Lecturer: Robinson Murdock **Name**________________________

Dec 13, 2000

Phys 121 — Fall 2000
Final Exam

1.	____________	(16)
2.	____________	(16)
3.	____________	(10)
4.	____________	(14)
5.	____________	(9)
6.	____________	(15)
MC	____________	(20)
Total	____________	(100)

Multiple Choice

1. A car drives a distance of 2.00 km along a long straight road, at a constant speed of 25.0 $\frac{m}{s}$, in a time of 80.0 s. Its average acceleration is:

a) 0.313 $\frac{m}{s^2}$
b) 25.0 $\frac{m}{s^2}$
c) 0 $\frac{m}{s^2}$
d) 0.0250 $\frac{m}{s^2}$

2. Consider a single object upon which a varying number of *non-zero* forces may act. In which of the following situations is it *impossible* for the object to maintain motion at a constant speed?

a) One single force acts on the object.
b) Two forces act on the object.
c) More than two forces act on the object.
d) None of the above.

3. While backing up your truck in a supermarket parking lot you collide with an empty (stationary) shopping cart, left by a careless shopper. The cart is crushed, while your truck sustains very little damage. This difference is because:

a) The mass of the truck is much greater than the mass of the cart, so the truck exerted a much greater force on the cart that the cart exerted on the truck.

b) The truck was moving before the collision so it exerted a force on the cart. The cart was not moving before the collision so it did not exert a force on the truck.

c) The impulse the truck imparted to the cart was much greater than the impulse that the cart imparted to the truck.

d) The forces exerted on the truck and the cart were the same magnitude, but the effect of those forces on the two colliding objects were different.

4. You are pushing a heavy sofa across a rough horizontal floor at a constant speed. Which of the following conditions *must* be true? (Assume the only forces acting on the sofa are your push, kinetic friction, weight and a normal force.)

a) The magnitude of the force of your push is greater than the weight of the sofa.

b) The magnitude of the force of your push is equal to the magnitude of the force of kinetic friction acting on the sofa.

c) The magnitude of the force of your push is greater than the magnitude of the force of kinetic friction acting on the sofa

d) The magnitude of the force of your push is equal to the weight of the sofa.

5. Suppose you doubled the strength of your push on the sofa in #4, while all other forces remained at the same strength. How would the sofa move now?

a) The sofa's speed would gradually increase.

b) The sofa would move at the same constant speed as in #4.

c) The sofa would move at a constant speed that is double the speed in #4.

d) None of the above.

6. A spinning ice skater starts with outstretched arms and then pulls them in close to her body to increase her angular velocity. Which of these statements is true about this situation (assuming frictional effects can be ignored)?

a) Angular momentum is not conserved, but rotational kinetic energy is conserved.

b) Both angular momentum and rotational kinetic energy are conserved.

c) Angular momentum is conserved, but rotational kinetic energy is not conserved.

d) Neither angular momentum nor rotational kinetic energy is conserved.

7. A mass M hanging from a vertical spring (spring constant k), moves up and down with simple harmonic motion with a period T, here on the Earth. If the mass/spring system were taken to the Moon, where gravity is weaker that on Earth, its new period would be:

a) Longer than it was on Earth.

b) The same as it was on Earth.

c) Shorter than it was on Earth.

d) It would not move with simple harmonic motion.

8. A single 60 m length of string, of mass 300 g is cut into two pieces, 20 m in length, the other 40 m in length. Both pieces are stretched with a tension of 200 N. Which statement is true about the speed of waves traveling on the two pieces?

a) Waves travel faster on the longer piece.

b) Waves travel faster on the shorter piece.

c) Waves travel at the same speed on both pieces.

d) It is impossible to tell.

9. Two facing loudspeakers are connected to two different sound generators. A listener halfway between the two loudspeakers hears successive periods of repeating loud and soft sound ("beating"). This means that:

a) The two sound waves have the same frequency but the generators are out of phase.

b) The two sounds have slightly different frequencies.

c) The two sounds have the same frequency and the generators are in phase.

d) The two sounds travel at slightly different speeds.

10. Two identical balloons are filled to the same size (volume), one with helium, the other with carbon dioxide. When released from a height of 1 m, it is observed that the helium balloon floats upward, whereas the carbon dioxide balloon sinks to the floor. This is because:

a) The weight of the two balloons is about the same but the buoyant force on the helium balloon is much stronger.

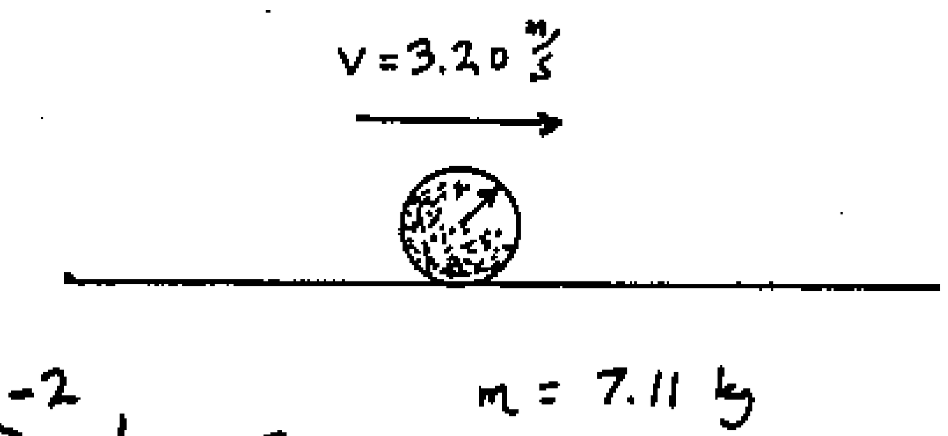
b) The buoyant force on the two balloons is about the same, but the carbon dioxide balloon is heavier.

c) Both the weight and buoyant force are different for the two balloons.

d) The weight and the buoyant force on both balloons are the same. This is caused by some other effect.

Problems

1. A solid uniform metal ball of radius 6.0 cm and mass 7.11 kg rolls without slipping on a flat surface with speed 3.20 $\frac{m}{s}$.



a) Find the moment of inertia of the ball (for an axis through its center). (3)

$$I = I_{sol\ ball} = \frac{2}{5}MR^2$$

$$= \frac{2}{5}(7.11\ kg)(0.060\ m)^2 = 1.02\times10^{-2}\ kg\cdot m^2$$

b) Find the angular speed of the ball as it rolls. (3)

$$\omega = \frac{v_{cm}}{r} = \frac{(3.20\ \frac{m}{s})}{(0.060\ m)} = 53.3\ \frac{rad}{s}$$

c) Find the kinetic energy of rotation of the ball. (2)

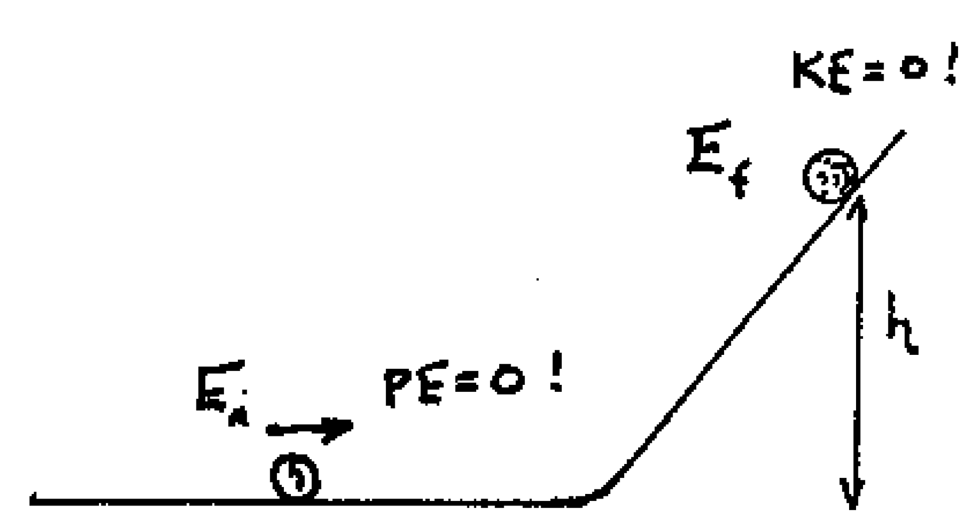
$$KE_{rot} = \frac{1}{2}I\omega^2 = \frac{1}{2}(1.02\times10^{-2}\ kg\ m^2)(53.3\ \frac{rad}{s})^2$$

$$= 14.6\ J$$

d) Find the *total* kinetic energy of the ball. (3)

$$KE_{Tot} = \frac{1}{2}Mv_{cm}^2 + \underbrace{\frac{1}{2}I\omega^2}_{=KE_{rot}} = \frac{1}{2}(7.11\ kg)(3.20\ \frac{m}{s})^2 + 14.6\ J$$

$$= 36.4\ J + 14.6\ J = 51.0\ J$$



e) The ball then continues to roll without slipping up a slope. Find the maximum height to which the ball rises. *(Hint: In this problem, there is no work done by non-conservative (friction) forces..* (5)

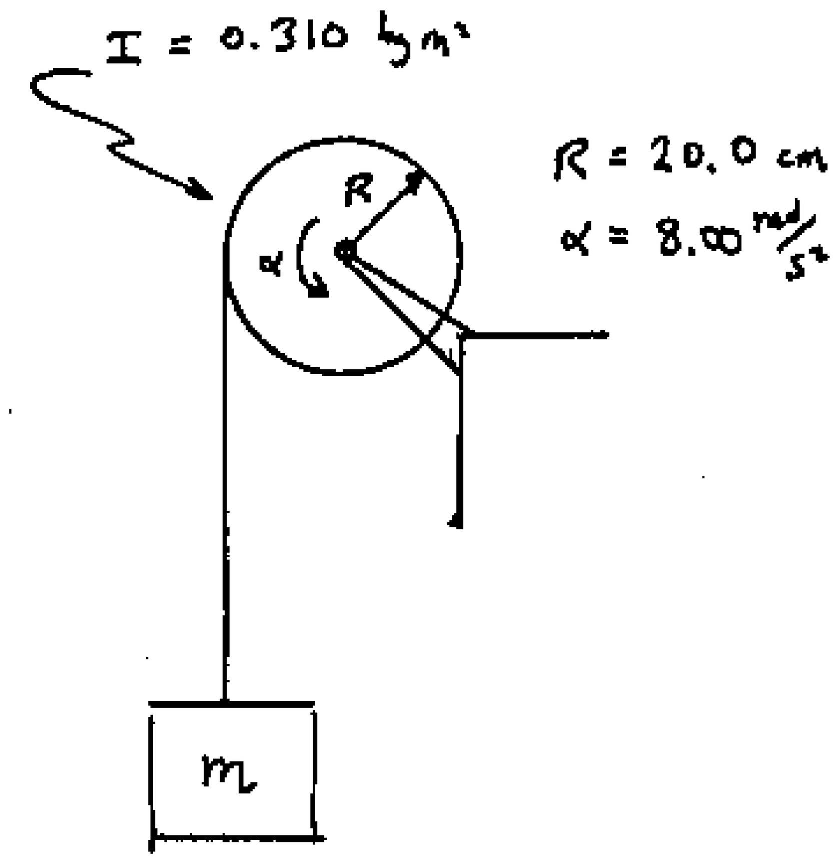
Mechanical energy is conserved:

Let initial height = 0 so $PE_o = 0$

$$E_o = E_f \Rightarrow 51.0\ J = mgh$$

$$h = \frac{51.0\ J}{mg} = \frac{51.0\ J}{(7.11\ kg)(9.80\ m/s^2)} = 0.73\ m$$

2. A mass m is attached to a string which is wrapped around the rim of a wheel of radius 20.0 cm. The wheel has a moment of inertia of $0.310\,\mathrm{kg\cdot m^2}$. The mass is released and as a result the wheel is given an angular acceleration of $8.00\,\frac{\mathrm{rad}}{\mathrm{s}^2}$.

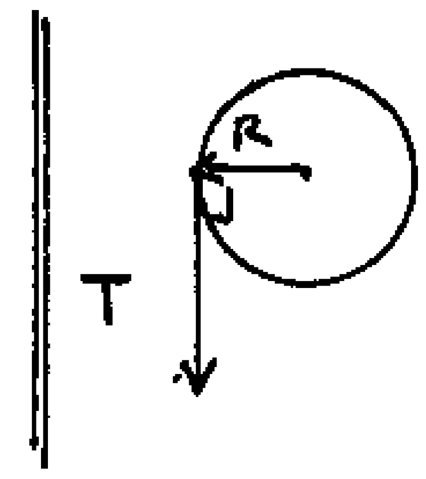


a) What is the net torque on the wheel? (3)

$$\tau_{net} = I\alpha = (0.310\ \mathrm{kg\cdot m^2})(8.00\ \mathrm{rad/s^2})$$
$$= 2.48\ \mathrm{N\cdot m}$$

b) Assuming that the the only torque on the wheel comes from the string (which pulls tangentially at the rim) find the tension in the string. (3)

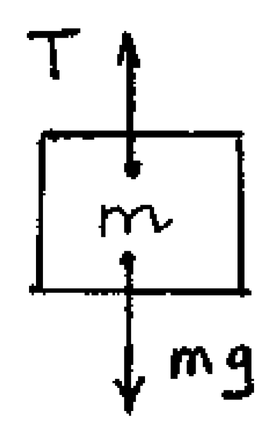
$$\tau_{net} = T\cdot R\cdot(1), \quad \text{so}$$
$$T = \tau_{net}/R = \frac{2.48\ \mathrm{N\cdot m}}{(0.20\ \mathrm{m})} = 12.4\ \mathrm{N}$$



c) What is the magnitude of the acceleration of mass m? *(Hint: It is the same as the tangential acceleration of the edge of the wheel.)* (2)

$$a_{(down)} = a_{T,\ wheel} = \alpha R = (8.00\ \mathrm{rad/s^2})(0.200\ \mathrm{m}) = 1.60\ \mathrm{m/s^2}$$

d) Draw a free-body diagram for the mass m, showing all the forces and their directions. (3)

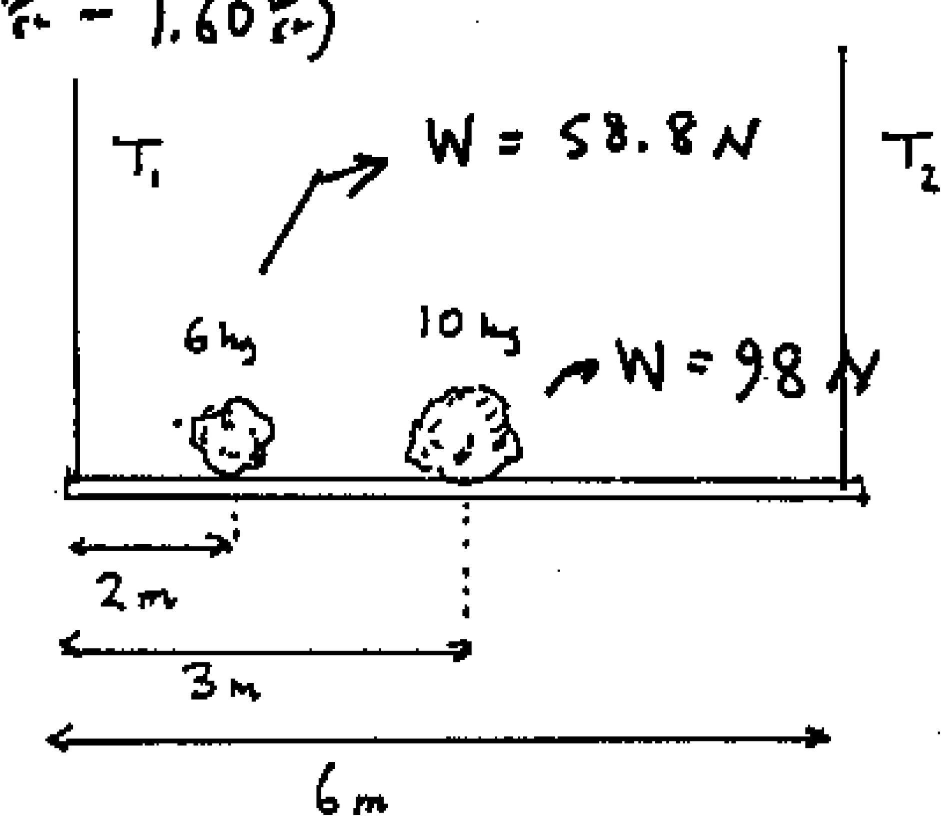


e) Now use Newton's 2^{nd} Law ($\mathbf{F}_{net} = m\mathbf{a}$) to find m. (5)

Sum of the downward forces will equal $m a_{down}$

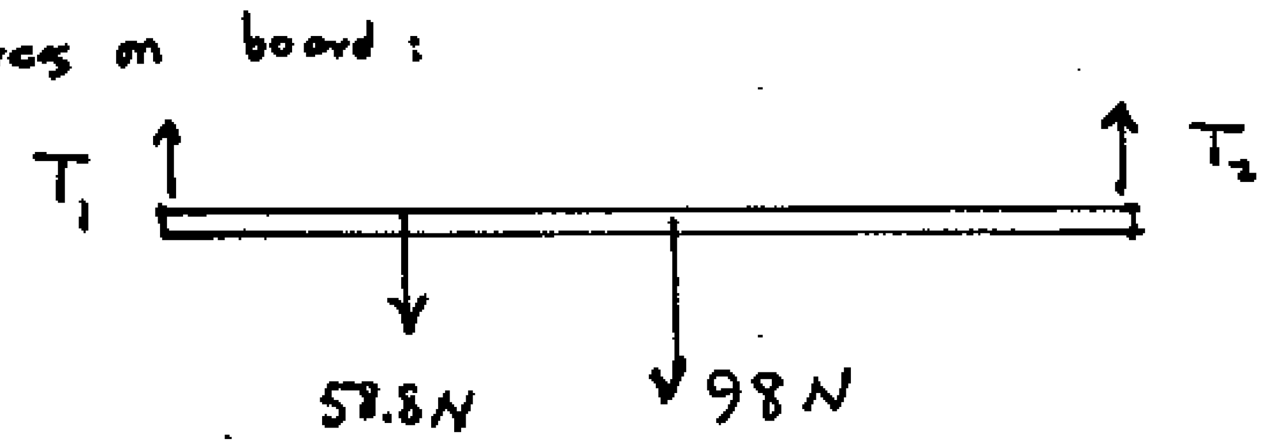
$$mg - T = m a_{down} \quad \text{so} \quad mg - m a_{down} = T, \quad \text{or:}$$
$$m(g - a_{down}) = T \qquad m = \frac{T}{(g - a_{down})} = \frac{(12.4\ \mathrm{N})}{(9.8\ \mathrm{m/s^2} - 1.60\ \mathrm{m/s^2})} = 1.51\ \mathrm{kg}$$

3. A 6.00 m— long board of negligible mass is help up by vertical cords at both ends. A rock of mass 6.0 kg is resting on the board 2.00 m from the left end and a rock of mass 10.0 kg is resting on the board at its center.



Find the tensions in the two cords. (10)

Forces on board:



$\Sigma\tau = 0$:

Axis at right end: $-T_1(6\ \mathrm{m}) + (58.8\ \mathrm{N})(4\ \mathrm{m}) + (98\ \mathrm{N})(3\ \mathrm{m}) = 0$

Solve for T_1: $T_1 = \dfrac{529.2\ \mathrm{N\cdot m}}{(6.0\ \mathrm{m})} = 88.2\ \mathrm{N}$

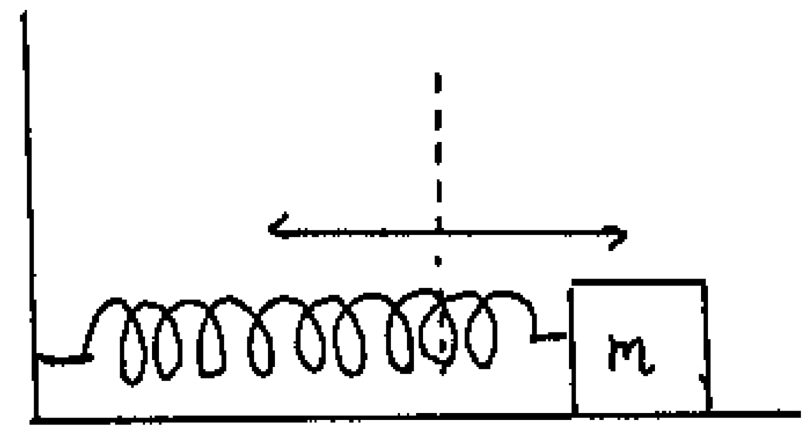
$\Sigma\tau = 0$

Axis at left end:

$$-(58.8\ \mathrm{N})(2\ \mathrm{m}) - (98\ \mathrm{N})(3\ \mathrm{m}) + T_2(6\ \mathrm{m}) = 0$$

Solve for T_2: $T_2 = \dfrac{411.6\ \mathrm{N\cdot m}}{(6\ \mathrm{m})} = 68.6\ \mathrm{N}$

4. A 0.500 kg mass is attached to the end of a horizontal spring and makes small oscillations while moving on a frictionless surface. It is found that the mass makes 30.0 oscillations in 10.0 s and the amplitude of its motion is 2.0 cm.



a) What is the frequency of oscillation of the mass? (2)

$$f = \frac{30.0 \text{ osc}}{10.0 \text{ sec}} = 3.00 \text{ Hz}$$

b) What is the force constant of the spring? (4)

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}} \qquad f^2 = \frac{1}{4\pi^2}\frac{k}{m} \qquad k = 4\pi^2 m f^2$$

$$\Rightarrow k = 4\pi^2 (0.500 \text{ kg})(3.00 \text{ s}^{-1})^2 = 177.7 \frac{\text{N}}{\text{m}}$$

c) What is the potential energy of the system when the spring is maximally extended? (3)

When $x = \pm A$, then

$$PE_{spring} = \tfrac{1}{2}kA^2 = \tfrac{1}{2}(177.7 \tfrac{\text{N}}{\text{m}})(0.020 \text{ m})^2 = 3.55 \times 10^{-2} \text{ J}$$

d) What is the speed of the mass as it passes through the center point of its motion? *(The surface is frictionless...)* (5)

By energy cons, the answer to (c) is the same as the KE at the center pos (where spring is not stretched). Then:

$$\tfrac{1}{2}mv^2 = 3.55 \times 10^{-2} \text{ J} \qquad v^2 = \frac{2(3.55\times10^{-2} \text{ J})}{(0.500 \text{ kg})} = 1.4\times10^{-1} \tfrac{\text{m}^2}{\text{s}^2} \qquad v = 0.377 \tfrac{\text{m}}{\text{s}}$$

5. A standing wave is set up on a string of length 130 cm whose ends are fixed and which is under a tension of 5.00 N. The frequency of the string's vibration is 250 Hz; the pattern of the string's vibration looks like the diagram shown here.

$f = 250$ Hz

a) What is the wavelength of this standing wave? (3)

$$L = 3 \cdot \frac{\lambda}{2} \text{ for this mode} \qquad \lambda = \tfrac{2}{3}L = \tfrac{2}{3}(1.30 \text{ m}) = 0.867 \text{ m}$$

b) What is the speed of waves on the string? (3)

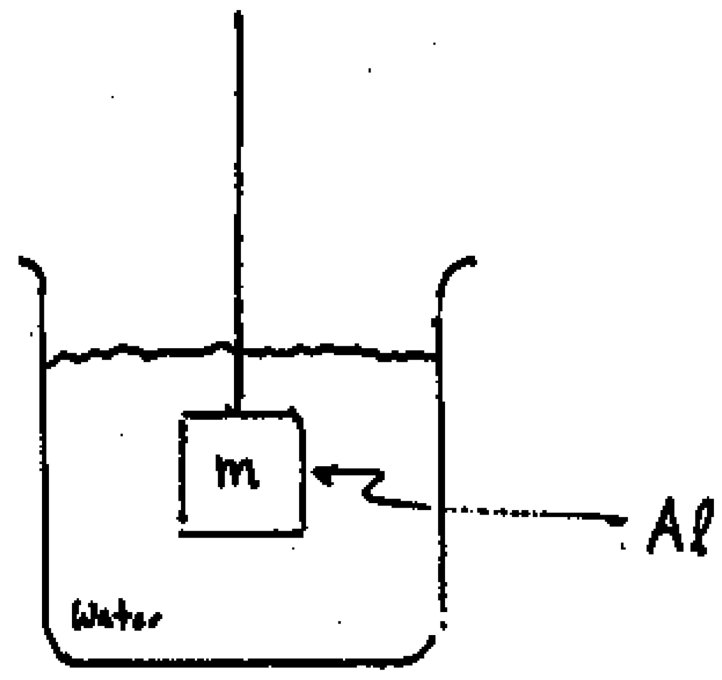
$$v = \lambda f = (0.867 \text{ m})(250 \text{ s}^{-1}) = 217 \tfrac{\text{m}}{\text{s}}$$

c) What is the mass per unit length (mass density) of the string? (3)

$$v = \sqrt{\frac{F}{(\frac{m}{L})}}, \text{ so } v^2 = \frac{F}{(\frac{m}{L})}$$

$$\left(\frac{m}{L}\right) = \frac{F}{v^2} = \frac{5.00 \text{ N}}{(217 \tfrac{\text{m}}{\text{s}})^2} = 1.1 \times 10^{-4} \frac{\text{kg}}{\text{m}}$$

6. A 1.00 kg piece of solid aluminum hangs from a string, completely immersed in water.



$m = 1.00\ \text{kg}$

$\rho_{Al} = 2.70\ \text{gm/cm}^3 = 2.70 \times 10^3\ \text{kg/m}^3$

a) What is the volume of the aluminum sample? (3)

$$\rho_{Al} = \frac{m_{Al}}{V_{Al}} \qquad V_{Al} = \frac{m_{Al}}{\rho_{Al}}$$

$$\rightarrow V_{Al} = \frac{(1.00\ \text{kg})}{(2.70 \times 10^3\ \text{kg/m}^3)} = 3.70 \times 10^{-4}\ \text{m}^3$$

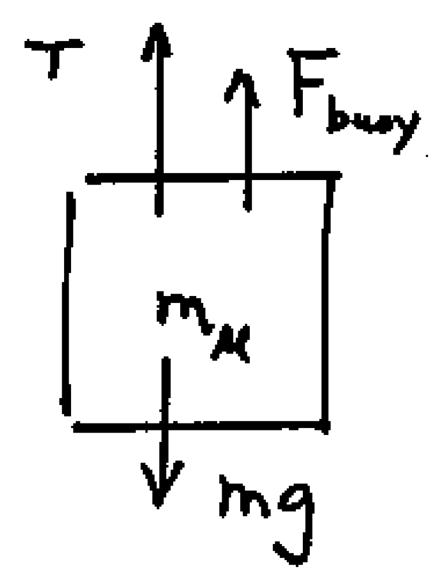
b) What is the weight of the fluid displaced by the sample? (3)

Vol of fl (water) disp'd is $3.70 \times 10^{-4}\ \text{m}^3$

Mass of fluid disp'd is $V_{Al} \cdot \rho_{H_2O} = (3.70 \times 10^{-4}\ \text{m}^3)\left(\frac{10^3\ \text{kg}}{\text{m}^3}\right) = 0.370\ \text{kg}$

Wt of fluid disp'd is $m_f g = (0.370\ \text{kg})(9.8\ \text{m/s}^2) = 3.63\ N$

c) Draw a (free–body) diagram showing all the forces acting on the mass as it hangs from the string, submersed. (4)



d) Find the tension in the string. (5)

Sum of the forces is zero:

$$T + F_{buoy} - mg = 0$$

From Arch Prnc, $F_{buoy} = W_{disp\ fl} = 3.63\ N$

$$T = m_{Al} g - F_{buoy} = (1.00\ \text{kg})(9.8\ \text{m/s}^2) - 3.63\ N$$

$$= 6.17\ N$$

$$v_x = v_{0x} + a_x t \qquad x = x_0 + v_{0x}t + \tfrac{1}{2}a_x t^2 \qquad v_x^2 = v_{0x}^2 + 2a_x(x - x_0) \qquad x = \tfrac{1}{2}(v_{0x} + v_x)t$$

$$v_y = v_{0y} + a_y t \qquad y = y_0 + v_{0y}t + \tfrac{1}{2}a_y t^2 \qquad v_y^2 = v_{0y}^2 + 2a_y(y - y_0) \qquad y = \tfrac{1}{2}(v_{0y} + v_y)t$$

$$g = 9.80\tfrac{\text{m}}{\text{s}^2} \qquad \mathbf{F}_{\text{net}} = m\mathbf{a} \qquad a_c = \frac{v^2}{r} \qquad F_c = \frac{mv^2}{r} \qquad f_s^{\max} = \mu_s F_N \qquad f_k = \mu_k F_N$$

$$F_{\text{grav}} = G\frac{m_1 m_2}{r^2}, \quad \text{where} \quad G = 6.67 \times 10^{-11}\tfrac{\text{N}\cdot\text{m}^2}{\text{kg}^2} \qquad g = 9.80\tfrac{\text{m}}{\text{s}^2}$$

$$W = Fd\cos\theta \qquad F_{\text{spr}} = -kx$$

$$\text{KE} = \tfrac{1}{2}mv^2 \qquad \text{PE}_{\text{grav}} = mgh \qquad \text{PE}_{\text{spr}} = \tfrac{1}{2}kx^2 \qquad P = \tfrac{W}{t} \qquad P = Fv$$

The change in total mechanical energy is the work done by the non–conservative forces:

$$\Delta E = \Delta\text{PE} + \Delta\text{KE} = W_{\text{non-cons}}$$

$$\mathbf{p} = m\mathbf{v} \qquad \mathbf{I} \equiv \Delta\mathbf{p} \qquad \mathbf{F} = \frac{\Delta\mathbf{p}}{\Delta t} \quad \text{(Constant force)}$$

For a system with no net external force, the total momentum is conserved.

$$\omega = \omega_0 + \alpha t \qquad \theta = \theta_0 + \omega_0 t + \tfrac{1}{2}\alpha t^2 \qquad \omega^2 = \omega_0^2 + 2\alpha(\theta - \theta_0)$$

$$v = r\omega \qquad a_c = \frac{v^2}{r} = \omega^2 r \qquad a_T = r\alpha \qquad \omega = 2\pi f \qquad T = \frac{1}{f}$$

$$\tau = rF\sin\phi \qquad \tau_{\text{net}} = I\alpha \qquad \text{KE}_{\text{rot}} = \tfrac{1}{2}I\omega^2 \qquad I = \sum_{\text{mass pts}} mr^2$$

$$I_{\text{disk}} = \tfrac{1}{2}MR^2 \qquad I_{\text{solid ball}} = \tfrac{2}{5}MR^2 \qquad I_{\text{rod,mid}} = \tfrac{1}{12}ML^2 \qquad I_{\text{rod,end}} = \tfrac{1}{3}ML^2$$

$$\text{KE}_{\text{roll, total}} = \tfrac{1}{2}Mv_{\text{cm}}^2 + \tfrac{1}{2}I\omega^2 \qquad v_{\text{cm}} = \omega r \qquad a_{\text{cm}} = \alpha r \qquad L = I\omega \qquad \tau = \frac{\Delta L}{\Delta t}$$

For a system with no net external *torque*, the total *angular* momentum is conserved.

$$\text{Statics:} \quad \sum\mathbf{F} = 0 \implies \left(\sum F_x = 0 \quad \text{and} \quad \sum F_y = 0\right), \quad \sum_{\text{any axis}} \tau = 0$$

$$f = \frac{1}{T} \qquad \omega = 2\pi f \qquad f = \frac{1}{2\pi}\sqrt{\frac{k}{m}} \qquad f = \frac{1}{2\pi}\sqrt{\frac{g}{L}} \qquad v_{\max} = A\omega \qquad a_{\max} = A\omega^2$$

$$\lambda f = v \qquad v_{\text{str}} = \sqrt{\frac{F}{\left(\frac{m}{L}\right)}} \qquad \text{Use} \ v_{\text{sound}} = 343\tfrac{\text{m}}{\text{s}} \qquad f_{\text{beat}} = |f_1 - f_2|$$

$$\rho = \frac{M}{V} \qquad \rho_{H_2O} = 1.0 \times 10^3\tfrac{\text{kg}}{\text{m}^3} \qquad \rho_{\text{Al}} = 2.70 \times 10^3\tfrac{\text{kg}}{\text{m}^3} \qquad \rho_{\text{Steel}} = 7.86 \times 10^3\tfrac{\text{kg}}{\text{m}^3}$$

$$P_2 - P_1 = \rho gh \qquad P = P_{\text{atm}} + \rho gh \qquad P = P_{\text{gauge}} + P_{\text{atm}}$$

Archimedes' Princ: Buoyant force equals weight of displaced fluid.