



CANDIDATE
NAME

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CIVICS
GROUP

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REGISTRATION
NUMBER

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PHYSICS

9478/02

Paper 2 Structured Questions

2nd September 2026

2 hours

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and registration number on all the work you hand in.
The use of an approved scientific calculator is expected, where appropriate.
Answer **all** questions.

Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use paper clips, highlighters, glue or correction fluid.
The number of marks is given in brackets [] at the end of each question or part question.

For Examiner's Use	
Q1	8
Q2	8
Q3	7
Q4	9
Q5	7
Q6	11
Q7	6
Q8	19
s.f.	
P2 Total	75

This document consists of **22** printed pages and **2** blank page.

Data

speed of light in free space

$$c = 3.00 \times 10^8 \text{ m s}^{-1}$$

permeability of free space

$$\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$$

permittivity of free space

$$\varepsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$$

$$\left(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^9 \text{ m F}^{-1} \right)$$

elementary charge,

$$e = 1.60 \times 10^{-19} \text{ C}$$

the Planck constant,

$$h = 6.63 \times 10^{-34} \text{ J s}$$

unified atomic mass constant,

$$u = 1.66 \times 10^{-27} \text{ kg}$$

rest mass of electron,

$$m_e = 9.11 \times 10^{-31} \text{ kg}$$

rest mass of proton,

$$m_p = 1.67 \times 10^{-27} \text{ kg}$$

molar gas constant,

$$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$$

the Avogadro constant,

$$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$$

the Boltzmann constant,

$$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$$

gravitational constant,

$$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$$

acceleration of free fall,

$$g = 9.81 \text{ m s}^{-2}$$

Formulae

uniformly accelerated motion

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

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

work done on / by a gas

$$W = p\Delta V$$

pressure

$$p = \frac{F}{A}$$

gravitational potential

$$\phi = -\frac{Gm}{r}$$

temperature

$$T / \text{K} = T / ^\circ\text{C} + 273.15$$

pressure of an ideal gas

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

mean translational kinetic energy of an ideal gas molecule

$$E = \frac{3}{2} kT$$

displacement of particle in s.h.m.

$$x = x_0 \sin \omega t$$

velocity of particle in s.h.m.

$$v = v_0 \cos \omega t = \pm \omega \sqrt{(x_0^2 - x^2)}$$

electric current

$$I = nAvq$$

resistors in series

$$R = R_1 + R_2 + \dots$$

resistors in parallel

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$$

capacitors in series

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \dots$$

capacitors in parallel

$$C = C_1 + C_2 + \dots$$

energy in a capacitor

$$U = \frac{1}{2} QV = \frac{1}{2} \frac{Q^2}{C} = \frac{1}{2} CV^2$$

charging a capacitor

$$Q = Q_0 \left[1 - e^{-\frac{t}{\tau}} \right]$$

discharging a capacitor

$$Q = Q_0 e^{-\frac{t}{\tau}}$$

RC time constant

$$\tau = RC$$

electric potential

$$V = \frac{Q}{4\pi\epsilon_0 r}$$

alternating current/voltage

$$x = x_0 \sin \omega t$$

magnetic flux density due to a long straight wire

$$B = \frac{\mu_0 I}{2\pi d}$$

magnetic flux density due to a flat circular coil

$$B = \frac{\mu_0 NI}{2r}$$

magnetic flux density due to a long solenoid

$$B = \mu_0 nI$$

energy states for quantum particle in a box

$$E_n = \frac{h^2}{8mL^2} n^2$$

radioactive decay

$$x = x_0 e^{-\lambda t}$$

radioactive decay constant

$$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$$

Answer **all** the questions in the spaces provided

- 1 A ball falls vertically in air from rest. The variation with time t of distance d moved by the ball is shown in Fig. 1.1.

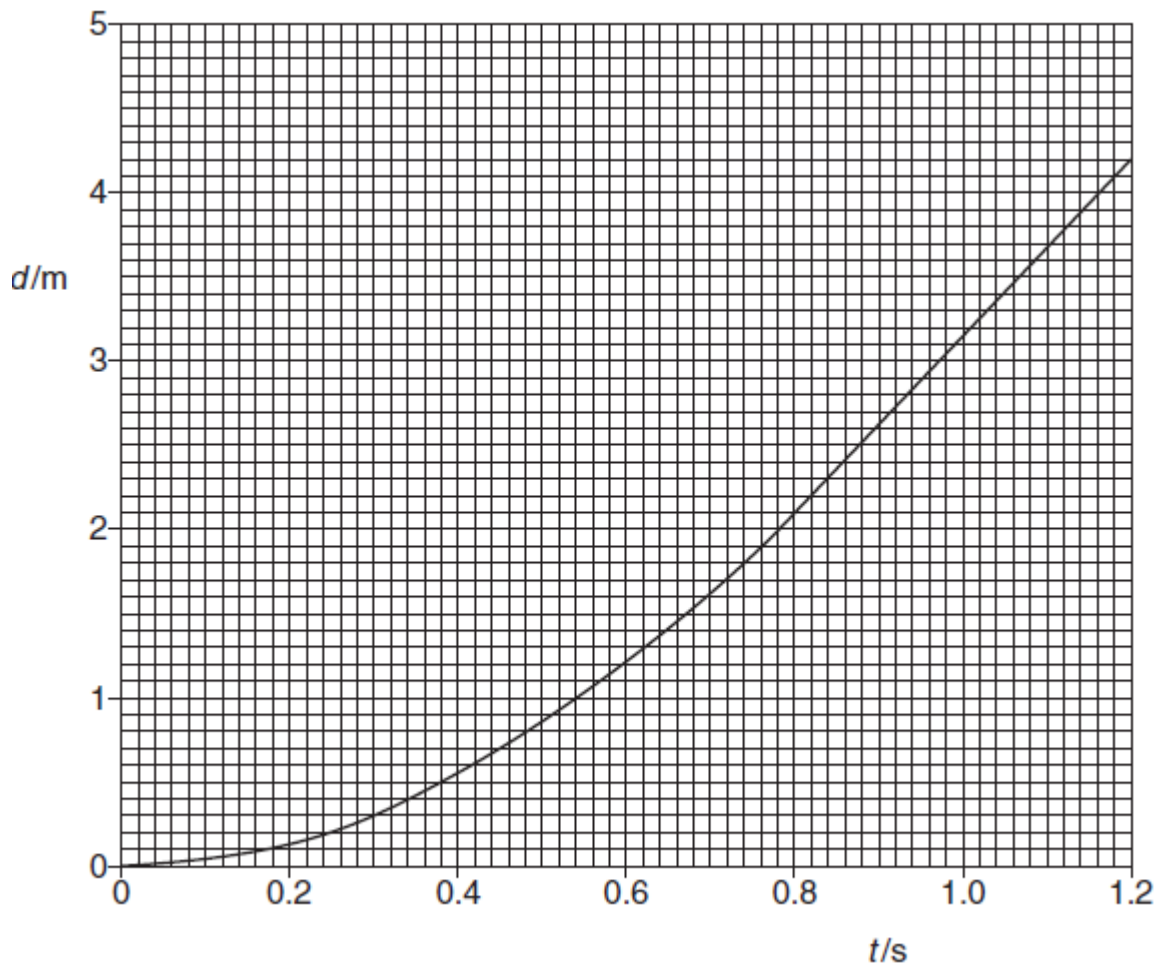


Fig. 1.1

- (a) With reference to Fig. 1.1,

1. explain how it can be deduced that the ball is initially at rest,

.....

 [1]

2. explain, with reference to forces acting on the ball, why air resistance is not negligible.

.....

 [2]

- (b) Use Fig. 1.1 to determine the speed of the ball at a time of 0.40 s after it has been released.

speed = ... m s^{-1} [2]

- (c) The same ball is now tossed vertically into the air with velocity V to reach a maximum displacement of 2.0 m.

Sketch a graph on the axis below to show the variation with time t of the velocity v of the ball from when it is tossed to when it returns to its original position.

Mark the instant at which the magnitude of acceleration is $g = 9.81 \text{ m s}^{-2}$ as t_1 and the instant at which the ball returns to original position as t_2 . No further calculations are required.

[3]



[Total: 8]

- 2 (a) State Newton's second law of motion.

.....

 [1]

- (b) At a construction site, sand is allowed to fall vertically from a stationary hopper at a steady rate of 100 g s^{-1} on to a horizontal conveyor belt. The belt is driven by an electric motor and moves at a constant velocity of 5.0 cm s^{-1} as shown in Fig. 2.1.

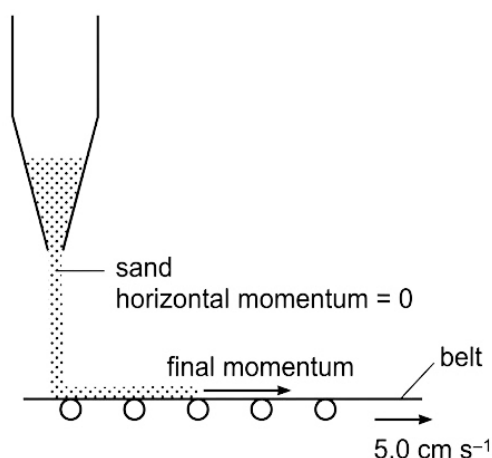


Fig. 2.1.

- (i) Using Newton's laws of motion, explain why the sand exerts a horizontal force on the conveyor belt.

.....

 [2]

- (ii) Show that the magnitude of this horizontal component of force exerted on the sand by the belt is 0.0050 N .

[1]

(iii) Determine

1. the rate at which the motor does work, P , to keep the belt moving at constant velocity, and

$$P = \dots\dots\dots \text{ W [1]}$$

2. the rate at which the sand gains kinetic energy, K .

$$K = \dots\dots\dots \text{ W [1]}$$

(iv) State the type of collision between the sand and the conveyor belt. With reference to your answers in (b)(iii), describe the energy transfers that occur as the sand is brought to the speed of the belt.

.....

 [2]

[Total: 8]

- 3 (a) Define *electric potential* at a point in an electric field.

.....
[1]

- (b) Two charged spheres of radius 2.0 mm are held 4.00 cm apart (centre-to-centre). Fig. 3.1 shows the variation with displacement x , of the electric potential V , between the two charged spheres. The charge on each sphere may be considered to be concentrated at its centre.

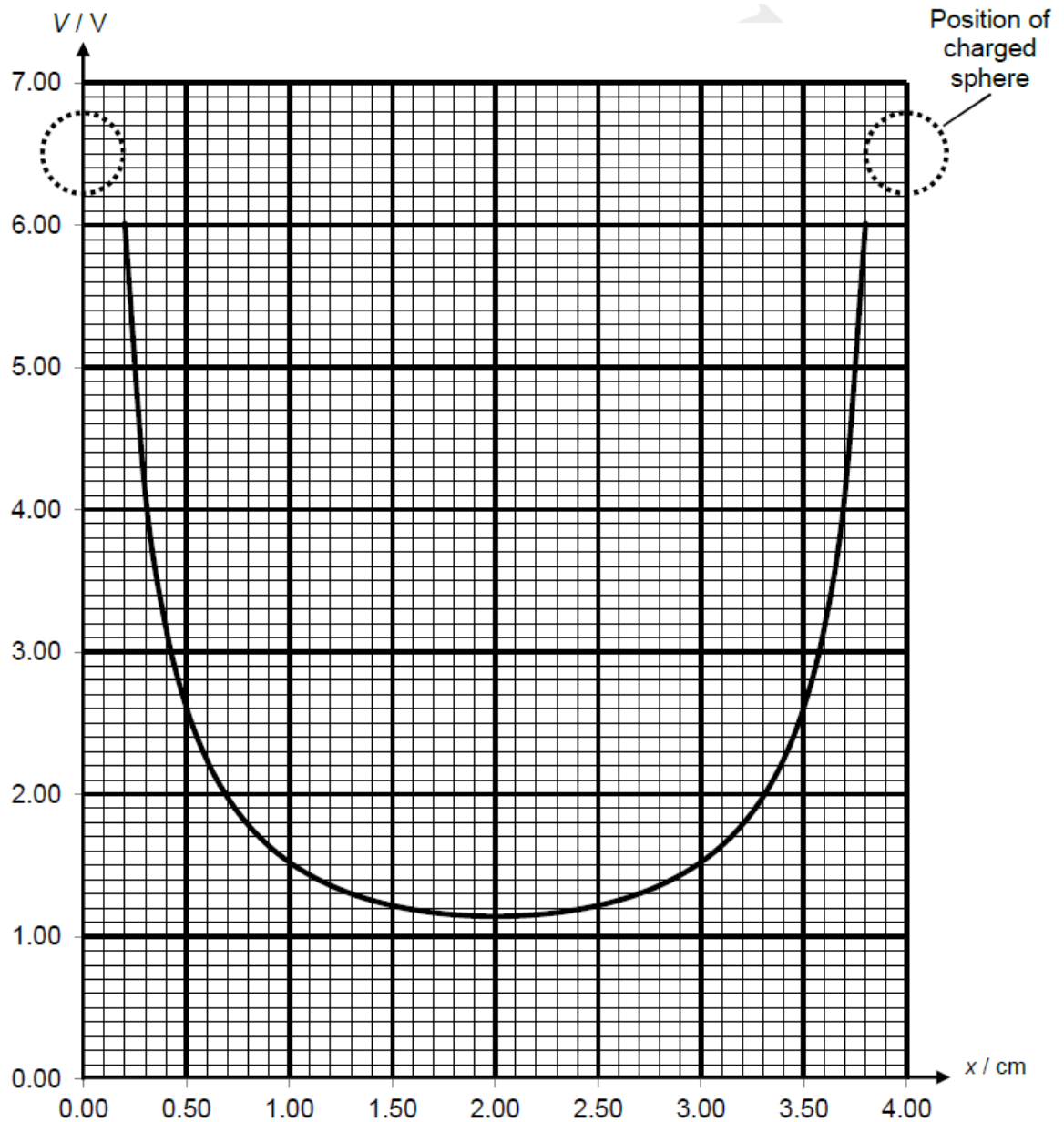


Fig. 3.1

- (i) Using Fig. 3.1, determine the magnitude of the electric field strength at $x = 1.00$ cm and state its direction.

electric field strength = ... N C^{-1} [2]

direction: [1]

- (ii) Explain, using Fig. 3.1, how it can be deduced that the charges on the two spheres are equal.

.....
[1]

- (iii) Using Fig. 3.1, determine the charge on each sphere.

charge = ... C [2]
 [Total: 7]

- 4 (a) Define the resistance of a circuit component.

.....
 [1]

- (b) With reference to energy transfers, distinguish between electromotive force (e.m.f.) and potential difference (p.d).

.....

 [1]

- (c) Fig. 4.1 shows a circuit containing cell of e.m.f. E with internal resistance r , a fixed resistor with resistance R_1 and a variable resistor with resistance R_2 .

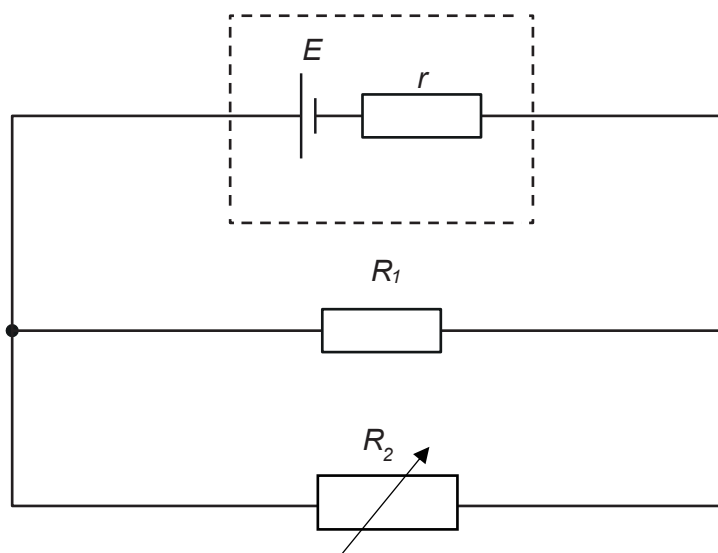


Fig. 4.1

With reference to the current in the cell, explain what happens to the current through R_1 when R_2 increases.

.....

 [3]

- (d) The e.m.f. E of the cell in Fig. 4.1 is 1.40 V. The internal resistance r of the cell is 0.13 Ω .
 R_1 has a resistance of 5.50 Ω .

At a particular resistance R_2 , the current through R_1 is measured to be 0.220 A.

Determine

- (i) the current through the cell

current = ... A [2]

- (ii) the resistance R_2 .

R_2 = ... Ω [2]

[Total: 9]

- 5 A double slit consists of two parallel slits, each of width 0.12 mm. The separation of the slits is 2.8 mm, as illustrated in Fig. 5.1.

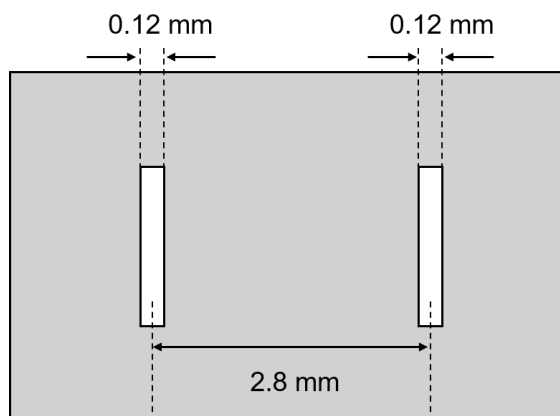


Fig. 5.1 (not to scale)

Parallel light of wavelength 670 nm is incident normally on the double slit.

A screen is placed parallel to the plane of the double slit at a distance of 1.2 m from the slits, as illustrated in Fig. 5.2

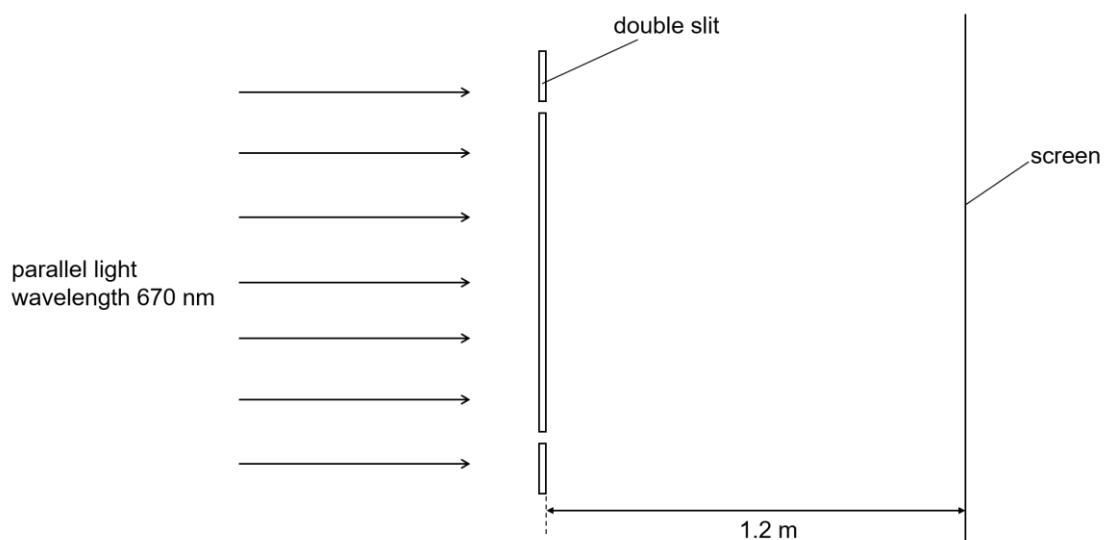


Fig. 5.2 (not to scale)

- (a) Initially, one of the two slits is covered.

Show that the width of the central fringe for a single-slit diffraction pattern on the screen is 13.4 mm.

(b) Both slits are now uncovered.

- (i)** Use the Rayleigh criterion to explain whether the diffraction patterns produced by the two slits are seen on the screen as being separated.

.....

 [2]

- (ii)** Using your answer in **(a)**, estimate the number of fringes within the central bright maximum.

number = ... [2]

[Total: 7]

- 6 (a) State Faraday's law of electromagnetic induction.

.....

 [1]

- (b) An aircraft is flying horizontally at constant speed v through the Earth's magnetic field, as shown in Fig. 6.1.

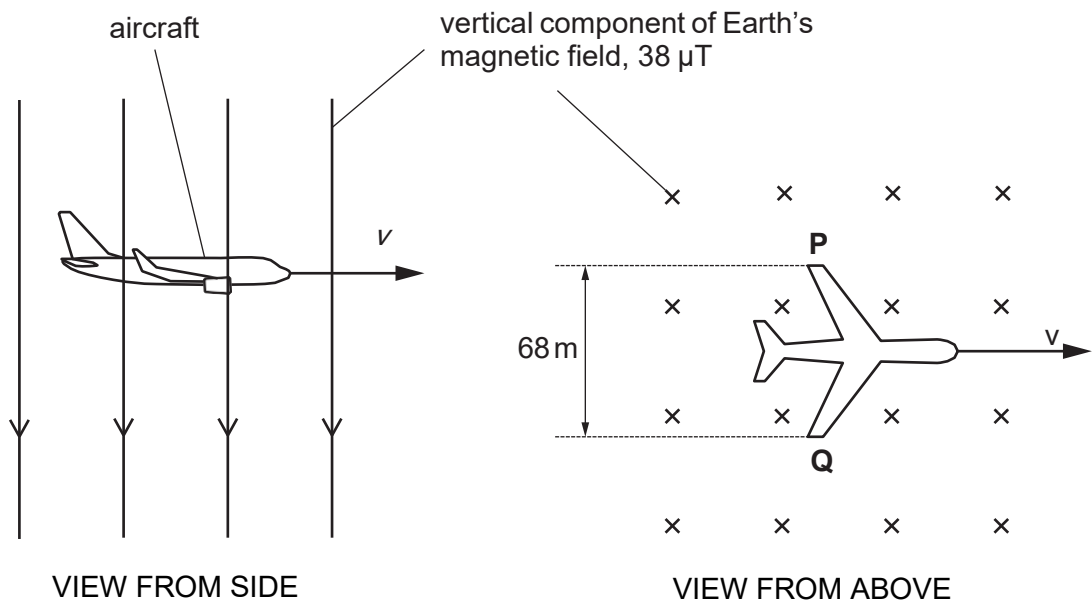


Fig. 6.1

At the location of the aircraft, the vertical component of the Earth's magnetic field is $38 \mu\text{T}$ towards the ground.

The distance between the wingtips P and Q of the aircraft is 68 m.

As the aircraft moves through the magnetic field, an electromotive force (e.m.f.) of 0.55 V is induced between the wingtips P and Q.

- (i) Calculate the magnetic flux cut by the wings of the aircraft in a time of 14 s.
 Provide a suitable unit with your answer.

magnetic flux = ...

unit = ... [2]

- (ii) Determine the area of flux cut by the wings in a time of 14 s.

area = ... m^2 [1]

- (iii) Use your answer in (b)(ii) or otherwise to determine the speed v of the aircraft.

$v = \dots\dots\dots \text{m s}^{-1}$ [2]

- (iv) Using Fleming's Left Hand Rule, explain clearly why the wingtip P is at the higher potential compared to wingtip Q.

.....

.....

.....

.....

..... [2]

- (c) A sinusoidal power source with alternating voltage V varies with time t according to

$$V = 16 \cos(38\pi t)$$

where V is in V and t is in s.

The circuit connection with the two resistors R_1 and R_2 each having resistance R and an ideal diode is shown in Fig. 6.2

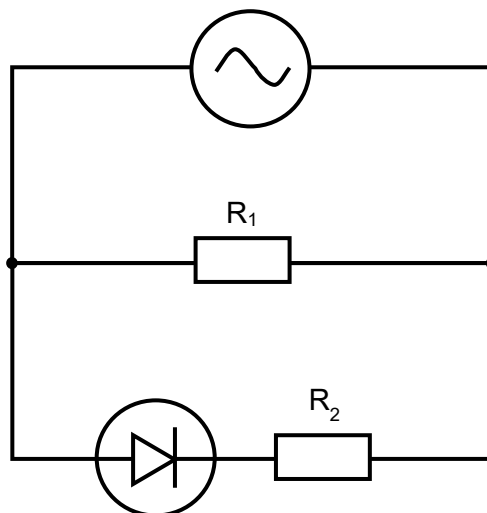


Fig. 6.2

- (i) Fill in the missing values in Table 6.1.

resistor	r.m.s. voltage, $V_{\text{r.m.s.}} / \text{V}$	peak voltage, V_0 / V
R_1		
R_2		

Table 6.1

[1]

- (ii) Compare the r.m.s voltages and peak voltages across resistors R_1 and R_2 , and explain your answers.

.....

.....

.....

.....

.....

..... [2]

[Total: 11]

- 7 Radium-224 has a half-life of 3.6 days. A freshly prepared sample of Radium-224 has an activity of 1.6×10^{14} Bq.

(a) Explain what is meant by the term *half-life*.

.....
[1]

(b) (i) Show that the mass of the freshly prepared sample is 27 mg. [2]

(ii) A 5.0 mg portion is extracted from the freshly prepared sample. After a period of time, the activity of this portion is found to be 2.1×10^{10} Bq.

Determine the time elapsed since the portion was extracted.

time elapsed = ... days [3]

[Total: 6]

8 Read the passage and answer the questions that follow.

The human heart beats in response to electrical impulses generated by specialised cells in the heart itself. In a healthy heart, these impulses travel through a natural pathway that coordinates each contraction, driving the heart to beat between 60 and 100 times per minute at rest, as shown in Fig. 8.1 below.

In a condition known as complete heart block, this pathway is disrupted. The lower chambers no longer receive reliable electrical signals, causing the heart to beat slowly and erratically, sometimes fewer than 40 times per minute. This is insufficient to sustain blood circulation, and the patient faces the risk of sudden cardiac arrest.

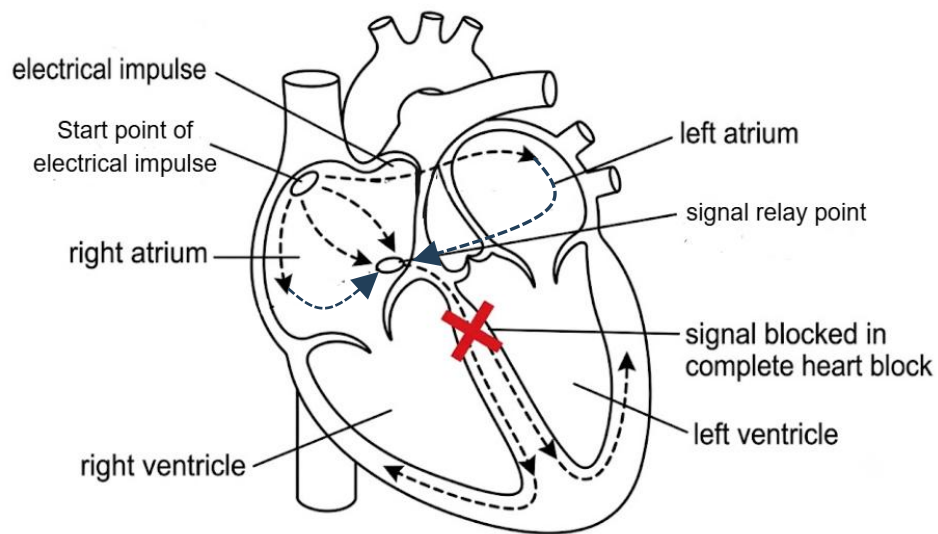


Fig. 8.1

In 1960, electrical engineer Wilson Greatbatch and surgeon William Chardack implanted the world's first fully implantable pacemaker into a human patient.

The device delivered regular electrical pulses to one of the heart's lower pumping chambers (the ventricles) via electrode leads, bypassing the blocked pathway and restoring a steady heart rate of 60 beats per minute. The timing of these pulses was controlled by a simple RC circuit known as a relaxation oscillator.

The pacemaker's timing circuit (RC Relaxation Oscillator) consists of a battery of electromotive force (e.m.f.) $\mathcal{E}$ and a resistor R connected in series, with a capacitor C connected across the output. A voltage-controlled switch S is connected to switch between charging and discharging of the capacitor C .

A simplified circuit diagram is shown in Fig. 8.2 below:

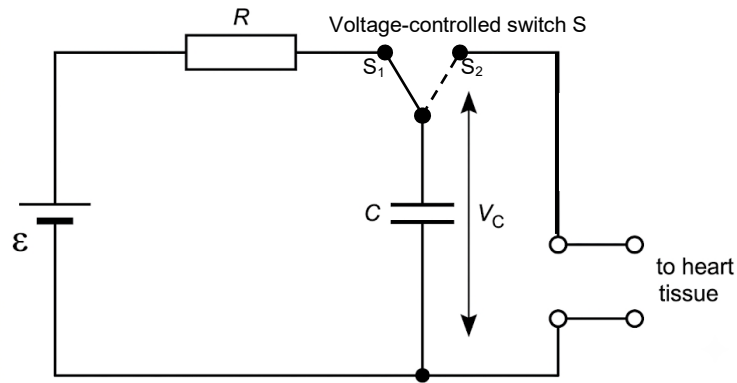


Fig. 8.2

The voltage-controlled switch S responds to the potential difference V_C across the capacitor. It is triggered to S_2 when V_C rises to an upper threshold voltage V_b , and switches to S_1 again when V_C falls to a lower threshold voltage V_s , where $V_s < V_b < \varepsilon$.

When switch S is at S_1 , the battery charges the capacitor through the resistor.

When V_C rises to V_b , the switch triggers to S_2 almost instantaneously, and the capacitor discharges rapidly through the heart tissue. This brief discharge delivers a voltage pulse to the heart tissue via output electrodes.

During this discharge, when V_C falls to V_s , the switch returns to S_1 and the capacitor begins recharging. The cycle then repeats, generating a regular train of pulses.

The resulting variation of V_C with time t is shown in Fig. 8.3.

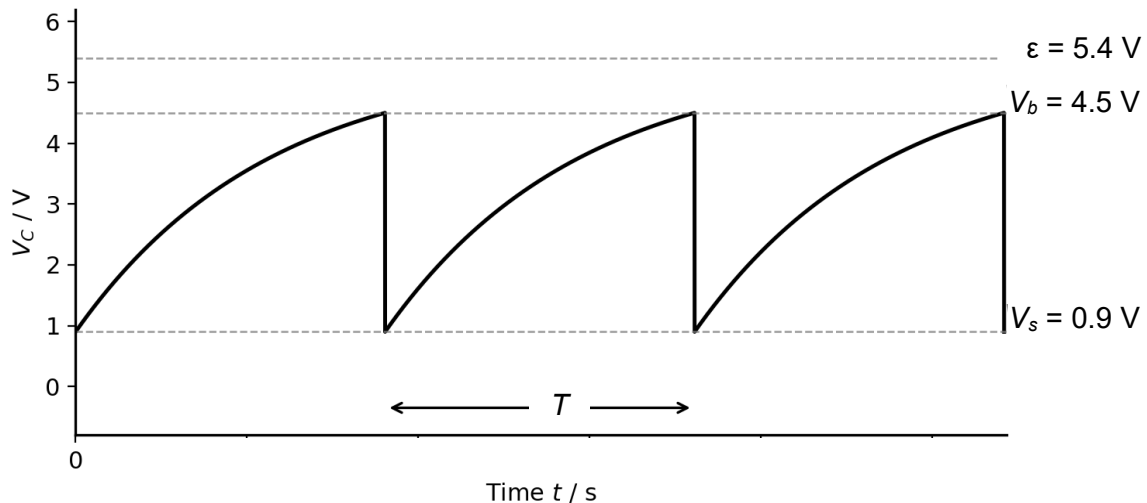


Fig. 8.3

Because the discharge time is very short compared to the charging time, the period T of the oscillation is approximately equal to the time taken for V_C to charge from V_s to V_b . It can be shown that:

$$T \approx RC \ln \left(\frac{\varepsilon - V_s}{\varepsilon - V_b} \right)$$

- (a) (i) The component values used in the Greatbatch pacemaker are given in the table below.

Component	Value
Timing resistor R	18 k Ω
Timing capacitor C	33 μ F

Hence, determine the pacing frequency of the Greatbatch pacemaker and comment whether this value is appropriate for a resting patient. State one limitation of this fixed-rate pacemaker.

Comment:

.....

Limitation:

.....[4]

- (ii) The resistance of the heart tissue is approximately 500 Ω . By calculating the charging and discharging time constants τ , comment on whether the assumption that the discharge is almost instantaneous is justified.

.....

.....[2]

- (b) Each time the switch closes, the capacitor discharges from V_b to V_s , delivering a pulse of energy to the heart tissue.

(i) Show that the energy delivered per pulse is $3.21 \times 10^{-4} \text{ J}$. [2]

(ii) Hence, using your answer to (a)(i) and (b)(i), calculate average power delivered to the heart tissue in one charging-discharging cycle.

average power = ... W [2]

(iii) The average power delivered during each discharge pulse is approximately 12.1 mW.

Explain why the average power delivered to the heart tissue in a charging-discharging cycle is much lower than the average power delivered during a discharge pulse.

.....

[2]

- (c) The capacity of a battery is the total charge it can deliver, expressed in ampere-hours (Ah), where $1 \text{ Ah} = 3600 \text{ C}$.

The original mercury-zinc battery used in this pacemaker had a capacity of 1.2 Ah at an e.m.f. of 5.4 V.

- (i) Calculate the total electrical energy stored in the mercury-zinc battery.

energy = ... J [2]

- (ii) Estimate the expected operational lifespan of the battery in years. Comment on your result.

.....

[2]

- (d) Over many years of operation, the capacitance of the timing capacitor will gradually increase due to physical degradation of its dielectric material.

- (i) Explain qualitatively why that would result in a decrease in pacing frequency.

.....

[1]

- (ii) Suggest, with reasoning, whether a slow decrease in pacing frequency over time would be dangerous for a patient with complete heart block.

.....

[2]

[Total: 19]

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