TURNING POINTS

2-3 The development of the photon theory of light

1. $h = 6.63 \times 10^{-34}$ Js, $c = 3.00 \times 10^{8}$ ms^{-1}, $\lambda = 535$ nm $= 535 \times 10^{-9}$ m, $\phi = 1.85$ eV

(a) $E = hf = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3.00 \times 10^{8}}{535 \times 10^{-9}}$

$= 3.7177\ldots \times 10^{-19}$ J

$= 3.72 \times 10^{-19}$ J to 3 sf

1.85 eV $= 1.85 \times 1.60 \times 10^{-19} = 2.96 \times 10^{-19}$ J

Max k.e. $= 3.72 \times 10^{-19} - 2.96 \times 10^{-19} = 7.60 \times 10^{-20}$ J

OR photon energy $= \frac{3.72 \times 10^{-19}}{1.60 \times 10^{-19}}$

$= 2.32$ eV

Max k.e. $= hf - \phi = 2.32 - 1.85 = 0.47$ eV

$= 0.47 \times 1.60 \times 10^{-19}$

$= 7.50 \times 10^{-20}$ J

2. $h = 6.63 \times 10^{-34}$ Js, $c = 3.00 \times 10^{8}$ ms^{-1}, $\lambda = 410$ nm $= 410 \times 10^{-9}$ m, max k.e. $= 2.10 \times 10^{-19}$ J

(a) $E = hf = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3.00 \times 10^{8}}{410 \times 10^{-9}}$

$= 4.85 \times 10^{-19}$ J to 3 sf

(b) $\phi = hf - E_{k\,max} = (4.85 - 2.10) \times 10^{-19}$ J

$= 2.75 \times 10^{-19}$ J

The answer given is 1.61×10^{-19} J
(If you calculate $2.10 - 0.485$ you get 1.61…..but that makes no sense and is not consistent with part (a) either, so it must be an error).

(c) $eV_s = E_{k\,max}$ hence $V_s = \frac{E_{k\,max}}{e}$

$= \frac{2.10 \times 10^{-19}}{1.60 \times 10^{-19}}$

$= 1.31$ V

3. The electrons need a photon each to liberate them from the metal surface. The photons must have sufficient energy to give the electrons so that they can overcome the attraction from the positive ions in the metal lattice. Blue photons are more energetic than red photons. The red photons do not have an energy at least equal to the metal's work function (the minimum required) but the blue ones do.
4. (a) Experimental observation in the photoelectric effect that cannot be explained using the wave theory of light:
    - electron emission required a minimum frequency i.e. was frequency dependent (wave theory said it shouldn't be)
    - electron emission is instant
    - the photoelectrons have a range of kinetic energies and a maximum kinetic energy (ANY ONE)

    (b) The explanations are:

    - the minimum frequency requirement is explained by the requirement that a single photon supplies a single electron with energy equal to or greater than the work function
    - the electron emission is instant because each photon supplies the energy to a single electron in one go
    - the electron's max k.e. is the difference between the photon energy and the work function. Electrons from the surface require least energy for release, those further in require more so there is a range of energies
      (ANY SINGLE CORRESPONDING EXPLANATION)