Physics 12 Unit 3 and 4 Draft 1 **Name:** Solutions.

Task 3: Planck's Constant Investigation and Planck's Constant with in-class validation task (5%)

Description:

- This activity is used to determine the value for Planck's Constant by using a device which utilises LED's.
- The task is broken in to two (2) sections. The first is used to derive the data and may be completed in groups. The second is used to analyse the data and activity itself.

Section 1: Data Acquisition

The device used for this activity is shown below:

INSTRUCTION SHEET

INSTRUCTIONS:

The operating instructions can be seen on the rear face of the instrument.

1) Connect a battery or Power Supply to the sockets marked "Input". Voltage can be between 9 and 12 Volts AC or DC. The instrument's 4mm safety banana plug INPUT terminals are marked + and -, but will convert the AC power to DC for the experiment. Reverse polarity connection will not damage the instrument.
2) Set a digital meter to a DC range of about 200uA. Connect to the "A" terminals.
3) Set a digital meter to a DC range of about 20 volts. Connect to the "V" terminals.
4) Set the rotary LED selector switch to select the 465 nanometer wavelength LED.
5) Starting at the "min" position, increase the voltage applied to the LED until the current through the LED reads 2uA on the digital meter set to microamps.

IMPORTANT NOTE:: it is good practice NOT to stare at LED light up close – particularly the shorter wavelengths (higher frequencies) because the light could have some Ultra Violet content which can, over time, damage the retina of the eye.

6) At 2uA through the LED, note and record the voltage applied to the LED by reading the digital meter set to volts.
7) Repeat steps from 4 to 6 after selecting the next LED.

1. **Data from Section 1** – Use this page to record your data which is to be used for Section 2. (4 marks)

Title: Voltage for different wavelength LED's 1

1

Wavelength (nm)	Voltage (V)
465	2.1
520	1.8
594	1.7
620	1.3
660	1.0
880	0.8
940	0.7

1 ruled

1 neatness. - easy to read?

Section 2: Data and activity analysis

Answer the following questions in the spaces provided.

1. Use your data to create a table showing the applied voltage against the frequency of the LED. (2 marks)

Title: Voltage for different freq LED's.

Frequency (Hz)	Voltage (V)
6.4516×10^{14}	2.1 V
5.7692×10^{14}	1.8 V
5.0505×10^{14}	1.7 V
4.8387×10^{14}	1.3 V
4.5454×10^{14}	1.0 V
3.4091×10^{14}	0.8 V
3.1915×10^{14}	0.7 V

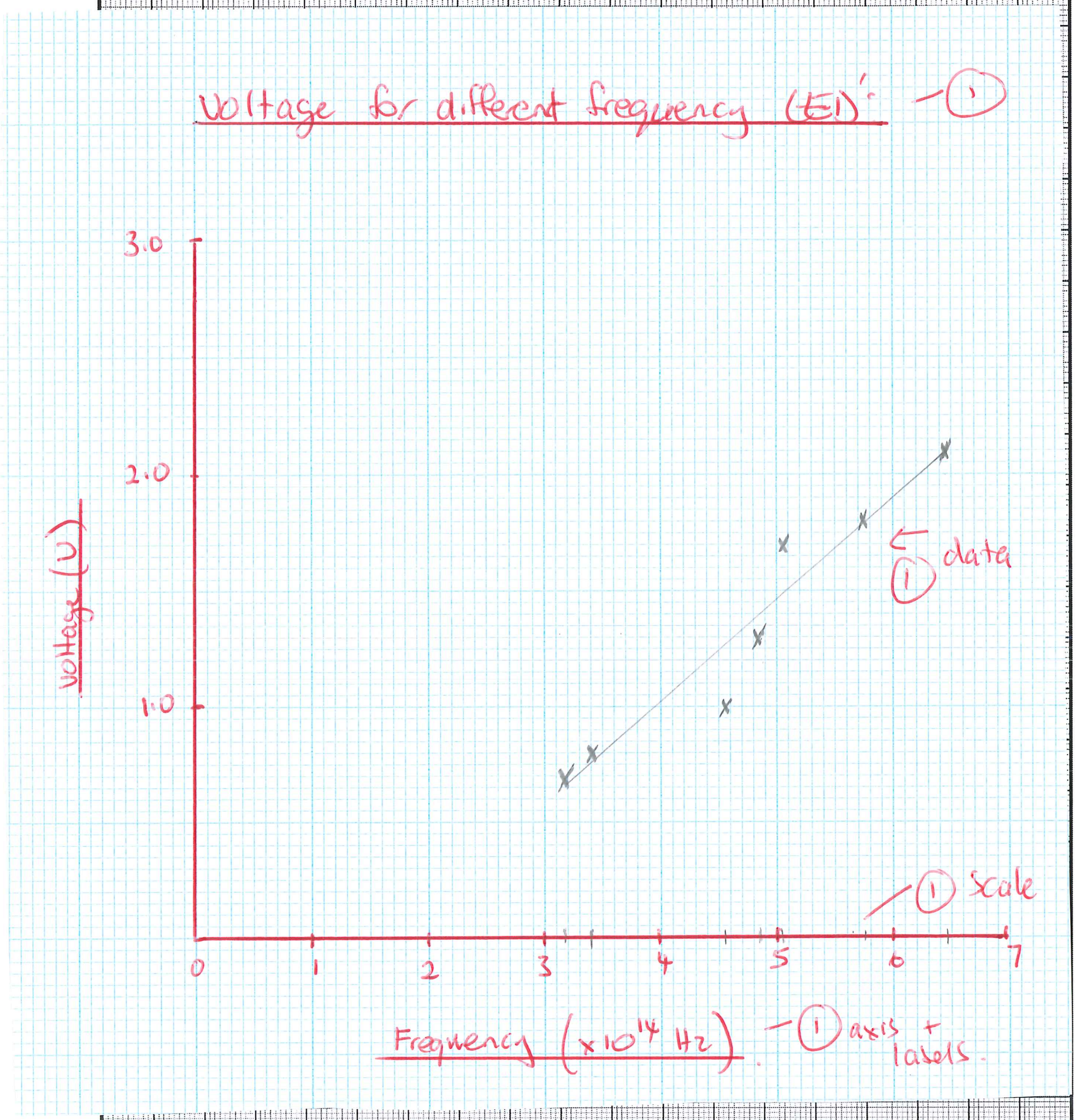
① completed table

$$c = \lambda f$$

① calculation

$$\therefore f = \frac{c}{\lambda} = \frac{3 \times 10^{8}}{\_\_\_ \times 10^{-9}} = \_\_\_\_\_\_ \text{ Hz}$$

2. Use your data from Q1 to draw a graph. (4 marks)



3. An LED is a two terminal semiconductor light source. In the unbiased condition a potential barrier is developed across the p-n junction of the LED. When we connect the LED to an external voltage in the forward biased direction, the height of potential barrier across the p-n junction is reduced. At a particular voltage the height of potential barrier becomes very low and the LED starts glowing, i.e., in the forward biased condition electrons crossing the junction are excited, and when they return to their normal state, energy is emitted. This particular voltage is called the **knee voltage** or the **threshold voltage**. Once the knee voltage is reached, the current may increase but the voltage does not change. (sourced from http://vlab.amrita.edu)

The amount of energy attained by the photons is proportional to the voltage.

E = V q

This energy is also proportional to the frequency shown by the equation:

E = h f

3.1 Determine the slope of the graph in Q2. (2 marks)

$$\text{slope} = \frac{\text{rise}}{\text{run}} = \frac{(2.1 - 0.65)}{(6.4\times10^{14} - 3.2\times10^{14})} \quad - 1$$

$$\text{slope} = \underline{4.68\times10^{-15}} \quad - 1$$

3.2 Use the equation above to show how the slope can be used to determine Planck's Constant. (3 marks)

$$E = hf = Vq$$

$$V = \frac{hf}{q}$$

$$V = \frac{h}{q}\times f$$

$$- 1$$

$$\frac{h}{q} = \text{slope}$$

$$\text{slope} = \frac{h}{q} = 4.68\times10^{-15}$$

$$\therefore h = 4.68\times10^{-15}\times q \quad - 1$$

$$h = 4.68\times10^{-15}\times 1.60\times10^{-19}$$

$$h = \underline{7.49\times10^{-34}}\ \text{Js} \quad - 1$$

4. Identify 2 random errors in the activity and how to rectify them. (2 marks)

4.1 Any issue that shifts data in any direction.
eg heat - resistance of wires, components etc...

4.2 eg. Resistance of wires affecting current
measurements - influenced by room temp ...
Insufficient precision.

Any (2) issues + rectification.

5. Identify 2 systematic errors in the activity and how to rectify them. (2 marks)

5.1 Any measurement problem - calibration -
affecting accuracy, not reliability.

5.2 Incorrectly used equipment.
Zero error, Scale error

Any (2) issues + rectification

6. Another experiment was performed at MIT where an apparatus was used to measure the retarding voltage as per the diagram below (Source: http://web.mit.edu/lululiu/Public/pixx/not-pixx/photoelectric.pdf)

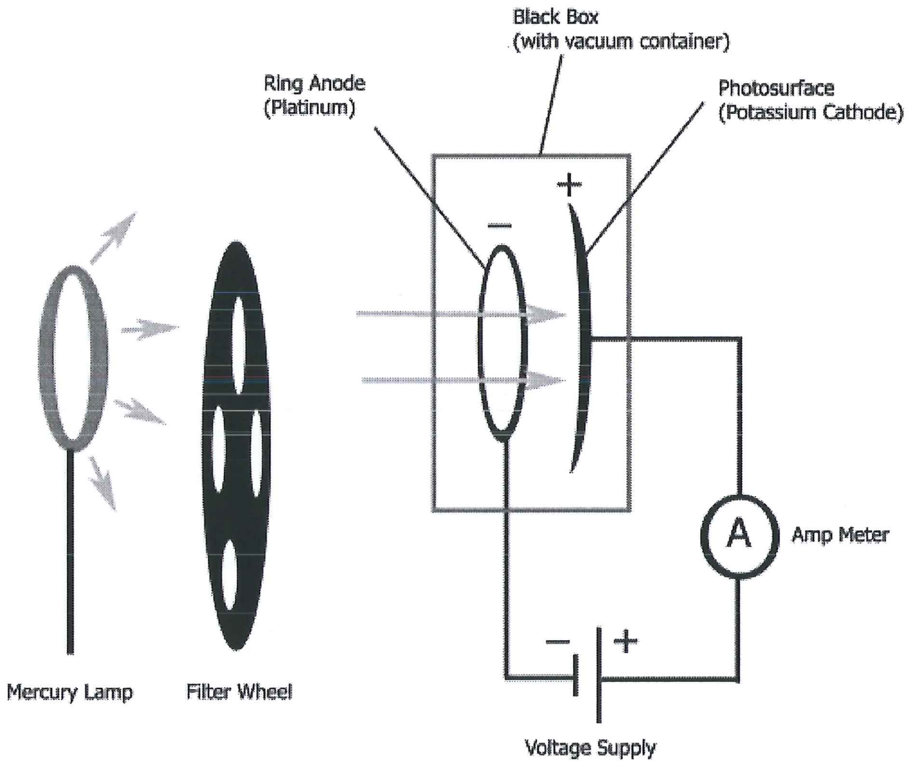


FIG. 1: Schematic of experimental setup with retarding voltage applied. Photons are incident on the photocathode and travel toward the anode to complete the circuit unless stopped by a high enough applied voltage.

An Oriel mercury lamp use was used at the same time as a filter to produce 4 wavelengths as per the table below:

Wavelengths (nm)
365.0 ± 2.0
404.7 ± 2.0
546.1 ± 2.0
577.0 ± 2.0

TABLE I: Spectrum from Oriel mercury lamp.

6.1 With reference to the photoelectric effect, what type of spectrum is produced by the lamp? (1 mark)

Emmision - line.

6.2 What does the term ± 2.0 mean? (1 mark)

True value may be ± 2.0 nm either side of the recorded value in the table.

6.3 The retarding voltage is used in conjunction with the ammeter. When the current stops at a certain voltage, this is called the retarding voltage. Explain how the retarding voltage can be used for a certain wavelength to determine Planck's Constant. (2 marks)

K_{max} = max kinetic energy of emitted e^-

hf = incoming energy

W_0 = work function for that metal → known

$K_{max} = hf - W_0$

when $V_r \times q = E_{kmax}$ → current stops.

$V_r \times q = hf$ or similar

$h = \frac{V_r \times q}{f}$

6.4 Why is the experiment conducted in a black box and has a vacuum? (2 marks)

Black box - to prevent incoming light coming in to contact with the photosurface / anode - 1

Vacuum - minimize photon / gas interactions or similar. 1

6.5 Examine the table below and complete the "Error" column: (1 mark)

Wavelength (λ)	St. Voltage (V_s)	Error (σ_{V_s})	Relative Error
365.0 nm	0.76 V		21.6%
404.7 nm	0.60 V		20.1%
546.1 nm	0.44 V		20.2%
577.0 nm	0.44 V		20.3%

6.6 At the conclusion of the report, the following statement was made:

> There are extensions on our experiment that may and should be explored in the future. Changing other variables, including intensity and the cathode/anode work function and observing its effects on the system, may provide us with further and confirming evidence on the particle nature of light.

6.6.1 Why would addressing the "intensity" be a possibility for future experiments? (1 mark)

Intensity = # of photons per second. See how it affects the calculation of h. - 1

6.6.2 What is "work function" and why would researching effects be beneficially for future experiments? (1 mark)

Work function is the minimum amount of energy needed to liberate an electron.

1

Are there any parameters that can change the work function of a material?

or similar