AP® PHYSICS B
2010 SCORING GUIDELINES (Form B)

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

$K_{max} = hf - \phi$

The work function can be determined when $K_{max} = 0$.

For a correct relationship for determining the work function — 1 point

$\phi = hf_0$

For correctly substituting f_0, determined from the graph — 1 point

$\phi = (4.14 \times 10^{-15}\ \text{eV•s})(4.5 \times 10^{14}\ \text{Hz})$

$\phi = 1.9\ \text{eV}$

One earned point was deducted if the answer was not expressed in eVs.

(b) 3 points

For using the correct equation — 1 point

$K_{max} = hf - \phi$

For correctly substituting the value of ϕ from part (a) — 1 point

For correctly substituting the value of f from the graph — 1 point

$K_{max} = (4.14 \times 10^{-15}\ \text{eV•s})(8 \times 10^{14}\ \text{Hz}) - 1.9\ \text{eV}$

$K_{max} = 1.4\ \text{eV}$

One earned point was deducted if the answer was not expressed in eVs.

Alternate solution: — *Alternate points*

For indicating a direct connection between the 1.5 V needed to stop the highest-energy electrons (as read from the graph) and the 1.5 eV maximum initial kinetic energy — *1 point*

For justifying that connection — *2 points*

(c) 2 points

For a correct relationship to calculate the wavelength of light — 1 point

$\lambda = c/f$

$\lambda = (3.00 \times 10^{8}\ \text{m/s})/(8 \times 10^{14}\ \text{Hz})$

For the correct answer — 1 point

$\lambda = 3.75 \times 10^{-7}\ \text{m}$

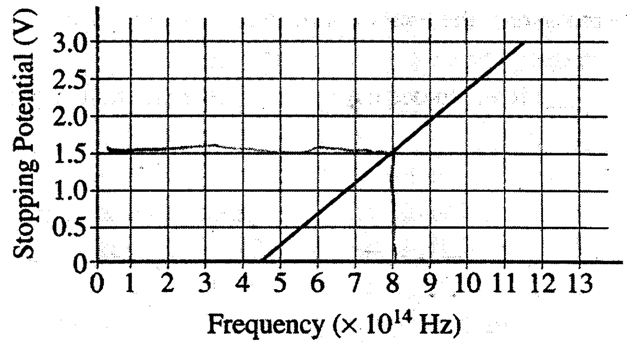
Alternatively, the equation $\lambda = hc/E$ can be used with E equal to the sum of the answers to parts (a) and (b).

(d) 3 points

For correctly indicating that the required wavelength would be longer — 1 point

For indicating that a lower K_{max} means the light must have a lower frequency — 1 point

For indicating that a lower frequency corresponds to a longer wavelength — 1 point



7. (10 points)

Your teacher gives you the above graph of stopping potential versus frequency for the photoelectric effect.

(a) Calculate the work function of the metal in eV.

the minimum frequency required is 4.5×10^{14} Hz.
∴ the work function ϕ is
$\phi = hf_0 = (4.14\times10^{-15})\times(4.5\times10^{14})$ ∴ 1.863 eV
$= 1.863$

(b) If the stopping potential is 1.5 V, determine the maximum kinetic energy of the emitted photoelectrons in eV.

at 1.5V, frequency is 8×10^{14} Hz
∴ maximum kinetic energy K_{max} is ∴ 1.449 eV
$K_{max} = h(f - f_0) = (4.14\times10^{-15})(8\times10^{14} - 4.5\times10^{14})$
$= 1.449$

(c) Calculate the wavelength of light that will eject photoelectrons with the maximum kinetic energy found in part (b).

ligt speed c is

$c = f\lambda$. ∴ 3.75×10^{-7} m

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

∴ $c = 3.00\times10^{8}$ m/s, $f = 8\times10^{14}$ Hz

$\lambda = 3.75\times10^{-7}$

(d) What would be the wavelength of light that will eject photoelectrons with a lower maximum kinetic energy than that found in part (b) ?

__✓__ It will be longer than that found in part (c).

_____ It will be the same as that found in part (c).

_____ It will be shorter than that found in part (c).

Explain your reasoning.

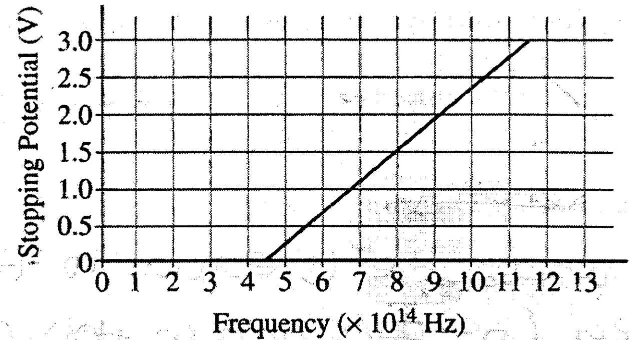
when photoelectrons with lower maximum kinetic energy than part (b), it has lower frequency than 8×10^{14} Hz.

∴ Since wavelength equation is

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

as frequency gets smaller, wavelength gets longer.

∴ wavelength will be ~~more~~ longer. than part (c)



7. (10 points)

Your teacher gives you the above graph of stopping potential versus frequency for the photoelectric effect.

(a) Calculate the work function of the metal in eV.

~~stopping potential = hf − ϕ~~

~~1.5~~ $\phi = \frac{1}{2}(11.5 - 4.5)(10^{14})(3.0)$

$= 10.5 \times 10^{14}$

(b) If the stopping potential is 1.5 V, determine the maximum kinetic energy of the emitted photoelectrons in eV.

$K_{max} = hf - \phi$

$= 8 \times 10^{14}(6.63 \times 10^{-34}\ J\cdot s) - 10.5 \times 10^{14}$

$= -1.05 \times 10^{15}$

(c) Calculate the wavelength of light that will eject photoelectrons with the maximum kinetic energy found in part (b).

~~f = 8×10~~

$\lambda = \frac{3.0 \times 10^8}{8 \times 10^{14}}$

$= 3.75 \times 10^{-7}\ m$

(d) What would be the wavelength of light that will eject photoelectrons with a lower maximum kinetic energy than that found in part (b) ?

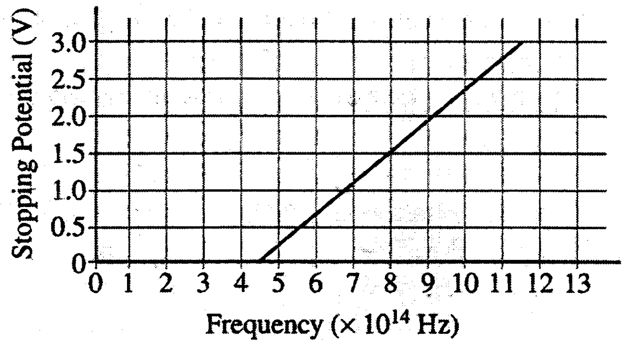
✓ It will be longer than that found in part (c).

_____ It will be the same as that found in part (c).

_____ It will be shorter than that found in part (c).

Explain your reasoning.

since ~~Kmax~~ $K_{max} = \frac{hc}{\lambda} - \phi$, where c, h and ϕ are constant, decreasing Kmax arises from an increase in λ.



7. (10 points)

Your teacher gives you the above graph of stopping potential versus frequency for the photoelectric effect.

(a) Calculate the work function of the metal in eV.

$\phi = \frac{K}{hf}$

(b) If the stopping potential is 1.5 V, determine the maximum kinetic energy of the emitted photoelectrons in eV.

$K = hf - \phi$

$K = (4.4 \times 10^{-15}) \times (1.5 \times 10^{14}) - (1.5)$

$K = 3.56\ eV$

(c) Calculate the wavelength of light that will eject photoelectrons with the maximum kinetic energy found in part (b).

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

$\frac{4.4 \times 10^{-15}}{3.56\ eV} = 1.23 \times 10^{-15}\ eV$

(d) What would be the wavelength of light that will eject photoelectrons with a lower maximum kinetic energy than that found in part (b) ?

__✓__ It will be longer than that found in part (c).

_____ It will be the same as that found in part (c).

_____ It will be shorter than that found in part (c).

Explain your reasoning.

Because the light would have less frequency.

Question 7

Sample: B-7A
Score: 10

Full credit was earned in all parts. Note that all substitutions are clearly shown, some explanatory information is included, and all final numerical answers are underlined.

Sample: B-7B
Score: 7

An incorrect relationship for the work function is used in part (a), so no credit was earned. A consistent substitution of the work function value from (a) into the correct equation is shown in part (b), and the response would have earned 3 points, but incorrect units are used and so 1 point was deducted. Parts (c) and (d) received full credit. Note that in part (d) the relationship between K_{max} and frequency is implicit in the equation used.

Sample: B-7C
Score: 2

One point was earned in part (b) for using the correct equation. A second point was earned for selecting the correct choice in part (d); the comment regarding "less frequency" is not connected to either the lower energy or the longer wavelength and so earned no justification point. No other meaningful work is shown in the remainder of the response.