Modern Physics Exam Review

Directions – Complete the following problems to help prepare you for the upcoming test.

2009 AP® PHYSICS B FREE-RESPONSE QUESTIONS

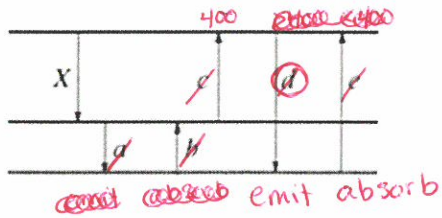
7. (10 points)

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

(a) Calculate the kinetic energy of the electron.

(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.

(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.



$E = \frac{hc}{\lambda}$ ↓λ ↑E

Justify your answer.

a) ① $\lambda = \frac{h}{p} = \frac{h}{mv}$ $v = \frac{h}{m\lambda} = \frac{6.63\times10^{-34}\,Js}{(9.11\times10^{-31}kg)(.85\times10^{-9}m)} = 8.6\times10^{5}\,m/s$

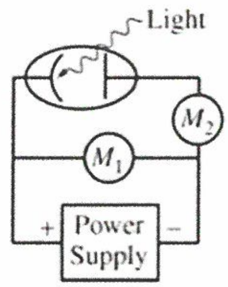
② $K = \frac{1}{2}mv^2 = \frac{1}{2}(9.11\times10^{-31}kg)(8.6\times10^{5}m/s)^2 = \boxed{3.4\times10^{-19}J}$

b) $K_{max} = hf - \phi$ $\phi = hf - K = \frac{hc}{\lambda} - K = \frac{(1.99\times10^{-25}Jm)}{250\times10^{-9}m} - 3.4\times10^{-19}J$

$\boxed{= 4.6\times10^{-19}J}$

c) d • $E = \frac{hc}{\lambda}$ A smaller wavelength corresponds to more energy, so it needs to be a larger transition

• The transition must be to a lower level because that is when energy is emitted/released



6. (10 points)

A student performs a photoelectric effect experiment in which light of various frequencies is incident on a photosensitive metal plate. This plate, a second metal plate, and a power supply are connected in a circuit, which also contains two meters, M_1 and M_2, as shown above.

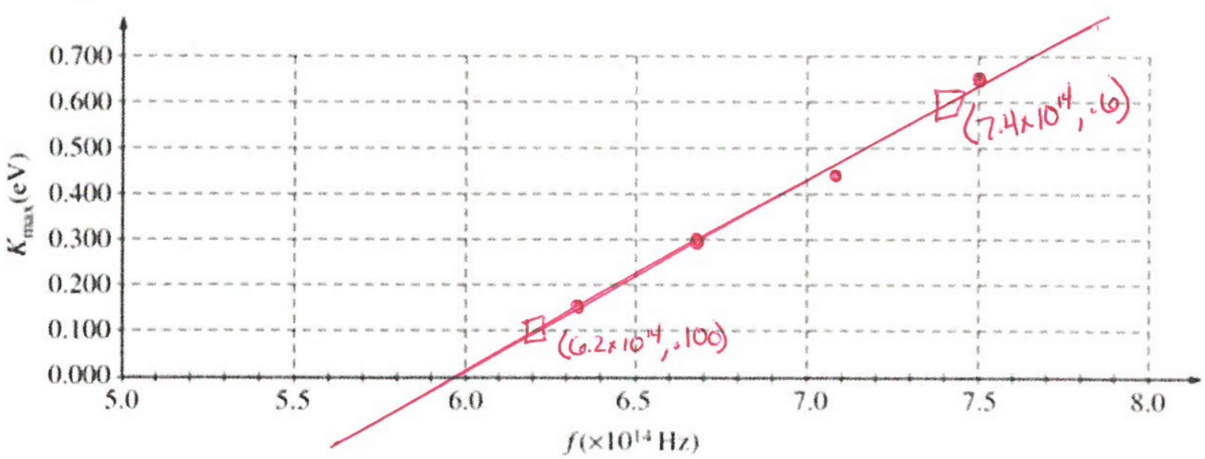
The student shines light of a specific wavelength λ onto the plate. The voltage on the power supply is then adjusted until there is no more current in the circuit, and this voltage is recorded as the stopping potential V_S. The student then repeats the experiment several more times with different wavelengths of light. The data, along with other values calculated from it, are recorded in the table below.

λ (m)	4.00×10^{-7}	4.25×10^{-7}	4.50×10^{-7}	4.75×10^{-7}
V_S (volts)	0.65	0.45	0.30	0.15
f (Hz)	7.50×10^{14}	7.06×10^{14}	6.67×10^{14}	6.32×10^{14}
K_{max} (eV)	0.65	0.45	0.30	0.15

(a) Indicate which meter is used as an ammeter and which meter is used as a voltmeter by checking the appropriate spaces below.

	M_1	M_2
Ammeter		✓
Voltmeter	✓	

(b) Use the data above to plot a graph of K_{max} versus f on the axes below, and sketch a best-fit line through the data.



(c) Use the best-fit line you sketched in part (b) to calculate an experimental value for Planck's constant. slope

(d) If the student had used a different metal with a larger work function, how would the graph you sketched in part (b) be different? Explain your reasoning.

c) $K_{max} = hf - \phi$

$y = mx + b$

slope $= h$

$m = \frac{\Delta y}{\Delta x} = \frac{.600\,eV - .100\,eV}{7.4\times10^{14}\,Hz - 6.2\times10^{14}\,Hz} = 4.2\times10^{-15}\,eV\cdot s$

(3.73×10^{-15} eVs → 4.55×10^{-15} eVs was accepted)

d) The graph would move to the right or down

- A larger ϕ means a greater/larger y intercept
- A larger ϕ means a greater/larger x intercept/threshold f
- A larger ϕ means a greater K needed to escape

7. (10 points)

It is possible for an electron and a positron to orbit around their stationary center of mass until they annihilate each other, creating two photons of equal energy moving in opposite directions. A positron is a particle that has the same mass as an electron and equal but opposite charge. The amount of kinetic energy of the electron-positron pair before annihilation is negligible compared to the energy of the photons created.

(a) Calculate, in eV, the rest energy of a positron.

(b) Determine, in eV, the energy each emitted photon must have.

(c) Calculate the wavelength of each created photon.

(d) Calculate the magnitude of the momentum of each photon.

(e) Determine the total momentum of the two-photon system.

a) ① $E = mc^2 = 9.11\times10^{-31}\,kg\,(3.00\times10^8\,m/s)^2 = 8.20\times10^{-14}\,J$

② $8.20\times10^{-14}\,J\left(\frac{1\,eV}{1.60\times10^{-19}\,J}\right) = \boxed{5.12\times10^5\,eV}$

b) $\boxed{E_\gamma = 5.12\times10^5\,eV}$ (all matter energy converts to photon energy)

c) $E = \frac{hc}{\lambda}$ $\lambda = \frac{hc}{E} = \frac{1.24\times10^3\,eV\cdot nm}{5.12\times10^5\,eV} = .00242\,nm$

$2.42\times10^{-3}\,nm$

$\boxed{= 2.42\times10^{-12}\,m}$

d) $p = \frac{h}{\lambda} = \frac{6.63\times10^{-34}\,Js}{2.42\times10^{-12}\,m} = \boxed{2.74\times10^{-22}\,kgm/s}$

e) $p_{total} = \boxed{Zero}$