Question 3 (10 points)

(a) 1 point

For the correct value of work required to raise the center of mass of the lead — 1 point
$W = mgh$

(b) 3 points

For a correct expression for the change in gravitational potential energy, mgh — 1 point

For a correct expression for the change in thermal energy, $mc\Delta T$ — 1 point
This point was also awarded for using the expression $nc_V\Delta T$, but in this case the final point was not awarded

Equating the two energy changes
$mgh = mc\Delta T$

For the correct answer — 1point
$\Delta T = \frac{gh}{c}$

(c) 2 points

For correctly substituting values in the answer to part (b) and a correct calculation — 1 point

For multiplying that value by 100 — 1 point

$$\Delta T_{cum} = 100\frac{(10\ \text{m/s}^2)(2.00\ \text{m})}{128\ \text{J/kg}\cdot\text{K}}$$

$$\Delta T_{cum} = 15.6\ \text{K}$$

(d) 2 points

The answers to parts (b) and (c) will not change, because ΔT does not depend on the mass.

For correctly saying "no" and including a correct physical explanation — 2 points

Full credit was awarded for "yes" plus an explanation if this was consistent with student's answers to (b) and (c).

Question 3 (continued)

(e) 2 points

For any completely correct answer referring to energy transfer — 2 points
For example: There is friction between the lead and the apparatus, resulting in a loss of heat to the surroundings.

Only one point was awarded for an answer that had a correct reference to energy transfer but also had incorrect statements.

Question 5 (10 points)

(a) 2 points

Using a relationship between the wavelength λ and the length L of the string, for example the general relationship $\lambda = \frac{2L}{n}$, where n is the number of loops in the standing wave pattern, or the specific relationship for this case $2\lambda = L$ which can be developed directly from information in the question

For correct substitution of values — 1 point
$\lambda = \frac{2(1.20\text{ m})}{4}$

For the correct answer — 1 point
$\lambda = 0.60\text{ m}$

(b) 2 points

Using the relationship for the speed of a wave
$\upsilon = \nu\lambda$

For correct substitution of values — 1 point
$\upsilon = (120\text{ Hz})(0.60\text{ m})$

For the correct answer — 1 point
$\upsilon = 72\text{ m/s}$

(c) 3 points

For indicating that the mass should be decreased — 1 point

For any two of the statements in the following explanation, one point each — 2 points
- The wavelength must decrease for there to be more loops on the string
- Given that the frequency is constant, the speed of the waves must decrease if the wavelength does
- This means that the tension must decrease, so the mass must be decreased

Question 5 (continued)

(d) 2 points

In one complete cycle, a point on the string begins at some position and travels until it returns to that position. For example, a point at an antinode that is at its highest point at the beginning of the cycle travels to its lowest point, and then back to the highest point. The amplitude of the standing wave is the distance from the center point (where the string would be straight) to one of these extremes, or one fourth the distance traveled.

For the correct answer — 2 points
Amplitude = 1 cm

One point was awarded for answering 2 cm, which is the result of interpreting "total vertical distance" as the distance between the highest and lowest points of the antinode and then correctly calculating an amplitude of 2 cm based on that interpretation.

For having all units on answers correct — 1 point

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Question 5

10 points total — **Distribution of points**

(a)

i. 2 points

For a correct calculation of the work done on the gas — 1 point

$W_{on} = -P\Delta V$

$W_{on} = -\left(600\ \text{N/m}^2\right)\left(9.0\ \text{m}^3 - 3.0\ \text{m}^3\right)$

$W_{on} = -3600\ \text{J}$

For recognition that the work done by the gas is the negative of the work done on the gas — 1 point

$W_{by} = 3600\ \text{J}$

ii. 3 points

For a correct expression or derivation of the expression for ΔU — 1 point

$\Delta U = \frac{3}{2} nR\,\Delta T$

For correct calculation of T's or ΔT using the ideal gas law, $PV = nRT$ — 1 point

$\Delta U = \frac{3}{2}(2\ \text{moles})\left(8.31 \frac{\text{J}}{\text{mol K}}\right)(325\ \text{K} - 108\ \text{K})$

OR since $P\,\Delta V = nR\,\Delta T$, $\Delta U = \frac{3}{2} P\,\Delta V = \frac{3}{2}\left(600\ \text{N/m}^2\right)\left(9\ \text{m}^3 - 3\ \text{m}^3\right)$

For the correct answer — 1 point

$\Delta U = 5400\ \text{J}$

Note: The equation $\Delta U = \frac{3}{2} nR\,\Delta T$ can be derived from the expressions for K_{avg} and v_{rms} found in the equation sheet as follows:

$U = NK_{avg}$, where N = number of molecules in the gas = nN_0

$U = nN_0 \frac{3}{2} k_B T$

$v_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3k_B T}{\mu}}$, so $\frac{R}{M} = \frac{k_b}{\mu}$

$R = k_B \frac{M}{\mu} = k_B N_0$

$U = \frac{3}{2} nRT$

$\Delta U = \frac{3}{2} nR\,\Delta T$

Question 5 (continued)

Distribution of points

(a) continued

iii. 1 point

For correct substitution of answers from parts i. and ii. into the first law of thermodynamics — 1 point

$\Delta U = Q + W_{on}$

$Q = \Delta U - W_{on}$

$Q = 5400\ \text{J} - (-3600\ \text{J})$

$Q = 9000\ \text{J}$

Alternate Solutions for parts ii. and iii. — *Alternate points*

Solving part iii. first:

$$Q = nc_P\,\Delta T = n\frac{5}{2}R\,\Delta T = (2\ \text{moles})\frac{5}{2}\left(8.31\frac{\text{J}}{\text{mol K}}\right)(325\ \text{K} - 108\ \text{K}) = 9000\ \text{J}$$

For a correct equation — *1 point*

For correct calculation of T's or ΔT — *1 point*

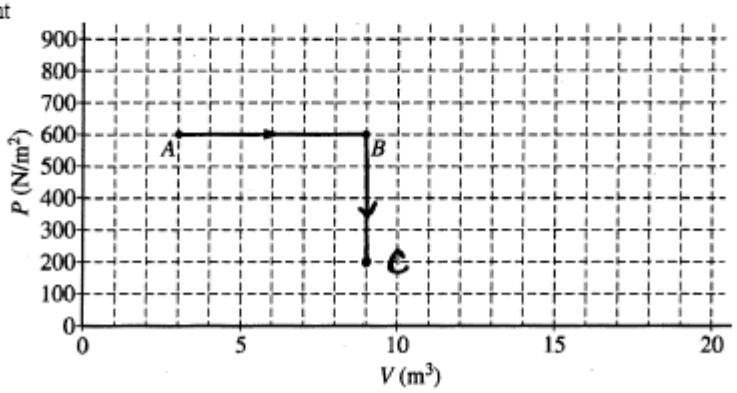
For the correct answer — *1 point*

Returning to solve part ii.:

$\Delta U = Q + W_{on} = 9000\ \text{J} + (-3600\ \text{J}) = 5400\ \text{J}$

For correct substitutions into the first law of thermodynamics of answers from parts i. and iii. — *1 point*

(b) 1 point



For point C plotted and labeled correctly as above, and for a correct straight line from point B to point C — 1 point

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Question 7

10 points total — **Distribution of points**

(a) 4 points

For a correct calculation of the photon frequency — 1 point

$f = \frac{c}{\lambda}$

$f = \left(3.00 \times 10^{8}\ \text{m/s}\right) / \left(1.219 \times 10^{-7}\,\text{m}\right) = 2.46 \times 10^{15}\,\text{Hz}$

For correct calculation of the photon energy in electron-volts or joules — 1 point

$E_{ph} = hf = \left(4.14 \times 10^{-15}\ \text{eV•s}\right)\left(2.46 \times 10^{15}\ \text{Hz}\right) = 10.2\ \text{eV}$ OR $1.63 \times 10^{-18}\ \text{J}$

The two points above were also awarded for correctly using $E = hc/\lambda$ or using $E = pc$ and the answer from part (b).

For indicating that the photon energy is the difference between the two energy levels — 1 point

$E_4 = E_2 + E_{ph}$

$E_4 = -13.6\ \text{eV} + 10.2\ \text{eV}$

For the correct numerical answer — 1 point

$E_4 = -3.4\ \text{eV}$ OR $-5.44 \times 10^{-19}\ \text{J}$

Alternate solution — *Alternate points*

For use of energy levels and the Bohr model* — *1 point*

$E_n = E_1/n^2$

For identifying the ground state energy — *1 point*

$E_1 = -54.4\ \text{eV}$

For using the correct quantum number — *1 point*

$n = 4$

For the correct answer — *1 point*

$E_4 = -3.4\ \text{eV}$

*Note: This equation is not on the equation sheet, nor is the Bohr model part of the Physics B curriculum. However, students were given credit for this correct solution.

(b) 2 points

$p = h/\lambda$ OR $p = E/c$

For substitution of appropriate values into either of the above equations — 1 point

$p = \left(6.63 \times 10^{-34}\ \text{J•s}\right) / \left(121.9 \times 10^{-9}\,\text{m}\right)$ OR $p = \left(1.63 \times 10^{-18}\,\text{J}\right) / \left(3.00 \times 10^{8}\ \text{m/s}\right)$

For the correct answer with correct units — 1 point

$p = 5.44 \times 10^{-27}\ \text{kg•m/s}$ (or $3.40 \times 10^{-8}\ \text{eV•s/m}$)

Question 7 (continued)

Distribution of points

(c) 2 points

$K_{max} = E_{ph} - \phi$

For correct substitution of photon energy from part (a), or a calculation of it — 1 point

$K_{max} = 10.2 \text{ eV} - 4.7 \text{ eV}$

For the correct answer in eV — 1 point

$K_{max} = 5.5 \text{ eV}$

(d) 2 points

$K_{max} = W = qV$

For using the definition of an eV as the work required to move a charge e through a 1-volt potential difference — 1 point

For the correct answer with units of volts — 1 point

$V = 5.5 \text{ V}$

Alternate solution — *Alternate points*

For understanding the relationship between electrical potential and energy — *1 point*

$V = K_{max}/q$

$V = (5.5 \text{ eV})\left(1.6 \times 10^{-19} \text{ J/eV}\right)/\left(1.6 \times 10^{-19} \text{ C}\right)$

For the correct answer with units of volts — *1 point*

$V = 5.5 \text{ V}$

2001 Physics B Solutions **Distribution of points**

Question 4 (15 points)

(a) 3 points

For using Snell's law OR indicating that the index of refraction is the slope of the graph — 1 point

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

For substituting or otherwise indicating use of data from the given graph — 1 point

$(1)(0.5) = n_2(0.8)$ OR $\text{slope} = \dfrac{0.8}{0.5}$

For the correct answer — 1 point

$n_2 = 1.60$

(Alternate solution) *(Alternate points)*

For using the expression for the critical angle — *1 point*

$\sin\theta_c = \dfrac{n_2}{n_1}$

For using data from the graph — *1 point*

The critical angle occurs when $\sin\theta_2 = 1$. From the graph, $\sin\theta_2 = \sin\theta_c = 0.625$

$0.625 = \dfrac{1}{n_1}$

For the correct answer — *1 point*

$n_2 = 1.60$

Two points were awarded for inverting the values from the graph to obtain $n_2 = 0.625$.

(b)

i. 2 points

For using the correct equation with the correct substitutions — 1 point

$f = v/\lambda$

$f = \left(3 \times 10^8 \text{ m/s}\right)/\left(675 \times 10^{-9} \text{ m}\right)$

For the correct answer — 1 point

$f = 4.44 \times 10^{14} \text{ Hz}$

ii. 2 points

For using the correct equation with the correct substitutions — 1 point

$v = c/n$

$v = \left(3 \times 10^8 \text{ m/s}\right)/1.60$

For the correct answer — 1 point

$v = 1.88 \times 10^8 \text{ m/s}$

If an incorrect answer was carried through to obtain a speed greater than 3×10^8 m/s, only one point was awarded for the solution. The second point could be earned if there was some indication that the student realized that the value must be incorrect, because it could not be greater than the speed of light.

Distribution of points

Question 4 (continued)

(b) (continued)
iii. 2 points

For using the correct equation with correct substitutions (consistent with previous answers) 1 point

$\lambda = v/f$

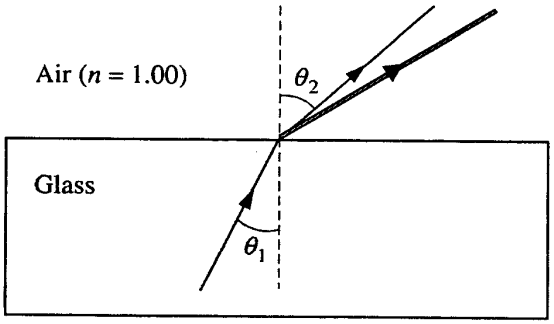
$\lambda = \left(1.88 \times 10^{8} \text{ m/s}\right)/\left(4.44 \times 10^{14} \text{ Hz}\right)$

For the correct answer 1 point

$\lambda = 423 \times 10^{-9} \text{ m} = 423 \text{ nm}$

Units point: For correct units on two of the three answers in part (b) 1 point

(c)
i. 1 point

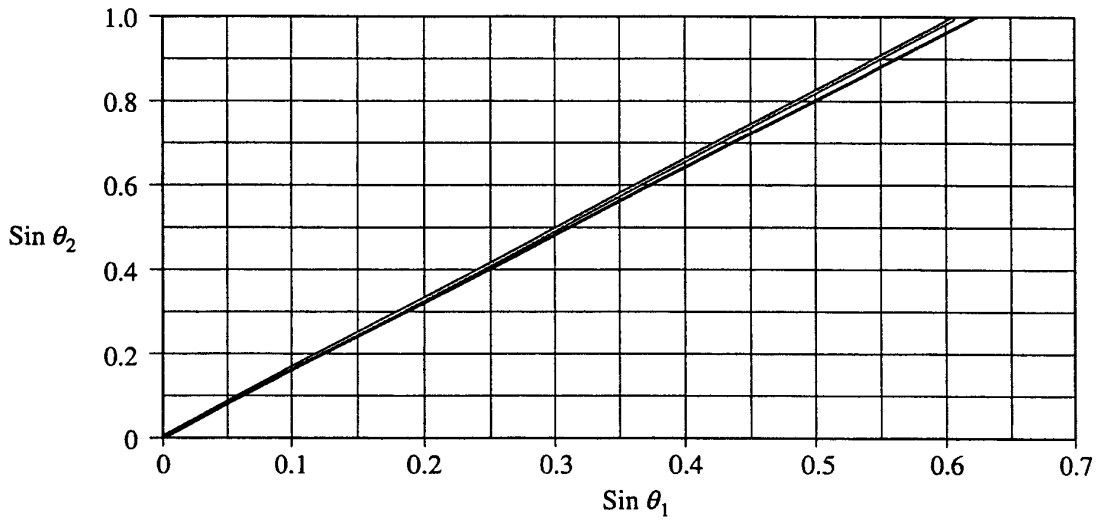


For correctly indicating on the figure that θ_2 increases 1 point

(continued on next page)

Question 4 (continued)

(c) (continued)
ii. 2 points



For a straight line that goes through the origin — 1 point
For a steeper slope than the given line — 1 point

Full credit was awarded for a line with less steep slope if it was consistent with the answer to part (a)

(d) 2 points

For the correct equation for the critical angle — 1 point

$$\sin\theta_c = \frac{n_2}{n_1}$$

$$\sin\theta_c = \frac{1}{1.66} = 0.602$$

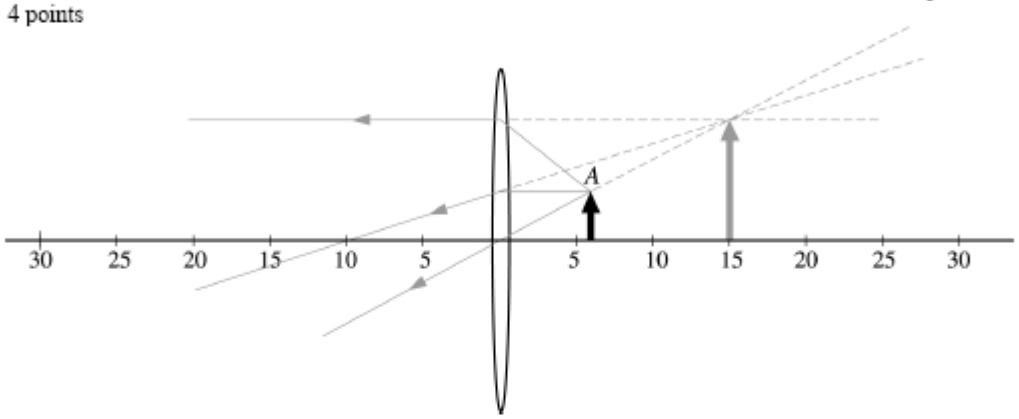
For the correct answer — 1 point

$\theta_c = 37°$ or 0.624 radians

Question 4

15 points total **Distribution of points**

(a) 4 points



For any two correct rays through the lens — 2 points
Two of the three principal rays shown on the diagram above were expected.
One point was subtracted for additional incorrect rays. No credit was awarded for reflected rays.

For correct extension of the rays backward — 1 point

For showing the image with correct size, position, and orientation — 1 point

(b) 2 points

For stating that the image is virtual, or for stating a choice consistent with the ray diagram in part (a) — 1 point
If there were no supporting diagrams or calculations, virtual was the only accepted answer.

For a correct explanation consistent with the choice given, such as: — 1 point
The light rays diverge on the left side of the lens, but appear to come from a point behind the object. OR The image is on the same side of the lens as the object.
OR The object is placed between the converging lens and the focal point.
This point was not awarded if additional wrong statements were part of the response.

(c) 3 points

For the lens equation OR for the lens equation with substituted quantities — 1 point

$\frac{1}{s_o} + \frac{1}{s_i} = \frac{1}{f}$ OR $\frac{1}{s_i} = \frac{1}{10\ \text{cm}} - \frac{1}{6\ \text{cm}}$

For the correct solution — 2 points

$s_i = -15$ cm (Minus sign was not necessary to receive full credit.)

Only 1 of the 2 answer points was awarded for the correct number without units.

Question 4 (cont'd.)

Distribution of points

(c) continued

Alternate Solution — *Alternate points*

Let x_o = distance from object to focal point and x_i = distance from image to focal point.

For the correct formula — *1 point*

$$\frac{x_i}{f} = \frac{f}{x_o}$$

For correct substitutions — *1 point*

$$\frac{x_i}{10\ \text{cm}} = \frac{10\ \text{cm}}{10\ \text{cm} - 6\ \text{cm}}$$

$$x_i = \frac{(10\ \text{cm})^2}{4\ \text{cm}} = 25\ \text{cm}$$

$$s_i = 25\ \text{cm} - 10\ \text{cm}$$

For the correct answer — *1 point*

$s_i = 15$ cm

(d) 2 points

For the correct image size to object size ratio with no units, or with units that cancel — 2 points

$$\frac{h_i}{h_o} = \frac{s_i}{s_o} = \frac{15\ \text{cm}}{6\ \text{cm}} = \frac{5}{2}$$

Notes:
Students could use either a calculation or a ray diagram to arrive at the final answer.
1 point only was awarded if the correct ratio was imbedded in extra calculations or if units were provided for the answer (for example, 2.5 cm).
No points were given for giving the object size to image size ratio.

(e) 4 points

Since the question asked for a description, a verbal response was expected, although the image position, size, and orientation could be determined from either a calculation or a ray diagram.

For the correct position:
- Image on the opposite side of the lens from the object — 1 point
- Distance from the image to the lens in the range 20 cm ± 3 cm — 1 point

For the correct size: image size same as object size, or for size consistent with value for position — 1 point

For the correct orientation: image is inverted — 1 point

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Question 5

10 points total **Distribution of points**

(a) 3 points

For an equation that uses the ratio of densities ρ_r/ρ_w to find the fraction of the total volume (or height) submerged 1 point

The weight of the raft equals the weight of the displaced water.

$W_r = W_w$

$m_r g = m_w g$

$\rho_r V_r g = \rho_w V_w g$

Solving for the volume of displaced water, which equals the submerged volume of the raft

$V_w = \frac{\rho_r}{\rho_w} V_r$

For recognizing that the submerged volume (or height) must be subtracted from the total volume (or height) 1 point

$V_{submerged} = Ah = V_r - V_w$

$Ah = V_r - \frac{\rho_r}{\rho_w} V_r = V_r \left(1 - \frac{\rho_r}{\rho_w}\right)$

$h = \frac{V_r}{A}\left(1 - \frac{\rho_r}{\rho_w}\right)$

$h = \frac{1.8 \text{ m}^3}{8.2 \text{ m}^2}\left(1 - \frac{650 \text{ kg/m}^3}{1000 \text{ kg/m}^3}\right)$

For the correct answer 1 point

$h = 0.077$ m

Some students misinterpreted the statement about the volume of the raft, taking it to mean the volume of the part above the water instead of the total volume. If the solution to part (b) showed work that demonstrated understanding of the concepts needed for part (a), appropriate credit for this part was awarded.

Question 5 (continued)

Distribution of points

(b) 4 points

For indicating that the buoyant force is equal to the weight of the raft — 1 point
$F_{buoy} = W_r$

For correct substitutions for calculating the buoyant force, either by directly calculating the raft's weight or calculating the weight of the displaced water — 1 point
$F_{buoy} = \rho_r V_r g = (650\ \text{kg/m}^3)(1.80\ \text{m}^3)(9.8\ \text{m/s}^2)$
OR $F_{buoy} = \rho_w V_w g = (1000\ \text{kg/m}^3)(1.17\ \text{m}^3)(9.8\ \text{m/s}^2)$

For the correct answer with units — 1 point
$F_{buoy} = 1.15 \times 10^4$ N (or 1.17×10^4 N using $g = 10\ \text{m/s}^2$)

For indicating that the direction of the buoyant force is up — 1 point

(c) 3 points

The additional weight that can be carried is equal to the weight of water displaced by the part of the raft now above water.

For indicating a correct equation for the net force — 1 point
$W_{addl} = W_{extra\ water}$ OR $W_{addl} = F_{buoyNEW} - W_{raft}$

The first equation above yields $W_{addl} = \rho_w V_{top} g = \rho_w A h g$

Substituting the algebraic expression for h from part (a) and simplifying yields $W_{addl} = \rho_w V_r g - \rho_r V_r g = V_r g(\rho_w - \rho_r)$, which is equivalent to substitution into the second equation above.

For correct numerical substitutions to get the weight (or mass) of the top of the raft — 1 point
$W_{addl} = (1.80\ \text{m}^3)(9.8\ \text{m/s}^2)(1000\ \text{kg/m}^3 - 650\ \text{kg/m}^3)$
$W_{addl} = 6200$ N (variation due to rounding earlier on was accepted)

For dividing the total weight (or mass) by the weight (or mass) of a person and indicating the correct number of people that the raft can carry. (The final answer must indicate a *whole* number of people.) — 1 point
$n = \dfrac{W_{addl}}{m_p g} = \dfrac{6200\ \text{N}}{(75\ \text{kg})(9.8\ \text{m/s}^2)} = 8.4$
A maximum of 8 people can be on the raft.

1997 Physics B Solutions **Distribution of points**

Question 1 (15 points)

(a) 3 points

For using Newton's second law 1 point
$F = ma$
Solving for the acceleration
$a = F/m$
For correctly substituting 1 point
$a = (4\text{ N})/(0.20\text{ kg})$
For the correct answer 1 point
$a = 20\text{ m/s}^2$

(b) 3 points

For using the correct kinematic equation 1 point
$s = s_0 + v_0 t + \frac{1}{2}at^2$
For the correct substitutions 1 point
$12\text{ m} = 0\text{ m} + (0\text{ m/s})t + \frac{1}{2}(20\text{ m/s}^2)t^2$
Solving for t
$t = \sqrt{\frac{2(12\text{ m})}{20\text{ m/s}^2}}$
For the correct answer 1 point
$t = 1.1\text{ s}$

(c) 2 points

For using the expression for the work done by an applied force, $W = Fs$, or indicating that the work is equal to the area under the curve 1 point
Substituting
$W = (4\text{ N})(12\text{ m})$
For the correct answer 1 point
$W = 48\text{ J}$

Question 1(continued)

(d) 2 points

For indicating that the kinetic energy of the object is equal to the work done by the applied force — 1 point

$$\frac{1}{2}mv^2 = W$$

Solving for the speed

$$v = \sqrt{\frac{2W}{m}}$$

Substituting the values when $x = 12$ m

$$v = \sqrt{\frac{2(48\ \text{J})}{0.20\ \text{kg}}}$$

For the correct answer — 1 point

$v = 22$ m/s

(Alternate solution 1) — *(Alternate points)*

For using the kinematic equation for speed — *1 point*

$$v_f^2 = v_0^2 + 2a(s_f - s_0)$$

Substituting

$$v_f^2 = (0\ \text{m/s})^2 + 2(20\ \text{m/s}^2)(12\ \text{m})$$

$$v_f^2 = 480\ \text{m}^2/\text{s}^2$$

For the correct answer — *1 point*

$v_f = 22$ m/s

(Alternate solution 2) — *(Alternate points)*

For using the kinematic equation for speed — *1 point*

$$v_f = v_0 + at$$

$$v_f = (0\ \text{m/s}) + (20\ \text{m/s}^2)(1.1\ \text{s})$$

For the correct answer — *1 point*

$v_f = 22$ m/s

(e) 3 points

Calculating the additional work done on the object by finding the area under the force versus displacement curve between $x = 12$ m and $x = 20$ m

$$W_A = \frac{1}{2} F_{max} \Delta x$$

Substituting

$$W_A = \frac{1}{2}(4 \text{ N})(8 \text{ m})$$

For the correct value for this additional work — 1 point

$W_A = 16$ J

For adding this value to the value obtained in part (c) — 1 point

$W_T = 48 \text{ J} + 16 \text{ J} = 64 \text{ J}$

Doing the same calculation for speed as in (d), using the value for the total work

$$v = \sqrt{\frac{2(64 \text{ J})}{0.20 \text{ kg}}}$$

For the correct answer — 1 point

$v = 25.3$ m/s

(f) 2 points

For using an expression for momentum or change in momentum — 1 point

$p = mv$ OR $\Delta p = m \Delta v$

Substituting

$\Delta p = (0.20 \text{ kg})(25.3 \text{ m/s} - 21.9 \text{ m/s})$

For the correct answer — 1 point

$\Delta p = 0.68 \text{ kg} \cdot \text{m/s}$

2001 Physics B Solutions **Distribution of points**

Question 2 (15 points)

(a) 4 points

For any indication that conservation of momentum is applicable — 1 point

$p_{before} = p_{after}$

$m_A v_{Ai} = m_B v_{Bf} + m_A v_{Af}$

Solving for v_{Bf}

$$v_{Bf} = \frac{m_A(v_{Ai} - v_{Af})}{m_B}$$

For correct substitution of values before the collision — 1 point

For correct substitution of values after the collision, including $v_{Af} = -0.70$ m/s — 1 point

$$v_{Bf} = \frac{(0.10 \text{ kg})(1.4 \text{ m/s} + 0.70 \text{ m/s})}{0.50 \text{ kg}}$$

For the correct answer — 1 point

$v_{Bf} = 0.42$ m/s

(b) 5 points

For any statement of an equation that can be used to find the time t for the ball to fall — 1 point

For example:

$$h = h_0 + v_0 t + \frac{1}{2}at^2$$

For correct substitution — 1 point

$$0 = 1.2 \text{ m} + 0(t) + \frac{1}{2}\left(-9.8 \text{ m/s}^2\right)t^2$$

For the correct value for t — 1 point

$t = 0.49$ s (same value obtained using $g = 10$ m/s^2)

For substituting the value of v from part (a) into a correct equation for the horizontal distance (i.e. having initial position and acceleration both zero) — 1 point

$d = vt = (0.42 \text{ m/s})(049 \text{ s})$

For the correct answer — 1 point

$d = 0.21$ m

Distribution of points

Question 2 (continued)

(c) 3 points

For any statement of the equation for speed — 1 point
$v_C = d/t$

For substituting the time from part (b) or correctly recalculating it — 1 point
$v_C = 0.15 \text{ m}/0.49 \text{ s}$

For the correct answer — 1 point
$v_C = 0.31 \text{ m/s}$

(d) 3 points

For an indication that the momentum in the y-direction is conserved — 1 point
$\mathbf{p}_{Ay} = -\mathbf{p}_{Cy}$

For an indication that the y-component of ball C's momentum was calculated — 1 point
$p_{Ay} = m_C v_C \sin 30°$

$p_{Ay} = (0.10 \text{ kg})(0.31 \text{ m/s}) \sin 30°$

For the correct answer — 1 point
$p_{Ay} = 0.015 \text{ kg} \cdot \text{m/s}$

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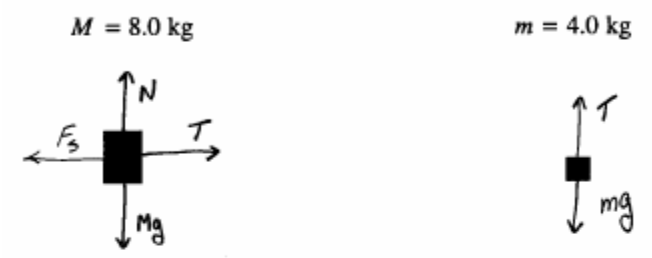
Question 1

10 points total **Distribution of points**

(a) 3 points



On the 4 kg mass:
For two vertical vectors, one up and one down, labeled correctly and no horizontal vectors — 1 point

On the 8 kg mass:
For two vertical vectors, one up and one down, labeled correctly — 1 point
For two horizontal vectors, one left and one right, labeled correctly — 1 point

Note: Labels could be in words, symbols, or correct numerical values. The two masses were considered independently. It was not necessary to indicate that the tension forces had the same magnitudes or that the weights were different.

(b) 2 points

For a correct approach using Newton's 2nd law and the static equilibrium condition for the 4 kg mass that leads to a relationship between tension and weight — 1 point

$T = mg$

$T = (4.0\text{ kg})(9.8\text{ m/s}^2)$

For the correct value — 1 point

$T = 39\text{ N}$ (40 N using $g = 10\text{ m/s}^2$)

(c) 3 points

For a correct application of Newton's 2nd law and the static equilibrium condition for the 8 kg mass leading to a relationship between tension from part (b) and spring force — 1 point

$T = F_s = k\Delta x$

$k = T/\Delta x$

For using the correct displacement of the spring from equilibrium — 1 point

$\Delta x = 0.05\text{ m}$

$k = 39\text{ N}/(0.25\text{ m} - 0.20\text{ m})$

For a correct calculation leading to a positive value of k using the tension from (b) — 1 point

$k = 780\text{ N/m}$ (800 N/m using 40 N from part (a))

Question 1 (continued)

Distribution of points

(d) 2 points

For a correct approach to an accelerating system for the 4 kg mass using kinematics — 1 point

$y = \frac{1}{2}gt^2$

$t = \sqrt{2y/g}$

$t = \sqrt{2(0.70\text{ m})/(9.8\text{ m/s}^2)}$

For a correct value of time — 1 point

$t = 0.38$ s (0.37 s using $g = 10\text{ m/s}^2$)

Note: An alternative approach using conservation of energy to determine the speed at the bottom and then use of a kinematics equation for time was also awarded full credit if done successfully

(e) 2 points

For a correct approach to calculating the frequency (f or ω) OR the period and then frequency of a mass-spring system — 1 point

$f = \frac{1}{T} = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$ (or $\omega = \sqrt{\frac{k}{m}}$)

$f = \frac{1}{2\pi}\sqrt{\frac{780\text{ N/m}}{8.0\text{ kg}}}$ (or $\omega = \sqrt{\frac{780\text{ N/m}}{8.0\text{ kg}}}$)

For a correct value of frequency (f or ω) consistent with the k value from part (c) — 1 point

$f = 1.6$ Hz (or $\omega = 10$ rad/s)

(f) 2 points

For using conservation of energy setting spring potential energy equal to kinetic energy — 1 point

$\frac{1}{2}mv^2 = \frac{1}{2}kA^2$

$v = \sqrt{\frac{k}{m}}A$

$v = \sqrt{\frac{780\text{ N/m}}{8.0\text{ kg}}}(0.05\text{ m})$

For a correct calculation of speed using the spring constant consistent with part (c) and the correct displacement from equilibrium — 1 point

$v = 0.49$ m/s (0.50 m/s using 800 N/m from part (c))

(Global) 1 point

For correct units on all numerical answer given and a reasonable number of digits in answers (not awarded for blank papers or no numerical answers)