PHY293 Quiz #4 – Solutions

November 30, 2017

This is the answer key to all four of the Quiz versions. Each 'sub-part' of each question was worth equal weight, so 33% of the quiz in all cases. All results here are rounded to 2 significant figures. Up to 3 significant figures acceptable. More than that is too much and should have 10% of the quiz grade deducted (only once if answers too all parts have too much (or too little) precision).

Version 1 4.1:1 $E_{max} = hc/\lambda_{min} - 1240/0.052 = 23.8$ keV

4.1:2 $E_{kin} = E_{tot} - mc^2 = (\gamma - 1)mc^2$. $E_{kin} = 23.8$ keV from the first part of the problem, so $\gamma = 1.046$, $v = 0.295c$ or 8.9×10^7 m/s

4.1:3 If you used the non-relativistic expression for the kinetic energy ($mv^2/2$) you'd find $v = 0.306c$, or slightly higher. The fact that these electrons are travelling at $\approx 30\%$ of the speed of light means that they are slightly relativisitic and so you should use the the relativistic formula. The non-relativistic approximation gives something about 3% higher. You didn't need to do the full non-relativistic calculation to get credit for this part of the question, but some explanaition for why the relativisitc answer but you needed some number to compare, and not just simply stating "because the relativistic formalism is right in all caes".

Version 2 4.2:1 $E_{max} = hc/\lambda_{min} - 1240/0.155 = 8.00$ keV

4.2:2 $E_{kin} = E_{tot} - mc^2 = (\gamma - 1)mc^2$. $E_{kin} = 8.0$ keV from the first part of the problem, so $\gamma = 1.016$, $v = 0.175c$ or 5.2×10^7 m/s

4.2:3 If you used the non-relativistic expression for the kinetic energy ($mv^2/2$) you'd find $v = 0.177c$, or slightly higher. The fact that these electrons are only travelling at $\approx 17\%$ of the speed of light means that they aren't really relativistic so, to two decimal place precision you **could** use either to derive the electron speed. But you needed some numerical support (see Quiz 1 solution). '

Version 3 4.3:1 280 nm light barely ejects electrons. This allows us to determine the work function for the metal: $\Phi = hc/\lambda = 1240/280 = 4.43$ eV

4.3:2 $E_e = E_\gamma - \Phi = hc/\lambda - \Phi = 1240/150 - 4.43 = 3.84$ eV. These are **very** non-relativistic electrons so $v^2 = (2E/m)c^2 = 7.67/511000c^2$ or $v = 0.0039c = 1.2 \times 10^6$ m/s

4.3:3 $E_e = E_\gamma - \Phi = h\nu - \Phi = 4.14 \times 3.7 - 4.43 = 10.9$ eV. These are also **very** non-relativistic electrons so $v^2 = (2E/m)c^2 = 10.9/511000c^2$ or $v = 0.0065c = 2.0 \times 10^6$ m/s

Version 4 4.4:1 $E_e = hc/\lambda - \Phi$. So the difference in energy between the electrons emitted by the 210 and 420 nm light is $E_{210} - E_{420} = hc/210 - hc/420 = 2.052$ eV independent of the workfunction of the metal. These electrons are very non-relativistic so we get $m/2(v_{210}^2 - v_{420}^2) = 2.952$ eV. Or $(v_{210}^2 - v_{420}^2)/c^2 = 2 \cdot 2.952/511000 = 1.15 \times 10^{-5}$ where I have divided left and right by c^2 to use the mass of the electron in eV/c^2. Putting in the speed of the electrons for the 420 nm light, I find $v_{210} = 0.003c = 1.04 \times 10^6$ m/s.

4.4:2 If the electrons are emerging with $v = 2.3 \times 10^5$ m/s then they have kinetic energy: $E_{kin} = mv^2/2 = mc^2/2(v/c)^2 = 511000/2 \cdot (2.3/3000)^2 = 0.15$ eV. But to emerge with 0.15 eV of kinetic energy the light (of wavelength $\lambda = 420$ nm) is transferring 1240/420=2.95 eV. So the workfunction of the metal is robbing the electrons of 2.95-0.15 = 2.80 eV. So one would need light with a wavelength of at least $hc/2.80$ eV $= 443$ nm to overcome the workfunction of this metal

4.4:3 Light of wavelength longer than 443 nm would only be able to transfer less than 2.80 eV of energy to the electrons bound in the metal. That would not be enough to overcome the workfunction in the metal, and thus the electrons would remain trapped inside the metal.