AP® PHYSICS B
2009 SCORING GUIDELINES

General Notes About 2009 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 7

10 points total **Distribution of points**

(a) 3 points

$\lambda = h/p = h/m\upsilon$

$\upsilon = h/m\lambda$

For substituting the correct value of the electron wavelength into a correct expression 1 point

For substituting a correct value of Planck's constant into a correct expression 1 point

$\upsilon = \left(6.63 \times 10^{-34}\ \text{J•s}\right)/\left(9.11 \times 10^{-31}\ \text{kg}\right)\left(0.85 \times 10^{-9}\ \text{m}\right)$

$\upsilon = 8.56 \times 10^{5}\ \text{m/s}$

For substituting the correct value of the electron mass into a correct expression for the kinetic energy 1 point

$K = m\upsilon^2/2$

$K = \left(9.11 \times 10^{-31}\ \text{kg}\right)\left(8.56 \times 10^{5}\ \text{m/s}\right)^2/2$

$K = 3.3 \times 10^{-19}\ \text{J}$ (or 2.1 eV)

(b) 3 points

For any indication that the student used the equation for the photoelectric effect 1 point

$K_{max} = hf - \phi$

$\phi = hf - K_{max} = (hc/\lambda) - K_{max}$

For substituting the correct value of the photon wavelength into the correct expression 1 point

For substituting for hc in appropriate energy units into the correct expression 1 point

$\phi = \left[\left(6.63 \times 10^{-34}\ \text{J•s}\right)\left(3.00 \times 10^{8}\ \text{m/s}\right)/\left(250 \times 10^{-9}\ \text{m}\right)\right] - 3.3 \times 10^{-19}\ \text{J}$

$\phi = 4.7 \times 10^{-19}\ \text{J}$ (or 2.9 eV)

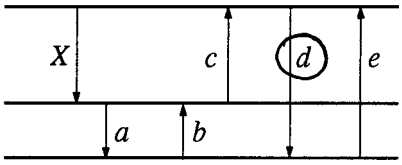
Units point

For correct units in both parts (a) and (b) 1 point

Question 7 (continued)

Distribution of points

(c) 3 points



For choosing the correct transition 1 point

For indicating that the emission of a photon requires the atom to go to a lower energy level 1 point

For indicating that $E = hc/\lambda$ for a photon, so a smaller wavelength means a larger energy difference 1 point

Notes:

- Two points could be earned by choosing transition *a* and stating that the emission of a photon requires a drop to a lower energy level.
- Two points could be earned by choosing transition *e* and stating that the shorter photon wavelength implies a larger difference between energy levels.

7. (10 points)

A photon of wavelength 250 nm ejects an electron from a metal. The ejected electron has a de Broglie wavelength of 0.85 nm.

(a) Calculate the kinetic energy of the electron.

$0.85\times10^{-9} = \frac{h}{mv}$ $\quad mv = \frac{6.63\times10^{-34}}{0.85\times10^{-9}} = 7.8\times10^{-25}$ kg m/s

$m_e = 9.11\times10^{-31}$ kg

$V = \frac{7.8\times10^{-25}}{9.11\times10^{-31}} = 856000$ m/s

$KE = \frac{1}{2}mv^2 = \frac{1}{2}(9.11\times10^{-31})(856000)^2 = \boxed{3.34\times10^{-19}\ J}$

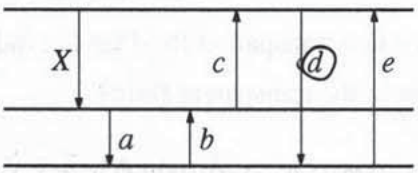
(b) Assuming that the kinetic energy found in (a) is the maximum kinetic energy that it could have, calculate the work function of the metal.

$KE_{max} = hf - \phi$ $\quad f = \frac{c}{\lambda} = 1.2\times10^{15}$

$3.34\times10^{-19} = (6.63\times10^{-34})(1.2\times10^{15}) - \phi$

$\boxed{\phi = 4.62\times10^{-19}\ J}$

(c) The incident photon was created when an atom underwent an electronic transition. On the energy level diagram of the atom below, the transition labeled X corresponds to a photon wavelength of 400 nm. Indicate which transition could be the source of the original 250 nm photon by circling the correct letter.



Justify your answer.

The 250 photon has a greater amount of energy than the 400 photon. Out of all the energy transitions shown, the only one that would release a photon with greater energy than the one shown for X is transition d. It goes from the highest energy level shown to the lowest, which maximizes the energy.

7. (10 points)

A photon of wavelength 250 nm ejects an electron from a metal. The ejected electron has a de Broglie wavelength of 0.85 nm.

(a) Calculate the kinetic energy of the electron.

$E = hf = h\frac{c}{\lambda}$

$E = (4.14 \cdot 10^{-15}\ \text{eV}\cdot\text{s})\ \frac{(3 \cdot 10^{8}\ \text{m/s})}{(0.85 \cdot 10^{-9}\ \text{m})} = 1461\ \text{eV}$

(b) Assuming that the kinetic energy found in (a) is the maximum kinetic energy that it could have, calculate the work function of the metal.

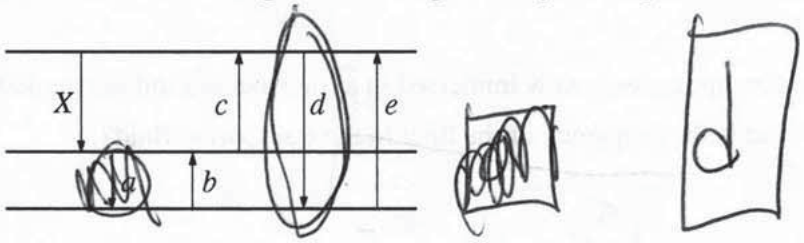
$K_{max} = hf - \phi$

$1461\ \text{eV} = hf - \phi$

$\phi = \frac{hc}{\lambda} - 1461\ \text{eV} = \frac{(4.14 \cdot 10^{-15}\ \text{eV}\cdot\text{s})(3 \cdot 10^{8}\ \text{m/s})}{(250 \cdot 10^{-9}\ \text{m})} - 1461\ \text{eV}$

$\phi = 1456\ \text{eV}$

(c) The incident photon was created when an atom underwent an electronic transition. On the energy level diagram of the atom below, the transition labeled X corresponds to a photon wavelength of 400 nm. Indicate which transition could be the source of the original 250 nm photon by circling the correct letter.



Justify your answer.

The charge would have to be small

The charge would have to be going down to release a photon (not c, e, or b). A photon with a shorter wavelength has a higher frequency, so more energy is necessary to create it. The charge must be bigger than X (not a), which leaves d.

7. (10 points)

A photon of wavelength 250 nm ejects an electron from a metal. The ejected electron has a de Broglie wavelength of 0.85 nm.

(a) Calculate the kinetic energy of the electron.

$$E = \frac{hc}{\lambda}$$

$$E = \frac{6.63 \cdot 10^{-34}(3.0 \cdot 10^{8})}{(250 \cdot 10^{-9})}$$

$$E = 7.96 \cdot 10^{-19}\ J$$

(b) Assuming that the kinetic energy found in (a) is the maximum kinetic energy that it could have, calculate the work function of the metal.

$K = hf - \Phi$

$7.96 \cdot 10^{-19} = (6.63 \cdot 10^{-34})$

$\lambda = \frac{h}{p} = \frac{v}{f}$

$.85 \cdot 10^{-9} = \frac{6.63 \cdot 10^{-34}}{p}$

$p = 7.8 \cdot 10^{-25}$ $\quad p = mv$

$7.8 \cdot 10^{-25} = (9.11 \cdot 10^{-31})v$

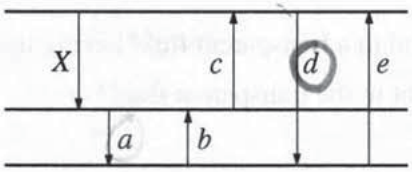
$v = 8.6 \cdot 10^{5}\ m/s$

$f = \frac{v}{\lambda} = \frac{8.6 \cdot 10^{5}}{.85 \cdot 10^{-9}} = 1.01 \cdot 10^{15}\ Hz$

$K = hf - \Phi$ $\quad 7.96 \cdot 10^{-19} = 6.63 \cdot 10^{-34}(1.01 \cdot 10^{15}) - \Phi$

$\Phi = 1.26 \cdot 10^{-19}\ J$

(c) The incident photon was created when an atom underwent an electronic transition. On the energy level diagram of the atom below, the transition labeled X corresponds to a photon wavelength of 400 nm. Indicate which transition could be the source of the original 250 nm photon by circling the correct letter.



Justify your answer.

$E = hf$

$E = \frac{hc}{\lambda}$

As λ decreases, energy increases.

d undergoes a large increase in energy, so the wavelength would be smaller

AP® PHYSICS B
2009 SCORING COMMENTARY

Question 7

Overview

This question assessed students' knowledge of modern physics, specifically wave-particle duality, the photoelectric effect, and energy-level diagrams. In part (a) students were asked to calculate the kinetic energy of an electron of known de Broglie wavelength. In part (b) they had to calculate the work function of the metal. In part (c) they were asked to identify the electronic transition that created the incident photon.

Sample: B-7A
Score: 10

This response earned all available points. There is a very nice justification in part (c). Note that in part (b) use of the correct wavelength is implied by the correct value for the frequency.

Sample: B-7B
Score: 7

In part (a) the response incorrectly uses the equation for a photon and earned no points. Part (b) correctly substitutes values into the photoelectric equation and earned all 3 points. Units are correct for the substituted values, so 1 point was earned. Part (c) is correct, with a good explanation, and also earned 3 points.

Sample: B-7C
Score: 4

Part (a) of the response does a fine calculation for the photon but earned no credit for the electron energy. Part (b) earned 1 point for using the photoelectric equation but calculates a frequency from the electron wavelength and thus earned no substitution points. Units are correct for the substituted values, so 1 point was earned. Part (c) lost 1 point for not indicating why the downward transition is correct and not the upward one.