

Answer **all** questions.

Total for this question: 20 marks

- 1** You are to investigate the light emitted by a light-emitting diode.

Figure 1 shows a circuit that has been set up for you. It consists of a light-emitting diode (LED) in series with a current-limiting resistor, a variable power supply, a milliammeter and a voltmeter.

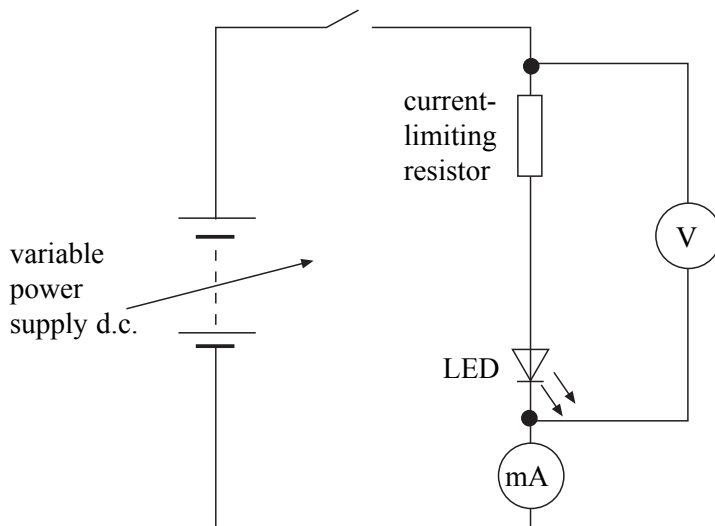


Figure 1

Close the switch in the circuit and increase the current until the LED just emits light.

- (a) Record

- (i) a value for the current flowing in the current-limiting resistor and LED,

(1 mark)

- (ii) a value for the potential difference across the LED-resistor combination.

(1 mark)

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Foundation Physics Mechanics Formulae

$$\text{moment of force} = Fd$$

$$v = u + at$$

$$s = ut + \frac{1}{2}at^2$$

$$v^2 = u^2 + 2as$$

$$s = \frac{1}{2}(u + v)t$$

$$\text{for a spring, } F = k\Delta l$$

$$\text{energy stored in a spring} = \frac{1}{2}F\Delta l = \frac{1}{2}k(\Delta l)^2$$

$$T = \frac{1}{f}$$

Foundation Physics Electricity Formulae

$$I = nAvq$$

$$\text{terminal p.d.} = E - Ir$$

$$\text{in series circuit, } R = R_1 + R_2 + R_3 + \dots$$

$$\text{in parallel circuit, } \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$$

$$\text{output voltage across } R_1 = \left(\frac{R_1}{R_1 + R_2} \right) \times \text{input voltage}$$

Waves and Nuclear Physics Formulae

$$\text{fringe spacing} = \frac{\lambda D}{d}$$

$$\text{single slit diffraction minimum } \sin \theta = \frac{\lambda}{b}$$

$$\text{diffraction grating } n\lambda = d \sin \theta$$

$$\text{Doppler shift } \frac{\Delta f}{f} = \frac{v}{c} \text{ for } v \ll c$$

$$\text{Hubble law } v = Hd$$

$$\text{radioactive decay } A = \lambda N$$

Properties of Quarks

Type of quark	Charge	Baryon number
up u	$+\frac{2}{3}e$	$+\frac{1}{3}$
down d	$-\frac{1}{3}e$	$+\frac{1}{3}$
\bar{u}	$-\frac{2}{3}e$	$-\frac{1}{3}$
\bar{d}	$+\frac{1}{3}e$	$-\frac{1}{3}$

Lepton Numbers

Particle	Lepton number L		
	L_e	L_μ	L_τ
e^-	1		
e^+	-1		
ν_e	1		
$\bar{\nu}_e$	-1		
μ^-		1	
μ^+		-1	
ν_μ		1	
$\bar{\nu}_\mu$		-1	
τ^-			1
τ^+			-1
ν_τ			1
$\bar{\nu}_\tau$			-1

Geometrical and Trigonometrical Relationships

$$\text{circumference of circle} = 2\pi r$$

$$\text{area of a circle} = \pi r^2$$

$$\text{surface area of sphere} = 4\pi r^2$$

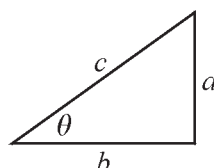
$$\text{volume of sphere} = \frac{4}{3}\pi r^3$$

$$\sin \theta = \frac{a}{c}$$

$$\cos \theta = \frac{b}{c}$$

$$\tan \theta = \frac{a}{b}$$

$$c^2 = a^2 + b^2$$



Detach this perforated page at the start of the examination.

Circular Motion and Oscillations

$$v = r\omega$$

$$a = -(2\pi f)^2 x$$

$$x = A \cos 2\pi ft$$

$$\text{maximum } a = (2\pi f)^2 A$$

$$\text{maximum } v = 2\pi f A$$

$$\text{for a mass-spring system, } T = 2\pi \sqrt{\frac{m}{k}}$$

$$\text{for a simple pendulum, } T = 2\pi \sqrt{\frac{l}{g}}$$

Fields and their Applications

$$\text{uniform electric field strength, } E = \frac{V}{d} = \frac{F}{Q}$$

$$\text{for a radial field, } E = \frac{kQ}{r^2}$$

$$k = \frac{1}{4\pi\epsilon_0}$$

$$g = \frac{F}{m}$$

$$g = \frac{GM}{r^2}$$

$$\text{for point masses, } \Delta E_p = GM_1 M_2 \left(\frac{1}{r_1} - \frac{1}{r_2} \right)$$

$$\text{for point charges, } \Delta E_p = kQ_1 Q_2 \left(\frac{1}{r_1} - \frac{1}{r_2} \right)$$

$$\text{for a straight wire, } F = BIl$$

$$\text{for a moving charge, } F = BQv$$

$$\phi = BA$$

$$\text{induced emf} = \frac{\Delta(N\phi)}{t}$$

$$E = mc^2$$

Temperature and Molecular Kinetic Theory

$$T/\text{K} = \frac{(pV)_T}{(pV)_{tr}} \times 273.16$$

$$pV = \frac{1}{3} Nm \langle c^2 \rangle$$

$$\text{energy of a molecule} = \frac{3}{2} kT$$

Heating and Working

$$\Delta U = Q + W$$

$$Q = mc\Delta\theta$$

$$Q = ml$$

$$P = Fv$$

$$\text{efficiency} = \frac{\text{useful power output}}{\text{power input}}$$

$$\text{work done on gas} = p\Delta V$$

$$\text{work done on a solid} = \frac{1}{2} F\Delta l$$

$$\text{stress} = \frac{F}{A}$$

$$\text{strain} = \frac{\Delta l}{l}$$

$$\text{Young modulus} = \frac{\text{stress}}{\text{strain}}$$

Capacitance and Exponential Change

$$\text{in series, } \frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$\text{in parallel, } C = C_1 + C_2$$

$$\text{energy stored by capacitor} = \frac{1}{2} QV$$

$$\text{parallel plate capacitance, } C = \frac{\epsilon_0 \epsilon_r A}{d}$$

$$Q = Q_0 e^{-t/RC}$$

$$\text{time constant} = RC$$

$$\text{time to halve} = 0.69 RC$$

$$N = N_0 e^{-\lambda t}$$

$$A = A_0 e^{-\lambda t}$$

$$\text{half-life, } t_{\frac{1}{2}} = \frac{0.69}{\lambda}$$

Momentum and Quantum Phenomena

$$Ft = \Delta(mv)$$

$$E = hf$$

$$hf = \Phi + E_{k(\text{max})}$$

$$hf = E_2 - E_1$$

(b) Assuming the charge on the electron, $e = -1.6 \times 10^{-19} \text{ C}$, calculate

(i) the energy lost by **one** electron as it moves through the LED-resistor combination,

(2 marks)

(ii) the number of electrons flowing through the LED every second.

(2 marks)

(c) As each electron moves through the LED, it donates **some** of its energy to a single photon of light that is released by the LED.

Suggest another mechanism by which an electron may lose energy as it moves through the LED.

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(1 mark)

- (d) In another experiment, four LEDs, each emitting a different colour of light were tested. The experimenter collected data of the minimum potential difference, V_{\min} , at which each LED began to emit light and the wavelength, λ , of the emitted light. **Table 1** shows these data of V_{\min} and λ .

<i>this column is for your convenience in answering parts (i) and (ii)</i>		
V_{\min}/V	λ/nm	
2.00	626	
2.10	592	
2.45	505	
2.65	470	

Table 1

The energy, E , of a photon is related to its frequency, f , by the equation

$$E = hf$$

where h is the Planck constant.

- (i) Use a **non-graphical** method to show that V_{\min} is inversely proportional to λ . Make your reasoning clear.

(3 marks)

- (ii) V_{\min} is given by

$$V_{\min} = \frac{hc}{e\lambda}$$

where c is the speed of electromagnetic radiation, $3.00 \times 10^8 \text{ m s}^{-1}$, and h is the Planck constant.

Calculate the value of h suggested by the above data.

(3 marks)

Total for this question: 19 marks

- 2 You are to investigate the fundamental frequency of a stationary wave on a stretched wire.

Figure 2 shows the arrangement that has been set up for you. A source of alternating current is connected to a wire under tension. The wire passes between the opposite poles of two magnets.

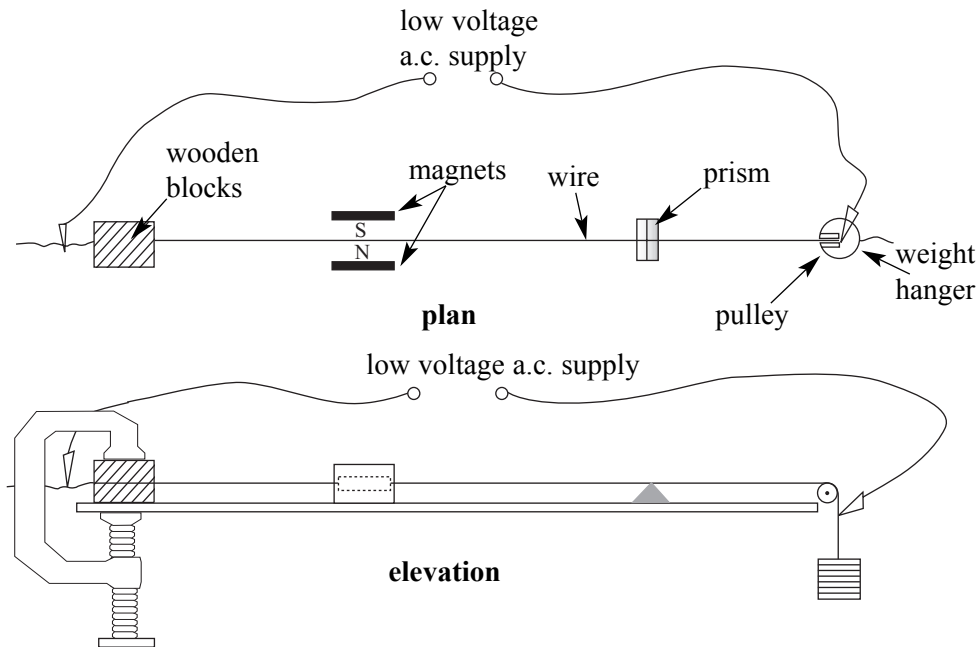


Figure 2

- (a) Switch on the low voltage a.c. supply and alter the length of the stretched wire by adjusting the position of the small moveable prism so that the wire oscillates with as large an amplitude as possible in a single loop.
- (i) Collect data in order to measure the oscillating length, l , in metres of wire. Record your data in the space below.

(1 mark)

SWITCH OFF THE POWER SUPPLY BEFORE YOU CONTINUE.

- (ii) State the frequency of the mains supply.

State the tension in the wire.
gravitational field strength, $g = 9.81 \text{ N kg}^{-1}$

(2 marks)

- (iii) The tension,
- T
- , in the wire is related to
- l
- and the frequency of oscillation,
- f
- , by

$$f = \frac{1}{2l} \sqrt{\frac{T}{\mu}}$$

where μ is the mass in kg of a one metre length of the wire.

Calculate μ .

(1 mark)

- (b) (i) Estimate the absolute uncertainty in your measurement of
- l
- .

(1 mark)

- (ii) Assume that the value of
- f
- is exact and that
- T
- is known to the nearest 0.01 N. Calculate the percentage uncertainty in your value of
- μ
- .

(3 marks)

- (d) The equation stated in part (a)(iii) suggests that f^2 is directly proportional to T . Explain how you would modify the experiment you carried out in part (a) in order to test this proportionality. Give clear details of the analysis you would carry out.

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(4 marks)

19

END OF QUESTIONS