



## **AP<sup>®</sup> Physics B 2005 Scoring Guidelines**

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**General Notes About 2005 AP Physics Scoring Guidelines**

1. The solutions contain the most common method(s) of solving the free-response questions and the allocation of points for these solutions. 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.
4. The scoring guidelines typically show numerical results using the value  $g = 9.8 \text{ m/s}^2$ , but use of  $10 \text{ m/s}^2$  is of course also acceptable.
5. Numerical answers that differ from the published answer due to differences in rounding throughout the question typically receive full credit. The exception is usually 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) 4 points



The velocities can be found from the slope of the position graph.

For showing a positive velocity of magnitude 1.5 m/s (i.e., 12 m/8 s) between  
0 s and 8 s inclusive

1 point

For showing zero velocity between 10 s and 18 s inclusive

1 point

For showing a negative velocity of magnitude 2.4 m/s (i.e., 12 m/5 s) between  
20 s and 25 s inclusive

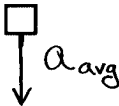
1 point

For showing two nonvertical transition regions; between  $t = 8$  s and 10 s and between  
 $t = 18$  s and 20 s

1 point

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**Question 1 (continued)**

	<b>Distribution of points</b>
(b)	
(i) 3 points	
For a definition or equation for average acceleration	1 point
$a_{\text{avg}} = \Delta v / \Delta t$ OR $v = v_0 + at$	
For the correct substitution from part (a)	1 point
$a_{\text{avg}} = (0 - 1.5 \text{ m/s}) / 2 \text{ s}$	
For the correct answer including units and sign	1 point
$a_{\text{avg}} = -0.75 \text{ m/s}^2$	
(ii) 1 point	
	
For a correctly drawn vector, with or without a label	1 point
(c) 2 points	
The acceleration is zero, so the normal force (apparent weight) is equal to the gravitational force.	
For a correct relationship leading to a calculation of apparent weight	1 point
$N = W = mg$ OR $N - W = ma$	
$W_{\text{app}} = (70 \text{ kg})(9.8 \text{ m/s}^2)$	
For the correct answer with units	1 point
$W_{\text{app}} = 686 \text{ N}$ (or $700 \text{ N}$ using $g = 10 \text{ m/s}^2$ )	

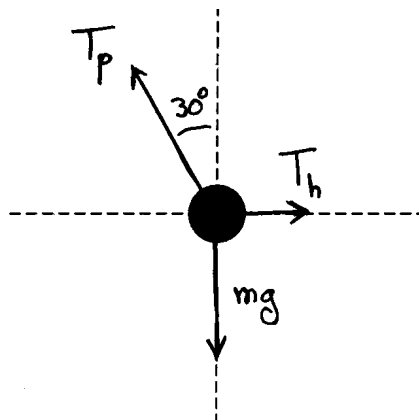
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**Question 2**

**10 points total**

**Distribution  
of points**

(a) 2 points



For each correctly drawn and labeled tension, with arrowhead in right direction  
One point was deducted for each of the following until score reached zero:

1 point each

No force of gravity

Each extraneous force

Any missing labels

Drawing all forces along correct lines with labels but no arrowheads received only one point.

Components of the tension in the pendulum string could be included in addition to or instead of the net tension, as long as they were clearly labeled as such.

(b) 4 points

For any indication that the net force is zero

1 point

For an attempt to determine the components of the tension in the pendulum string

1 point

For correctly determining these components

1 point

$$T_h = T_p \sin 30^\circ$$

$$mg = T_p \cos 30^\circ$$

$$\frac{T_h}{mg} = \frac{\sin 30^\circ}{\cos 30^\circ} = \tan 30^\circ$$

$$T_h = mg \tan 30^\circ$$

$$T_h = (1.8 \text{ kg})(9.8 \text{ m/s}^2) \tan 30^\circ$$

For the correct answer with units

1 point

$$T_h = 10 \text{ N}$$

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**Question 2 (continued)**

	<b>Distribution of points</b>
(b) (continued)	
<i>Alternate solution</i>	<i>Alternate points</i>
For indicating that the addition of the three force vectors gives a 30-60-90 right triangle	2 points
For a correct trigonometric relationship between forces	1 point
$\frac{T_h}{mg} = \tan 30^\circ$	
For the correct answer with units	1 point
$T_h = 10 \text{ N}$	
<p>If no forces were drawn in part (a), one point could be earned for writing the component equations <math>T = mg \sin \theta</math> and <math>T = mg \cos \theta</math>, and two points for <math>T = mg \tan \theta</math>.</p>	
(c)      4 points	
For any indication of conservation of energy	1 point
For any indication of the need to use a change in height	1 point
$mgh_0 + \frac{1}{2}mv_0^2 = mgh_f + \frac{1}{2}mv_f^2$	
For setting $v_0 = 0$	1 point
$\frac{1}{2}mv_f^2 = mg \Delta h$	
$v_f = \sqrt{2g \Delta h}$	
$\Delta h = L - L \cos 30^\circ$	
$v_f = \sqrt{2gL(1 - \cos 30^\circ)}$	
$v_f = \sqrt{2(9.8 \text{ m/s}^2)(2.3 \text{ m})(1 - \cos 30^\circ)}$	
For the correct answer, with units	1 point
$v_f = 2.5 \text{ m/s}$	
<p>A solution that used the kinematic equation <math>v_f^2 = v_0^2 + 2as</math> could only receive full credit if the student explained how the equation is equivalent to conservation of energy.</p>	

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**Question 3**

**15 points total**

**Distribution  
of points**

(a) 4 points

For use of the correct formula for the electric field  $E$

1 point

$$E = k \frac{q}{r^2} \quad \text{OR} \quad E = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2}$$

For adding the two  $E$  vectors from the charges

1 point

$$E_O = \left| \left( +k \frac{2q}{a^2} \right) + \left( -k \frac{q}{a^2} \right) \right|$$

For the correct (positive) expression for the magnitude of the field

1 point

$$E_O = k \frac{q}{a^2}$$

For any indication that the field is in the  $+y$ -direction

1 point

(b) 3 points

For use of the correct formula for the potential  $V$

1 point

$$V = k \frac{q}{r} \quad \text{OR} \quad V = \frac{1}{4\pi\epsilon_0} \frac{q}{r}$$

For adding the two potentials

1 point

$$V_O = \left| k \frac{2q}{a} + k \frac{q}{a} \right|$$

For the correct (positive) answer

1 point

$$V_O = \frac{3kq}{a}$$

(c) (i) and (ii) 4 points

For determining the distance  $r$  between charges in terms of  $x_0$  and  $a$  in either part (i) or (ii)

1 point

$$r = \sqrt{x_0^2 + a^2}$$

For use of Coulomb's law in either part (i) or (ii)

1 point

$$F = k \frac{q_1 q_2}{r^2}$$

For *both* correct substitution of charges into Coulomb's law *and* correct substitution of the previously determined expression for  $r$  in either part (i) or (ii)

1 point

For correct (positive) answer for both part (i) and (ii)

1 point

$$\text{For part (i): } F_q = \left| k \frac{(-q)(q)}{x_0^2 + a^2} \right| = k \frac{q^2}{x_0^2 + a^2}$$

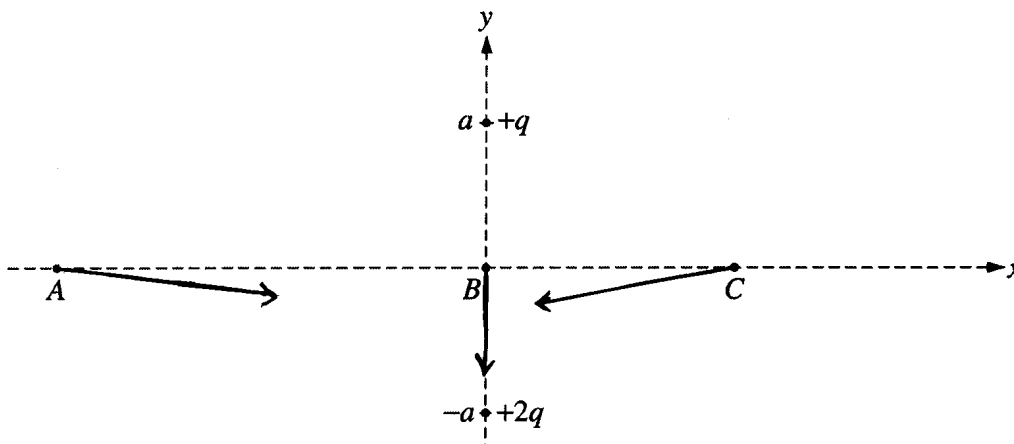
$$\text{For part (ii): } F_q = \left| k \frac{(-q)(2q)}{x_0^2 + a^2} \right| = k \frac{2q^2}{x_0^2 + a^2}$$

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Question 3 (continued)

Distribution  
of points

(d) 4 points



For having all three vectors on the same side of the  $x$ -axis (i.e., recognizing that the vertical components should all be in the same direction)

1 point

For a single resultant vector from  $A$  pointing down and to the right, toward a point below the  $x$ -axis and above  $+2q$

1 point

For a single resultant vector from  $C$  pointing down and to the left, toward a point below the  $x$ -axis and above  $+2q$

1 point

For a single resultant vector pointing straight down from  $B$

1 point

Magnitudes of the vectors and any components that may have been drawn were not evaluated.



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Question 4

15 points total

Distribution  
of points

(a) 2 points

For checking any length-measuring device and not the stopwatch

2 points

Only one point was awarded for checking any length-measuring device and the stopwatch.

No points were awarded if no length-measuring device was checked or all the equipment was checked.

(b) 3 points

For a diagram including at least a laser, a slide, and a screen

1 point

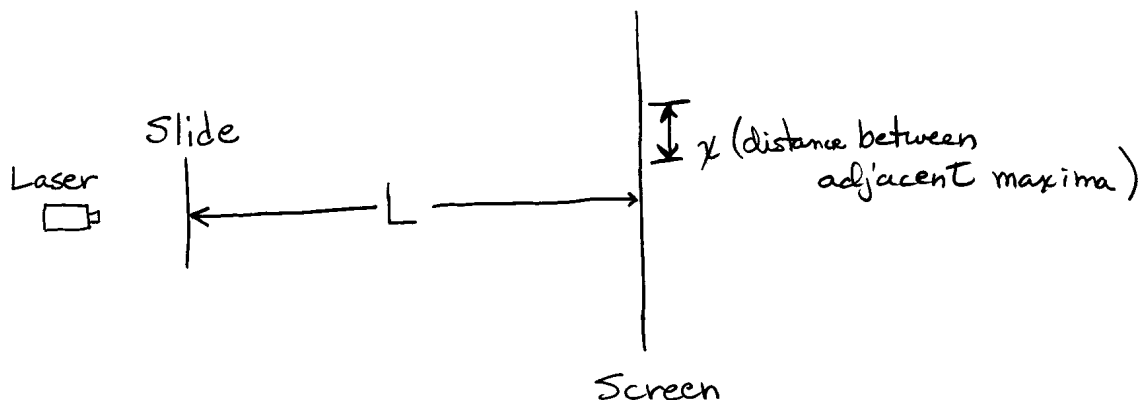
For correctly labeling the equipment

1 point

For correctly identifying the two distances to be measured, with symbols

1 point

Example diagram:

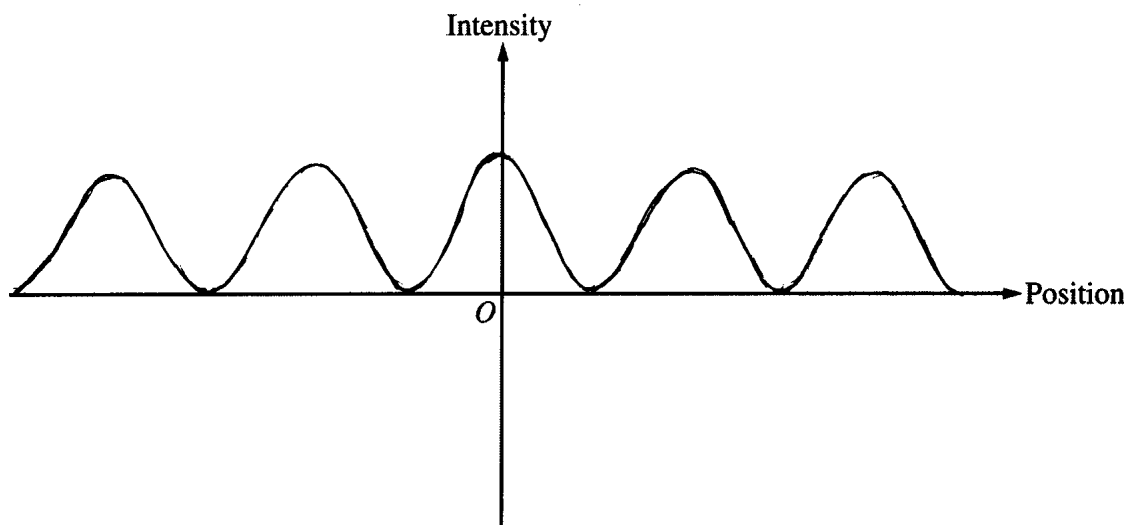


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Question 4 (continued)

Distribution  
of points

(c) 3 points



Points could only be earned in the following order, with each successive point dependent on earning the previous point.

For a central maximum	1 point
For a continuous graph with approximately equally spaced maxima	1 point
For nothing else incorrect (e.g., no negative intensity)	1 point

(d) 4 points

For appropriate use of equipment (including all items checked in (a))	1 point
For indicating a measurement of the distance from the slits to the screen	1 point
For indicating appropriate measurements of the maxima (e.g., the distance between adjacent maxima or the distance of successive maxima from the center)	1 point
For a complete and clear description	1 point

For example:

Set up the laser to shine on the slide, and set the screen far away on the other side of the slide.

Measure the distance  $L$  from the slide to the screen with the tape measure.

Use the ruler to measure the distance  $x$  between adjacent maxima.

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Question 4 (continued)

Distribution  
of points

(e) 3 points

Points could only be earned in the following order, with each successive point dependent on earning the previous point.

For using appropriate equations

1 point

For explicitly identifying, in some other part of the question, the symbols used here

1 point

For correct correlation of symbols in equations to symbols in diagram in part (b)

1 point

$$x_m \approx \frac{m\lambda L}{d} \quad \text{OR} \quad d \sin \theta = m\lambda \quad \text{and} \quad \tan \theta = \frac{x_m}{L} \quad (\text{since } \sin \theta \approx \tan \theta \text{ for small angles),}$$

where  $m$  is an integer,  $x_m$  is the distance of a maximum of order  $m$  from the central maximum,  $\lambda$  is the wavelength,  $L$  is the distance between slits and the screen, and  $d$  is the slit separation

Solving for  $d$

$$d \approx \frac{\lambda L}{x} \quad \text{using distances } x \text{ between adjacent maxima and } \Delta m = 1$$

$$\text{OR} \quad d \approx \frac{m\lambda L}{x_m} \quad \text{using distances from center of pattern}$$

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**Question 5**

**10 points total**

**Distribution  
of points**

(a) 3 points

For an equation that uses the ratio of densities  $\rho_r/\rho_w$  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

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

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

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

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

For the correct answer

1 point

$$h = 0.077 \text{ m}$$

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.

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**Question 5 (continued)**

		<b>Distribution of points</b>
(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
	$F_{buoy} = 1.15 \times 10^4 \text{ N}$ (or $1.17 \times 10^4 \text{ N}$ 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
	$W_{addl} = W_{extra \text{ water}}$ OR $W_{addl} = F_{buoyNEW} - W_{raft}$	
	The first equation above yields $W_{addl} = \rho_w V_{top} g = \rho_w Ahg$	
	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
	$W_{addl} = (1.80 \text{ m}^3)(9.8 \text{ m/s}^2)(1000 \text{ kg/m}^3 - 650 \text{ kg/m}^3)$	
	$W_{addl} = 6200 \text{ N}$ (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 <i>whole</i> number of people.)	1 point
	$n = \frac{W_{addl}}{m_p g} = \frac{6200 \text{ N}}{(75 \text{ kg})(9.8 \text{ m/s}^2)} = 8.4$	
	A maximum of 8 people can be on the raft.	

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**Question 6**

**10 points total**

**Distribution  
of points**

(a) 2 points

For writing the ideal gas equation of state

$$PV = nRT$$

For an indication that  $V = AH$

$$PAH = nRT$$

$$H = \frac{nR}{PA}T$$

1 point

1 point

Note: Simply writing  $PAH = nRT$  or the equivalent earned both points. If the student tried to rearrange the equation, algebra mistakes were not penalized in this part.

(b) 4 points

For labeling both axes with linear numerical scales

1 point

For having neither axis labeled with its scale starting at zero (no penalty for showing zero at the end of an axis and a “break” in the axis)

1 point

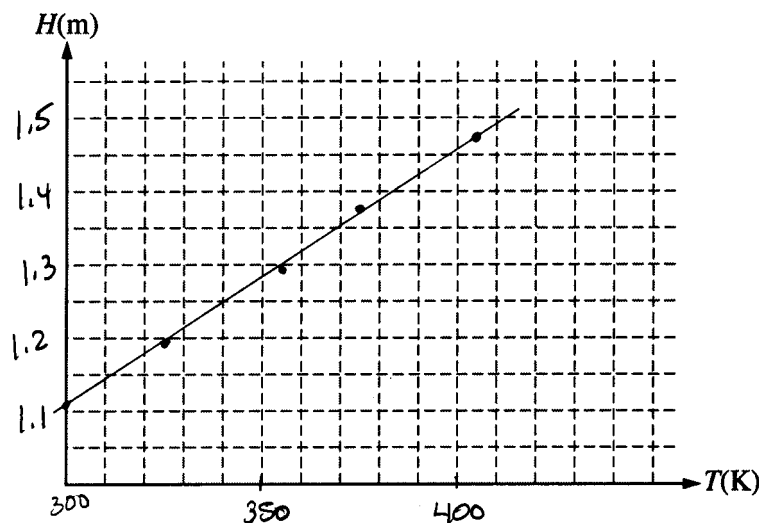
For accurately plotting five data points that closely fit a straight line with a positive slope

2 points

One point was lost if some points were inaccurately plotted.

Both points were lost if the data points were not visible, even if a line was drawn.

Example answer shown below. The question did not ask for a best-fit line, and it was not required for this part. However, a line is shown in the example, since it could be used in the determination of  $n$ .



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Question 6 (continued)

	Distribution of points
(c) 4 points	
From part (a), $H = \frac{nR}{PA}T$	
For any clear indication that the student used more than one data point For example: Setting up a slope calculation using subtraction, averaging calculated values for $n$ or the ratio $H/T$ , or using a linear regression on the calculator	1 point
For the correct slope of a best-fit line through the data points (this point not awarded if slope method not used)	1 point
For correct substitutions into a correct expression containing $n$ using consistent units for the values of $P$ , $R$ , $A$ , and $H$	1 point
Example using the line shown above, which happens to go through the first and last data points	
Slope of line = $\frac{nR}{PA}$	
Slope = $\frac{(1.47 - 1.11)\text{m}}{(405 - 300)\text{K}} = \frac{0.36 \text{ m}}{105 \text{ K}}$	
$n = \frac{PA}{R}(\text{slope})$	
$n = \frac{(1 \times 10^5 \text{ Pa})(0.027 \text{ m}^2)}{8.31 \text{ J}/(\text{mol}\cdot\text{K})} \left( \frac{0.36 \text{ m}}{105 \text{ K}} \right)$	
For a numerical answer that follows from substitutions into the correct expression above $n = 1.11$ moles	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

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

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

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

1 point

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

The two points above were also awarded for correctly using  $E = hc/\lambda$  or using

$$E = pc \text{ and the answer from part (b).}$$

For indicating that the photon energy is the difference between the two energy levels

1 point

$$E_4 = E_2 + E_{\text{ph}}$$

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

For the correct numerical answer

1 point

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

*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

$$p = h/\lambda \quad \text{OR} \quad p = E/c$$

For substitution of appropriate values into either of the above equations

1 point

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

For the correct answer with correct units

1 point

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



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**Question 7 (continued)**

	<b>Distribution of points</b>
(c) 2 points	
$K_{\max} = E_{\text{ph}} - \phi$	
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
$V = 5.5 \text{ V}$	
<i>Alternate solution</i>	<i>Alternate points</i>
For understanding the relationship between electrical potential and energy	<i>1 point</i>
$V = K_{\max}/q$	
$V = (5.5 \text{ eV})(1.6 \times 10^{-19} \text{ J/eV}) / (1.6 \times 10^{-19} \text{ C})$	
For the correct answer with units of volts	<i>1 point</i>
$V = 5.5 \text{ V}$	