Quantum Questions:

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.

Answer: ________________ eV

Question 3 **(6 marks)**

Silicon is a semiconducting material commonly used to make photovoltaic cells. Manufacturers of a solar-powered watch wanted to determine the work function of the silicon under low levels of artificial light. To test the solar-powered watch, the manufacturer used a light source which emitted photons with wavelengths of 510.6 nm and 578.2 nm.

The photoelectrons emitted were found to have a maximum kinetic energy of 5.36×10^{-20} J.

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

(1 mark)

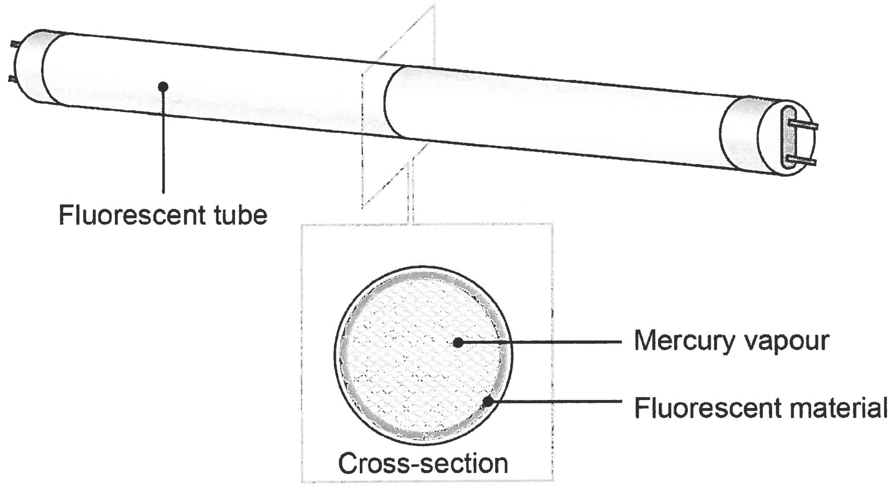
(b) Determine the maximum energy in joules of the highest energy incident photons.

(2 marks)

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

Question 14 **(13 marks)**

A fluorescent light contains mercury vapour which is excited by an electric discharge from end to end inside the tube. This excitation causes some of the mercury atoms to ionise or produce high energy photons. These high energy photons then interact with the fluorescent material coating the inside of the tube to produce visible light.



Some of the energy levels below the ionisation level for a mercury atom are shown in the energy level diagram below.

	Ionisation level
n = 4	-4.38×10^{-19} J
n = 3	-6.02×10^{-19} J
n = 2	-9.25×10^{-19} J
n = 1	-16.7×10^{-19} J

A photon with energy of 17.9×10^{-19} J collides with an electron in the ground state of a vaporised mercury atom.

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

Answer ______________ m s^{-1}

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

An electron with energy of 10.5×10^{-19} J collides with a ground state electron in a mercury atom.

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

(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)

The photons emitted from the electron transition of the mercury atom then interact with the fluorescent material coating the inside of the tube.

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

Question 15 **(19 marks)**

An experiment was conducted to determine a value for Planck's constant. The experiment involved setting up five individual, single frequency light emitting diodes (LEDs). Each LED only emits one frequency of light when a turn on voltage (voltage above a certain threshold value) is applied across its terminals.

The relationship between the frequency of the emitted light and the voltage is given by the equation below.

$E = hf = q_e(V_0 + \mathrm{k})$ where
h is Planck's constant
f is the frequency of light emitted by the diode
q_e is the charge on an electron
V_0 is the turn on voltage
k is the threshold voltage (constant dependent on the material)

The experiment produced the following results.

LED colour	Maximum wavelength (λ) (nm)	Turn on voltage (V_0)	1/λ (m^{-1})
Blue	450	2.53	
Green	550	2.04	
Yellow	570	1.88	
Red	690	1.37	
Infra-red	890	0.88	

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

(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)

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

Answer ______________________ V m

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

Answer ______________________ J s

A spare grid is provided at the end of this Question/Answer booklet. If you need to use it, cross out this attempt and clearly indicate that you have redrawn it on the spare page.

Question 15 (continued)

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

Answer ____________________ V

(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)

One: ____________________

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Two: ____________________

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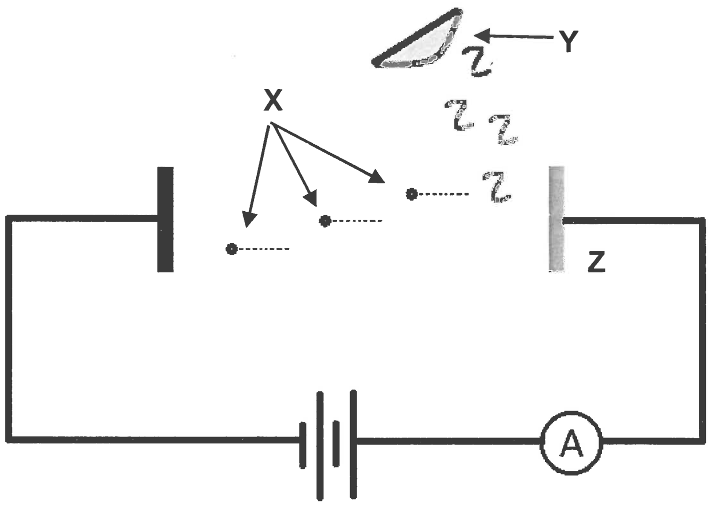
DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

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		
Z		

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

(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)

(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)

Answer: ________________ V