Dec. 15, 1999 **Name**____________________________________

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

Physics 121, Final Exam

1.	__________________	(18)
2.	__________________	(14)
3.	__________________	(24)
4.	__________________	(10)
5.	__________________	(14)
Mult Choice	__________________	(20)
Total	__________________	(100)

For all projectile problems, neglect air resistance.

<u>Multiple Choice</u> (2 pts each)

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

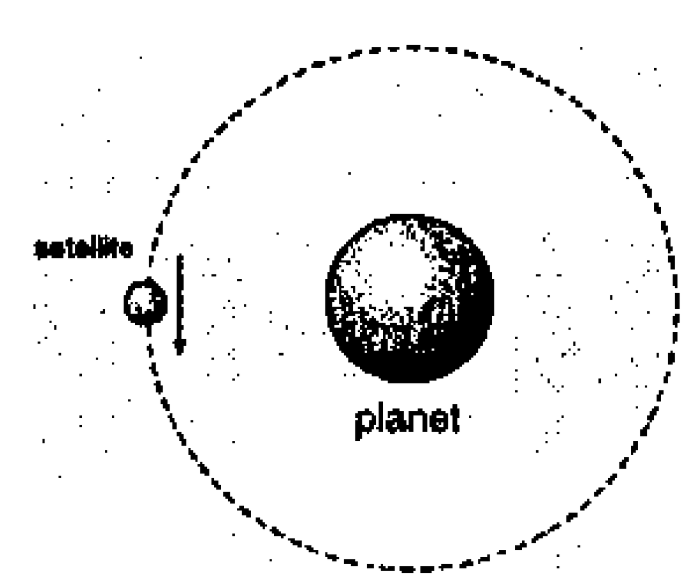
(A) $\frac{kg^2 \cdot m}{s}$

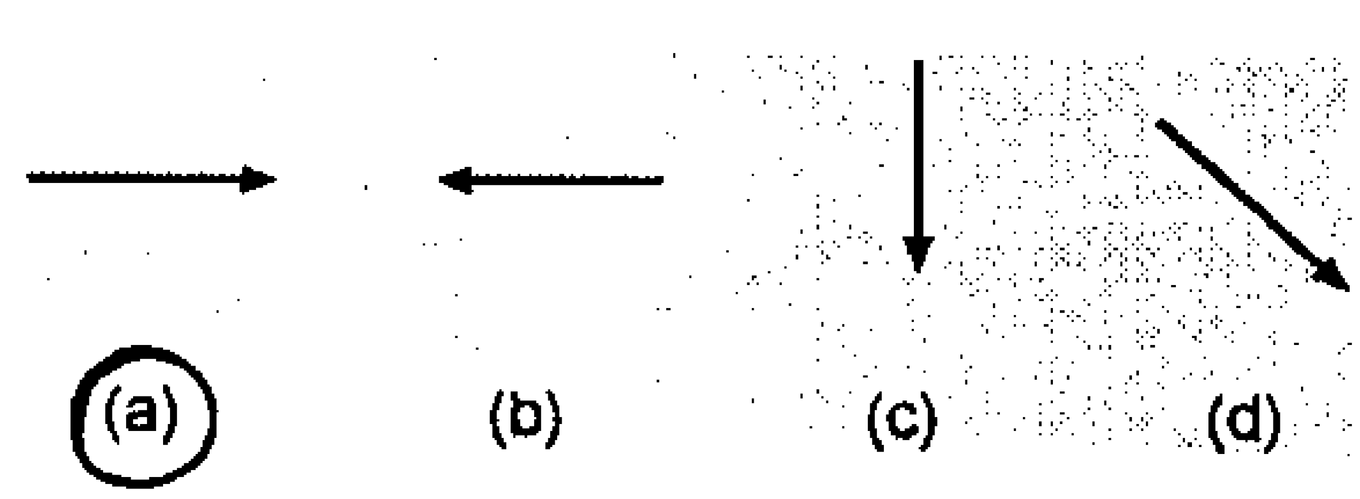
(B) $\frac{kg \cdot m^2}{s}$

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

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

2. A satellite is in circular orbit around a planet (with const. speed). At the instant shown in the figure, which arrow indicates the direction of the net force on the satellite?





3. A uniform cylinder of mass M and radius R and a uniform sphere of mass M and radius R are both rotating about their symmetry axes with angular frequency ω . For this case,
(A) The cylinder has more kinetic energy than the sphere.
(B) The sphere has more kinetic energy than the cylinder.
(C) Both objects have the same kinetic energy.
(D) One cannot compare their kinetic energies without knowing the value of ω .

4. The classroom demonstration wherein a (skater/ wacky professor / student "volunteer") stands on a freely rotating platform, then pulls in his arms and turns faster is an example of the conservation of
(A) Tangential acceleration.
(B) Torque.
(C) Angular momentum.
(D) Rotational energy.

5. The value of the gravitational acceleration (g) on the Moon is 1/6 its value on the Earth's surface. If we bring a simple pendulum to the Moon, how does its period compare with its period on the Earth?
(A) It is 6 times the period on Earth.
(B) It is $\sqrt{6}$ times the period on Earth.
(C) It is $\frac{1}{\sqrt{6}}$ times the period on Earth.
(D) It is 1/6 times the period on Earth.

6. Two (point) sources of waves radiate in all directions, both in phase and with wavelength 0.800 m. Point A is approximately in front of both speakers and is 3.0 m from one source and 4.2 m from the other. The interference of the waves at A is
(A) Constructive.
(B) Destructive.
(C) Alternately constructive and destructive.
(D) One cannot say without knowing the speed of sound in the medium.

7. What is the wavelength of a wave with speed $12\frac{m}{s}$ and period 0.25 s ?
(A) 1.5 m
(B) 3.0 m
(C) 24 m
(D) 48 m

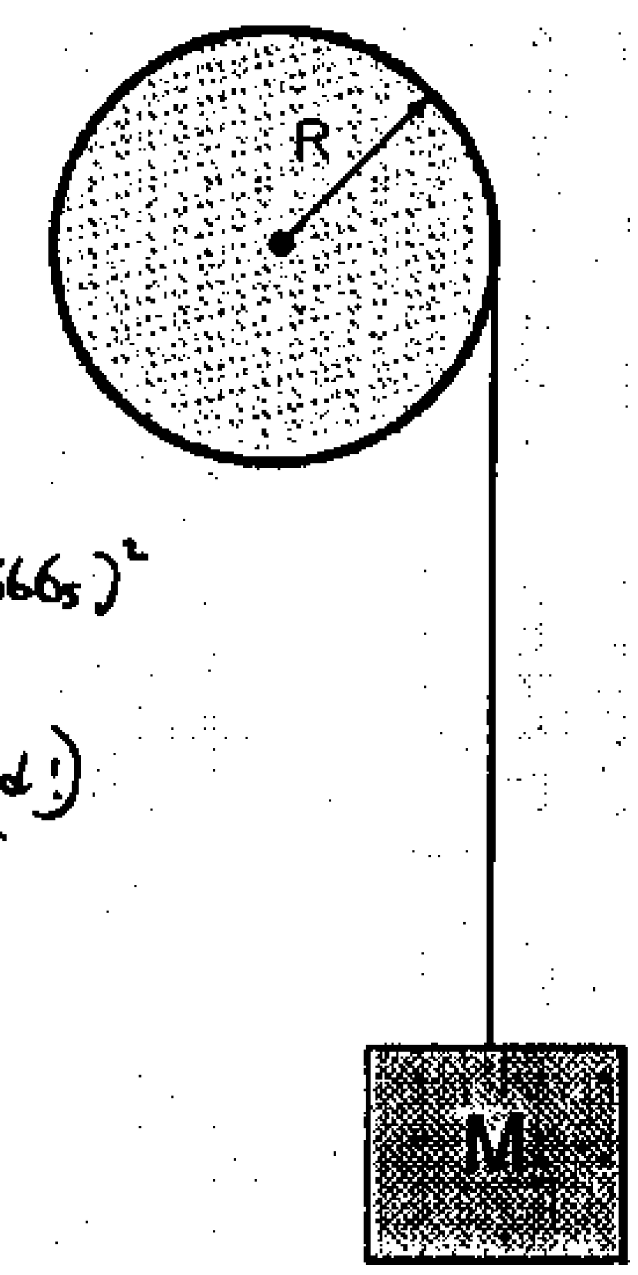
8. Which one of the following superpositions will result in beats?
(A) The superposition of waves that travel with different speeds.
(B) The superposition of waves that travel in opposite directions.
(C) The superposition of waves that are identical except for slightly different frequencies.
(D) The superposition of waves that are identical except for slightly different amplitudes.

9. A projectile is fired horizontally from a cliff with an initial speed of 50.0 m/s. What is the magnitude of the acceleration of the projectile 3.00 s after it is fired?
(A) $9.8\frac{m}{s^2}$
(B) $16.6\frac{m}{s^2}$
(C) $29.4\frac{m}{s^2}$
(D) $4.07\frac{m}{s^2}$

10. Two pieces of metal (A and B) are completely submerged in a fluid. B has twice the volume and twice the mass of A. The buoyant force on B is
(A) ½ the buoyant force on A.
(B) The same as the buoyant force on ~~B~~. A
(C) Twice the buoyant force on A.
(D) Four times the buoyant force on A.

Problems. (Show your work)

1. A 2.30 kg mass is suspended from a string which is wrapped around the outer edge of a uniform cylinder of radius 27.0 cm. The cylinder rotates freely about an axle through its center. The mass is allowed to fall. A student finds that when the mass starts from rest, it falls 1.00 m in 0.866 s.

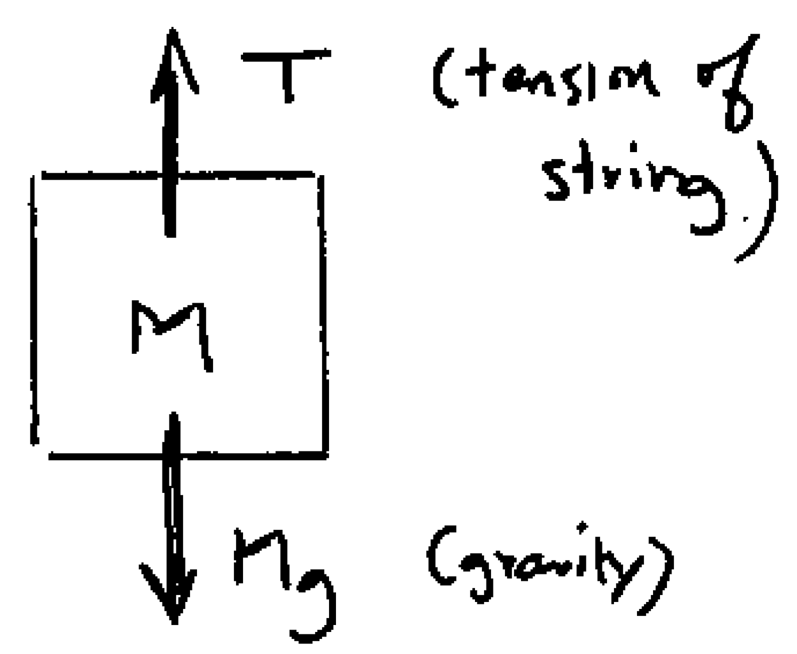


a) Find the acceleration of the mass. (3)

With axis $\downarrow x$, $x = 0 + \frac{1}{2} a_x t^2$ $\quad 1.00\,\text{m} = \frac{1}{2} a_x (0.866\,\text{s})^2$

$$a_x = \frac{2.00\,\text{m}}{(0.866\,\text{s})^2} = 2.67\,\text{m/s}^2 \quad \text{(downward!)}$$

b) In the space given here, draw a free-body diagram for the mass; that is, show all the forces acting on it as it falls. (2)



c) Using Newton's second law of motion, find the tension in the string as the mass falls. (4)

Sum forces in downward direction & use accel. found in part (a)

$$Mg - T = Ma_x$$

$$T = Mg - Ma_x = M(g - a_x) = (2.30\,\text{kg})(9.80\,\text{m/s}^2 - 2.67\,\text{m/s}^2) = 16.4\,\text{N}$$

d) Find the angular acceleration of the cylinder. (Hint: What is the tangential acceleration of the edge of the cylinder?) (3)

$$a_T = a_x = \alpha R$$

$$\alpha = \frac{a_T}{R} = \frac{2.67\,\text{m/s}^2}{(0.270\,\text{m})} = 9.88\,\text{s}^{-2}$$

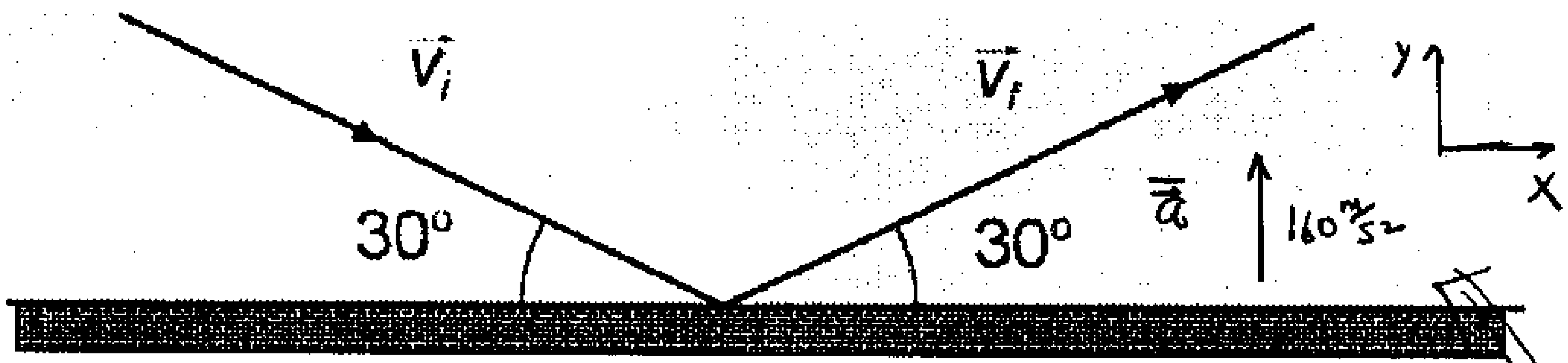
e) What is the torque acting on the cylinder as the mass falls? (3)

$$\tau = TR = (16.4\,\text{N})(0.270\,\text{m}) = 4.43\,\text{N}\cdot\text{m}$$

f) Find the moment of inertia of the cylinder. (3)

$$I = \frac{\tau}{\alpha} = \frac{4.43\,\text{N}\cdot\text{m}}{9.88\,\text{s}^{-2}} = 0.448\,\text{kg}\,\text{m}^2$$

2. Billy is playing air hockey, and he manages to bank the puck off the wall as shown. The puck's initial and final speeds are essentially the same; both are 4.0 m/s. The initial and final velocities make angles of 30.0° with the wall as shown. The mass of the puck is 75 grams, and the puck is in contact with the wall for 0.025 sec.



Magnitude 160 m/s², points away from wall

a) Calculate the average acceleration of the puck for the 0.025 sec time interval while it is in contact with the wall. Determine the magnitude and direction of this vector, and sketch that vector on the figure. (8)

Changes in vel. components for collision w/ wall:

$$\Delta V_x = (4.0 \tfrac{m}{s} \cos 30°) - (4.0 \tfrac{m}{s} \cos 30°) = 0$$

$$\Delta V_y = (4.0 \tfrac{m}{s} \sin 30°) - (-4.0 \tfrac{m}{s} \sin 30°) = +4.0 \tfrac{m}{s}$$

$$\bar{a}_x = \frac{\Delta V_x}{\Delta t} = 0$$

$$\bar{a}_y = \frac{\Delta V_y}{\Delta t} = \frac{+4.0 \tfrac{m}{s}}{(0.025\ s)} = +160 \tfrac{m}{s^2}$$

b) What was the average force exerted by the puck on the wall? State the magnitude and direction of this vector, and explain your reasoning! (6)

The average force on the puck for the collision was

$$\bar{F}_x = m\bar{a}_x = 0 \qquad \bar{F}_y = m\bar{a}_y = (0.075\ kg)(160 \tfrac{m}{s^2}) = 12.0\ N$$

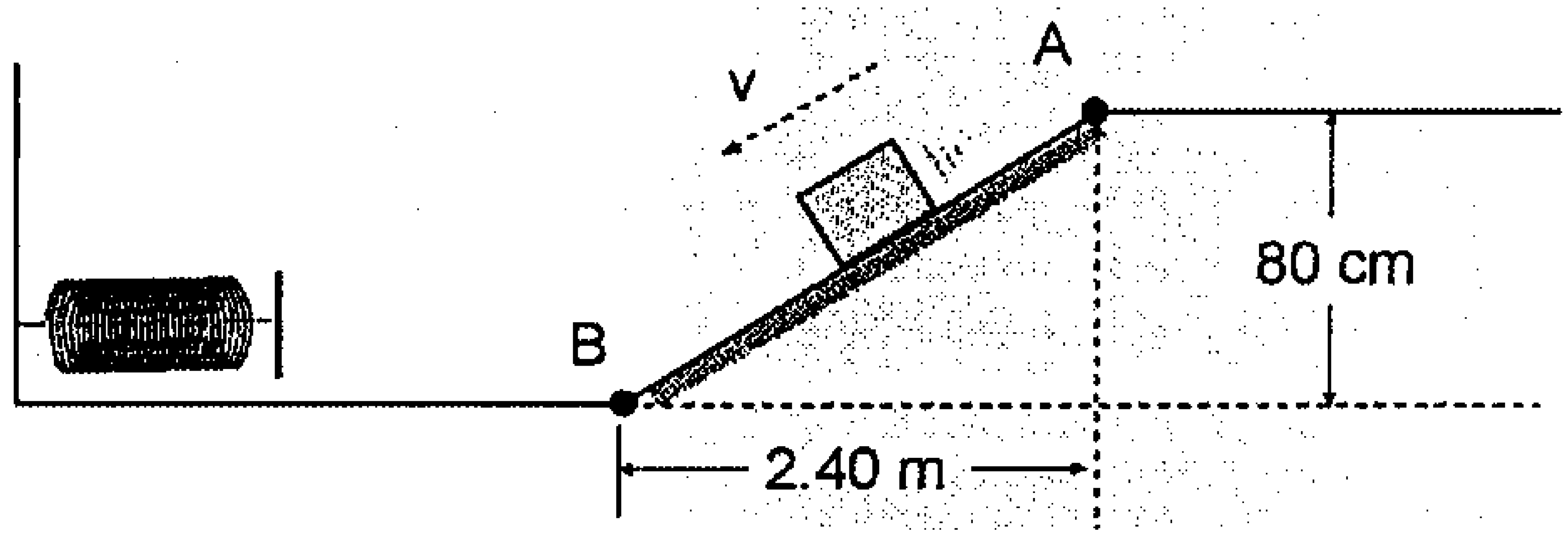
and this force come from the wall.

By Newton's 3rd Law, the avg. force of the puck on the wall is the opposite of this vector, namely it has components

$$\bar{F}_x' = 0 \qquad \bar{F}_y' = -12.0 N$$

So it has magnitude 12.0 N and points toward the wall (−y dir. in picture).

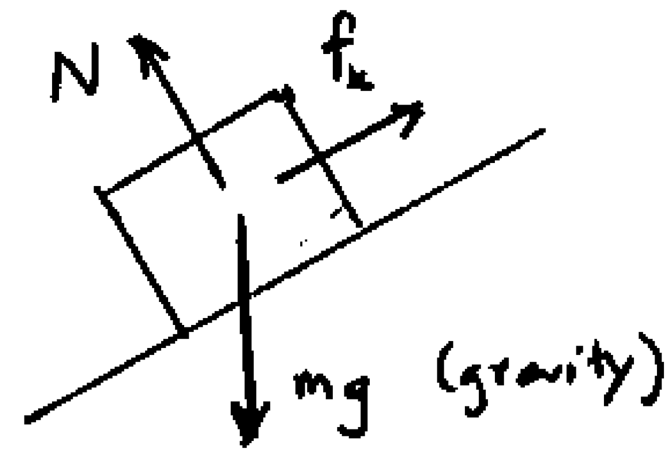
3. A 0.60 kg block is sliding along the surface shown. When it passes the point A, its speed is 1.9 m/s and when it passes the point B, its speed is 4.0 m/s. Point A is 80 cm above point B, and the horizontal distance between them is 2.40 m. The surface between A and B might be rough; it is not known whether friction can be neglected or not.



a) Draw a free body diagram for the block as it slides from A to B down the ramp. Be sure to show all the forces acting on the block, and do **not** assume that friction can be neglected. (4)

$\vec{N}$ = normal force of ramp

$\vec{f}_k$ = force of kin. friction of ramp.



b) Calculate the work done by gravity on the block as it moved from A to B. (5)

$$W_{grav} = -\Delta PE_{grav} = -mg\,\Delta y = -(0.60\,\text{kg})(9.80\,\tfrac{\text{m}}{\text{s}^2})(-0.80\,\text{m})$$

$$= 4.7\ \text{J}$$

c) How much work was done by friction (if any) on the block as it moved from A to B? (5)

Between A and B,

$$\Delta KE = KE_B - KE_A = \tfrac{1}{2}(0.60\,\text{kg})(4.0\,\tfrac{\text{m}}{\text{s}})^2 - \tfrac{1}{2}(0.60\,\text{kg})(1.9\,\tfrac{\text{m}}{\text{s}})^2 = +3.72\ \text{J}$$

Then, using the result of part (b),

$$\Delta KE + \Delta PE = W_{fric} = -4.7\ \text{J} + 3.72\ \text{J} = -1.0\ \text{J}$$

d) After the block passes the point B, it hits the ideal spring and compresses it. The spring has k = 25 N/m and the horizontal surface from B to the wall is perfectly smooth; friction can be neglected there. How much does the block compress the spring? (5)

Energy is conserved between $\underline{B}$ and when the spr. is $\underline{\text{maximally}}$ $\underline{\text{squished}}$.

We have: (Using $PE_{sp} = \tfrac{1}{2}kx^2$)

$$\tfrac{1}{2}(0.60\,\text{kg})(4.0\,\tfrac{\text{m}}{\text{s}})^2 = \tfrac{1}{2}(25\,\tfrac{\text{N}}{\text{m}})\,x^2$$

Solve for x:

$$x^2 = \frac{(0.60\,\text{kg})(4.0\,\tfrac{\text{m}}{\text{s}})^2}{25\,\tfrac{\text{N}}{\text{m}}} = 0.38\ \text{m}^2$$

$$x = 0.62\ \text{m}$$

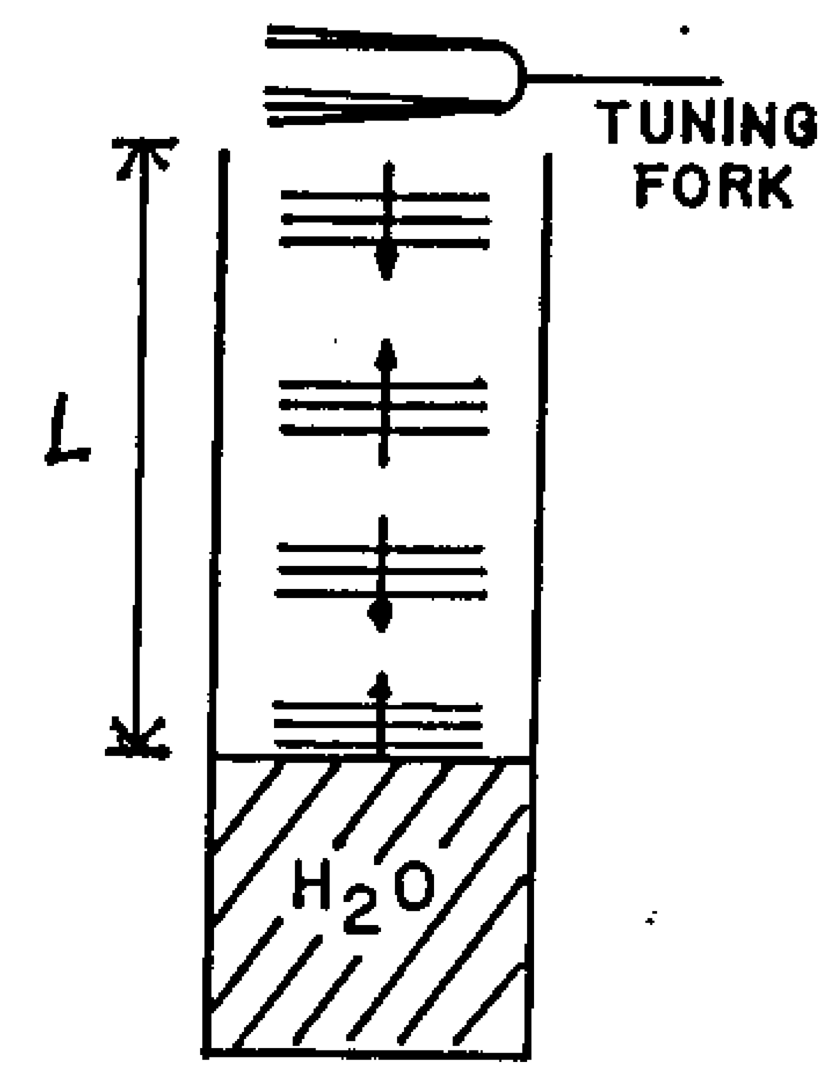
e) If the block sticks to the end of the spring, then the block will just oscillate back and forth around the spring's equilibrium position. Calculate the time that is required for the block to make one complete oscillation. (5)

Freq. of osc. motion will be

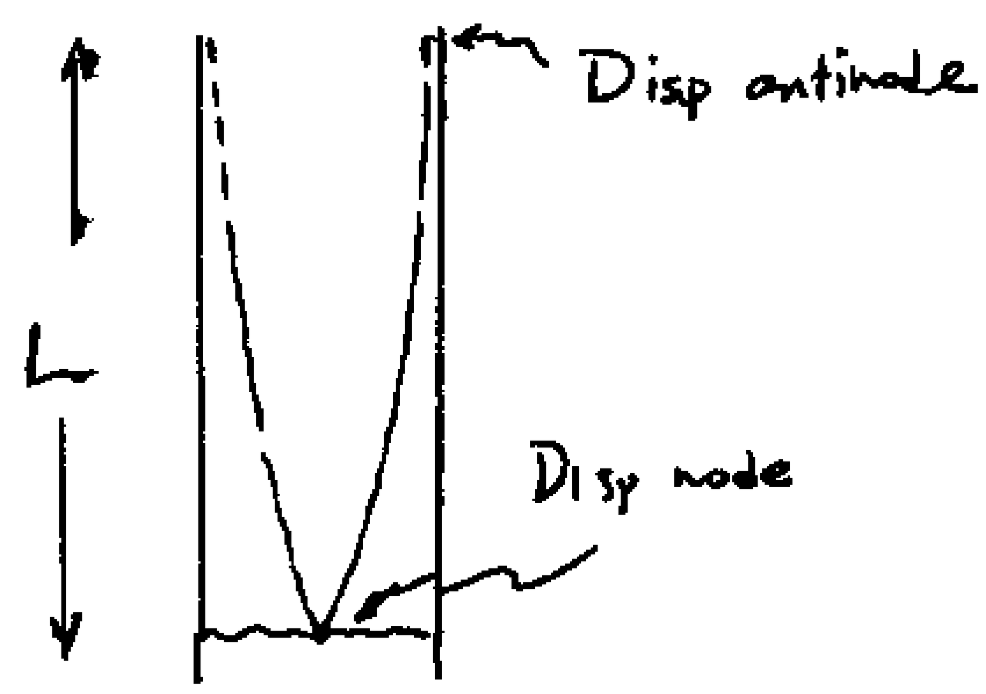
$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}} = \frac{1}{2\pi}\sqrt{\frac{25\,\tfrac{\text{N}}{\text{m}}}{(0.60\,\text{kg})}} = 1.03\ \text{sec}^{-1}$$

Period is $T = 1/f = 0.97\ \text{s}$

4. In order to determine the frequency of sound waves produced by a tuning fork, you set up standing sound waves in a tube partially filled with water. You find a resonance when the length of the column of air is 32.7 cm. Assume that this is the <u>shortest</u> possible air column that can resonate at this frequency, and that the speed of sound in air is 343 m/s.



a) Sketch the longitudinal standing waves, and label the displacement nodes and antinodes clearly. (2)



b) Calculate the frequency of these sound waves. (4)

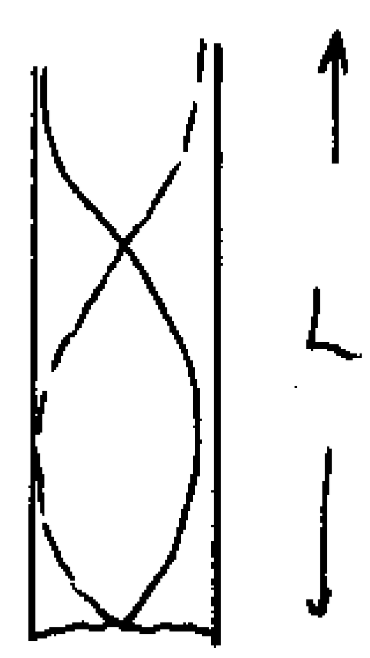
$L = \lambda/4$ (quarter of wavelength)

So $\lambda = 4L = 4(0.327\ m) = 1.31\ m$

$$f = \frac{v_{sound}}{\lambda} = \frac{343\ m/s}{1.31\ m} = 262\ Hz$$

c) If you lower the water level in the tube, where will you find the next resonance using the same tuning fork, i.e., at the same frequency? Calculate the length of the air column that would produce that resonance. (4)

Sketch of wave will be:



with $L = \frac{3}{4}\lambda$

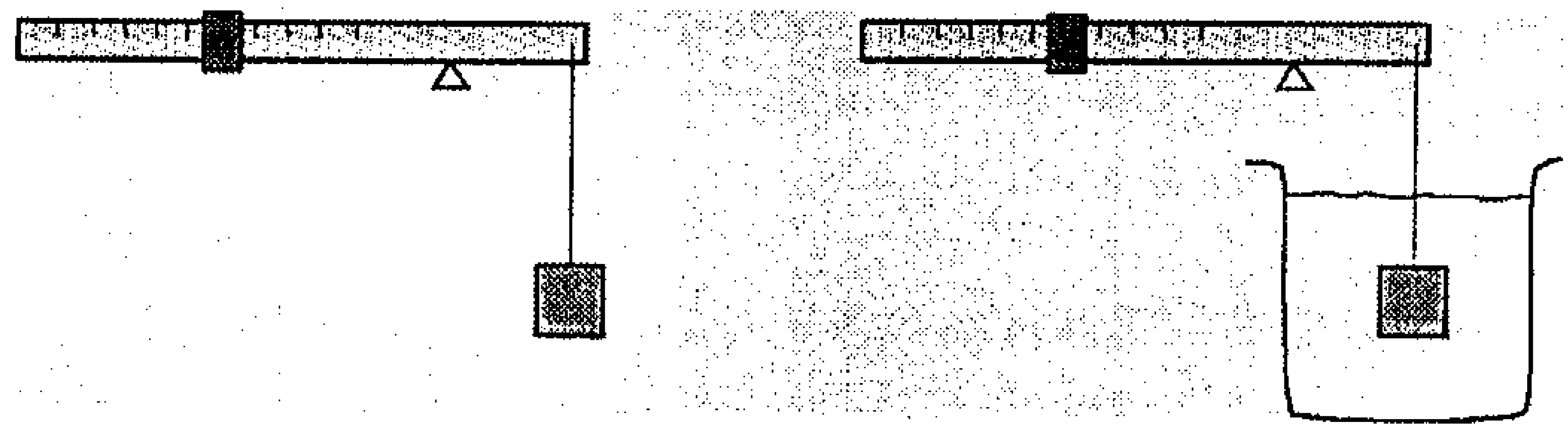
(Same λ as before!)

The new air column length is

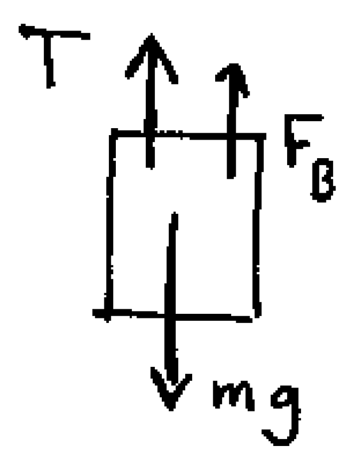
$$L = \tfrac{3}{4}\lambda = \tfrac{3}{4}(1.31\ m) = 0.982\ m$$

$$= 98.2\ cm$$

5. A sample of an unkown metal is "weighed" in air and is found to have a mass of 550 g. When it is "weighed" while submerged in water, the scale reading is 388 g. The difference in these readings is due to the buoyant force of the water!



a) What is the magnitude of the buoyant force while the sample is under water? (A free-body diagram may be of use.) (4)



$F_B + T$
$= mg$

$$T = (0.388\ kg)(9.80\ \tfrac{m}{s^2}) = 3.80\ N$$
$$mg = (0.550\ kg)(9.80\ \tfrac{m}{s^2}) = 5.39\ N$$
$$F_B = mg - T = 1.59\ N$$

b) What is the weight of the displaced water? (2)

$$W_{disp} = F_B = 1.59\ N$$

c) What is the mass of the displaced water? (2)

$$m_{disp} = \frac{W_{disp}}{g} = \frac{(1.59\ N)}{(9.80\ \frac{m}{s^2})} = 0.162\ kg$$

d) What is the volume of the displaced water? The density of water is $1.00 \times 10^3 \frac{kg}{m^3}$.
(2)

$$m = \rho V$$

$$V_{disp} = \frac{m_{disp}}{\rho_{H_2O}} = \frac{(0.162\ kg)}{(1.00 \times 10^3\ kg/m^3)} = 1.62 \times 10^{-4}\ m^3$$

e) What is the density of the metal? (4)

$$V_{metal} = V_{disp} = 1.62 \times 10^{-4}\ m^3$$

$$\rho_{metal} = \frac{m_{metal}}{V_{metal}} = \frac{0.550\ kg}{1.62 \times 10^{-4}\ m^3} = 3.40 \times 10^3\ kg/m^3$$
$$= 3.40\ g/cm^3$$