Name Units? Units?

Class Time: 10am 11am 1pm

Dec. 10, 2003

Phys 2010 — Fall 2003
Final Exam

1.	______	(10)
2.	______	(14)
3.	______	(10)
4.	______	(10)
5.	______	(10)
6.	______	(13)
7.	______	(6)
8.	______	(7)
MC.	______	(20)
Total	______	(100)

On the Problems, you must show all your work and include the right units with your answers!

Multiple Choice

Choose (with a circle around the letter) the best answer from among the four.

1. If we increase the length of a simple pendulum by a factor of 4, its period increases by a factor of

a) 16
b) 4
c) 2
d) 1 (i.e. it stays the same)

2. A block, attached to the end of a spring, executes simple harmonic motion about its equilbibrium position. When the block is at its maximum displacement from the equilibrium position, its instantaneous acceleration has a magnitude which is

a) Zero.
b) The maximum value.
c) Somewhere between zero and the maximum.
d) Cannot be determined.

3. The velocity of propagation of a transverse wave on a 2.0 m –long string fixed at both ends is 200 $\frac{\text{m}}{\text{s}}$. Which one of the follwoing is *not* a possible resonant frequency for the string?

a) 25 Hz
b) 50 Hz
c) 100 Hz
d) 200 Hz

4. If you double the tension in a violin string, the fundamental frequency of that string will increase by a factor of

a) 4

b) 2

c) $\sqrt{2}$

d) 1 (i.e. it will not change)

5. An unknown tuning fork is sounded with one whose frequency is 440 Hz and a beat frequency of 4 Hz is heard. What is the freequency of the unknown tuning fork?

a) It must be 436 Hz.

b) It must be 440 Hz

c) It must be 444 Hz

d) It could be either 436 or 444 Hz, there is no way to tell.

6. A tube which is open at both ends has a length of 0.60 m. What is the *longest* possible wavelength for sound waves which resonate in this tube?

a) 0.30 m

b) 0.60 m

c) 1.20 m

d) 2.40 m

7. A sound wave with an intensity of $10^{-6}\,\mathrm{W/m^2}$ has an *intensity level* of

a) 10^{-5} decibels

b) 60 decibels

c) 180 decibels

d) 10^5 decibels

8. Of the following, the one which is *not* a unit of pressure is

a) $\mathrm{N/m^2}$

b) Atmosphere

c) $\mathrm{N \cdot m}$

d) Torr

9. As a submerged rock sinks deeper and deeper into water of constant density, the buoyant force acting on the rock:

a) Increases.

b) Decreases.

c) Remains constant.

d) Can increase or decrease depending on the rock's shape.

10. A fluid flows through a pipe which has a circular cross-section of varying size. If the fluid moves at $2.0\,\frac{\mathrm{m}}{\mathrm{s}}$ in a part of the pipe where the diameter is 8.0 cm, what is its speed in a part of the pipe where the diameter is 4.0 cm?

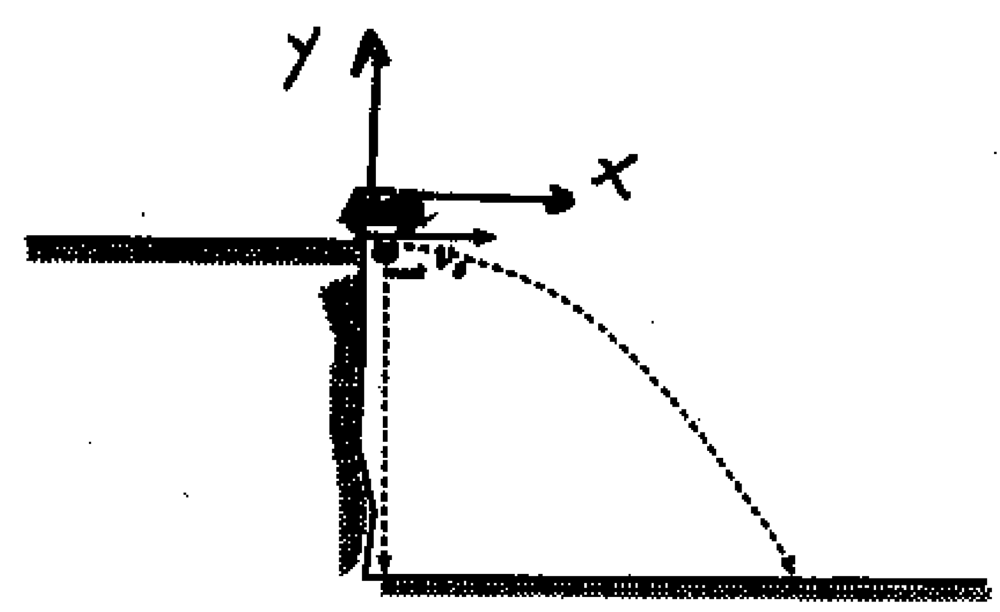
a) $0.50\,\frac{\mathrm{m}}{\mathrm{s}}$

b) $1.0\,\frac{\mathrm{m}}{\mathrm{s}}$

c) $4.0\,\frac{\mathrm{m}}{\mathrm{s}}$

d) $8.0\,\frac{\mathrm{m}}{\mathrm{s}}$

Problems



1. A car is moving toward the edge of a cliff at a speed of 26.8 $\frac{m}{s}$ (60 miles/hr); as it leaves the edge its velocity is horizontal. It reaches the ground below 3.8 s later.

a) How high is the cliff? (4)

What is the value of y at $t = 3.8\,s$?
With $v_{oy} = 0$ and $a_y = -9.80\,\frac{m}{s^2}$ then

$$y = v_{oy}t + \tfrac{1}{2}a_y t^2 = 0 + \tfrac{1}{2}(-9.8\,\tfrac{m}{s^2})(3.8\,s)^2 = -70.8\,m$$

The cliff is $\boxed{70.8\,m}$ high.

b) How far from the edge of the cliff does the car land? (4)

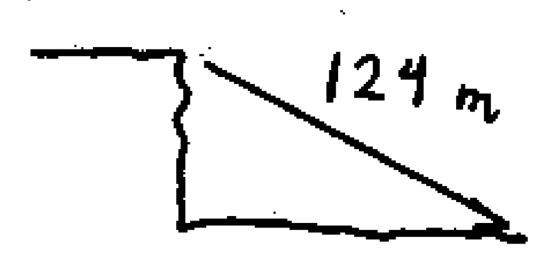
At impact the x-coord of the car is (using $v_{ox} = 26.8\,\frac{m}{s}$, $a_x = 0$):

$$x = v_{ox}t + \tfrac{1}{2}a_x t^2 = (26.8\,\tfrac{m}{s})(3.8\,s) = 102\,m.$$

The horizontal dist traveled by the car is $\boxed{102\,m}$

The (vector) displacement of the car at impact has magnitude:

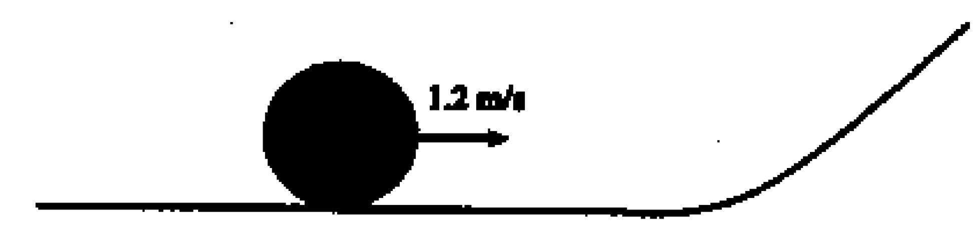
$$r = \sqrt{(102\,m)^2 + (70.8\,m)^2} = \boxed{124\,m}$$



c) A rock, knocked loose by the car falls straight down with zero initial velocity. Does it hit the ground sooner than, at the same time as, or later than the car? Justify your answer. (2)

Since $v_{oy} = 0$ for both the rock and the car then
$y = -\frac{1}{2}gt^2$ for both and if both fall the same distance to the ground below the time of impact will be the same. So both hit the ground at the $\boxed{\text{same time.}}$

2. A uniform cylinder of mass 0.600 kg and radius 5.00 cm rolls without slipping on a flat surface; the speed of its center of mass is 1.20 $\frac{m}{s}$.



a) What is angular velocity of the cylinder? (2)

For rolling w/o slipping, $V_{cm} = \omega R$ so:

$$\omega = \frac{V_{cm}}{R} = \frac{1.20 \, \frac{m}{s}}{(5.00 \times 10^{-2} m)} = \boxed{24.0 \, \frac{rad}{s}}$$

b) What is the translational kinetic energy of the cylinder? (3)

$$KE_{trans} = \frac{1}{2} m V_{cm}^2 = \frac{1}{2}(0.600 \text{ kg})(1.20 \, \tfrac{m}{s})^2 = \boxed{0.432 \text{ J}}$$

c) What is the rotational kinetic energy of the cylinder? (3)

Use: $KE_{rot} = \frac{1}{2} I \omega^2$ with $I = I_{cyl} = \frac{1}{2} m R^2$

$$KE_{rot} = \frac{1}{2}\left(\frac{1}{2} m R^2\right)\omega^2 = \frac{1}{4}(0.600 \text{ kg})(5.00 \times 10^{-2} m)^2 (24.0 \, \tfrac{rad}{s})^2$$

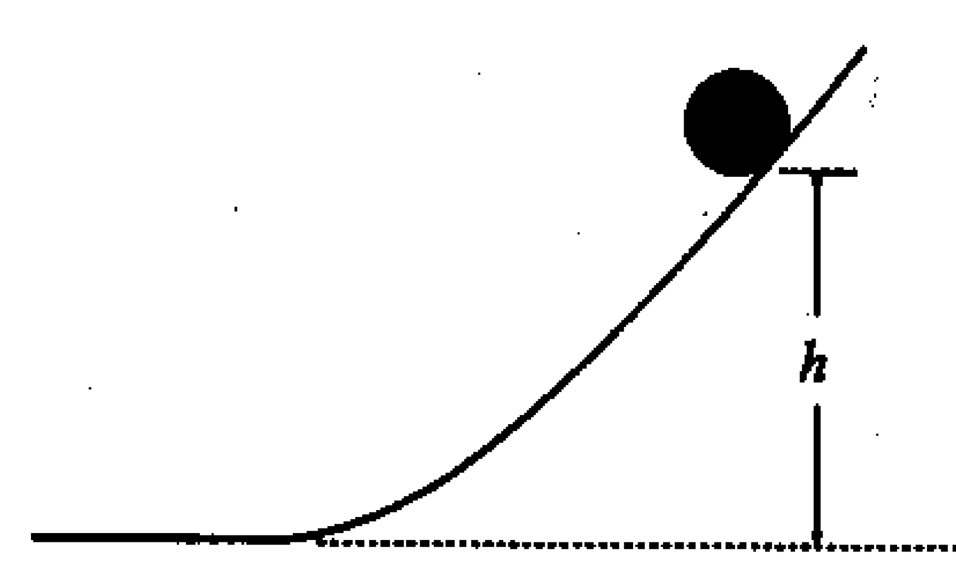
$$= \boxed{0.216 \text{ J}}$$

d) What is the total kinetic energy of the cylinder? (1)

Adding parts (b) and (c)

$$KE_{Tot} = KE_{Trans} + KE_{rot} = 0.432 \text{ J} + 0.216 \text{ J} = \boxed{0.648 \text{ J}}$$

e) The cylinder then rolls (without slipping) up a slope. What is the height attained by the cylinder as it momentarily comes to rest? (Recall that for no-slip rolling, energy is conserved!) (5)



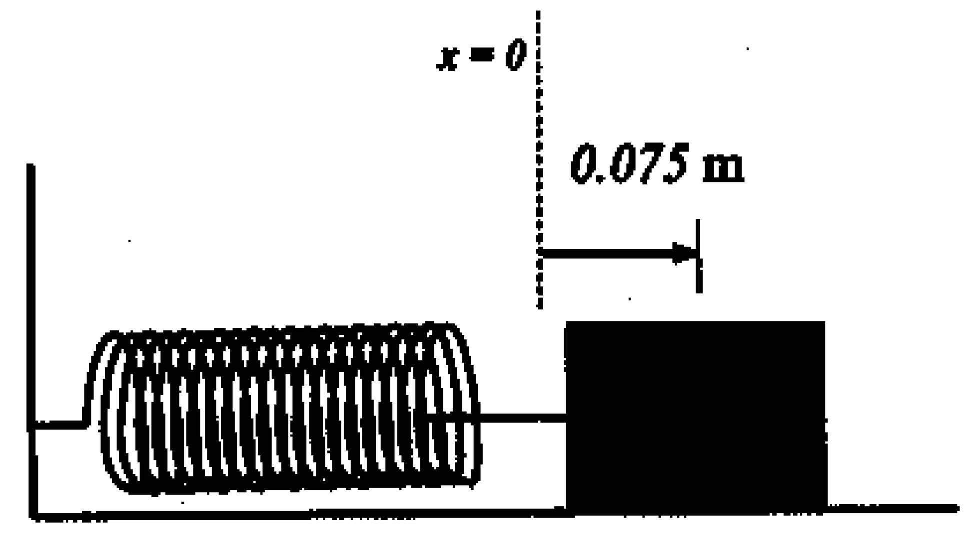
At maximum height there is only potential energy (mgh) which equals the total energy found in (d), from energy conservation.

So:

$$mgh = 0.648 \text{ J} \qquad \text{Solve for } h:$$

$$h = \frac{(0.648 \text{ J})}{(0.600 \text{ kg})(9.80 \, \frac{m}{s^2})} = \boxed{0.110 \text{ m}}$$

3. A large block with a mass of 4.0 kg is connected to a spring. The block is pulled 0.075 m from the spring's equilibrium position and released. It then executes simple harmonic motion with a frequency of 2.5 Hz as it slides on a frictionless surface.



a) What is the spring constant of the spring? (3)

Since $f = \frac{\omega}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$ then with

$f = 2.5\ Hz$, $m = 4.0\ kg$, get:

$$f^2 = \frac{1}{4\pi^2}\frac{k}{m} \rightarrow k = 4\pi^2 m f^2 = 4\pi^2 (4.0\,kg)(2.5\,s^{-1})^2$$
$$= \boxed{987\ N/m}$$

b) What is the total energy (kinetic plus potential) of the system? (3)

Amplitude of motion is $A = 0.075\,m$, so

$$E_{Tot} = \frac{1}{2}kA^2 = \frac{1}{2}(987\,N/m)(0.075\,m)^2 = \boxed{2.8\ J}$$

c) What is the maximum acceleration of the block? (2)

Angular freq. of motion is

$$\omega = 2\pi f = 2\pi(2.5\,s^{-1}) = 15.7\ rad/s$$

so using $a_{max} = \omega^2 A$,

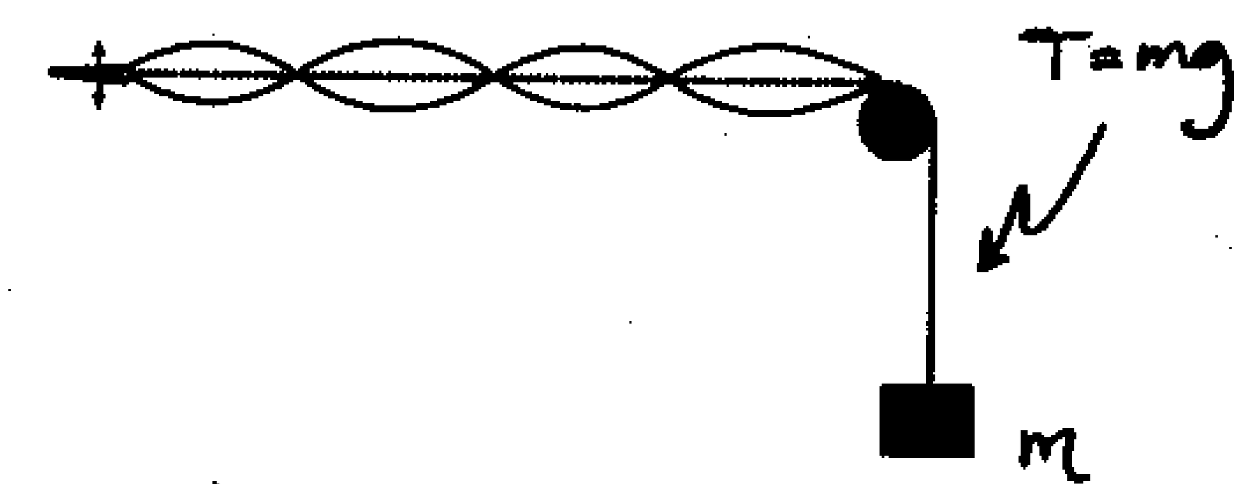
$$a_{max} = (15.7\,s^{-1})^2(0.075\,m) = \boxed{18.5\ m/s^2}$$

d) What is the maximum speed of the block? (2)

Likewise, using $v_{max} = \omega A$,

$$v_{max} = (15.7\,s^{-1})(0.075\,m) = \boxed{1.18\ m/s}$$

4. A 1.75 kg mass is hung from one end of a string over a pulley whose other end is connected to a vibrator. The length of the string, from vibrator to the pulley is 2.00 m, and four loops are observed. The linear mass density of the string is 0.0050 kg/m.



a) What is the wavelength of the standing waves in the string? (3)

Each "loop" is a half-wavelength so the length of the string contains 2 full wavelengths;

$$2.00\,\text{m} = 2\lambda \quad \longrightarrow \quad \lambda = \boxed{1.00\,\text{m}}$$

b) What is the wave velocity in the string? (4)

Use $v = \sqrt{F/\mu}$ where F = str. tension = mg = $(1.75\,\text{kg})(9.80\,\frac{\text{m}}{\text{s}^2})$ = $17.2\,\text{N}$

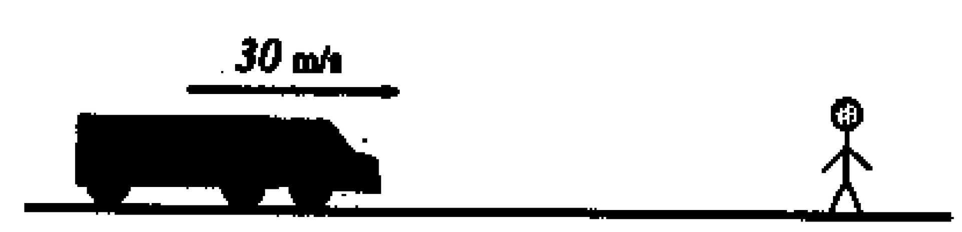
Then:

$$v = \sqrt{\frac{17.2\,\text{N}}{0.005\,\text{kg/m}}} = 58.6\,\frac{\text{m}}{\text{s}}$$

c) What is the frequency of the vibrator? (3)

$$f = \frac{v}{\lambda} = \frac{58.6\,\frac{\text{m}}{\text{s}}}{(1.00\,\text{m})} = \boxed{58.6\,\text{Hz}}$$

5. As a fire engine approaches you at a speed of $30.0\,\frac{\text{m}}{\text{s}}$, you hear its horn sound with a frequency of 275 Hz. What is the actual frequency of the horn? (Assume that the speed of sound in air is $340\,\frac{\text{m}}{\text{s}}$ today.) (5)



Here, $V_s = 30\,\frac{\text{m}}{\text{s}}$, $V_o = 0$ & motion is "toward". With $f_o = 275\,\text{Hz}$, the Doppler formula gives:

$$f_o = \left(\frac{1}{1 - V_s/V}\right) f_s$$

$$f_s = \left(1 - \frac{V_s}{V}\right) f_o = \left(1 - \frac{30}{340}\right)(275\,\text{Hz}) = \boxed{251\,\text{Hz}}$$

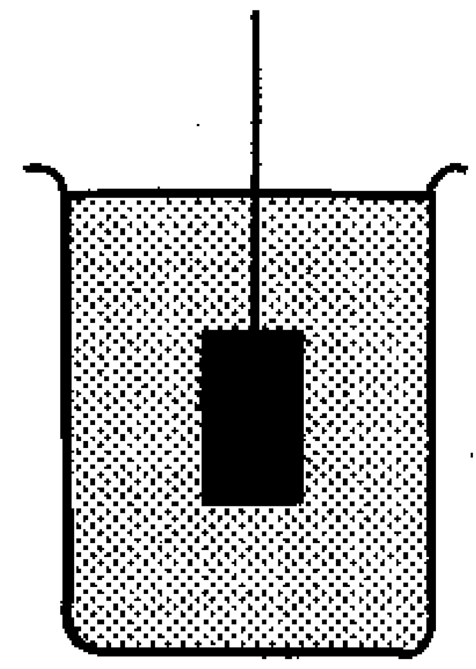
b) A the fire engine passes you and speeds away at $30.0\,\frac{\text{m}}{\text{s}}$, what frequency do you now hear from its horn? (5)

Now $V_s = 30\,\frac{\text{m}}{\text{s}}$ again and motion is "away", with $f_s = 251\,\text{Hz}$ as found in (a). Doppler formula gives:

$$f_o = \left(\frac{1}{1 + V_s/V}\right) f_s = \left(\frac{1}{1 + 30/340}\right)(251\,\text{Hz})$$

$$= \boxed{230\,\text{Hz}}$$

6. A solid metal cylinder whose density is 2700 $\frac{kg}{m^3}$ and volume is 1.50×10^{-4} m^3 is suspended from a string and completely immersed in water. (The density of water is 1000 $\frac{kg}{m^3}$.)



a) What is the (true) weight of the cylinder? (5)

From its density and volume, the mass of the cylinder is

$$m = \rho V = (2700\ \tfrac{kg}{m^3})(1.50\times10^{-4}\ m^3) = 0.405\ kg$$

Then the weight of the cylinder is

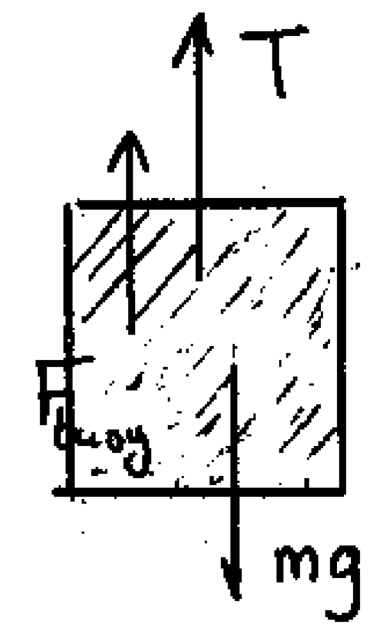
$$W = mg = (0.405\ kg)(9.80\ \tfrac{m}{s^2}) = \boxed{3.97\ N}$$

b) What is the buoyant force on the cylinder? (5)

The buoyant force is the weight of the displaced water:

$$F_{buoy} = (\rho_{water} V)g = (1000\ \tfrac{kg}{m^3})(1.50\times10^{-4}\ m^3)(9.80\ \tfrac{m}{s^2})$$

$$= \boxed{1.47\ N}$$



c) What is the tension in the string? (3)

Forces on the cylinder sum to zero, so:

$$T + F_{buoy} - mg = 0 \rightarrow T = mg - F_{buoy} = 3.97\ N - 1.47\ N$$
$$= \boxed{2.50\ N}$$

7. A "meter stick" made of steel has a length of 1.0000 m when its temperature is 20.0 °C. What is the temperature of the stick when it has a length of 1.0010 m? (The coefficient of linear expansion for steel is 12×10^{-6}/C°.) (6)

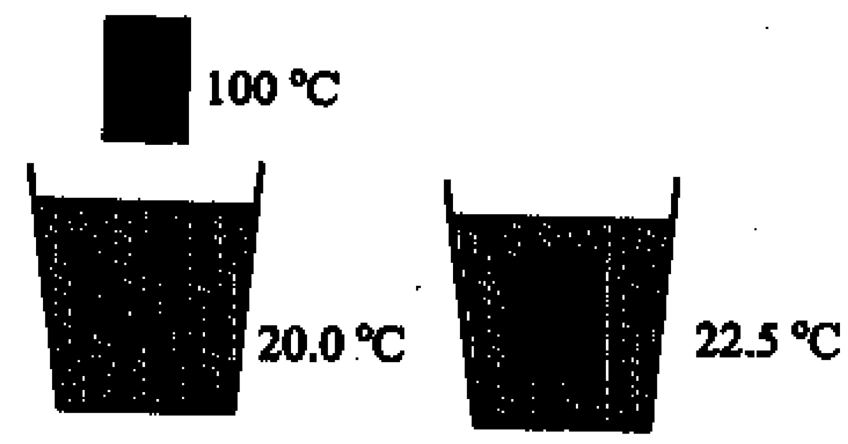
The initial length is $L_0 = 1.0000\ m$ and the change in length is $\Delta L = 0.0010\ m$. The change in temp that gives this ΔL is found from $\Delta L = \alpha L_0 \Delta T$. So:

$$\Delta T = \frac{\Delta L}{\alpha L_0} = \frac{(0.0010\ m)}{(12\times10^{-6}/C^\circ)(1.0000\ m)} = 83.3\ C^\circ$$

This is the increase in T to give the new length. The value of T is

$$T_{new} = T_0 + \Delta T = 20.0^\circ C + 83.3\ C^\circ$$
$$= \boxed{103.3^\circ C}$$

8. A sample of metal of mass 0.100 kg is heated to 100°C and is placed into 0.400 kg of water which is initially at a temperature of 20.0°C. When the two attain thermal equilibrium their temperature is 22.5°C.



a) How much heat was gained by the water? (The specific heat capacity of water is 4186 $\frac{\mathrm{J}}{\mathrm{kg \cdot C^\circ}}$.) (3)

Temp change of the water is $\Delta T_{water} = +2.5\ \mathrm{C^\circ}$

Heat gained by the water is

$$Q = mc\Delta T = (0.400\ \mathrm{kg})\left(4186\ \frac{\mathrm{J}}{\mathrm{kg\,C^\circ}}\right)(2.5\ \mathrm{C^\circ}) = \boxed{4.2 \times 10^3\ \mathrm{J}}$$

b) Neglecting the heat absorbed by the container and surroundings, the answer for (a) is the same as the heat lost by the metal as it cooled. What is the specific heat capacity of the metal? (4)

The heat <u>lost</u> by the metal (the abs. value of Q_{metal}, which is negative) is

$$|Q_{metal}| = (0.100\ \mathrm{kg})\, c_{metal}\, (100^\circ\mathrm{C} - 22.5^\circ\mathrm{C}) = 4.2 \times 10^3\ \mathrm{J}$$

(It is the <u>same</u> as the heat gained by the water, from (a).) Then:

$$c_{metal} = \frac{(4.2 \times 10^3\ \mathrm{J})}{(0.100\ \mathrm{kg})(100.0^\circ\mathrm{C} - 22.5^\circ\mathrm{C})} = \boxed{540\ \frac{\mathrm{J}}{\mathrm{kg \cdot C^\circ}}}$$

$$1\,\text{in} = 2.54\,\text{cm} \qquad 1\,\text{m} = 3.281\,\text{ft} \qquad 1\,\text{mi} = 5280\,\text{ft} \qquad 1\,\text{yd} = 36\,\text{in}$$

$$g_{\text{earth}} = 9.80\,\tfrac{\text{m}}{\text{s}^2} \qquad G = 6.67\times10^{-11}\,\tfrac{\text{N}\cdot\text{m}^2}{\text{kg}^2} \qquad M_{\text{earth}} = 5.98\times10^{24}\,\text{kg}$$

$$A_x = A\cos\theta \qquad A_y = A\sin\theta \qquad A = \sqrt{A_x^2 + A_y^2} \qquad \tan\theta = (A_y/A_x)$$

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

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

$$\mathbf{F} = m\mathbf{a} \qquad f_k = \mu_k F_N \qquad f_s^{\text{MAX}} = \mu_s F_N \qquad F = G\frac{m_1 m_2}{r^2} \qquad g = G\frac{M}{R^2}$$

$$a_c = \frac{v^2}{r} \qquad F_c = \frac{mv^2}{r} \qquad C = 2\pi r$$

$$W = Fs\cos\theta \qquad \text{KE} = \tfrac{1}{2}mv^2 \qquad W_{\text{tot}} = \Delta\text{KE} \qquad \text{PE}_{\text{grav}} = mgy \qquad \text{PE}_{\text{spr}} = \tfrac{1}{2}kx^2$$

$$P = \frac{W}{t} \qquad P = Fv \qquad \mathbf{p} = m\mathbf{v} \qquad \overline{\mathbf{F}} = \frac{\Delta\mathbf{p}}{\Delta t}$$

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

$$\omega = \frac{2\pi}{T} = 2\pi f \qquad v = \omega r \qquad a_T = \alpha r \qquad a_c = \omega^2 r \qquad \tau = Fr\sin\phi \qquad \tau = I\alpha$$

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

$$\text{KE}_{\text{rot}} = \tfrac{1}{2}I\omega^2 \qquad W = \tau\theta \qquad L = I\omega$$

$$v_{\text{cm}} = \omega R \qquad a_{\text{cm}} = \alpha R \qquad \text{KE}_{\text{roll}} = \tfrac{1}{2}mv_{\text{cm}}^2 + \tfrac{1}{2}I\omega^2 \qquad E = \tfrac{1}{2}mv_{\text{cm}}^2 + \tfrac{1}{2}I\omega^2 + mgh$$

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

$$F_{\text{spr}} = -kx \qquad E_{\text{tot}} = \tfrac{1}{2}kx^2 + \tfrac{1}{2}mv^2 = \tfrac{1}{2}kA^2 = \tfrac{1}{2}mv_{\max}^2 \qquad T = 2\pi\sqrt{\frac{L}{g}} \qquad \omega = \sqrt{\frac{MgL}{I}}$$

$$f = \frac{1}{T} \qquad \lambda f = v \qquad v = \sqrt{\frac{F}{(m/L)}} = \sqrt{\frac{F}{\mu}}$$

$$I = \frac{P}{4\pi r^2} \qquad \beta = (10\,\text{dB})\log_{10}\left(\frac{I}{I_0}\right) \qquad I_0 = 10^{-12}\,\text{W/m}^2$$

$$f_o = \left(\frac{1 \pm \frac{v_o}{v}}{1 \mp \frac{v_s}{v}}\right) f_s = \left(\frac{v \pm v_o}{v \mp v_s}\right) f_s \qquad \text{Signs: } \begin{cases}\text{Toward}\\ \text{Away}\end{cases} \qquad f_{\text{Beat}} = |f_1 - f_2|$$

$$\rho = \frac{m}{V} \qquad P = \frac{F}{A} \qquad P_2 = P_1 + \rho gh \qquad F_{\text{Buoy}} = W_{\text{disp fluid}} = \rho_{\text{fluid}}V_{\text{disp}}g$$

$$\text{Flow rate} = A_1 v_1 = A_2 v_2 \qquad P_1 + \tfrac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \tfrac{1}{2}\rho v_2^2 + \rho g y_2$$

$$T = T_C + 273.15 \qquad \Delta L = \alpha L_0 \Delta T \qquad \Delta V = \beta V_0 \Delta T \qquad \beta = 3\alpha \qquad Q = cm\Delta T$$