AP® Physics B
2008 Scoring Guidelines
Form B

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AP® PHYSICS
2008 SCORING GUIDELINES

General Notes About 2008 AP Physics Scoring Guidelines

1. The solutions contain the most common method of solving the free-response questions and the allocation of points for this solution. Some also contain a common alternate solution. Other methods of solution also receive appropriate credit for correct work.

2. Generally, double penalty for errors is avoided. For example, if an incorrect answer to part (a) is correctly substituted into an otherwise correct solution to part (b), full credit will usually be awarded. One exception to this may be cases when the numerical answer to a later part should be easily recognized as wrong, e.g., a speed faster than the speed of light in vacuum.

3. Implicit statements of concepts normally receive credit. For example, if use of the equation expressing a particular concept is worth one point, and a student's solution contains the application of that equation to the problem but the student does not write the basic equation, the point is still awarded. However, when students are asked to derive an expression it is normally expected that they will begin by writing one or more fundamental equations, such as those given on the AP Physics exam equation sheet. For a description of the use of such terms as "derive" and "calculate" on the exams, and what is expected for each, see "The Free-Response Sections—Student Presentation" in the *AP Physics Course Description*.

4. The scoring guidelines typically show numerical results using the value $g = 9.8 \text{ m/s}^2$, but use of 10 m/s^2 is of course also acceptable. Solutions usually show numerical answers using both values when they are significantly different.

5. Strict rules regarding significant digits are usually not applied to numerical answers. However, in some cases answers containing too many digits may be penalized. In general, two to four significant digits are acceptable. Numerical answers that differ from the published answer due to differences in rounding throughout the question typically receive full credit. Exceptions to these guidelines usually occur when rounding makes a difference in obtaining a reasonable answer. For example, suppose a solution requires subtracting two numbers that should have five significant figures and that differ starting with the fourth digit (e.g., 20.295 and 20.278). Rounding to three digits will lose the accuracy required to determine the difference in the numbers, and some credit may be lost.

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Question 1

10 points total **Distribution of points**

(a) 2 points

For a correct expression of conservation of momentum 1 point

$m_w v_w = m_s v_s$

$v_s = \frac{m_w v_w}{m_s} = \frac{(70 \text{ kg})(0.55 \text{ m/s})}{35 \text{ kg}}$

For the correct final answer 1 point

$v_s = 1.1 \text{ m/s}$

(b) 2 points

For correct use of the impulse–momentum relationship 1 point

$F_{avg}\Delta t = m_s \Delta v_s$

$F_{avg} = \frac{m_s \Delta v_s}{\Delta t} = \frac{(35 \text{ kg})(1.1 \text{ m/s} - 0 \text{ m/s})}{0.60 \text{ s}}$

For the correct final answer 1 point

$F_{avg} = 64 \text{ N}$

Alternate solution *Alternate points*

For correct calculation of the average acceleration of the son during the push *1 point*

$a_s = \frac{\Delta v_s}{\Delta t}$

$a_s = \frac{1.1 \text{ m/s}}{0.6 \text{ s}} = 1.83 \text{ m/s}^2$

For the correct final answer using Newton's second law *1 point*

$F_{avg} = m_s a_s = (35 \text{ kg})(1.83 \text{ m/s}^2)$

$F_{avg} = 64 \text{ N}$

(c) 3 points

For indicating that the average force exerted on the mother by the son is equal in magnitude to that exerted on the son by the mother 1 point

For indicating that the average force exerted on the mother by the son is opposite in direction to that exerted on the son by the mother 1 point

For a correct justification invoking Newton's third law 1 point

Question 1 (continued)

Distribution of points

(d) 3 points

For correctly finding the acceleration of the mother — 1 point

In the following solution, the positive direction for all quantities is to the right relative to the figure shown in the question.

$v_{wf}^2 = v_{wi}^2 + 2a_w\Delta x_w$

$0 = (0.55 \text{ m/s})^2 + 2a_w(-7 \text{ m})$

$a_w = 0.022 \text{ m/s}^2$

For recognizing that the accelerations of both the mother and the son are the same magnitude, since the acceleration is caused by friction — 1 point

$F_{fric} = \mu N = \mu mg = ma$

$a = \mu g$

$|a_w| = |a_s|$

$a_s = -0.022 \text{ m/s}^2$

For correctly finding the displacement of the son, with units — 1 point

$v_{sf}^2 = v_{si}^2 + 2a_s\Delta x_s$

$0 = (1.1 \text{ m/s})^2 + 2\left(-0.022 \text{ m/s}^2\right)\Delta x_s$

$\Delta x_s = 28 \text{ m}$

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Question 2

15 points total **Distribution of points**

(a) 2 points

For correct use of a kinematic relationship to find acceleration, and correct substitution of values 1 point

$$x = x_0 + v_0 t - \frac{1}{2}at^2$$

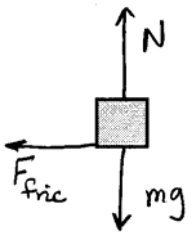
$$a = -\frac{2[(x - x_0) - v_0 t]}{t^2}$$

$$a = \frac{2[55\text{ m} - (25\text{ m/s})(3.0\text{ s})]}{(3.0\text{ s})^2}$$

For the correct final answer, regardless of sign or units 1 point

$a = -4.4\ \text{m/s}^2$

(b) 3 points



For each correct force for which the vector was correctly drawn and labeled, 1 point was awarded. 3 points

For each extraneous or incorrect force vector, 1 point was deducted with the minimum possible score being zero.

(c)

(i) 3 points

For equating the frictional force to *ma* 1 point

$\Sigma F = F_{fric} = ma$

For a correct expression for the frictional force 1 point

$F_{fric} = \mu N = \mu mg$

Substituting the expression for F_{fric} into Newton's second law

$\mu mg = ma$

$$\mu = \frac{a}{g} = \frac{4.4\ \text{m/s}^2}{9.8\ \text{m/s}^2}$$

For the correct final answer, without units 1 point

$\mu = 0.45$ ($\mu = 0.44$ for $g = 10\ \text{m/s}^2$)

Question 2 (continued)

Distribution of points

(ii) 1 point

For indicating that the friction is static — 1 point

(d) 3 points

For correct use of a kinematic relationship to find acceleration — 1 point

$v = v_0 + at$

$a_x = \frac{v_x - v_{0x}}{t} = \frac{25 \text{ m/s} - 0 \text{ m/s}}{10 \text{ s}} = 2.5 \text{ m/s}^2$

For correct substitutions into Newton's second law — 1 point

$\Sigma F = ma = kx$

$kx = ma_x$

$x = \frac{ma}{k} = \frac{(900 \text{ kg})(2.5 \text{ m/s}^2)}{9200 \text{ N/m}}$

For the correct answer with units — 1 point

$x = 0.24$ m

(e) 3 points

For indicating that the extension of the spring is less than in part (d) — 1 point

For a correct justification — 2 points

For example: When the truck is moving at a constant speed, the crate is also moving at the same constant speed with zero acceleration. This means the net force on the crate must be zero; since the bed of the truck is frictionless, the force of the spring on the crate must also zero, and so the spring is not extended at all.

Notes: A single point could be awarded for partial justification, e.g., for either of the statements above given in the absence of the other.

The justification points could only be earned if the point was awarded for the proper extension of the spring.

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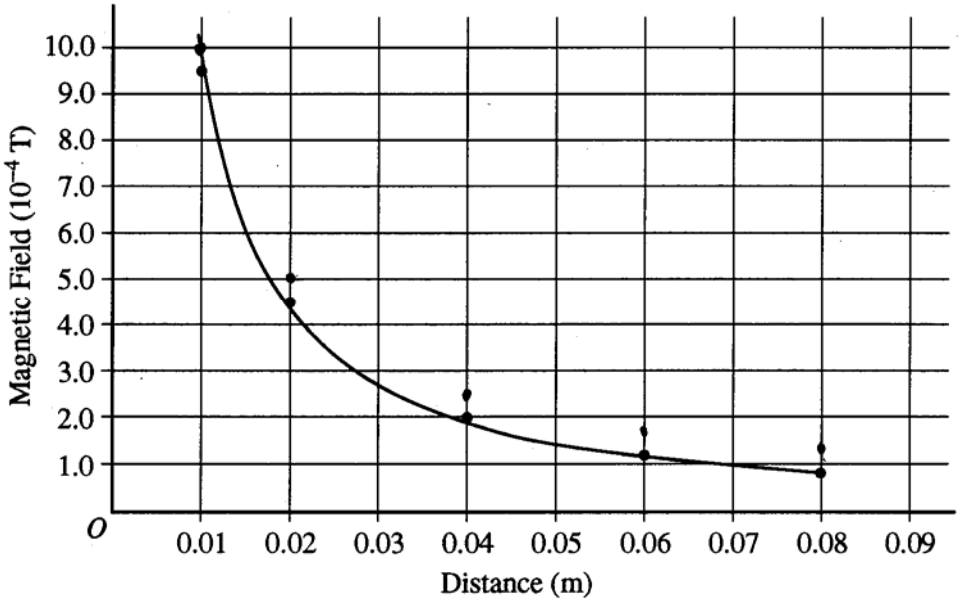
Question 3

15 points total **Distribution of points**

(a) 2 points



For each new point being above one of the points shown on the graph — 1 point

For each new point being about the same distance from the old point, a distance equal to one-half the distance between the horizontal grid lines shown — 1 point

(b) 3 points

For an attempted application of a correct relationship to find the current I — 1 point

$$B = \frac{\mu_0}{2\pi}\frac{I}{r}$$

$$I = \frac{2\pi rB}{\mu_0}$$

For correct substitutions using one of the new data points plotted in part (a), for example, using the point $(0.01\text{ m},\ 10.0 \times 10^{-4}\text{ T})$ — 1 point

$$I = \frac{2\pi(0.01\text{ m})\left(10.0 \times 10^{-4}\text{ T}\right)}{4\pi \times 10^{-7}\ (\text{T}\cdot\text{m})/\text{A}}$$

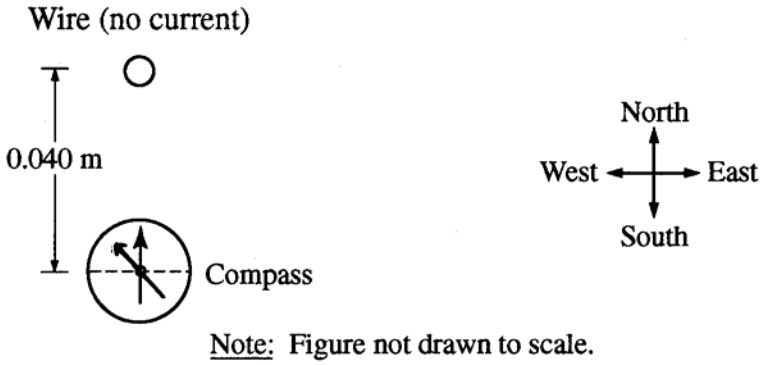
For the correct answer — 1 point

$I = 50$ A

Question 3 (continued)

Distribution of points

(c) 2 points



Note: Figure not drawn to scale.

For the direction that the needle points being toward the northwest quadrant 2 points
Note: If the needle was drawn pointing directly to the west, 1 point was awarded. If the needle was drawn pointing directly to the north, no points were awarded.

(d) 4 points

For a correct relationship to find the westward component of **B**, and a correct substitution of the current determined in part (b) 1 point

$$B_w = \frac{\mu_0}{2\pi}\frac{I}{r} = \left(\frac{4\pi \times 10^{-7}\ (\text{T•m})/\text{A}}{2\pi}\right)\left(\frac{35\ \text{A}}{0.040\ \text{m}}\right)$$

For the correct answer for B_w 1 point

$B_w = 17.5 \times 10^{-5}\ \text{T}$

For a correct relationship relating the northward and westward components to the angle 1 point

$$\tan\theta = \frac{B_w}{B_n} = \frac{17.5 \times 10^{-5}\ \text{T}}{5.0 \times 10^{-5}\ \text{T}} = 3.5$$

For the correct answer 1 point
$\theta = 74°$ or 1.3 rad

(e) 2 points

For correct substitution of both values into Ohm's law 1 point
$\mathcal{E} = IR$

$$R = \frac{\mathcal{E}}{I} = \frac{120\ \text{V}}{35\ \text{A}}$$

For the correct answer including units 1 point
$R = 3.4\ \Omega$

Question 3 (continued)

		Distribution of points
(f)	2 points	
	For correct substitution of values into a correct expression for power $P = IV$ (or $P = I^2R$ or $P = V^2/R$) $P = (35\text{ A})(120\text{ V})$	1 point
	For the correct answer including units $P = 4200\text{ W}$	1 point

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Question 4

10 points total **Distribution of points**

(a) 3 points

For a correct expression for the volume flow rate I_V 1 point

$I_V = Av$

For a correct substitution for area (only if the first point was awarded) 1 point

$A = \pi r^2$

$I_V = \pi r^2 v = (3.14)(0.015 \text{ m})^2 (6.0 \text{ m/s})$

For the correct answer 1 point

$I_V = 4.2 \times 10^{-3} \text{ m}^3/\text{s}$

(b) 3 points

For a correct application of Bernoulli's equation to point 1 in the feeder pipe below ground and point 2 at the surface where the water emerges 1 point

$P_1 + \rho g y_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g y_2 + \frac{1}{2}\rho {v_2}^2$

$P_1 = P_{abs}$ and $P_2 = P_{atm}$

$P_{abs} = P_{atm} + \rho g (y_2 - y_1) + \frac{1}{2}\rho \left({v_2}^2 - v_1^2\right)$

For the correct use of the equation of continuity to find v_1 1 point

$A_1 v_1 = A_2 v_2$

$v_1 = \frac{v_2 A_2}{A_1} = \frac{v_2 \pi {r_2}^2}{\pi {r_1}^2} = \frac{(6.0 \text{ m/s})(0.015 \text{ m})^2}{(0.025 \text{ m})^2} = 2.2 \text{ m/s}$

${v_2}^2 - {v_1}^2 = (6.0 \text{ m/s})^2 - (2.2 \text{ m/s})^2 = 31 \text{ m}^2/\text{s}^2$

$P_{abs} = 1.0 \times 10^5 \text{ Pa} + \left(10^3 \text{ kg/m}^3\right)\left(9.8 \text{ m/s}^2\right)(2.5 \text{ m}) + \frac{1}{2}\left(10^3 \text{ kg/m}^3\right)\left(31 \text{ m}^2/\text{s}^2\right)$

For the correct answer with units 1 point

$P_{abs} = 1.4 \times 10^5 \text{ Pa}$

Question 4 (continued)

Distribution of points

(c) 4 points

For correct use of kinematics or conservation of energy or Torricelli's theorem to find the exit speed, with correct substitution of values — 1 point

$v_2^2 = 2gh$

$v_2 = \sqrt{2gh} = \sqrt{2\left(9.8 \text{ m/s}^2\right)(4.0 \text{ m})}$

For the correct answer for the exit speed — 1 point

$v_2 = 8.9 \text{ m/s}$

For correct use of the equation of continuity to find r_{new}, with correct substitution of values — 1 point

$Av = A_{new}v_{new}$

$\pi r^2 v = \pi r_{new}^2 v_{new}$

$r_{new}^2 = r^2 \dfrac{v}{v_{new}} = (0.015 \text{ m})^2 \dfrac{(6.0 \text{ m/s})}{(8.9 \text{ m/s})}$

For the correct answer with units, consistent with the new exit speed found above — 1 point

$r_2 = 1.2 \times 10^{-2} \text{ m}$

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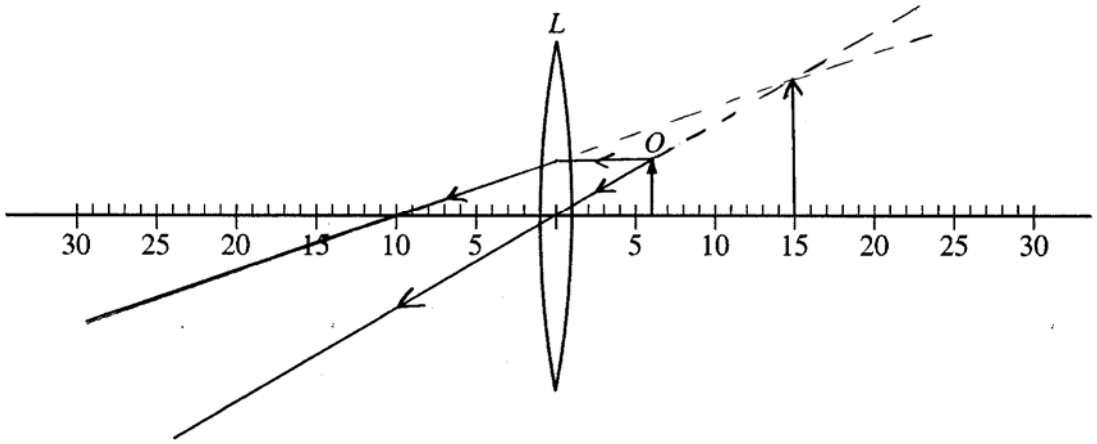
Question 5

10 points total **Distribution of points**

(a) 3 points

Example:



For each correct ray from the object used to locate the image, 1 point was awarded, to a maximum of 2 points — 2 points

For the correct size and orientation of the image — 1 point

(b)

(i) 1 point

For an indication that the image is virtual — 1 point

(ii) 1 point

For a correct justification — 1 point

Example: The rays emerging from the lens did not actually converge at the image but only appear to have done so.

This point was only awarded if the point for part (b)(i) was awarded.

(c) 2 points

For correct use of the equation relating image distance to object distance and focal length, with correct substitutions — 1 point

$$\frac{1}{s_i} + \frac{1}{s_o} = \frac{1}{f}$$

$$s_i = \frac{fs_o}{s_o - f}$$

$$s_i = \frac{(10.0\text{ cm})(6.0\text{ cm})}{6.0\text{ cm} - 10.0\text{ cm}}$$

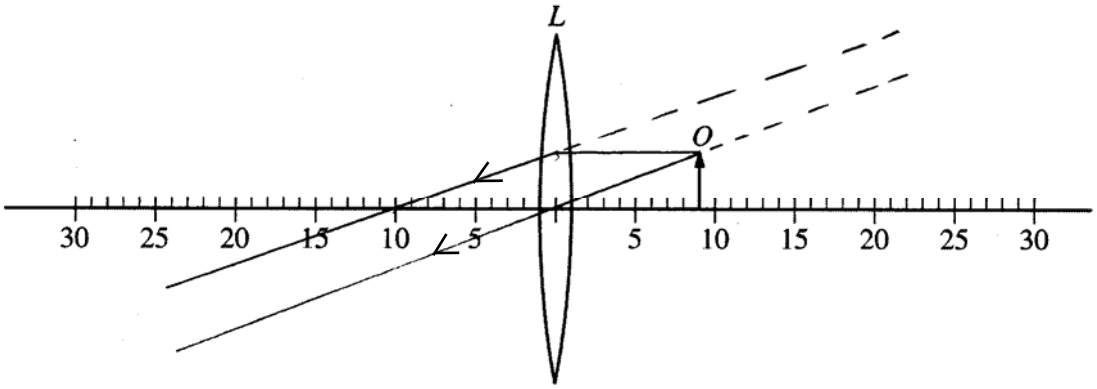
For the correct answer with the correct sign — 1 point

$s_i = -15$ cm

Question 5 (continued)

Distribution of points

(d) 3 points
Example:



For an indication that the height of the new image is larger — 1 point
For a correct justification (only when the previous point has been awarded) — 2 points

Justification approach 1: — 2 points
The rays passing through the lens become less diverging from each other due to the geometry. Their extensions meet further away from the lens making the image larger.

Justification approach 2: Construct a new ray diagram — 2 points
For each correct ray from the object used to locate the image, 1 point was awarded, to a maximum of 2 points. The student must explicitly refer to the diagram as the justification for the larger height in order for the diagram to be considered.

Justification approach 3: Calculate the change in magnification
For a correct calculation of the image location after the object is moved — 1 point

$$\frac{1}{s_i} + \frac{1}{s_o} = \frac{1}{f}$$

$$s_i = \frac{fs_o}{s_o - f} = \frac{(10.0\text{ cm})(9.0\text{ cm})}{9.0\text{ cm} - 10.0\text{ cm}} = -90\text{ cm}$$

For a correct calculation of the magnification both prior to moving the object and after the object is moved, leading to the conclusion that the new image is larger — 1 point

$$M_1 = -\frac{s_i}{s_o} = -\frac{-15\text{ cm}}{6\text{ cm}} = +2.5$$

$$M_2 = -\frac{s_i}{s_o} = -\frac{-90\text{ cm}}{9\text{ cm}} = +10$$

The magnification increases so the height of the new image is larger.

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Question 6

10 points total **Distribution of points**

(a) 4 points

Apply the ideal gas law to pairs of points, recognizing that nR is the same at all three points.

For example, comparing points 1 and 2 and points 1 and 3

For correct use of the ideal gas law at points 1 and 2, with correct substation of values — 1 point

$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$, with $V_1 = V_2$

$T_2 = \frac{T_1P_2}{P_1} = \frac{(300\text{ K})\left(500 \times 10^3\text{ Pa}\right)}{100 \times 10^3\text{ Pa}}$

For the correct temperature at point 2 — 1 point

$T_2 = 1500\text{ K}$

For correct use of the ideal gas law at points 1 and 3, with correct substitution of values — 1 point

$\frac{P_1V_1}{T_1} = \frac{P_3V_3}{T_3}$, with $P_1 = P_3$

$T_3 = \frac{T_1V_3}{V_1} = \frac{(300\text{ K})\left(6.0 \times 10^{-4}\text{ m}^3\right)}{1.0 \times 10^{-4}\text{ m}^3}$

For the correct temperature at point 3 — 1 point

$T_3 = 1800\text{ K}$

(b) 2 points

Approach 1: Calculate the area enclosed by the triangular path

For recognition that the magnitude of the work done on the gas in one cycle is equal to the area enclosed by the triangular path — 1 point

$W_{tot} = \frac{1}{2}(V_3 - V_1)(P_2 - P_1)$

For the correct answer — 1 point

$W_{tot} = \frac{1}{2}\left[(6.0 - 1.0) \times 10^{-4}\text{ m}^3\right]\left[(500 - 100) \times 10^3\text{ Pa}\right]$

$W_{tot} = 100\text{ J}$

Question 6 (continued)

Distribution of points

(b) (continued)

Approach 2: Calculate the work done on the gas in each of the three processes and take the sum

For recognition that the work done on the gas is equal to the sum of the work done in each of the three processes — 1 point

$W_{tot} = W_{1\to2} + W_{2\to3} + W_{3\to1}$

For a correct computation of the numerical value — 1 point

$W_{1\to2} = -P_1(V_2 - V_1)$, but $V_2 = V_1$, so $W_{1\to2} = 0$

$$W_{2\to3} = -\frac{\left[(500 + 100)\times 10^3 \text{ Pa}\right]}{2}\left[(6.0 - 1.0)\times 10^{-4} \text{ m}^3\right] = -150 \text{ J}$$

$$W_{3\to1} = -P_3(V_1 - V_3) = -\left(100\times 10^3 \text{ Pa}\right)\left[(1.0 - 6.0)\times 10^{-4} \text{ m}^3\right] = +50 \text{ J}$$

$W_{3\to1} = +50$ J

$W_{tot} = W_{1\to2} + W_{2\to3} + W_{3\to1} = 0 - 150 \text{ J} + 50 \text{ J} = -100 \text{ J}$

Note: The minus sign was not necessary since the question asks only for the amount of work; the sign is asked for in part (c).

(c) 1 point

For indicating that the work done on the gas in one complete cycle is negative — 1 point

(d) 3 points

For an application of the first law of thermodynamics to process $1 \to 2$, recognizing that the work done from point 1 to point 2 is zero — 1 point

$\Delta U = Q + W$

$Q = \Delta U - W$

$Q = \Delta U$

For a correct expression for Q from point 1 to point 2, with correct substitution of values — 1 point

$$Q = \frac{3}{2}nR\Delta T = \frac{3}{2}(0.0040 \text{ mol})(8.31 \text{ J/mol•K})(1500 \text{ K} - 300 \text{ K})$$

For the correct answer — 1 point

$Q = 60$ J

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Question 7

10 points total **Distribution of points**

(a) 3 points

For a correct equation relating energy and wavelength 1 point

$E_\gamma = hf = \dfrac{hc}{\lambda}$

For correct substitutions (and conversions if necessary) 1 point

$\lambda = \dfrac{hc}{E_\gamma} = \dfrac{\left(6.63 \times 10^{-34}\ \text{J·s}\right)\left(3.00 \times 10^{8}\ \text{m/s}\right)}{\left(1.02 \times 10^{6}\ \text{eV}\right)\left(1.60 \times 10^{-19}\ \text{J/eV}\right)}$ OR

$\lambda = \dfrac{hc}{E_\gamma} = \dfrac{\left(1.24 \times 10^{3}\ \text{eV·nm}\right)\left(10^{-9}\ \text{m/nm}\right)}{1.02 \times 10^{6}\ \text{eV}}$

For the correct answer with units 1 point

$\lambda = 1.22 \times 10^{-12}\ \text{m}$

(b) 2 points

For correct use of the equation relating wavelength and momentum (or energy and momentum) and correct substitution of values 1 point

$\lambda = \dfrac{h}{p_\gamma}$ (or $E = pc$)

$p_\gamma = \dfrac{h}{\lambda} = \dfrac{6.63 \times 10^{-34}\ \text{J·s}}{1.22 \times 10^{-12}\ \text{m}}$ OR $p = \dfrac{E}{c} = \dfrac{\left(1.02 \times 10^{6}\ \text{eV}\right)\left(1.6 \times 10^{-19}\ \text{J/eV}\right)}{3.0 \times 10^{8}\ \text{m/s}}$

For the correct answer with units 1 point

$p_\gamma = 5.43 \times 10^{-22}\ \text{kg·m/s}$

(c) 3 points

For an indication that momentum is conserved 1 point

$p_\gamma = p_{nuc}$

For a correct expression for the momentum of the nucleus 1 point

$p_{nuc} = m_{nuc} v_{nuc}$

For either a correct substitution from part (b) or the correct answer 1 point

$v_{nuc} = \dfrac{p_{nuc}}{m_{nuc}} = \dfrac{p_\gamma}{m_{nuc}} = \dfrac{5.43 \times 10^{-22}\ \text{kg·m/s}}{4.48 \times 10^{-26}\ \text{kg}} = 1.21 \times 10^{4}\ \text{m/s}$

Question 7 (continued)

Distribution of points

(d) 2 points

For correct use of the expression for kinetic energy 1 point

$K_{nuc} = \frac{1}{2}mv_{nuc}^2$

For a correct substitution from part (c) 1 point

$K_{nuc} = \frac{1}{2}\left(4.48 \times 10^{-26}\ \text{kg}\right)\left(1.21 \times 10^{4}\ \text{m/s}\right)^2 = 3.28 \times 10^{-18}\ \text{J}$