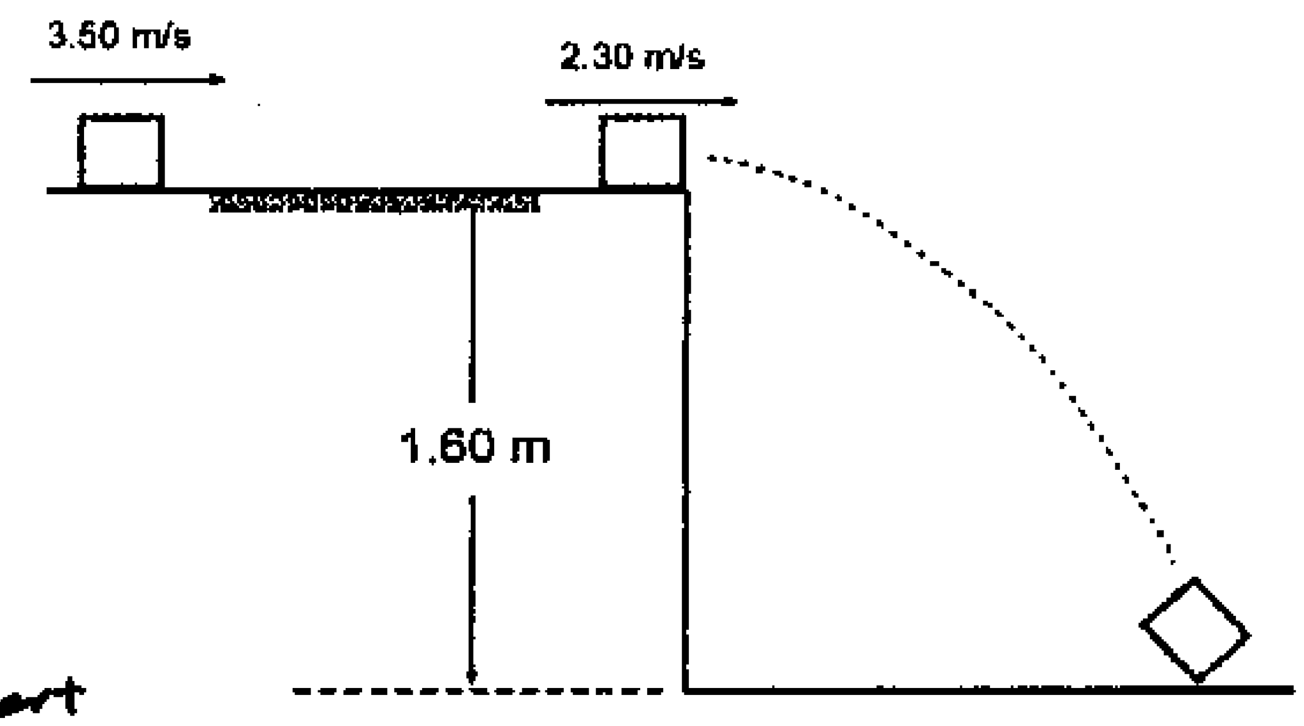
$$v = \frac{2\pi r}{T}, \quad \text{so} \quad T = \frac{2\pi r}{v} :$$

$$T = \frac{2\pi\,(6.70\times10^8\ m)}{1.37\times10^4\ m/s} = \boxed{3.06\times10^5\ s}$$

In more practical units,

$$T = (3.06\times10^5\ s)\left(\frac{1\ hr}{3600\ s}\right) = 85.0\ hr = 3.54\ days$$

3. A 2.10 kg mass begins sliding on a slightly rough horizontal table whose surface is 1.60 m above the floor. When the mass begins its motion, its speed is $3.50\frac{m}{s}$. When it comes to the edge of the table, its speed is $2.30\frac{m}{s}$.



a) What was the work done by friction during the block's slide to the edge? (4)

(Friction is the only force doing work for this part of the motion.)

$$W_{fric} = W_{net} = \Delta KE = KE_f - KE_o = \frac{1}{2}(2.10\,kg)(2.30\tfrac{m}{s})^2 - \frac{1}{2}(2.10\,kg)(3.50\tfrac{m}{s})^2$$

$$= \boxed{-7.30\text{ J}}$$

b) What is the speed of the block just before it strikes the floor? (6)

Between edge of table and floor, mechanical energy is conserved.

$$E_o = mgh + \frac{1}{2}mv_o^2 = (2.10\,kg)(9.8\tfrac{m}{s^2})(1.60\,m) + \frac{1}{2}(2.10\,kg)(2.30\tfrac{m}{s})^2$$

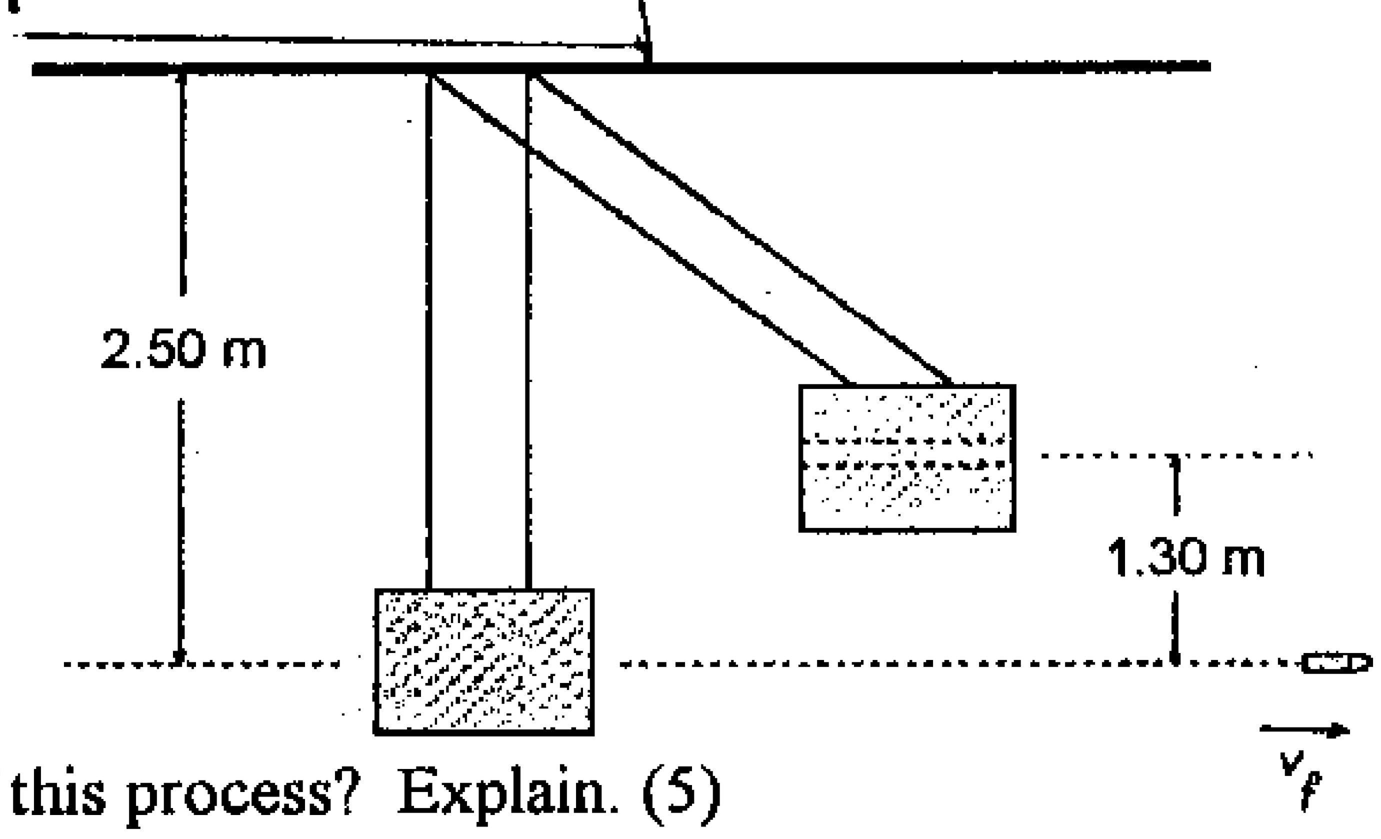
$$= 38.5\text{ J}$$

$$= E_f = \frac{1}{2}mv_f^2 .$$

Solve for v_f: $v_f^2 = \dfrac{2(38.5\text{ J})}{(2.10\,kg)} = 36.6\,\tfrac{m^2}{s^2}$

$$\Rightarrow \boxed{v_f = 6.05\tfrac{m}{s}}$$

4. A 0.055-kg bullet is fired with a speed of $715\frac{m}{s}$ at a 5.40-kg block of wax suspended from the ceiling by a rope of length 2.50 m. The bullet passes through the block and exits with a speed v_f and the block rises a vertical height of 1.30 m before coming to rest. Assume that the collision tiem is very short and that friction with the air and in the rope can be neglected.



a) Is linear momentum conserved during any part of this process? Explain. (5)

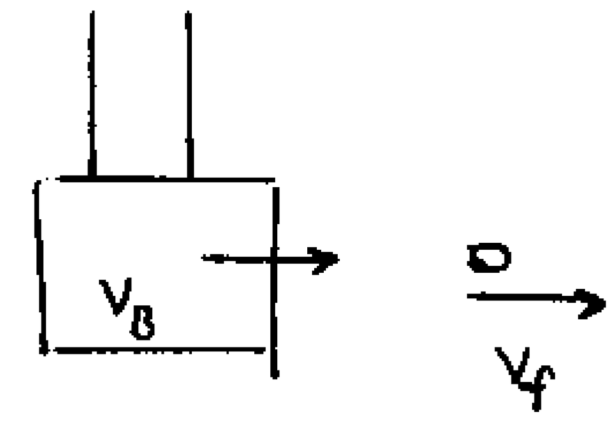
During the brief interaction between to bullet and block, linear momentum (of bullet + block) is conserved.

During this short time the outside force of gravity has a small effect on this system.

b) Is mechanical energy conserved during any part of this process? Explain. (5)

After the bullet has left the block, mech. energy is conserved as the block swings upward. This is because no non-conservative (friction-type) forces act on the block during this period.

c) Find the speed of the bullet v_f as it exits the block and the speed V_B of the block immediately after the collision. (12)



Mechanical energy conserved for the rising block, as given in part (b). Then:

$$\frac{1}{2}M_B V_B^2 = M_B g h \quad \Rightarrow \quad V_B^2 = 2gh = 2(9.80\tfrac{m}{s^2})(1.30m) = 25.5\tfrac{m^2}{s^2} \quad \rightarrow \quad \boxed{V_B = 5.05\tfrac{m}{s}}$$

Mom. conserved for bullet/block collision:

$$(0.055\,kg)(715\tfrac{m}{s}) = (0.055\,kg)v_f + (5.40\,kg)(5.05\tfrac{m}{s})$$

Use value of V_B already found

Solve for v_f: $(0.055\,kg)v_f = 12.1\,\tfrac{kg\,m}{s}$ $\boxed{v_f = 219\tfrac{m}{s}}$

5. A physics professor decides to play some of his vinyl records and switches on his turntable. Starting from rest, the turntable attains a rotation rate of $33.3\frac{rev}{min}$ in 1.8 seconds. (We'll assume that during this period the angular acceleration was constant.)

a) Express the final rotation rate of the record in $\frac{rad}{s}$. (3)

$$33.3\tfrac{rev}{min} = (33.3\tfrac{rev}{min})\left(\frac{2\pi\ rad}{rev}\right)\left(\frac{1\ min}{60\ s}\right) = \boxed{3.49\tfrac{rad}{s}}$$

b) Find the angular acceleration of the record; express the answer in $\frac{rad}{s^2}$. (3)

$$\alpha = \frac{\omega-\omega_0}{t} = \frac{3.49\frac{rad}{s} - 0}{1.8s} = \boxed{1.94\tfrac{rad}{s^2}}$$

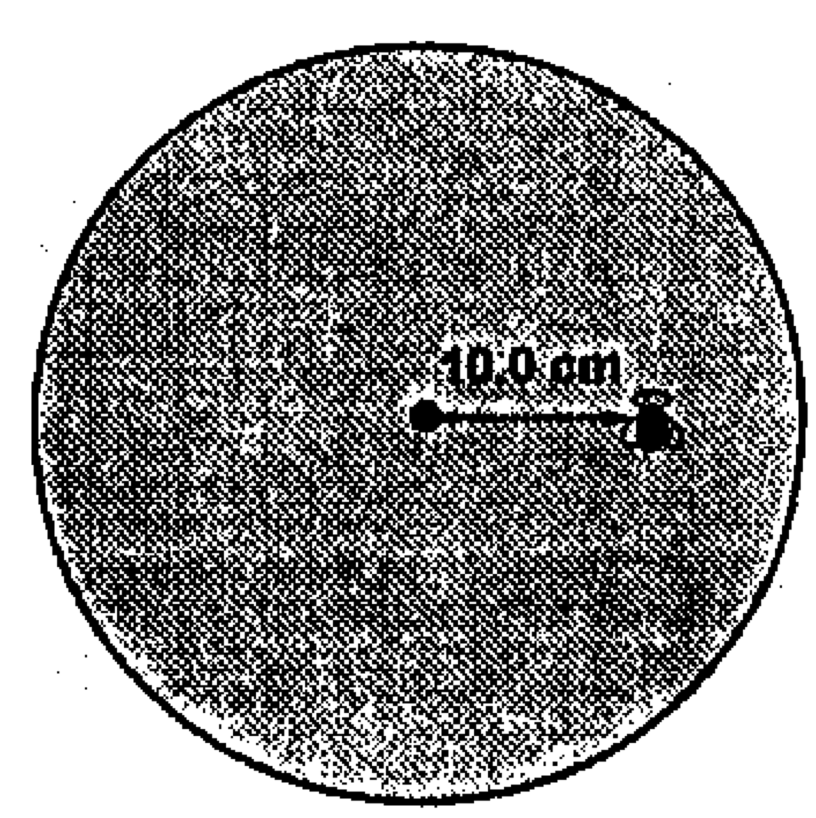
c) How many *revolutions* did the record make during the 1.8 second period? (5)

$$\theta = \omega_0 t + \tfrac{1}{2}\alpha t^2 = 0 + \tfrac{1}{2}(1.94\tfrac{rad}{s^2})(1.8s)^2 = 3.14\ rad$$

In revolutions,

$$\theta = (3.14\ rad)\left(\frac{1\ rev}{2\pi\ rad}\right) = \boxed{0.50\ rev}$$

d) As you might expect, flies are attracted to the physics professor's music, and after the record attains its final (constant) rotational speed, one of them lands on the record at a distance of 10.0 cm from its center. Find the linear speed of the fly and the magnitude of its acceleration. (5)



Since at that time, angular speed is $\omega = 3.49\frac{rad}{s}$, linear speed (v_T) is

$$v_T = \omega r = (3.49\tfrac{rad}{s})(0.100m) = 0.349\tfrac{m}{s}$$

The centripetal accel. of the fly is

$$a_c = \omega^2 r = (3.49\tfrac{rad}{s})^2(0.100m) = 1.22\tfrac{m}{s^2}$$

Since the tangential accel of the fly is zero, this is also the magnitude of its acceleration: