Photons Assignment 1 *SOLUTIONS*

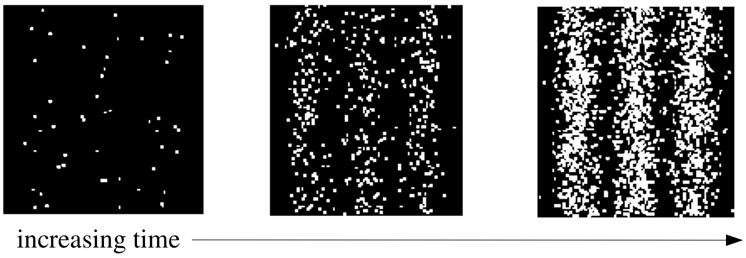
1. A photographic plate exposed to very low intensity light shows an increasing number of dots over time. Each dot is the product of one photon of light being absorbed. /2

2.
a) $f = \frac{c}{\lambda} = \frac{3.00\times10^{8}}{4.50\times10^{-7}} = 6.67\times10^{14}$ Hz

$E = hf = 6.63\times10^{-34}\times6.67\times10^{14} = 4.42\times10^{-19}$ J (or 2.76 eV) /2

b) $p = \frac{h}{\lambda} = \frac{6.63\times10^{-34}}{4.50\times10^{-7}} = 1.47\times10^{-27}$ kg m s^{-1} /2

3.



increasing time → /2

4.
a)
1. Place a filter over the light source so that the light reaching the photoelectric cell is monochromatic
2. Set the variable voltage source to zero (so that the potential difference between the cathode and anode is zero to start with)
3. Allow the light to shine on the photoelectric cell. If the frequency of light is high enough, a current will be produced in the circuit
4. Increase the voltage. This increased voltage should lead to a reduced current.
5. Continue to increase the voltage until the current is reduced to zero.
6. Calculate the work being done to stop the electrons using $W = q\Delta V$. This work is the maximum kinetic energy K_{max} of the electrons.
7. Repeat steps 1-6 for various filters (frequencies of light).

incident on a metal surface. /4

b)
(i) $E = hf = 6.63\times10^{-34}\times 6.0\times10^{14} = 3.978\times10^{-19}$ J so $3.978\times10^{-19} / 1.60\times10^{-19} = 2.5$ eV
/2

(ii) $K_{max} = hf - W$ so $W = hf - K_{max} = hf - eV_s = 6.63\times10^{-34}\times6.0\times10^{14} - 1.60\times10^{-19}\times1.49 = 1.594\times10^{-19}$ J
$1.594\times10^{-19} / 1.60\times10^{-19} = 1.0$ eV which is just enough.
A shorter and just as valid way to do this question:
Work function is the difference between the stopping voltage and the maximum electron energy in eV (since 1 V corresponds to stopping 1 eV). So 2.5 – 1.49 = 1.0 eV which is just enough.
/3

c)
(i) It will increase. Greater intensity is more photons. Each photon frees one electron, and current is effectively the number of electrons passing a point per second, so more photons → more current.
/2

(ii) It would not.
/1

5.

1. Greater frequency leads to greater **maximum** kinetic energy, but the electrons may have any kinetic energy within the range less than this.
   Reason: Electrons within a metal are bound by different amounts of energy (the work function is the **minimum** energy required to release electrons.
2. There is a minimum 'threshold' frequency f_0 for each particular metal
   Reason: A photon transfers all or none of its energy, which is dependent on frequency. Photons with energy less than the work function will not cause electrons to be emitted.
3. Increasing the intensity increases **only** the number of electrons emitted
   Reason: Intensity of light is the number of photons. Each photon releases one electron.
4. Electrons are emitted instantaneously
   Reason: As soon as a photon collides with the metal, if it has enough energy it will instantly pass on its energy therefore instantly releasing an electron.

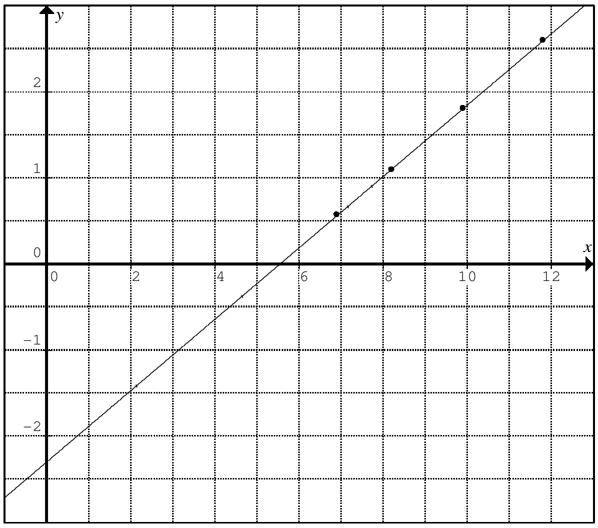
/4

Photons Assignment 2 *SOLUTIONS*

1.

a) Kmax vs Frequency

Kmax ($\times 10^{-19}$ J)



Frequency ($\times 10^{14}$ Hz)

/3

b) Using the line of best that you have drawn on the graph:

(1) $f_0 \approx 5.55 \times 10^{14}$ Hz (shown as x intercept on graph) /1

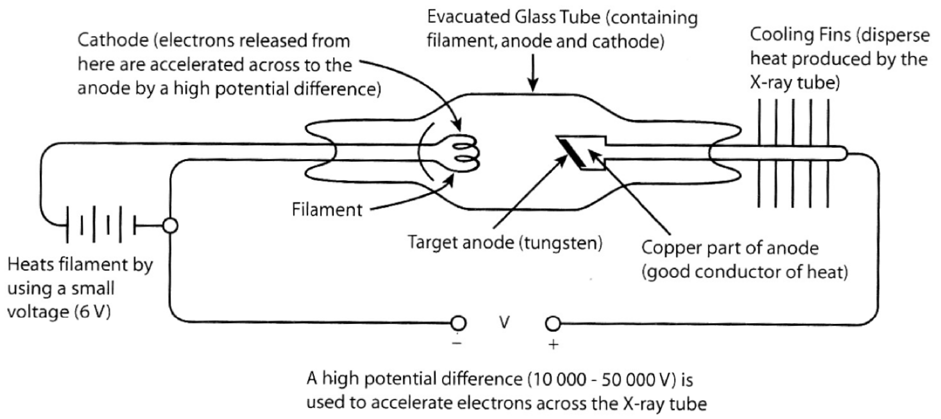
(2) $W \approx 2.3 \times 10^{-19}$ J (with $-W$ shown as y intercept on graph)

/1

(3) $K_{\max} = hf - W$ is the equation for a straight line with slope h and y intercept $-W$ /1

2.

a)

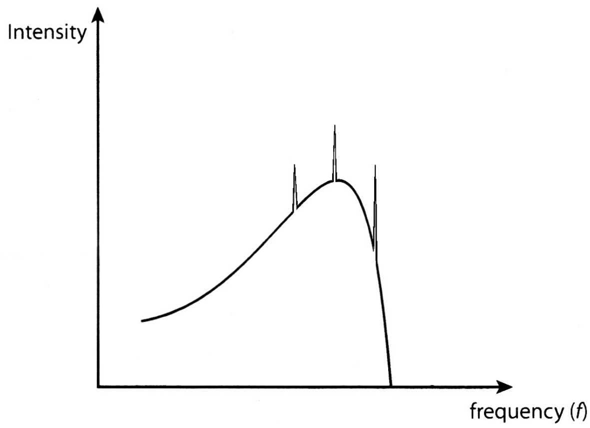


/3

b) The filament is heated allowing electrons to leave it, and a high potential difference is placed between the cathode and the anode which causes the electrons to be accelerated towards the anode. On striking the anode, the electrons interact with the electric fields of the atoms in the metal, and some of the kinetic energy is converted into X-ray photons due to the deceleration. /2

c) 1: Hard, 2: High melting point. /1

d) Most of the electrons' kinetic energy becomes heat, so if not cooled the anode will melt. /1 e)



/2

f)

(1) There are infinite X-ray frequencies within the range as an electron can be any distance from a metal nucleus and therefore slow down any given amount. /1

(2) A direct hit of an electron on a nucleus produces the highest possible frequency. /1

3.

a) Consider max energy photons:

$E = hf \quad \therefore E_{max} = hf_{max}$

Electrons have energy K, and max energy photons are when all energy from an electron is converted into photon, so when $E_{max} = K$

$\therefore K = hf_{max}$

$\therefore f_{max} = \frac{K}{h}$

K is equal to the work done to accelerate the electrons, so K=$W = q\Delta V$

$K = q\Delta V = e\Delta V \quad \{\text{since charge on an electron is } e = 1.60\times10^{-19}\}$

$\therefore f_{max} = \frac{e\Delta V}{h}$

/2

b) $f_{max} = \frac{e\Delta V}{h} \quad \therefore \Delta V = \frac{hf_{max}}{e} = \frac{6.63\times10^{-34}\times3.00\times10^{17}}{1.60\times10^{-19}} = 1.24\times10^{3}\text{ V}$ /2

4.

a)

- density (more dense means more attenuation)
- thickness (the more the rays must pass through, the more they are attenuated)
- average atomic number (the bigger the atoms, the more the attenuation) /3

b) The X-rays produced will have a higher frequency (or hardness, penetrating power, etc) /1

c) Higher filament current increases number of X-rays thereby improving contrast /1