AP® PHYSICS B
2010 SCORING GUIDELINES

General Notes

1. The solutions contain the most common method of solving the free-response questions and the allocation of points for the 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 — for example, 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 1 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 Exams 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.

Question 7

10 points total | **Distribution of points**

(a) 2 points

$\upsilon = f\lambda$

For substitution of the appropriate values of the speed of light and the wavelength into the correct expression — 1 point

$$f = \frac{\upsilon}{\lambda} = \frac{c}{\lambda} = \frac{3.0 \times 10^{8}\ \text{m/s}}{400 \times 10^{-9}\ \text{m}}$$

For the correct answer — 1 point

$f = 7.5 \times 10^{14}$ Hz

(b) 2 points

$K_{max} = hf - \phi$

$\phi = hf - K_{max}$

For consistent substitution of the maximum kinetic energy into the correct expression — 1 point

For consistent substitution of the frequency into the correct expression — 1 point

$\phi = \left(6.63 \times 10^{-34}\ \text{J•s}\right)\left(7.5 \times 10^{14}\ \text{Hz}\right) - 1.1 \times 10^{-19}\ \text{J}$

$\phi = 3.9 \times 10^{-19}$ J

(c) 2 points

$eV = K_{max}$

For substitution of the appropriate values of the maximum kinetic energy and the charge of the electron into the correct expression — 1 point

$$V = \frac{K_{max}}{e} = \frac{1.1 \times 10^{-19}\ \text{J}}{1.6 \times 10^{-19}\ \text{C}}$$

For the correct magnitude of the stopping potential — 1 point

$V = 0.69$ V

Question 7 (continued)

Distribution of points

(d) 3 points

$K = \frac{1}{2}mv^2$

For substitution of the appropriate values of the maximum kinetic energy and the mass of the electron into the correct expression — 1 point

$$v = \sqrt{\frac{2K_{max}}{m}} = \sqrt{\frac{2\left(1.1 \times 10^{-19}\ \text{J}\right)}{9.11 \times 10^{-31}\ \text{kg}}} = 4.91 \times 10^{5}\ \text{m/s}$$

For consistent substitution of velocity and mass of the electron into the correct expression — 1 point

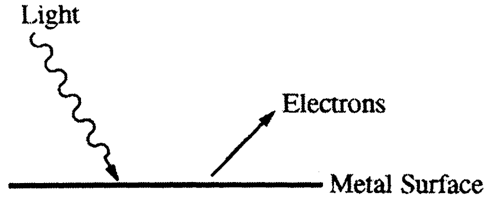
$$p = mv = \left(9.11 \times 10^{-31}\ \text{kg}\right)\left(4.91 \times 10^{5}\ \text{m/s}\right)$$

For the correct answer — 1 point

$$p = 4.5 \times 10^{-25}\ \text{kg} \bullet \text{m/s}$$

Units 1 point

For using correct units in completed answers — 1 point



7. (10 points)

Light of wavelength 400 nm is incident on a metal surface, as shown above. Electrons are ejected from the metal surface with a maximum kinetic energy of 1.1×10^{-19} J.

(a) Calculate the frequency of the incoming light.

$c = f\lambda \quad f = \frac{c}{\lambda} = \frac{3\times10^8}{4\times10^{-7}}$ $\boxed{f = 7.5\times10^{14}\ \text{Hz}}$

(b) Calculate the work function of the metal surface.

$KE = hf - \phi$

$1.1\times10^{-19} = (6.63\times10^{-34})(7.5\times10^{14}) - \phi$

$\boxed{3.87\times10^{-19}\ \text{J} = \phi}$

(c) Calculate the stopping potential for the emitted electrons.

$V_{stop} = eV\ (KE_{max})\left(\frac{1}{1.6\times10^{-19}}\right) = \frac{1.1\times10^{-19}}{1.6\times10^{-19}} = \boxed{.69\ \text{eV}}$

(d) Calculate the momentum of an electron with the maximum kinetic energy.

$KE = \frac{1}{2}mv^2$

$1.1\times10^{-19}\ \text{J} = \frac{1}{2}(9.11\times10^{-31})v^2$

$2.41\times10^{11} = v^2$

$4.9\times10^5 = v$

$p = mv$

$= (9.11\times10^{-31})(4.9\times10^5)$

$\boxed{p = 4.5\times10^{-25}\ \text{kg}\cdot\text{m/s}}$

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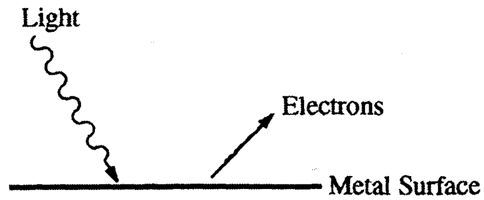


7. (10 points)

Light of wavelength 400 nm is incident on a metal surface, as shown above. Electrons are ejected from the metal surface with a maximum kinetic energy of 1.1×10^{-19} J.

(a) Calculate the frequency of the incoming light.

$v = \lambda f$ $\quad f = \left(\frac{3\times10^{8} m/s}{400\times10^{-9} m}\right)$

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

$f = 7.5\times10^{14} Hz$

(b) Calculate the work function of the metal surface.

$E_k = hf - W$

$hf - E_k = W$

$6.63\times10^{-34} J\cdot s (7.5\times10^{14} Hz) - 1.1\times10^{-19} J = W$

$W = 3.87\times10^{-19} J$

(c) Calculate the stopping potential for the emitted electrons.

$E_k = Vq$ $\quad V = \frac{1.1\times10^{-19} J}{1.6\times10^{-19} C}$

$V = \frac{E_k}{q}$

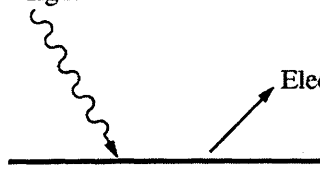
$V = 0.688 V$

(d) Calculate the momentum of an electron with the maximum kinetic energy.

$p = \lambda h$

$p = (400\times10^{-7} m)(6.63\times10^{-34} J\cdot s)$

$p = 2.65\times10^{-40} kg\cdot m/s$



7. (10 points)

Light of wavelength 400 nm is incident on a metal surface, as shown above. Electrons are ejected from the metal surface with a maximum kinetic energy of 1.1×10^{-19} J.

(a) Calculate the frequency of the incoming light.

$\lambda = 400 \times 10^{-9} m$

$KE = 1.1 \times 10^{-19} J$

$h = 6.63 \times 10^{-34} J \cdot s$

$E = hf \qquad f = \frac{E}{h} = \frac{1.1 \times 10^{-9} J}{6.63 \times 10^{-34} J \cdot s} = 1.66 \times 10^{14}$ 1/s

$f = 1.66 \times 10^{14}$ /s

(b) Calculate the work function of the metal surface.

$K_{max} = hf - \phi \qquad \phi = hf - K_{max}$

$\phi = (6.63 \times 10^{-34} J \cdot s)(1.66 \times 10^{14}/s) - (1.1 \times 10^{-19} J) = 5.8 \times 10^{-23} J$

$\phi = 5.8 \times 10^{-23} J$

(c) Calculate the stopping potential for the emitted electrons.

(d) Calculate the momentum of an electron with the maximum kinetic energy.

$\lambda = \frac{h}{p} \qquad p = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34} J \cdot s}{400 \times 10^{-9} m} = 1.66 \times 10^{-27} kg \cdot \frac{m}{s}$

$p = 1.66 \times 10^{-27} kg \cdot \frac{m}{s}$

Question 7

Overview

The intent of this question was to assess students' knowledge of the photoelectric effect. In part (a) students were asked to calculate the frequency of light given its wavelength. In part (b) they had to find the work function of the metal surface. In part (c) students were asked for the stopping potential for the electrons. Part (d) asked students to calculate the momentum of the electrons given the kinetic energy maximum.

Sample: B7-A
Score: 9

The only point lost in this response was for the incorrect units of eV in part (c).

Sample: B7-B
Score: 7

All 3 points lost are for part (d), which appears to be using a poorly rearranged form of the de Broglie equation with the given light wavelength.

Sample: B7-C
Score: 3

Part (a) begins with the wrong equation (Planck's) and earned no credit. Part (b) earned full credit for using a correct equation and consistent substitutions. Part (c) earned no credit. In part (d) the response uses the de Broglie equation with the photon wavelength and thus earned no credit. There are correct units on all given answers so the units point was earned.