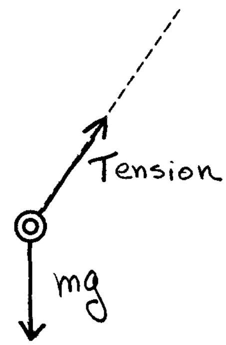
AP® Physics B
2003 Scoring Guidelines
Form B

Question 1

15 points total | **Distribution of points**

(a) 3 points



One point for each correctly drawn and appropriately labeled force — 2 points
For no incorrect forces — 1 point

(b) 5 points

For use of the correct equation relating acceleration and velocity — 1 point
$\mathbf{a} = \Delta \mathbf{v}/t$

For correctly calculating the magnitude of the acceleration — 1 point
$a = \dfrac{65\ \text{m/s} - 0}{30\ \text{s}} = \dfrac{13}{6}\ \text{m/s}^2\ \ (\text{or } 2.17\ \text{m/s}^2)$

For using an equation relating distance and acceleration — 1 point
$d = d_0 + v_0 t + \dfrac{1}{2}at^2 \quad \text{OR} \quad v^2 = v_0^2 + 2a\,\Delta d$

For substituting the calculated acceleration — 1 point
$d = \dfrac{1}{2}\left(\dfrac{13}{6}\ \text{m/s}^2\right)(30\ \text{s})^2 \quad \text{OR} \quad d = (65\ \text{m/s})^2 \Big/ 2\left(\dfrac{13}{6}\ \text{m/s}^2\right)$

For the correct answer — 1 point
$d = 975\ \text{m}$

Alternate solution — *Alternate points*

For use of the correct equation for average speed — *1 point*
$v_{avg} = (v_f + v_0)/2$

For correctly calculating the average speed — *1 point*
$v_{avg} = (65\ \text{m/s} + 0)/2 = 32.5\ \text{m/s}$

For using the appropriate equation relating distance to speed — *1 point*
$d = v_{avg} t$

For substituting v_{avg} into the equation — *1 point*
$d = (32.5\ \text{m/s})(30\ \text{s})$

For the correct answer — *1 point*
$d = 975\ \text{m}$

Question 1 (continued)

	Distribution of points
(c) 5 points	
For using the correct x and y components of the tension $T_x = T\sin\theta$ and $T_y = T\cos\theta$	1 point
For the correct equation relating the forces along the x-axis $T\sin\theta = ma$	1 point
For the correct equation relating the forces along the y-axis $T\cos\theta = mg$	1 point
For combining these two equations to eliminate the tension $\tan\theta = a/g$ $\tan\theta = \left(2.17\ \text{m/s}^2\right)/\left(9.8\ \text{m/s}^2\right)$	1 point
For the correct answer $\theta = 12.5°$ (or $12.2°$ using $g = 10\ \text{m/s}^2$)	1 point
(d) 2 points	
For indicating that one would need to know the mass of the airplane, with some attempt to give an explanation that relates to the mass.	1 point
For a correct explanation Example: The kinetic energy is the only form of mechanical energy in this case. The velocity is known, but you need the mass to calculate the kinetic energy.	1 point

Question 2

15 points total | **Distribution of points**

(a) 3 points

For correct equation for power $P = IV$	1 point
For the correct answer P = 3 mW (or 0.003 W) One point was subtracted for incorrect or missing unit	2 points

(b) 3 points

For the correct equation for work or energy W (or energy) = Pt	1 point
For correct substitution of power from part (a) W (or energy) = (0.003 W)(60 s)	1 point
For the correct answer consistent with substitution of power from part (a), with correct units W (or energy) = 0.180 J	1 point

(c) 5 points

For the correct efficiency equation $\text{efficiency} = \dfrac{W_o}{W_i}$	1 point
For correct substitution of W_i (work done in 60 s) from part (b)	1 point
For indicating that the work output W_o equals the change in gravitational potential energy $W_o = mg\,\Delta h$	1 point
For correct calculation of work output in 60 s $W_o = (0.012\text{ kg})(9.8\text{ m/s}^2)(1\text{ m}) = 0.12\text{ J}$ (or same answer using $g = 10\text{ m/s}^2$)	1 point
For correct calculation of efficiency consistent with calculation made in part (b). $\text{efficiency} = \dfrac{0.12\text{ J}}{0.18\text{ J}} = 66.7\%$ (or 65.3% using $g = 9.8\text{ m/s}^2$ and unrounded value for W_o)	1 point

Alternately, full credit could also be obtained by calculating efficiency using the ratio of power output to power input, in which case

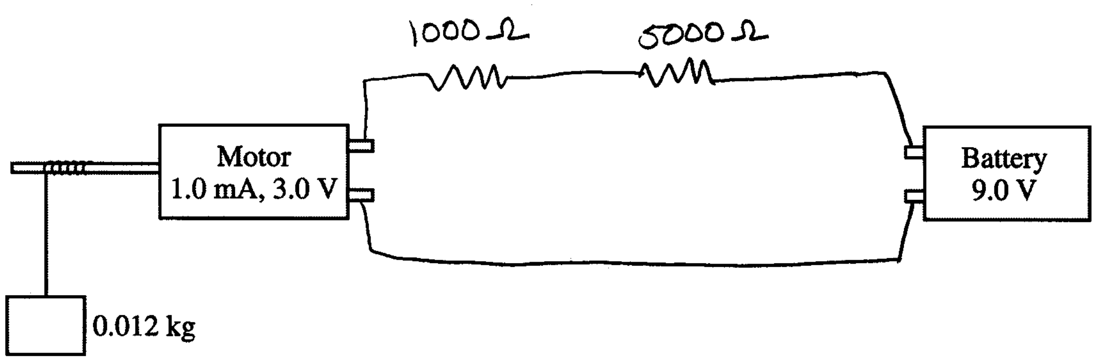
$$\text{eff} = \frac{P_o}{P_i} = \frac{(0.012\text{ kg})(9.8\text{ m/s}^2)(1\text{ m})/60\text{ s}}{0.003\text{ W}} = 65.3\% \text{ (or 66.7\% using } g = 10\text{ m/s}^2)$$

Similar point allocations were assigned using this method.

Question 2 (continued)

Distribution of points

(d) 4 points



For a calculation or notation that 6 V was the voltage drop across the resistor needed in order to reduce the voltage across the motor from 9 V to 3 V. — 1 point

Series resistance needed to produce this voltage drop = $\dfrac{6.0\text{ V}}{1.0\text{ mA}} = 6000\ \Omega$

For the selection of a 1000 Ω and a 5000 Ω resistor — 1 point

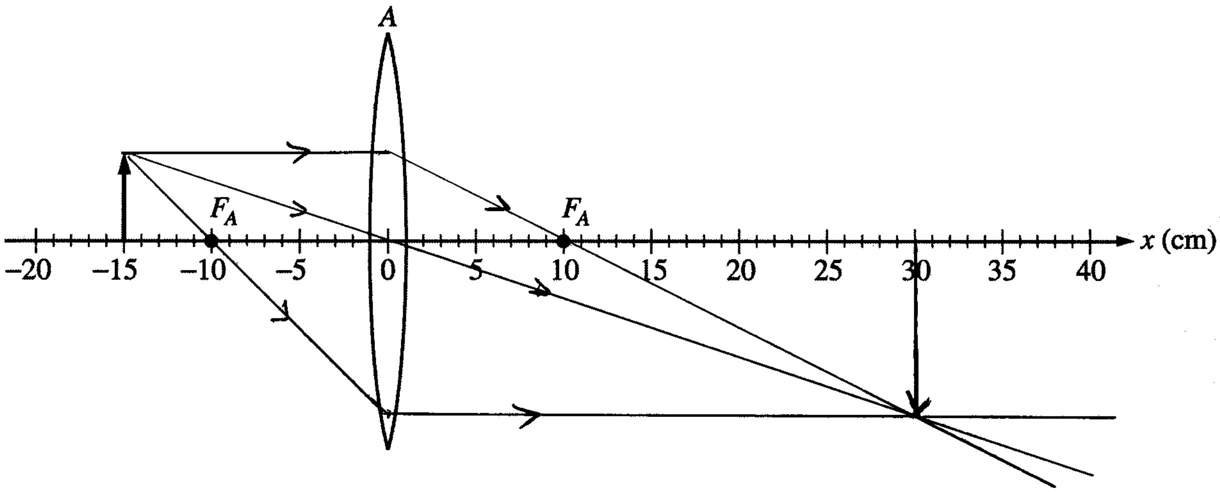
For the placement of the 1000 Ω and 5000 Ω resistor in series — 1 point

For an appropriate sketch of the system with appropriate symbols and labels for resistors — 1 point

Question 3

15 points total **Distribution of points**

(a) 4 points



One point for each correctly drawn ray passing through the lens (maximum of 2 points) 2 points

For the intersection of the rays occurring at 30 cm ± 5 cm 1 point

For correctly drawing the image 1 point

(b) 3 points

For using the lens equation 1 point

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

For correct substitutions 1 point

$$\frac{1}{15\text{ cm}} + \frac{1}{s_i} = \frac{1}{10\text{ cm}}$$

For answer consistent with substitutions 1 point

$s_i = 30\text{ cm}$

Question 3 (continued)

Distribution of points

(c) 3 points

For correct equation relating ratio of image to object heights to ratio of image to object distances — 1 point

$\frac{h_i}{h_o} = -\frac{s_i}{s_o}$ OR $\frac{|h_i|}{|h_o|} = \frac{|s_i|}{|s_o|}$

For consistent substitution — 1 point

$\frac{h_i}{5 \text{ cm}} = -\frac{30 \text{ cm}}{15 \text{ cm}}$ OR $\frac{|h_i|}{5 \text{ cm}} = \frac{30 \text{ cm}}{15 \text{ cm}}$

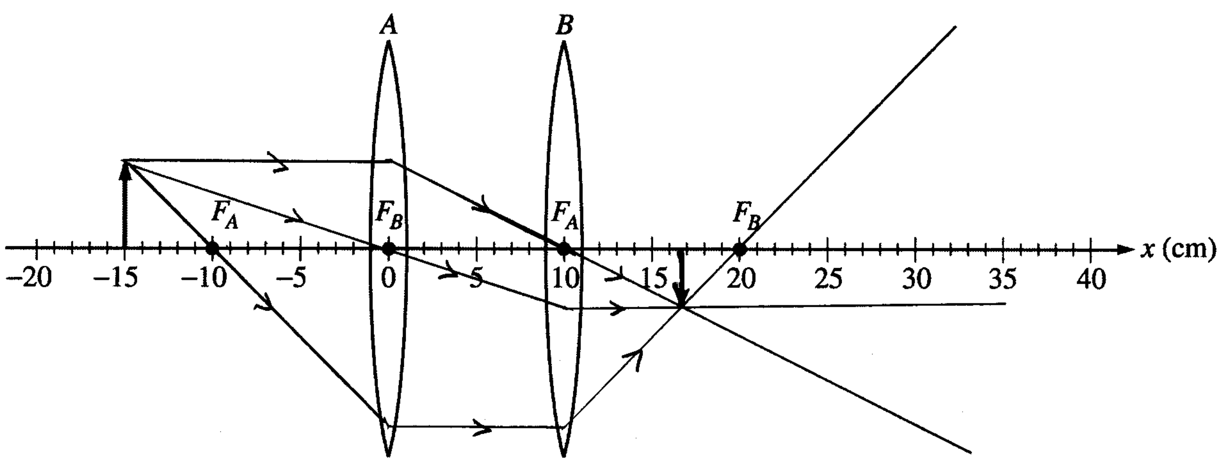
For answer consistent with substitutions — 1 point

$h_i = -10$ cm OR $|h_i| = 10$ cm

Note: Since the minus sign in the first answer just indicates the image is inverted, it was not necessary for full credit, since the question could be interpreted as asking only for the actual size of the image.

(d) 3 points

Method 1: Ray diagram



One point for each correctly drawn ray passing through both lenses (maximum of 2 points) — 2 points

For the image location at 16.6 cm ± 3 cm — 1 point

Question 3 (continued)

Distribution of points

Method 2: Mathematical approach using the lens equation

The image produced by the first lens becomes the virtual object for the second lens.

For the correct object distance to substitute into the lens equation for the second lens — 1 point

$s_o' = -(30\text{ cm} - 10\text{ cm}) = -20\text{ cm}$ (The minus indicates that the object is virtual.)

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

$$\frac{1}{-20\text{ cm}} + \frac{1}{s_i'} = \frac{1}{10\text{ cm}}$$

For the final image location with respect to the second lens — 1 point

$s_i' = 6.7\text{ cm}$

For the final image location on the scale shown — 1 point

$x_i = s_i' + 10\text{ cm} = 16.7\text{ cm}$

(e) 2 points

For checking spaces consistent with answer to part (d) and a correct explanation — 2 points

Explanation had to either refer to ray diagram, or, if a mathematical approach was used in part (d), had to be consistent with answer to part (d).

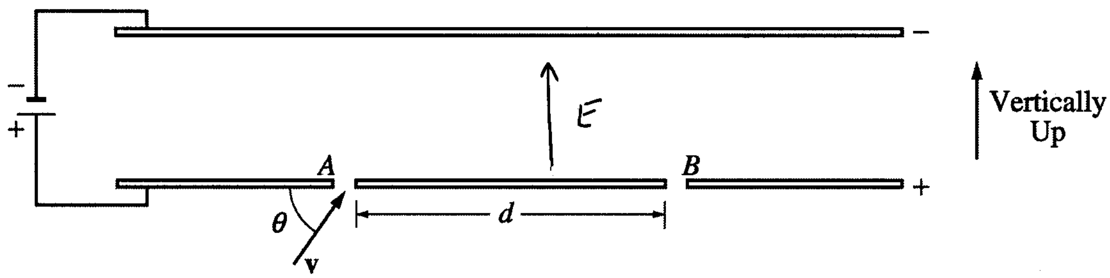
No points were awarded for students who checked spaces without any explanations.

Question 4

15 points total **Distribution of points**

(a) 4 points

i. (1 point)

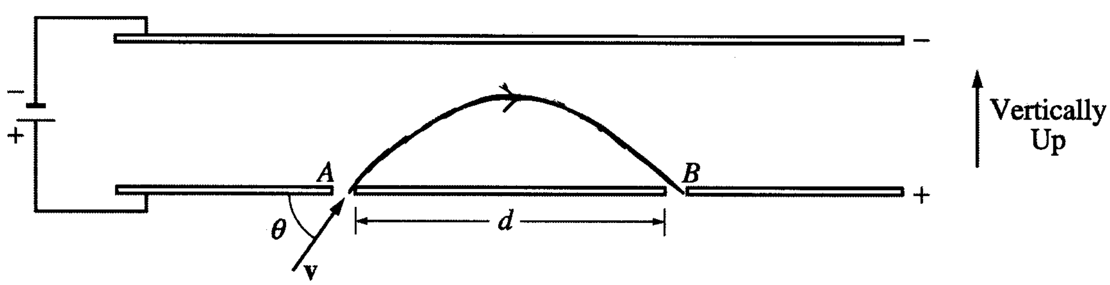


For a correctly drawn and labeled vector for **E**, directed vertically upward as shown in the diagram above — 1 point

ii. (1point)

For a vector directed vertically downward representing the force on an electron in the field, as shown in the diagram above — 1 point

iii. (2 points)



For a curved path from *A* to *B* — 1 point
For the path being symmetrical about the midpoint of *d* — 1 point

Question 4 (continued)

Distribution of points

(b) 2 points

For using the equation that relates the force on a charged particle to the electric field — 1 point

$F = qE$

Equating this force to the net force in Newton's second law, $F_{net} = ma$

$qE = ma$

For the correct answer — 1 point

$a = \dfrac{qE}{m}$

(c) 4 points

In the electric field the electron is accelerated vertically downward.

$\upsilon_y(t) = \upsilon_y - at$, where υ_y is the vertical component of the electron's velocity at point A

The time t_1 to reach maximum vertical displacement occurs when $\upsilon_y(t_1) = 0$. Solving for t_1:

$t_1 = \dfrac{\upsilon_y}{a}$

For using the correct component for υ_y — 1 point

$\upsilon_y = \upsilon \sin\theta$

For indicating that the total time is twice t_1 — 1 point

$t_{tot} = 2t_1 = \dfrac{2\upsilon\sin\theta}{a}$

For correct substitution of a from part (b) — 1 point

$t_{tot} = \dfrac{2\upsilon\sin\theta}{\frac{qE}{m}}$

For the correct answer — 1 point

$t_{tot} = \dfrac{2m\upsilon\sin\theta}{qE}$

Alternately, the kinematic equations $\upsilon_y(t) = \upsilon\sin\theta - at$ OR $y(t) = y_0 + (\upsilon\sin\theta)t - \frac{1}{2}at^2$ could be used. When the electron reaches B at time t_{tot}, $\upsilon_y(t_{tot}) = -\upsilon\sin\theta$, and $y(t_{tot}) = y_0$. Substituting these values and the expression for a from part (b) into the respective equations above and solving either equation for t_{tot} gives the answer, $t_{tot} = \dfrac{2m\upsilon\sin\theta}{qE}$. This approach also received full credit with awarding of points similar to those above.

Question 4 (continued)

Distribution of points

(d) 3 points

While the electron is in the field the horizontal component of its velocity is constant.

For the correct equation relating distance to time — 1 point

$d = \upsilon_x t_{tot}$

For using the correct component for υ_x — 1 point

$\upsilon_x = \upsilon \cos\theta$

For correct substitutions for υ_x and total time — 1 point

$$d = (\upsilon \cos\theta)\left(\frac{2m\upsilon \sin\theta}{qE}\right)$$

$$d = \frac{2m\upsilon^2 \sin\theta \cos\theta}{qE}$$

(e) 2 points

For an indication that the distance *d* would be less — 1 point

For any reasonable explanation — 1 point

Example: The additional gravitational force downward would increase the downward acceleration thus decreasing the total time the electron would be in the field.

Question 5

10 points total | **Distribution of points**

(a) 2 points

For a statement of the ideal gas law — 1 point

$pV = nRT$

$\left(200 \text{ N/m}^2\right)\left(20 \text{ m}^3\right) = \left(1 \text{ mol}\right)\left(8.32 \text{ J}/\left(\text{mol}\cdot\text{K}\right)\right)T$

For the correct answer — 1 point

$T = 481 \text{ K}$

(b) 2 points

For indicating that the work W done on the gas is equal to the area enclosed by the cycle or for $W = -p\Delta V$ — 1 point

W = area of triangle enclosed by cycle $= \frac{1}{2}bh = \frac{1}{2}\left(60 \text{ m}^3 - 20 \text{ m}^3\right)\left(400 \text{ N/m}^2 - 200 \text{ N/m}^2\right)$

For the correct answer — 1 point

$W = 4000 \text{ J}$

(c) 2 points

i. (1 point)

For indicating that heat is removed from the gas during one complete cycle — 1 point

ii. (1 point)

Using the first law of thermodynamics

$\Delta U = Q + W$

Recognizing that $\Delta U = 0$ for a closed cycle

$Q = -W$

For the correct answer consistent with part (b) — 1 point

$Q = -4000 \text{ J}$

Note: Since the question could be interpreted as asking for the magnitude of the heat added to or remove from, the minus sign was not necessary for full credit.

Question 5 (continued)

	Distribution of points
(d) 2 points	
For indicating that the internal energy of the gas after one cycle is the same as before	1 point
For a reasonable justification	1 point
Example: The internal energy of the gas is a function of the temperature and the temperature is the same at the beginning and end of each cycle.	
(e) 2 points	
For indicating that the entropy of the gas after one cycle is the same as before	1 point
For a reasonable justification	1 point
Example: The entropy is a function of the state of the gas, and after one complete cycle the gas has returned to its original state.	

Question 6

10 points total	**Distribution of points**
(a) 6 points	
i. (3 points)	
For correct use of the equation relating work to the distance raised	1 point
$W = mgh$	
For correct use of the equation relating mass to density and volume	1 point
$m = \rho V$	
Combining the two relationships	
$W = \rho Vgh = \left(1000 \text{ kg/m}^3\right)\left(0.35 \text{ m}^3\right)\left(9.8 \text{ m/s}^2\right)\left(50 \text{ m} + 35 \text{ m}\right)$	
For the correct answer	1 point
$W = 290{,}000$ J (or 300,000 J using $g = 10 \text{ m/s}^2$)	
ii. (2 points)	
For correct use of the equation relating power to work and time	1 point
$P = \dfrac{W}{\Delta t}$	
$P = \dfrac{290{,}000 \text{ W}}{\left(2 \text{ hr}\right)\left(60 \text{ min/hr}\right)\left(60 \text{ s/min}\right)}$	
For the correct answer	1 point
$P = 40$ W (or 41 W using $g = 10 \text{ m/s}^2$)	
(b) 4 points	
i. (3 points)	
For correct use of equation of continuity	1 point
$\upsilon_1 A_1 = \upsilon_2 A_2$	
For using the radius of each pipe as half the diameter	1 point
Substituting the given values:	
$\left(0.50 \text{ m/s}\right)\pi\left(\dfrac{0.03 \text{ m}}{2}\right)^2 = \upsilon_2 \pi\left(\dfrac{0.0125 \text{ m}}{2}\right)^2$	
For the correct answer	1 point
$\upsilon_2 = 2.88$ m/s	
ii. (2 points)	
For indicating the need to use Bernoulli's equation	1 point
For an explanation of how to use Bernoulli's equation	1 point
Example: $p_1 + \rho g h_1 + \frac{1}{2}\rho \upsilon_1^2 = p_2 + \rho g h_2 + \frac{1}{2}\rho \upsilon_2^2$	
If the subscript 1 represents quantities at the pump and subscript 2 represent quantities at the house, then all the quantities are known except the pressure at the house, so the equation can be solved for this pressure.	

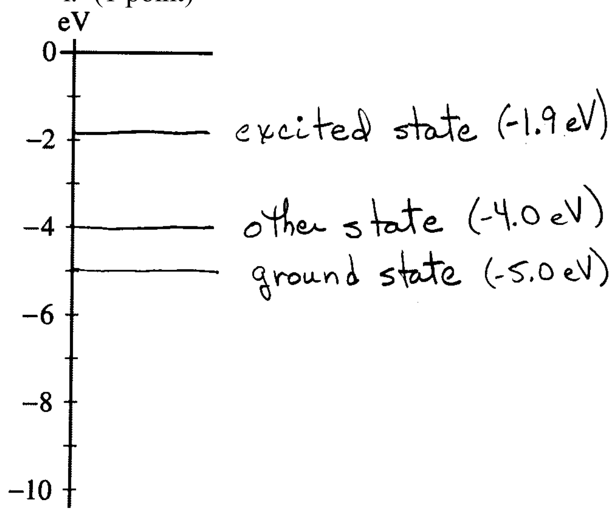
Question 7

10 points total **Distribution of points**

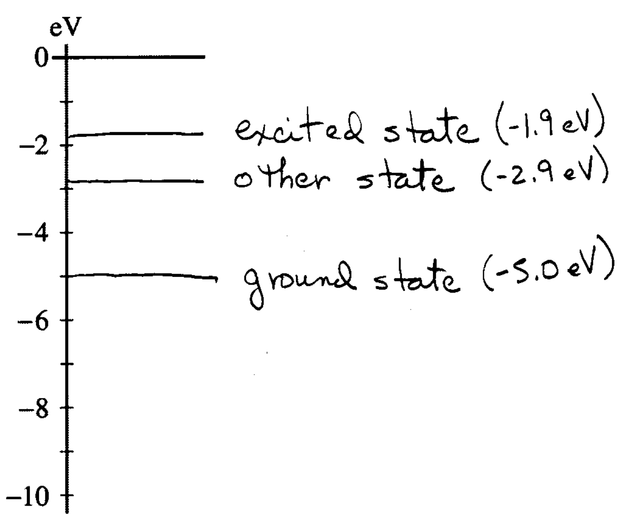
(a) 7 points

There were two possible "other" or intermediate energy levels asked for in part iii., so there were two possible correct energy level diagrams depending on which "other" energy level was used.

i. (1 point)



OR



For drawing a horizontal line on the diagram at –5 eV — 1 point

ii. (3 points)

For correct equation(s) to calculate the energy of a 400 nm photon — 1 point

$E = hf$ and $f = c/\lambda$, so

$E = hc/\lambda$

$E = \left(1.24\times10^3\ \text{eV}\cdot\text{nm}\right)/\left(400\ \text{nm}\right)$

For the correct answer — 1 point

$E = 3.1$ eV

For drawing a horizontal line on the diagram at −1.9 eV to represent the first excited state, which is 3.1 eV above the ground state — 1 point

iii. (3 points)

Using the same equations to calculate the energy of a 600 nm photon:

$$E = \frac{hc}{\lambda} = \frac{1.24\times10^3\ \text{eV}\cdot\text{nm}}{600\ \text{nm}}$$

For the correct answer — 1 point

$E = 2.1$ eV

This photon could represent a transition from the first excited state to an intermediate state, in which case the intermediate state is at E = –4.0 eV. Or the photon could represent a transition from an intermediate state to the ground state, in which case the intermediate state is at –2.9 eV. — 1 point

For drawing a horizontal line on the diagram at either –4.0 eV or –2.9 eV — 1 point

Note: Although the value of *hc* is given in the table of information, many students substituted *h* and *c* separately.

Question 7 (continued)

Distribution of points

(b) 3 points

If the intermediate state is at -4.0 eV, then the transition from the intermediate state to the ground level at -5.0 eV is 1.0 eV. If the intermediate state is at -2.9 eV, then the transition from the first excited state at -1.9 eV to the intermediate state is 1.0 eV.

For calculation of 1.0 eV by subtraction of energy levels — 1 point

Since $E = \dfrac{hc}{\lambda}$

$$\lambda = \frac{hc}{E} = \frac{1.24 \times 10^3 \text{ eV} \cdot \text{nm}}{1.0 \text{ eV}}$$

For calculation of wavelength — 1 point

$\lambda = 1240$ nm

For statement that this wavelength is not seen because it is in the infrared or outside the range of wavelengths for “white light” given in the problem — 1 point