



AP[®] Physics B 2003 Scoring Guidelines Form B

The materials included in these files are intended for use by AP teachers for course and exam preparation; permission for any other use must be sought from the Advanced Placement Program[®]. Teachers may reproduce them, in whole or in part, in limited quantities for noncommercial, face-to-face teaching purposes. This permission does not apply to any third-party copyrights contained herein. This material may not be mass distributed, electronically or otherwise. These materials and any copies made of them may not be resold, and the copyright notices must be retained as they appear here.

These materials were produced by Educational Testing Service[®] (ETS[®]), which develops and administers the examinations of the Advanced Placement Program for the College Board. The College Board and Educational Testing Service (ETS) are dedicated to the principle of equal opportunity, and their programs, services, and employment policies are guided by that principle.

The College Board is a national nonprofit membership association whose mission is to prepare, inspire, and connect students to college and opportunity. Founded in 1900, the association is composed of more than 4,300 schools, colleges, universities, and other educational organizations. Each year, the College Board serves over three million students and their parents, 22,000 high schools, and 3,500 colleges through major programs and services in college admissions, guidance, assessment, financial aid, enrollment, and teaching and learning. Among its best-known programs are the SAT[®], the PSAT/NMSQT[®], and the Advanced Placement Program[®] (AP[®]). The College Board is committed to the principles of equity and excellence, and that commitment is embodied in all of its programs, services, activities, and concerns.

For further information, visit www.collegeboard.com

Copyright © 2003 College Entrance Examination Board. All rights reserved. College Board, Advanced Placement Program, AP, AP Vertical Teams, APCD, Pacesetter, Pre-AP, SAT, Student Search Service, and the acorn logo are registered trademarks of the College Entrance Examination Board. AP Central is a trademark owned by the College Entrance Examination Board. PSAT/NMSQT is a registered trademark jointly owned by the College Entrance Examination Board and the National Merit Scholarship Corporation. Educational Testing Service and ETS are registered trademarks of Educational Testing Service. Other products and services may be trademarks of their respective owners.

For the College Board's online home for AP professionals, visit AP Central at apcentral.collegeboard.com.

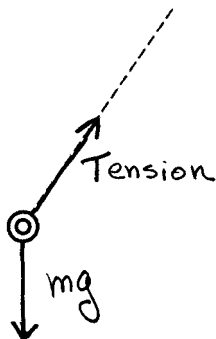
AP[®] PHYSICS B
2003 SCORING GUIDELINES (Form B)

Question 1

15 points total

**Distribution
of points**

(a) 3 points



One point for each correctly drawn and appropriately labeled force
For no incorrect forces

2 points
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

$$a = \frac{65 \text{ m/s} - 0}{30 \text{ s}} = \frac{13}{6} \text{ m/s}^2 \quad (\text{or } 2.17 \text{ m/s}^2)$$

For using an equation relating distance and acceleration

1 point

$$d = d_0 + v_0 t + \frac{1}{2} a t^2 \quad \text{OR} \quad v^2 = v_0^2 + 2a \Delta d$$

For substituting the calculated acceleration

1 point

$$d = \frac{1}{2} \left(\frac{13}{6} \text{ m/s}^2 \right) (30 \text{ s})^2 \quad \text{OR} \quad d = (65 \text{ m/s})^2 / 2 \left(\frac{13}{6} \text{ m/s}^2 \right)$$

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

$$v_{\text{avg}} = (v_f + v_0) / 2$$

For correctly calculating the average speed

1 point

$$v_{\text{avg}} = (65 \text{ m/s} + 0) / 2 = 32.5 \text{ m/s}$$

For using the appropriate equation relating distance to speed

1 point

$$d = v_{\text{avg}} t$$

For substituting v_{avg} into the equation

1 point

$$d = (32.5 \text{ m/s})(30 \text{ s})$$

For the correct answer

1 point

$$d = 975 \text{ m}$$

**AP PHYSICS B
2003 SCORING GUIDELINES (Form B)**

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 $\tan \theta = a/g$ $\tan \theta = (2.17 \text{ m/s}^2)/(9.8 \text{ m/s}^2)$	1 point
For the correct answer $\theta = 12.5^\circ$ (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

AP[®] PHYSICS B
2003 SCORING GUIDELINES (Form B)

Question 2

15 points total

**Distribution
of points**

(a) 3 points

For correct equation for power

$$P = IV$$

For the correct answer

$$P = 3 \text{ mW (or } 0.003 \text{ W)}$$

One point was subtracted for incorrect or missing unit

1 point

2 points

(b) 3 points

For the correct equation for work or energy

$$W \text{ (or energy)} = Pt$$

For correct substitution of power from part (a)

$$W \text{ (or energy)} = (0.003 \text{ W})(60 \text{ s})$$

For the correct answer consistent with substitution of power from part (a), with correct units

$$W \text{ (or energy)} = 0.180 \text{ J}$$

1 point

1 point

1 point

(c) 5 points

For the correct efficiency equation

$$\text{efficiency} = \frac{W_o}{W_i}$$

For correct substitution of W_i (work done in 60 s) from part (b)

For indicating that the work output W_o equals the change in gravitational potential energy

$$W_o = mg \Delta h$$

For correct calculation of work output in 60 s

$$W_o = (0.012 \text{ kg})(9.8 \text{ m/s}^2)(1 \text{ m}) = 0.12 \text{ J (or same answer using } g = 10 \text{ m/s}^2)$$

For correct calculation of efficiency consistent with calculation made in part (b).

$$\text{efficiency} = \frac{0.12 \text{ J}}{0.18 \text{ J}} = 66.7\% \text{ (or } 65.3\% \text{ using } g = 9.8 \text{ m/s}^2 \text{ and unrounded value for } W_o)$$

1 point

1 point

1 point

1 point

1 point

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

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

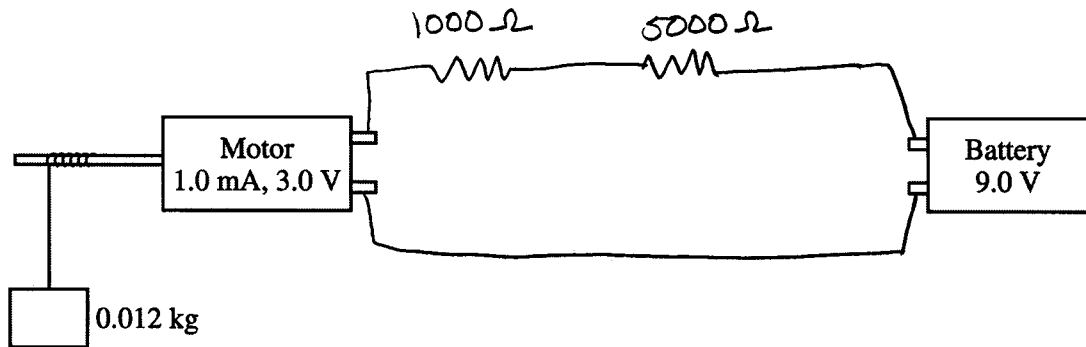
Similar point allocations were assigned using this method.

AP PHYSICS B
2003 SCORING GUIDELINES (Form B)

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

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

For the selection of a $1000\ \Omega$ and a $5000\ \Omega$ resistor 1 point

For the placement of the $1000\ \Omega$ and $5000\ \Omega$ resistor in series 1 point

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

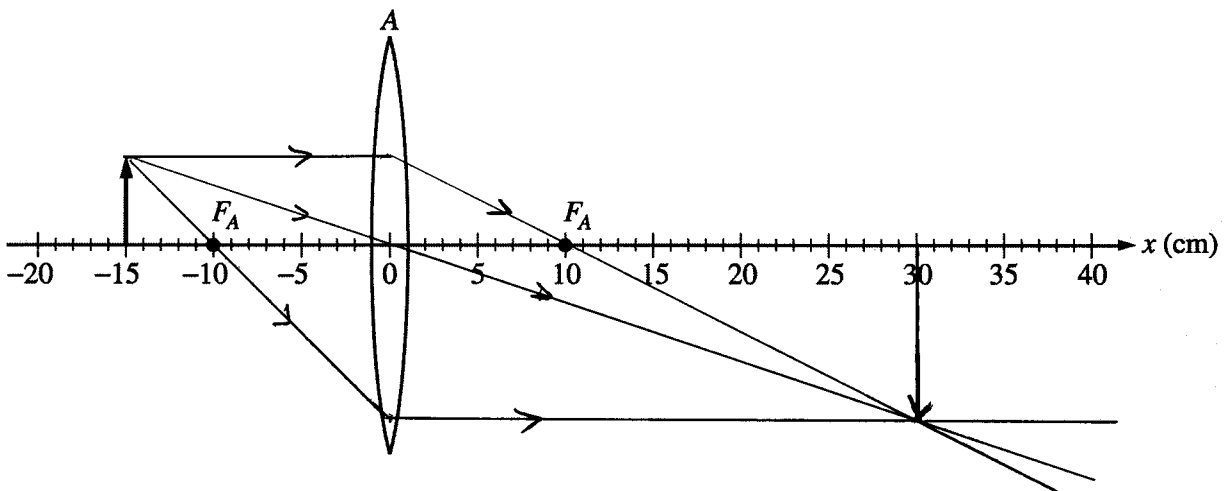
AP[®] PHYSICS B
2003 SCORING GUIDELINES (Form B)

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 \pm 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
$s_i = 30 \text{ cm}$	

**AP PHYSICS B
2003 SCORING GUIDELINES (Form B)**

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

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

For consistent substitution

1 point

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

For answer consistent with substitutions

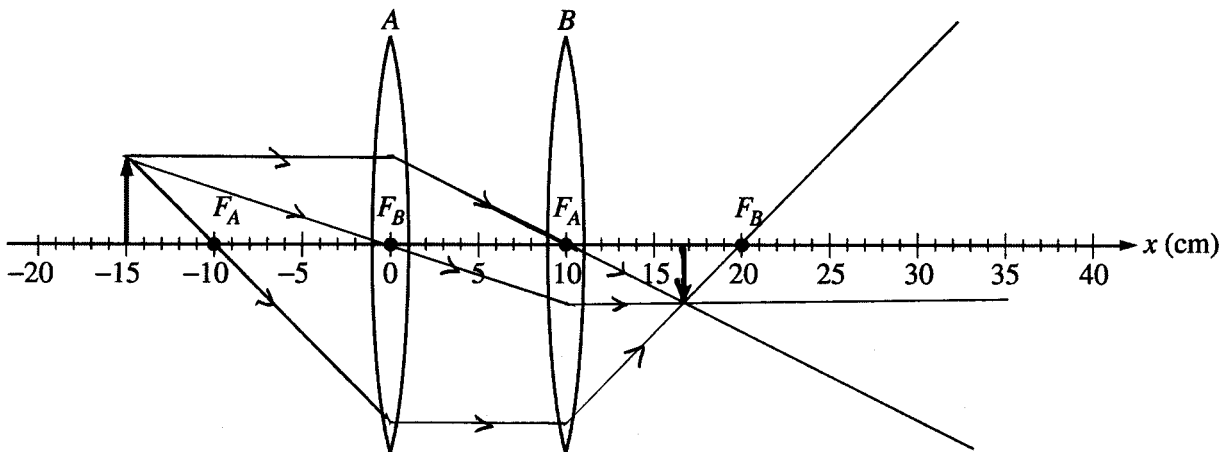
1 point

$$h_i = -10 \text{ cm} \text{ OR } |h_i| = 10 \text{ cm}$$

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 $16.6 \text{ cm} \pm 3 \text{ cm}$

1 point

**AP PHYSICS B
2003 SCORING GUIDELINES (Form B)**

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

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

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

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

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.

AP[®] PHYSICS B
2003 SCORING GUIDELINES (Form B)

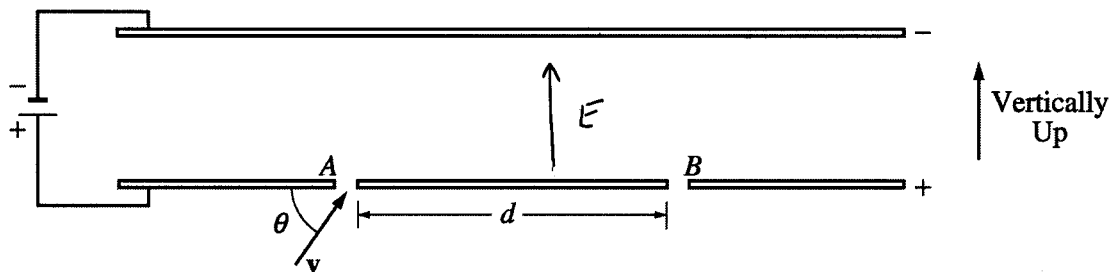
Question 4

15 points total

**Distribution
of points**

(a) 4 points

i. (1 point)



For a correctly drawn and labeled vector for \mathbf{E} , directed vertically upward as shown in the diagram above

1 point

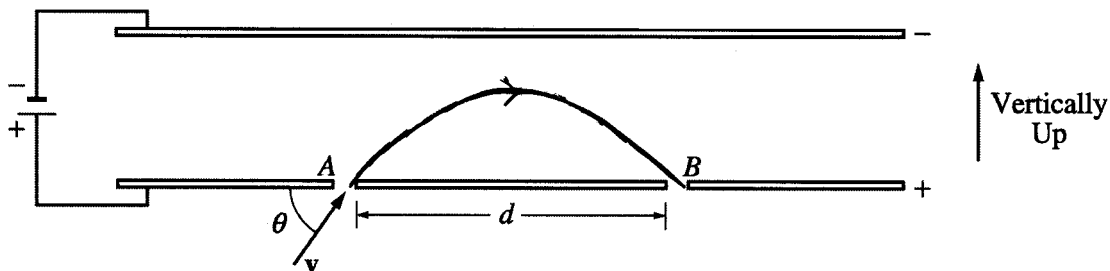
ii. (1 point)



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
 For the path being symmetrical about the midpoint of d

1 point
1 point

**AP PHYSICS B
2003 SCORING GUIDELINES (Form B)**

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 $F = qE$	1 point
	Equating this force to the net force in Newton's second law, $F_{net} = ma$ $qE = ma$	
	For the correct answer $a = \frac{qE}{m}$	1 point
(c)	4 points	
	In the electric field the electron is accelerated vertically downward. $v_y(t) = v_y - at$, where v_y is the vertical component of the electron's velocity at point A	
	The time t_1 to reach maximum vertical displacement occurs when $v_y(t_1) = 0$. Solving for t_1 :	
	$t_1 = \frac{v_y}{a}$	
	For using the correct component for v_y	1 point
	$v_y = v \sin \theta$	
	For indicating that the total time is twice t_1	1 point
	$t_{tot} = 2t_1 = \frac{2v \sin \theta}{a}$	
	For correct substitution of a from part (b)	1 point
	$t_{tot} = \frac{2v \sin \theta}{\frac{qE}{m}}$	
	For the correct answer $t_{tot} = \frac{2mv \sin \theta}{qE}$	1 point
	<i>Alternately</i> , the kinematic equations $v_y(t) = v \sin \theta - at$ OR $y(t) = y_0 + (v \sin \theta)t - \frac{1}{2}at^2$ could be used. When the electron reaches B at time t_{tot} , $v_y(t_{tot}) = -v \sin \theta$, 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, $t_{tot} = \frac{2mv \sin \theta}{qE}$. This approach also received full credit with awarding of points similar to those above.	

**AP PHYSICS B
2003 SCORING GUIDELINES (Form B)**

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
$d = v_x t_{tot}$	
For using the correct component for v_x	1 point
$v_x = v \cos \theta$	
For correct substitutions for v_x and total time	1 point
$d = (v \cos \theta) \left(\frac{2mv \sin \theta}{qE} \right)$	
$d = \frac{2mv^2 \sin \theta \cos \theta}{qE}$	
(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.	

AP[®] PHYSICS B
2003 SCORING GUIDELINES (Form B)

Question 5

10 points total

**Distribution
of points**

(a) 2 points

For a statement of the ideal gas law

$$pV = nRT$$

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

For the correct answer

$$T = 481 \text{ K}$$

1 point

1 point

(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

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

For the correct answer

$$W = 4000 \text{ J}$$

1 point

(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.

**AP PHYSICS B
2003 SCORING GUIDELINES (Form B)**

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.	

AP[®] PHYSICS B
2003 SCORING GUIDELINES (Form B)

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

$$W = mgh$$

1 point

For correct use of the equation relating mass to density and volume

$$m = \rho V$$

1 point

Combining the two relationships

$$W = \rho Vgh = (1000 \text{ kg/m}^3)(0.35 \text{ m}^3)(9.8 \text{ m/s}^2)(50 \text{ m} + 35 \text{ m})$$

For the correct answer

$$W = 290,000 \text{ J (or } 300,000 \text{ J using } g = 10 \text{ m/s}^2)$$

1 point

ii. (2 points)

For correct use of the equation relating power to work and time

1 point

$$P = \frac{W}{\Delta t}$$

$$P = \frac{290,000 \text{ W}}{(2 \text{ hr})(60 \text{ min/hr})(60 \text{ s/min})}$$

For the correct answer

$$P = 40 \text{ W (or } 41 \text{ W using } g = 10 \text{ m/s}^2)$$

1 point

(b) 4 points

i. (3 points)

For correct use of equation of continuity

1 point

$$v_1 A_1 = v_2 A_2$$

For using the radius of each pipe as half the diameter

1 point

Substituting the given values:

$$(0.50 \text{ m/s})\pi\left(\frac{0.03 \text{ m}}{2}\right)^2 = v_2\pi\left(\frac{0.0125 \text{ m}}{2}\right)^2$$

For the correct answer

1 point

$$v_2 = 2.88 \text{ m/s}$$

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

$$\text{Example: } p_1 + \rho gh_1 + \frac{1}{2} \rho v_1^2 = p_2 + \rho gh_2 + \frac{1}{2} \rho v_2^2$$

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.

AP[®] PHYSICS B
2003 SCORING GUIDELINES (Form B)

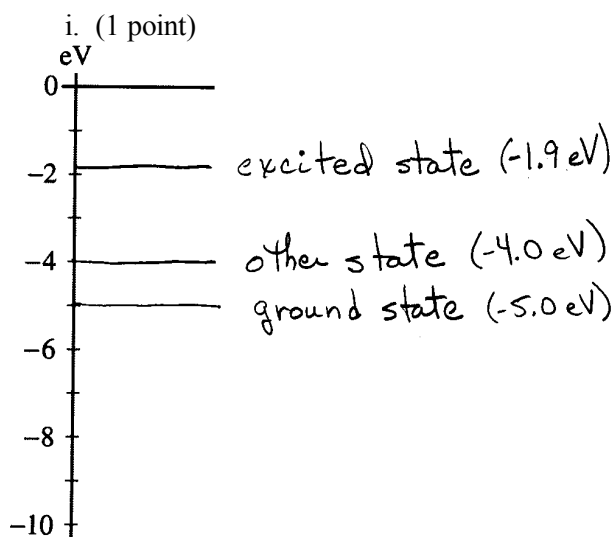
Question 7

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.



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

$$E = hc/\lambda$$

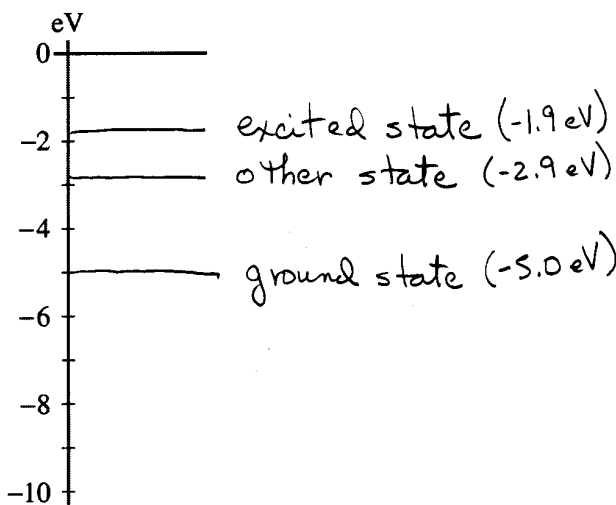
$$E = (1.24 \times 10^3 \text{ eV} \cdot \text{nm}) / (400 \text{ nm})$$

For the correct answer 1 point

$$E = 3.1 \text{ eV}$$

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

OR



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

$$E = \frac{hc}{\lambda} = \frac{1.24 \times 10^3 \text{ eV} \cdot \text{nm}}{600 \text{ nm}}$$

For the correct answer 1 point

$$E = 2.1 \text{ eV}$$

This photon could represent a transition from the first excited state to an intermediate state, in which case the intermediate state is at $E = -4.0 \text{ eV}$. 1 point

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 .

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.

**AP PHYSICS B
2003 SCORING GUIDELINES (Form B)**

Question 7 (continued)

(b) 3 points

**Distribution
of 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 $E = \frac{hc}{\lambda}$

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

For calculation of wavelength

1 point

$$\lambda = 1240 \text{ nm}$$

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