7 Read the passage below and answer the questions that follow.

Measuring the Planck constant

A simple experiment can be carried out in the laboratory to calculate one of the fundamental constants which is central to the tenets of quantum physics – Planck constant h.

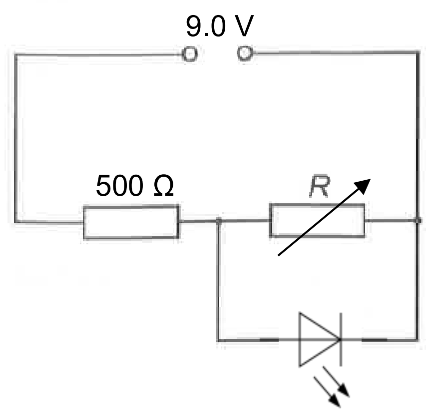


Fig. 7.1 A circuit for determining the Planck constant

A light-emitting diode (LED) is connected in parallel to a variable resistor. These are connected in series to a resistor of 500 Ω and a power supply of electromotive force (e.m.f.) of 9.0 V and of negligible internal resistance, as shown in Fig. 7.1.

The light-emitting diode (LED), which is a type of diode, emits light when a large enough potential difference, which is known as threshold p.d. V is applied across the semi-conducting diode. This effect is called electroluminescence. The electrons in the semiconductor are excited to a higher energy level. The excited electrons recombine with holes (electron deficient sites) within the semiconducting material, emitting out light. During the recombination process, the energy that the electron had previously gained is released in the form of a photon.

The threshold p.d. V is the minimum potential difference needed to start a current flowing through an LED. To measure V, the experiment is carried out in a blacked-out room where light is isolated from the LED. The resistance of the variable resistor is varied until light is detected from the LED. The threshold p.d. allows the determination of the amount of energy required to emit photons of light of wavelength λ, thus the value of Planck constant h.

(a) **(i)** Suggest why a light-emitting diode (LED) does not operate at full power with an alternating current power supply as compared to a direct current power supply.

……………………………………………………………………………………………………..

…………………………………………………………………………………………………... [1]

(ii) When the experiment is carried out in a blacked-out room, the light emitted may not be strong enough to be detected by human eye at voltages just above the threshold p.d. V. Suggest how the experiment can be improved with the use of another electrical device in the circuit to determine if the threshold p.d. V is achieved.

…………………………………………………………………..……..…….…………..

………………………………………………………………...…………..……........... [1]

(iii) The LEDs have sufficiently large resistance.

Determine the resistance R of the variable resistor needed to achieve the threshold p.d. V of 1.66 V for a green LED.

R = ………………….. Ω [2]

(b) By considering the definition of potential difference, show that the threshold p.d. V is related to the wavelength λ of the emitted light photon by the following equation:

$$V = \frac{hc}{e\lambda}$$

where c is the speed of light and e is the elementary charge

[2]

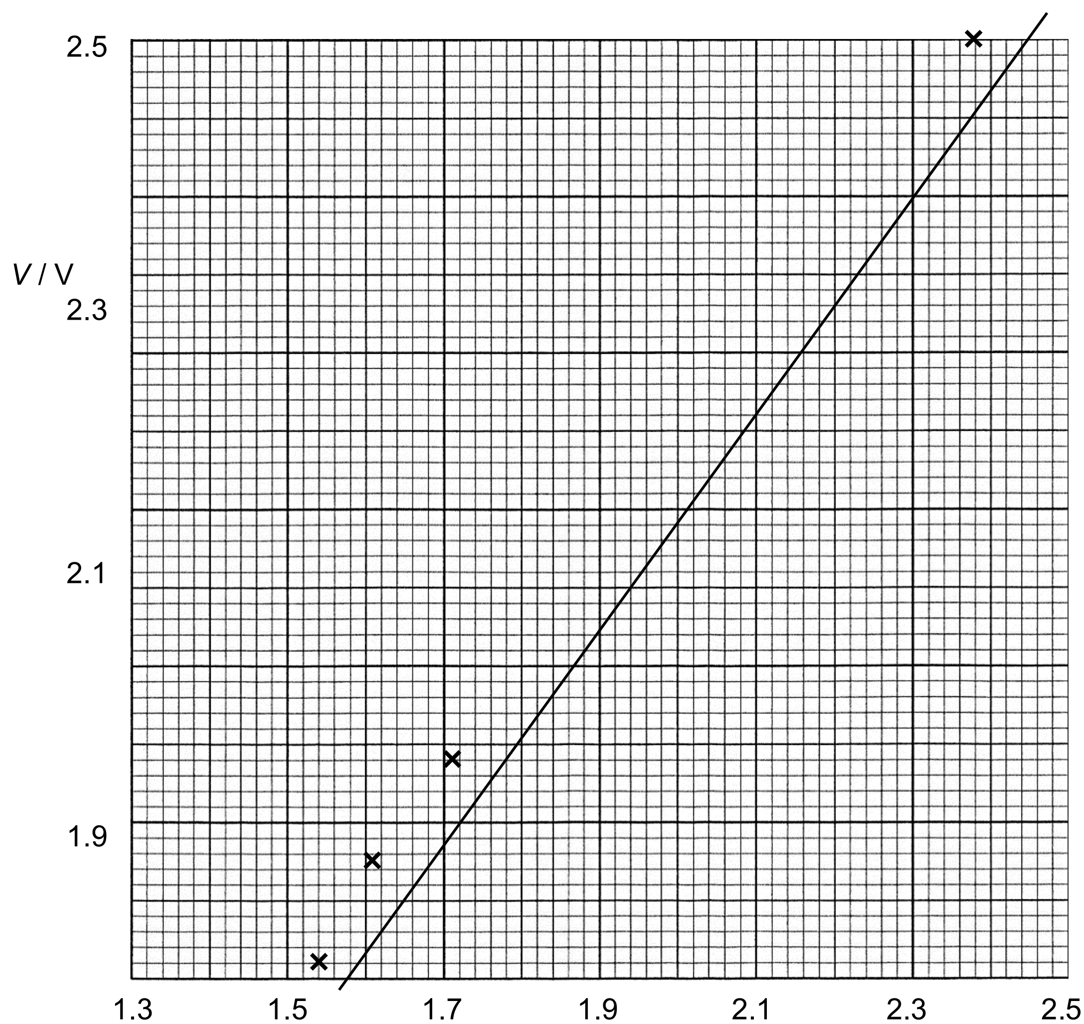
(c) The experiment is repeated with other LEDs of different wavelengths.

Data relating the wavelength λ of the light photons emitted by the LED and the threshold p.d. V needed across the LED are given for five LEDs in Fig. 7.2.

LED colour	V / V	λ / nm	$\frac{1}{\lambda}$ / 10^6 m^{-1}
Blue	2.50	420	2.38
Green	1.66	563	1.78
Yellow	1.58	585	1.71
Red 1	1.45	620	1.61
Red 2	1.32	650	1.54

Fig. 7.2

With the experimental data, the variation with $\frac{1}{\lambda}$ of V is shown in Fig. 7.3.



$\frac{1}{\lambda}$ / 10^6 m^{-1}

Fig. 7.3

(i) Determine the gradient of the line that is drawn in Fig. 7.3.

gradient = …………………... [2]

(ii) Determine the value of Planck constant h.

h = ………………….. J s [1]

(d) In reality, the best-fit line drawn does not go through the origin as theorised.

Suggest any reason for the discrepancy.

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……………………………………………………..…………...……….….……........... [1]

[Total: 10]