AP® PHYSICS B
2008 SCORING GUIDELINES

General Notes About 2008 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 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 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.

Question 7

10 points total — **Distribution of points**

(a) 2 points

For correct substitutions into the relationship between the de Broglie wavelength and the momentum — 1 point

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

$$p = \frac{6.63 \times 10^{-34}\ \text{J}\bullet\text{s}}{0.038 \times 10^{-9}\ \text{m}}$$

For a correct answer — 1 point

$$p = 1.74 \times 10^{-23}\ \frac{\text{kg}\bullet\text{m}}{\text{s}}$$

(b) 2 points

Calculating the speed of an electron

$$\upsilon = \frac{p}{m} = \frac{1.74 \times 10^{-23}\ \text{kg}\bullet\text{m/s}}{9.11 \times 10^{-31}\ \text{kg}} = 1.91 \times 10^{7}\ \text{m/s}$$

For correct substitutions into a correct expression for kinetic energy — 1 point

$$K = \frac{1}{2}m\upsilon^2$$

$$K = \frac{1}{2}\left(9.11 \times 10^{-31}\ \text{kg}\right)\left(1.91 \times 10^{7}\ \text{m/s}\right)^2$$

For a correct answer — 1 point

$$K = 1.66 \times 10^{-16}\ \text{J}$$

(c) 3 points

For any indication of conservation of energy — 1 point

$$K = qV$$

For correct substitutions into a correct expression — 1 point

$$V = \frac{K}{q} = \frac{\left(1.66 \times 10^{-16}\ \text{J}\right)}{\left(1.60 \times 10^{-19}\ \text{C}\right)}$$

For a correct answer — 1 point

$$V = 1.04 \times 10^{3}\ \text{V}$$

Question 7 (continued)

	Distribution of points
(d) 3 points	
For any indication that this process is the photoelectric effect	1 point
$K_{max} = hf - \phi$	
For recognizing that $K_{max} = 0$	1 point
$f = \dfrac{\phi}{h} = \dfrac{4.5 \text{ eV}}{4.14 \times 10^{-15} \text{ eV}\bullet\text{s}}$	
For a correct answer with units	1 point
$f = 1.09 \times 10^{15}$ Hz	

7. (10 points)

In an electron microscope, a tungsten cathode with work function 4.5 eV is heated to release electrons that are then initially at rest just outside the cathode. The electrons are accelerated by a potential difference to create a beam of electrons with a de Broglie wavelength of 0.038 nm. Assume nonrelativistic equations apply to the motion of the electrons.

(a) Calculate the momentum of an electron in the beam, in kg•m/s .

solution: $\because \lambda = \frac{h}{mv}$

$\therefore mv = \frac{h}{\lambda} = \frac{6.63\times10^{-34} J\cdot s}{0.038\times10^{-9} m} \doteq 1.74\times10^{-23} kg\cdot m/s$

(b) Calculate the kinetic energy of an electron in the beam, in joules.

solution: ~~$E = \frac{1}{2}mv^2 =$~~

$v = \frac{1.74\times10^{-23} kg\cdot m/s}{9.11\times10^{-31} kg} \doteq 1.92\times10^{7} m/s$

$\therefore E = \frac{1}{2}mv^2 = \frac{1}{2}\times 9.11\times10^{-31} kg \times (1.92\times10^{7} m/s)^2 \doteq 1.67\times10^{-16} J$

(c) Calculate the accelerating voltage.

solution: $\because E = q\cdot\Delta V$

$\therefore \Delta V = \frac{E}{q} = \frac{1.67\times10^{-16} J}{1.60\times10^{-19} C} \doteq 1.04\times10^{3} V$

(d) Suppose that light, instead of heat, is used to release the electrons from the cathode. What minimum frequency of light is needed to accomplish this?

solution: $E = hf - W$

$\therefore 0 = 6.63\times10^{-34} J\cdot s \cdot f - 4.5\times1.60\times10^{-19} J$

$\therefore f \doteq 1.09\times10^{15} Hz$

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7. (10 points)

In an *electron microscope*, a tungsten cathode with work function 4.5 eV is heated to release electrons that are then initially at rest just outside the cathode. The electrons are accelerated by a potential difference to create a beam of electrons with a de Broglie wavelength of 0.038 nm. Assume nonrelativistic equations apply to the motion of the electrons.

(a) Calculate the momentum of an electron in the beam, in kg•m/s .

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

$p = \frac{h}{\lambda} = \frac{6.63\times10^{-34}\ J\cdot s}{0.038\times10^{-9}\ m} = 1.745\times10^{-23}\ kg\,m/s$

(b) Calculate the kinetic energy of an electron in the beam, in joules.

$KE = \frac{1}{2}mv^2$ $\quad p = mv$ $\quad v = \frac{p}{m} = \frac{1.745\times10^{-23}\ kg\,m/s}{9.11\times10^{-31}\ kg} = 19151886.3\ m/s$ or $1.915\times10^{7}\ m/s$

$KE = \frac{1}{2}(9.11\times10^{-31}\ kg)(1.915\times10^{7}\ m/s)^2$

$KE = 1.671\times10^{-16}\ J$

(c) Calculate the accelerating voltage.

$KE = U_E$

$U_E = qV$

$\frac{1.671\times10^{-16}\ J}{1.60\times10^{-19}\ C} = V = 1044.219\ V$

(d) Suppose that light, instead of heat, is used to release the electrons from the cathode. What minimum frequency of light is needed to accomplish this?

$hf = pc$

$f = \frac{pc}{h} = \frac{1.745\times10^{-23}\ kg\,m/s\ (3\times10^{8}\ m/s)}{6.63\times10^{-34}\ J\cdot s} = 7.896\times10^{18}\ Hz$

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7. **(10 points)**

In an electron microscope, a tungsten cathode with work function 4.5 eV is heated to release electrons that are then initially at rest just outside the cathode. The electrons are accelerated by a potential difference to create a beam of electrons with a de Broglie wavelength of 0.038 nm. Assume nonrelativistic equations apply to the motion of the electrons.

(a) Calculate the momentum of an electron in the beam, in kg•m/s .

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

$.038 \times 10^{-9} m = \frac{6.63 \times 10^{-34} J \cdot s}{p}$

$p = 1.74 \times 10^{-23} kg \cdot m/s$

$v = f\lambda$

(b) Calculate the kinetic energy of an electron in the beam, in joules.

$K_E = hf - \phi$

$3 \times 10^8 m/s = .038 \times 10^{-9} m \; f$

$K_E = 4.14 \times 10^{-15} eV \cdot s \, (7.89 \times 10^3) - 4.5 eV$

$f = 7.89 \times 10^{18}$

$K_E = -4.5 J$

(c) Calculate the accelerating voltage.

$V = \frac{kQ}{r}$

(d) Suppose that light, instead of heat, is used to release the electrons from the cathode. What minimum frequency of light is needed to accomplish this?

$0 = hf - \phi$

$0 = 4.14 \times 10^{-15} eV \cdot s \; f - 4.5 eV$

$f = 1.09 \times 10^{15}$

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Question 7

Overview

The intent of this question was to test student knowledge of topics in modern physics, specifically wave-particle duality and the photoelectric effect. In part (a) students were asked to calculate the momentum of an electron given its de Broglie wavelength. In part (b) they had to find the kinetic energy of the electron. In part (c) students were asked for the accelerating voltage required to create the beam of electrons. Part (d) asked students to calculate the threshold frequency given the work function of a tungsten cathode.

Sample: B7A
Score: 10

Full credit was awarded for all four parts.

Sample: B7B
Score: 7

Parts (a), (b), and (c) all received full credit. Part (d) earned no credit, as there is no recognition of a photoelectric effect process.

Sample: B7C
Score: 4

Part (a) earned full credit. In part (b) the student incorrectly calculates the kinetic energy, so no points were earned. No relevant work is shown in part (c), so no credit was earned. Two points were earned in part (d) for identifying a photoelectric effect process, but the correct numerical answer does not include units.