Answers:

Question 2 (4 marks)

An electron with 2.80 eV of kinetic energy bombards an atom with a single ground state electron. The atom's electron is excited and later transitions back to the ground state, emitting a single 518 nm photon. Calculate the kinetic energy of the bombarding electron after it scattered off the atom.

Energy of emitted photon

$$\Delta E = hf = \frac{hc}{\lambda} = \frac{6.63\times10^{-34} \times 3.00\times10^{8}}{518\times10^{-9}} = 3.84 \times 10^{-19}\, J$$

$$\Delta E = \frac{3.84\times10^{-19}}{1.60\times10^{-19}} = 2.40\ eV$$ 1-2

Energy of scattered electron

$$E_{final} = E_{initial} - \Delta E$$

$$E_{final} = 2.80 - 2.40 = 0.400\ eV$$ 1-2

Question 3 **(6 marks)**

(a) State why **all** photoelectrons emitted from the silicon do not have the same kinetic energy for a given incident wavelength. (1 mark)

Description	Marks
electrons not on the surface will require more energy to escape the crystal lattice structure **or** work function is the minimum energy required	1
Total	**1**
Accept other relevant answers	

(b) Determine the maximum energy in joules of the highest energy incident photons. (2 marks)

Description	Marks
$E = hf = \frac{hc}{\lambda}$	1
$= \frac{6.63\times10^{-34}\times3\times10^{8}}{510.6\times10^{-9}} = 3.90\times10^{-19}$ J	1
Total	**2**

(c) Calculate the work function of the silicon in joules. (3 marks)

Description	Marks
$E_k = hf - W$ $W = hf - E_k$	1
$= \frac{6.63\times10^{-34}\times3\times10^{8}}{510.6\times10^{-9}} - 5.36\times10^{-20}$ $= 3.90\times10^{-19} - 5.36\times10^{-20}$	1
$= 3.36\times10^{-19}$ J	1
Total	**3**

Question 14 **(13 marks)**

(a) Calculate the velocity of any electron emitted from the ground state mercury atom. (3 marks)

Description	Marks
$E_k = E_e - E_{ionisation}$ $= 17.9 \times 10^{-19} – 16.7 \times 10^{-19}$ $= 1.2 \times 10^{-19}$	1
$\frac{1}{2} mv^2 = 1.2 \times 10^{-19}$	1
$v = \sqrt{\frac{2 \times 1.2 \times 10^{-19}}{9.11 \times 10^{-31}}}$ $= 5.13 \times 10^5$ m s^{-1}	1
Total	**3**

(b) Describe why some of the mercury atoms in the tube need to be ionised. (2 marks)

Description	Marks
to create free electrons	1
to hit other mercury atoms to excite electrons and produce more photons **or** to create charges for pathway for electrical current **or** to produce high energy photons for fluorescence to occur	1
Total	**2**

(c) Calculate the possible energies the incident electron can have after this collision. (3 marks)

Description	Marks
1 →2 $\Delta E = (16.7 - 9.25) \times 10^{-19}$ J $= 7.45 \times 10^{-19}$ J	1
$\Delta E = (10.5 - 7.45) \times 10^{-19}$ J $= 3.05 \times 10^{-19}$ J (scattered electron)	1
or J $= 10.5 \times 10^{-19}$ J (elastic collision)	1
Total	**3**

(d) Determine the part of the spectrum to which the lowest energy emitted photons belong when subject to an incident electron with energy 10.5×10^{-19} J. (2 marks)

Description	Marks
$f = E/h = 7.45 \times 10^{-19} / 6.63 \times 10^{-34} = 1.12 \times 10^{15}$ Hz or $\lambda = 2.67 \times 10^{-7}$ m	1
This is UV therefore all transitions to the ground state must be UV.	1
Total	**2**

(e) Explain how the emitted photons produced by the mercury atoms produce visible light in the fluorescent material. (3 marks)

Description	Marks
the high energy photons (UV) are absorbed causing the electrons of the fluorescent material to jump to a higher state	1
these electrons then fall back to the ground state in a series of steps	1
emitting light some of which is in the visible spectrum	1
Total	**3**

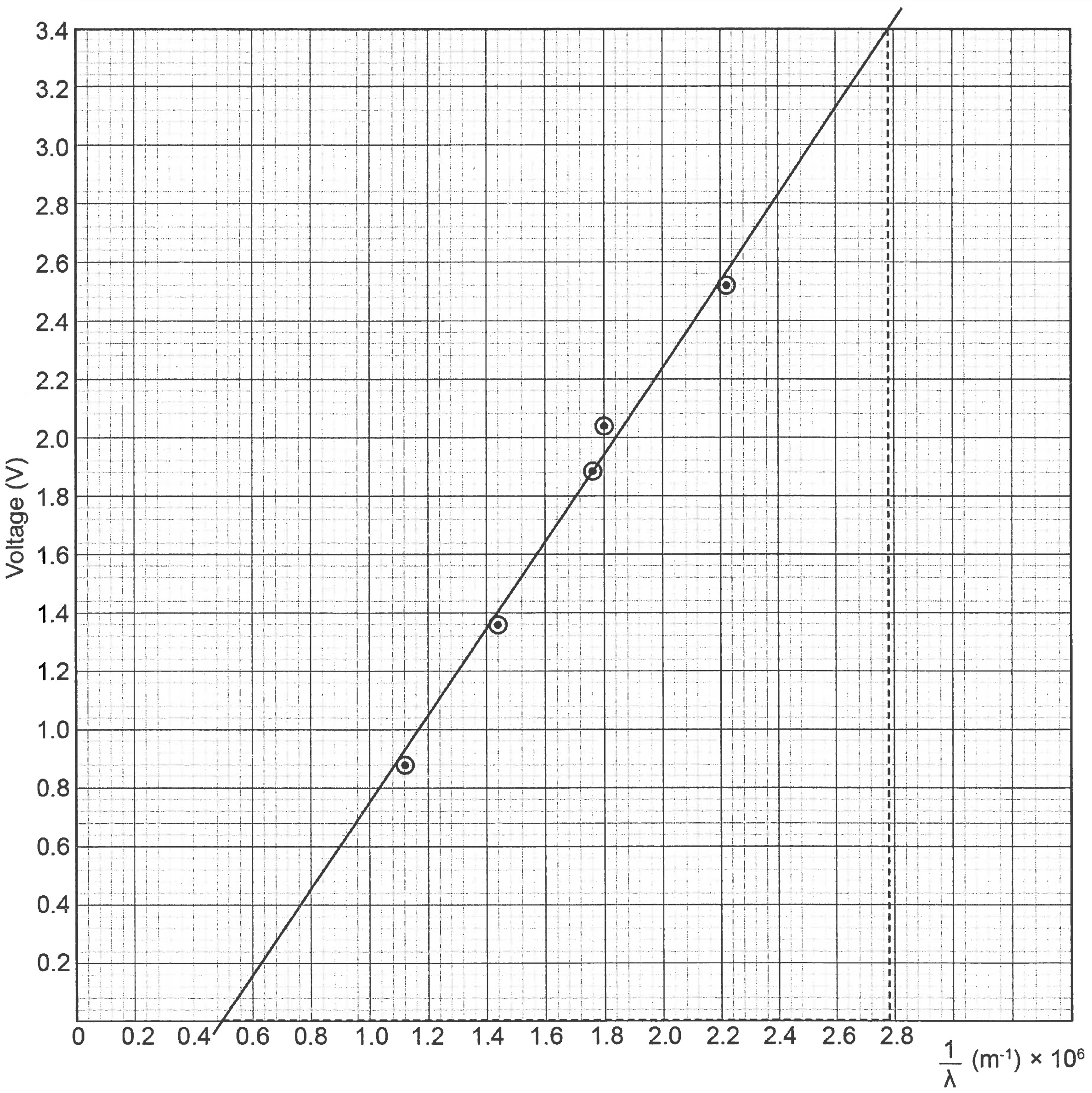
Question 15 **(19 marks)**

(a) Complete the table above for values of 1/λ. (2 marks)

Description	Marks
10^6	1
2.22 (2.2), 1.82 (1.8), 1.75 (1.8), 1.45 (1.4), 1.12 (1.1)	1
Total	**2**

(b) Plot a graph of voltage against 1/λ, with voltage on the y-axis, and draw a line of best fit. Error bars are not required. (5 marks)

Description	Marks
axes correct labels	1
axes correct units	1
appropriate scale	1
plotting	1
line of best fit	1
Total	**5**



Question 15 (continued)

(c) Use the graph to calculate the gradient of the line of best fit. Show construction lines. (3 marks)

Description	Marks
drawing construction lines	1
formulae and working gradient = 3.4 – 0.0/2.78 – 0.50	1
= 1.49 (1.5) × 10^{-6} V m (range 1.4 × 10^{-6} to 1.6 × 10^{-6} V m)	1
Total	3

(d) Use the gradient from part (c) and the provided equation to calculate a value for Planck's constant. (3 marks)

Description	Marks
$h = \frac{q_e V_0 \lambda}{c}$ $h = \frac{q_e \times gradient}{c}$	1
$= \frac{1.6 \times 10^{-19} \times 1.49 \times 10^{-6}}{3 \times 10^{8}}$	1
= 7.9 × 10^{-34} J s	1
Total	3

(e) From your graph, determine the value for k in this experiment. (2 marks)

Description	Marks
showing working on graph or calculation	1
a value of approximately 0.7 ± 0.1 (0.60 → 0.95)	1
Total	2

(f) Describe **two** possible sources of experimental error in the performance of this experiment and how they might be modified to produce a more accurate result. (4 marks)

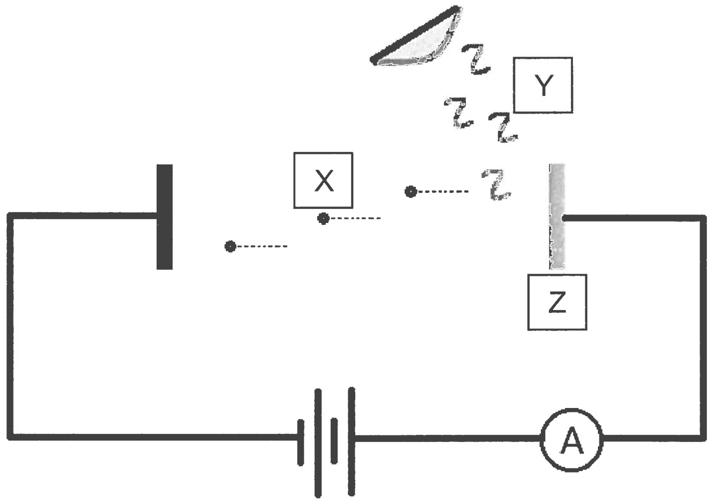
Description	Marks
Source/s of error	
Any **two** of the following: • accuracy of wavelength • accuracy of voltage readings • energy required to start LED lights (may not be same for each light)	1–2
Produce/s (a) more accurate result/s	
Any **two** of the following: • repeat readings of voltage • repeat reading of wavelength • use more accurate voltage devices • repeat the experiment several times and average the results • use a wider/greater range of LED lights	1–2
Total	4
Accept other relevant answers	

Section Two: Problem-solving **50% (90 Marks)**

This section has **seven (7)** questions. You must answer **all** questions. Write your answers in the space provided. Suggested working time for this section is 90 minutes.

Question 14 **(13 marks)**

The equipment below is used in an experiment to test the particle nature of light.



(a) The part "Y" is the monochromatic light. Name and describe the function of the parts labelled "X" and "Z" (4 mark)

Label	Name	Description of function/behaviour
X	Photoelectrons	Carriers of the electric current, moving from one plate to another
Z	Photoemmisive plate/emitter plate/target metal/photocathode	Releases photoelectrons when hit by incident light

1 mark each entry

(b) Describe what the "work function" means in the context of this experiment. (2 marks)

It is the minimum energy required to remove an electron from the metal 1-2

(c) To test for the particle nature of light, the light source is monochromatic (i.e.: consisting of a single colour). If the frequency of the light is decreased, photocurrent will halt. Explain how this observation supports the particle model of light: (3 marks)

The wave model predicts that the intensity of light should be the determining factor as to whether or not photoelectrons are ejected, not frequency. 1

The fact that a threshold frequency exists can be explained using bundles of light (photons), transferring their energy to the electrons upon collision with them. The energy of each photon is proportional to the frequency of the light (E=hf) 1

If this energy (frequency) is too low, electrons will not gain sufficient energy to escape the 'potential well'. As this is what we observe with the Photoelectric effect, it supports the particle model for light. 1

Or similar...

(d) Calculate the minimum voltage required between the two plates to ensure the ammeter detects zero current when the wavelength of the incident light is 345 nm and the work function is 1.50 eV (i.e. find the stopping voltage). (4 marks)

Energy of light

$E = hf = \frac{hc}{\lambda} = \frac{6.63\times10^{-34}\times3.00\times10^{8}}{345\times10^{-9}} = 5.765 \times 10^{-19}\,J$ 1-2

Converts energy into eV (or eV into J)

$E = \frac{5.765\times10^{-19}}{1.60\times10^{-19}} = 3.603\ eV$ 1

Find stopping voltage via kinetic energy

$E_k = E_{light} - W$

$E_k = 3.603 - 1.50 = 2.103\ eV$

$1\ eV\ caused\ by\ 1\ V\ potential\ difference\ for\ fundamental\ charge$

Stopping voltage is 2.10 V 1