



## 2

**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	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$
	$(\frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \text{ m F}^{-1})$
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 unit	$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$
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	$W = p\Delta V$
gravitational potential	$\phi = -\frac{Gm}{r}$
hydrostatic pressure	$p = \rho gh$
pressure of an ideal gas	$p = \frac{1}{3} \frac{Nm}{V} \langle c^2 \rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0^2 - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\epsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \dots$
capacitors in parallel	$C = C_1 + C_2 + \dots$
energy of charged capacitor	$W = \frac{1}{2} QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \dots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \dots$
Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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

1 (a) State

(i) what may be deduced from the difference in the temperatures of two objects,

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

(ii) the basic principle by which temperature is measured.

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

(b) By reference to your answer in (a)(ii), explain why two thermometers may not give the same temperature reading for an object.

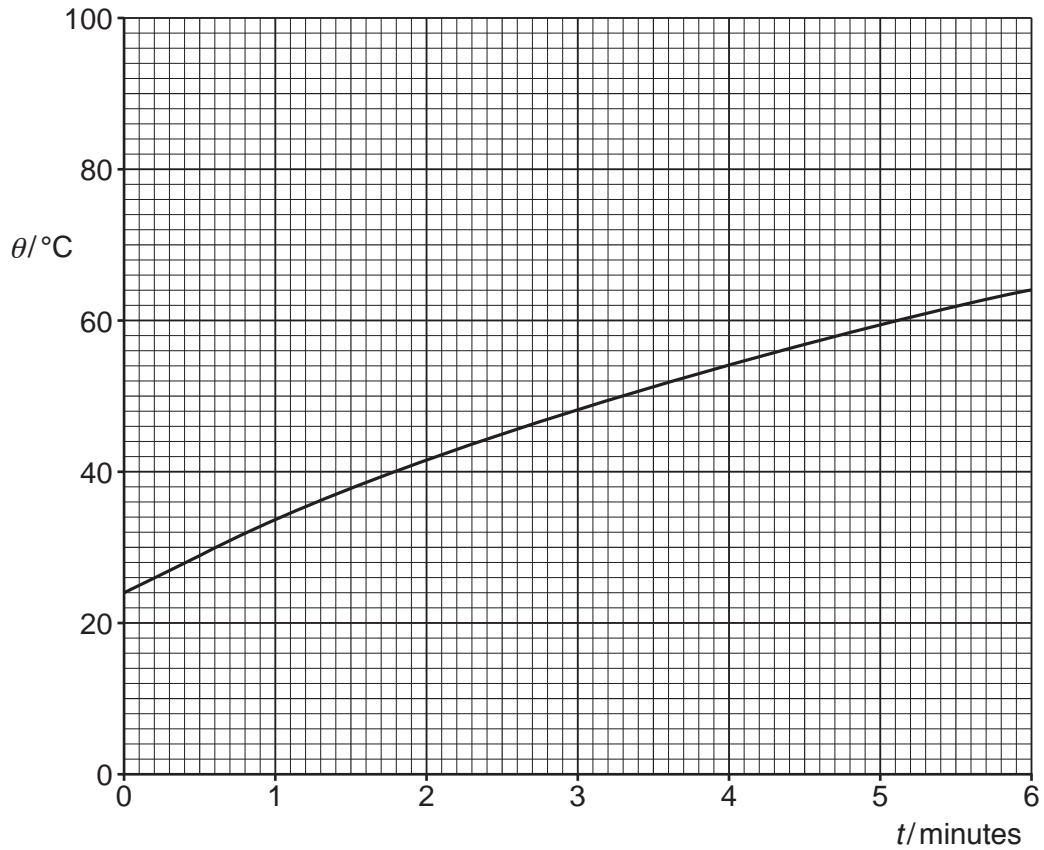
.....  
 .....  
 ..... [2]

(c) A block of aluminium of mass 670g is heated at a constant rate of 95W for 6.0 minutes. The specific heat capacity of aluminium is  $910 \text{ J kg}^{-1} \text{ K}^{-1}$ . The initial temperature of the block is  $24^\circ\text{C}$ .

(i) Assuming that no thermal energy is lost to the surroundings, show that the final temperature of the block is  $80^\circ\text{C}$ .

[3]

- (ii) In practice, there are energy losses to the surroundings.  
The actual variation with time  $t$  of the temperature  $\theta$  of the block is shown in Fig. 1.1.



**Fig. 1.1**

1. Use the information in (i) to draw, on Fig. 1.1, a line to represent the temperature of the block, assuming no energy losses to the surroundings. [1]
2. Using Fig. 1.1, calculate the total energy loss to the surroundings during the heating process.

energy loss = ..... J [2]

[Total: 10]

- 2 (a) State, by reference to simple harmonic motion, what is meant by *angular frequency*.

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

- (b) A thin metal strip is clamped at one end so that it is horizontal. A load of mass  $M$  is attached to its free end. The load causes a displacement  $s$  of the end of the strip, as shown in Fig. 2.1.

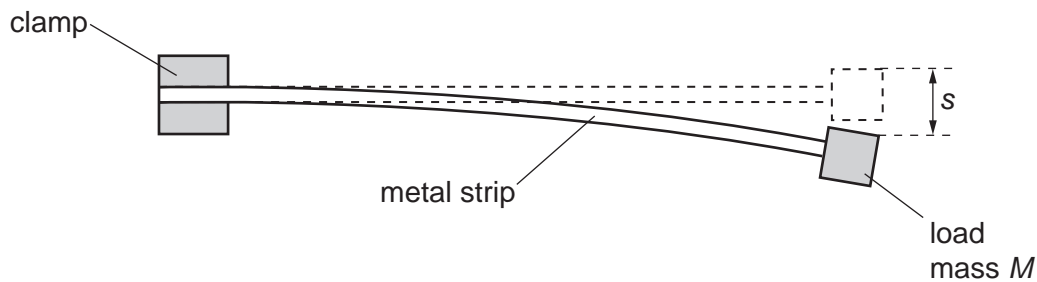


Fig. 2.1

The load is displaced vertically and then released. The load oscillates. The variation with the acceleration  $a$  of the displacement  $s$  of the load is shown in Fig. 2.2.

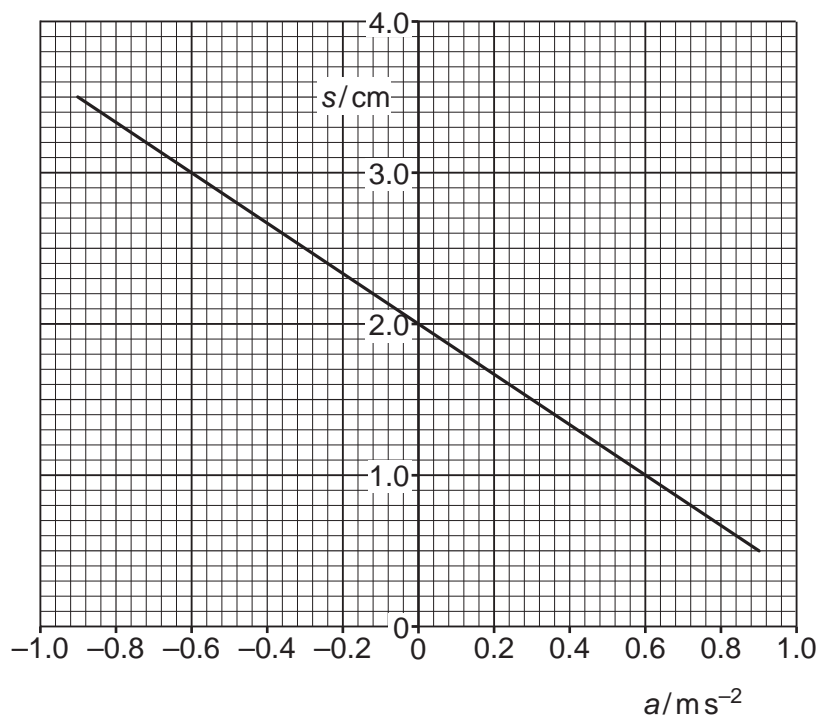


Fig. 2.2

(i) Use Fig. 2.2 to determine

1. the displacement of the load before it is made to oscillate,

displacement = ..... cm

2. the amplitude of the oscillations of the load.

amplitude = ..... cm  
[2]

(ii) Show that the load is undergoing simple harmonic motion.

.....  
.....  
.....  
..... [3]

(iii) Calculate the frequency of oscillation of the load.

frequency = ..... Hz [3]

[Total: 9]

- 3 (a) Define *gravitational field strength*.

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

- (b) Explain why, for changes in vertical position of a point mass near the Earth's surface, the gravitational field strength may be considered to be constant.

.....  
 .....  
 .....  
 ..... [2]

- (c) The orbit of the Earth about the Sun is approximately circular with a radius of  $1.5 \times 10^8$  km. The time period of the orbit is 365 days.

Determine a value for the mass  $M$  of the Sun. Explain your working.

$M =$  ..... kg [5]

[Total: 8]



- 4 A coaxial cable is frequently used to connect an aerial to a television receiver. Such a cable is illustrated in Fig. 4.1.

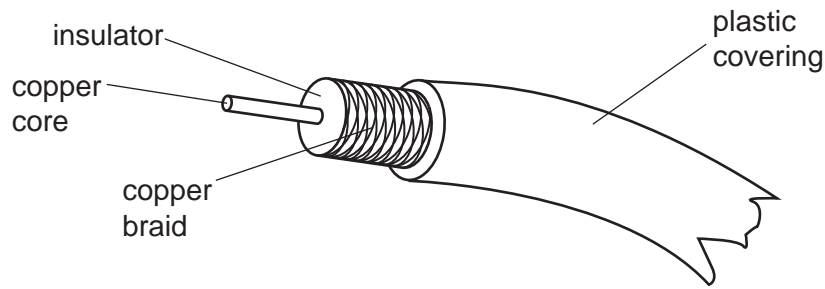


Fig. 4.1

- (a) Suggest two functions of the copper braid.

1. ....  
 .....  
 2. ....  
 ..... [2]

- (b) Suggest two reasons why a wire pair is not usually used to connect the aerial to the receiver.

1. ....  
 .....  
 2. ....  
 ..... [2]

- (c) The coaxial cable connecting an aerial to a receiver has length 14 m.  
 The cable has an attenuation per unit length of  $190 \text{ dB km}^{-1}$ .

Calculate the fractional **loss** in signal power during transmission of the signal along the cable.

fractional loss = ..... [4]

[Total: 8]

[Turn over

5 (a) (i) State Coulomb's law for the force between two point charges.

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

(ii) Two point charges are situated in a vacuum and separated by a distance  $R$ . The force between the charges is  $F_C$ .

On Fig. 5.1, sketch a graph to show the variation of the force  $F$  between the charges with separation  $x$  for values of  $x$  from  $x = R$  to  $x = 4R$ .

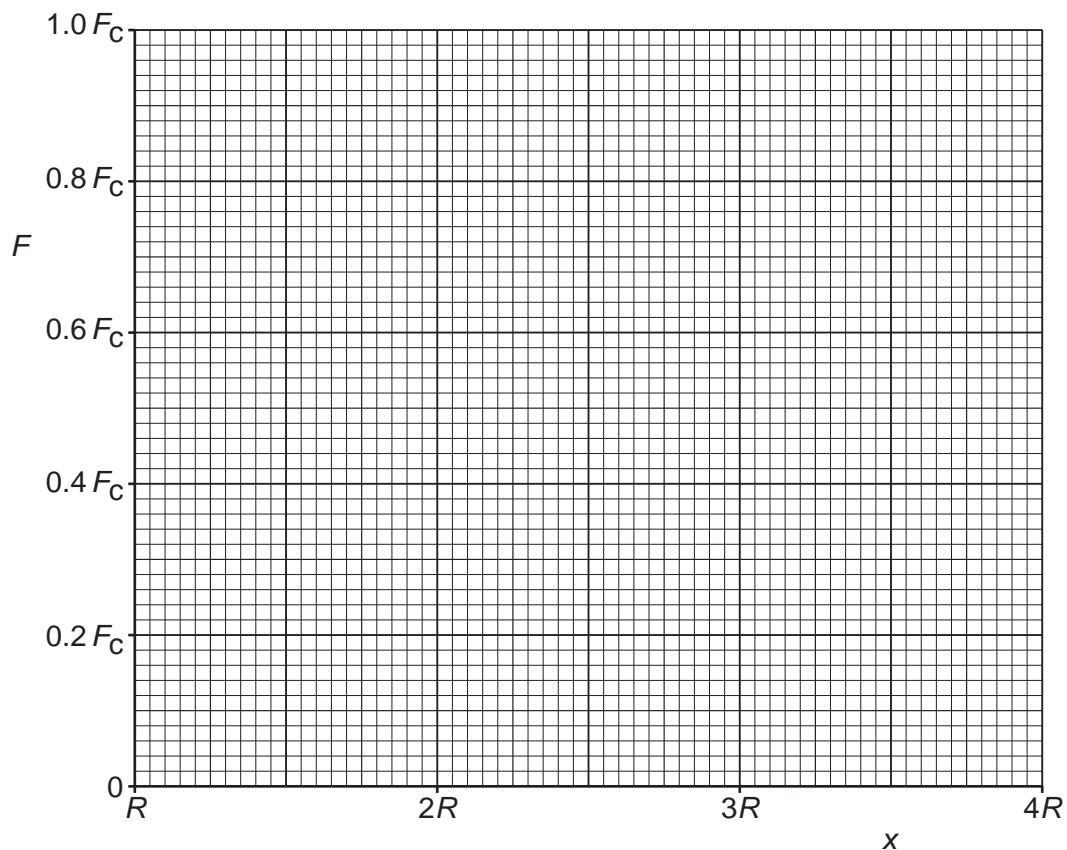


Fig. 5.1

[3]

(b) Two coils C and D are placed close to one another, as shown in Fig. 5.2.

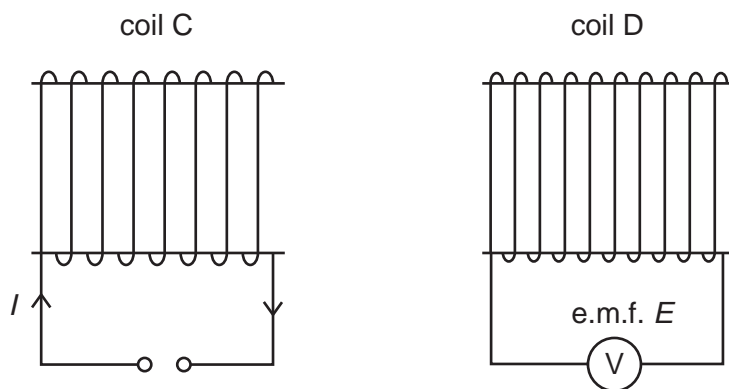


Fig. 5.2

The variation with time  $t$  of the current  $I$  in coil C is shown in Fig. 5.3.

On Fig. 5.4, show the variation with time  $t$  of the e.m.f.  $E$  induced in coil D for time  $t = 0$  to time  $t = t_5$ .

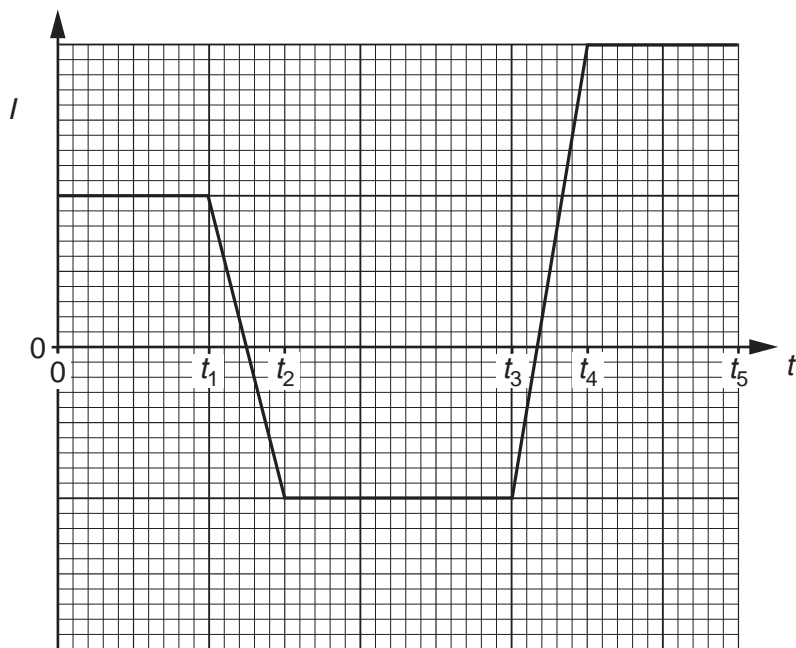


Fig. 5.3

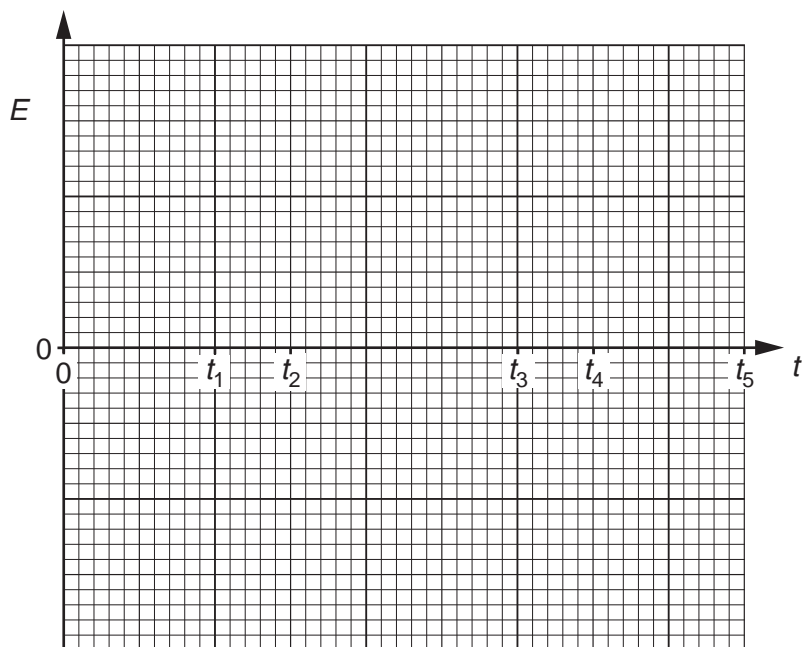


Fig. 5.4

[4]

[Total: 8]

- 6 Two capacitors P and Q, each of capacitance  $C$ , are connected in series with a battery of e.m.f.  $9.0\text{V}$ , as shown in Fig. 6.1.

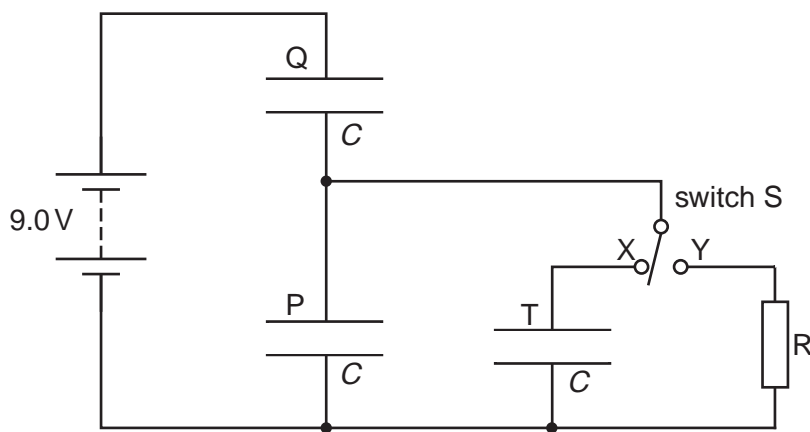


Fig. 6.1

A switch S is used to connect either a third capacitor T, also of capacitance  $C$ , or a resistor R, in parallel with capacitor P.

- (a) Switch S is in position X.

Calculate

- (i) the combined capacitance, in terms of  $C$ , of the three capacitors,

capacitance = ..... [2]

- (ii) the potential difference across capacitor Q. Explain your working.

potential difference = ..... V [2]

- (b) Switch S is now moved to position Y.  
State what happens to the potential difference across capacitor P and across capacitor Q.

capacitor P: .....

.....

.....

capacitor Q: .....

.....

.....

[4]

[Total: 8]

7 The circuit of an amplifier incorporating an ideal operational amplifier (op-amp) is shown in Fig. 7.1.

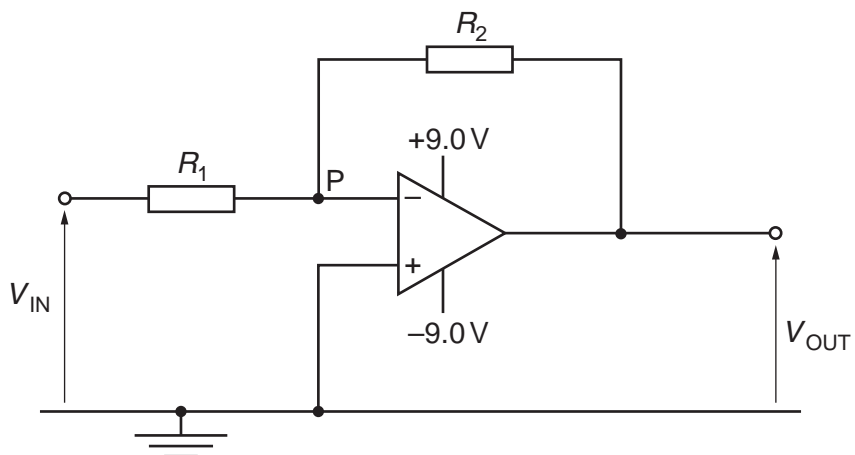


Fig. 7.1

(a) By reference to the properties of an ideal op-amp,

(i) explain why point P is referred to as a *virtual earth*,

.....

.....

.....

.....

..... [4]

(ii) derive an expression, in terms of the resistances  $R_1$  and  $R_2$ , for the gain of the amplifier circuit.

[4]

- (b) In the circuit of Fig. 7.1, the ratio  $\frac{R_2}{R_1}$  is 4.5.

The variation with time  $t$  of the input potential  $V_{IN}$  is shown in Fig. 7.2.

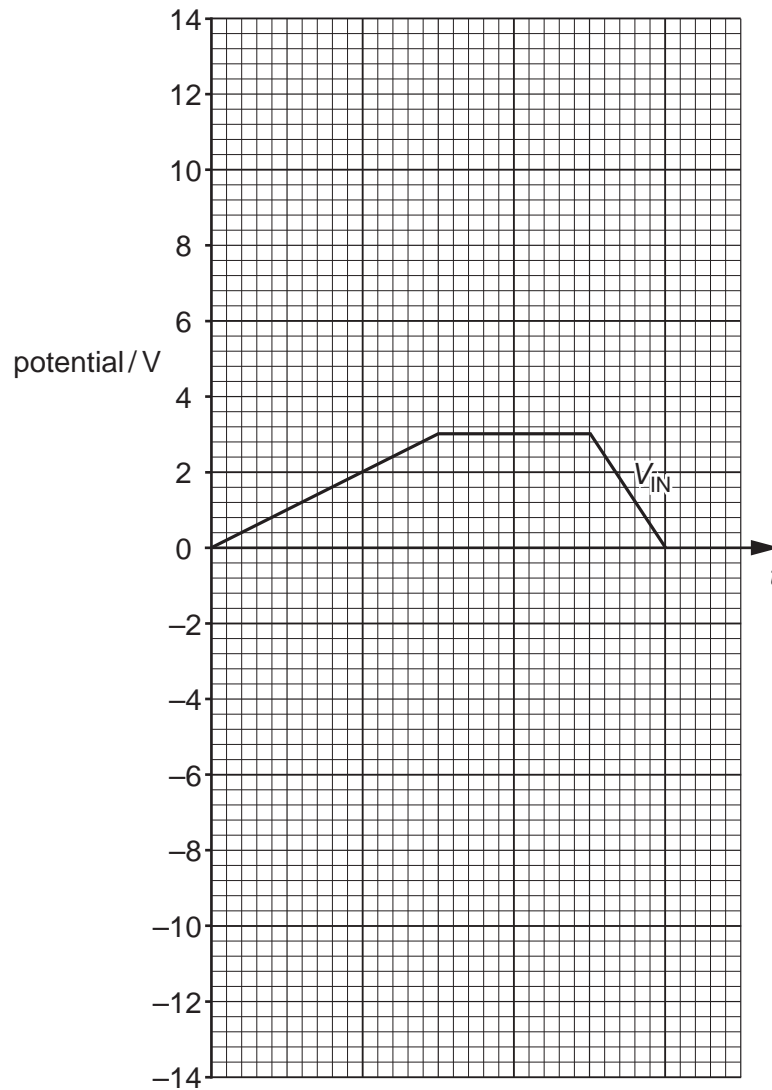


Fig. 7.2

On Fig. 7.2, show the variation with time  $t$  of the output potential  $V_{OUT}$ .

[3]

[Total: 11]

8 A thin slice of conducting material is placed normal to a uniform magnetic field of flux density  $B$ , as shown in Fig. 8.1.

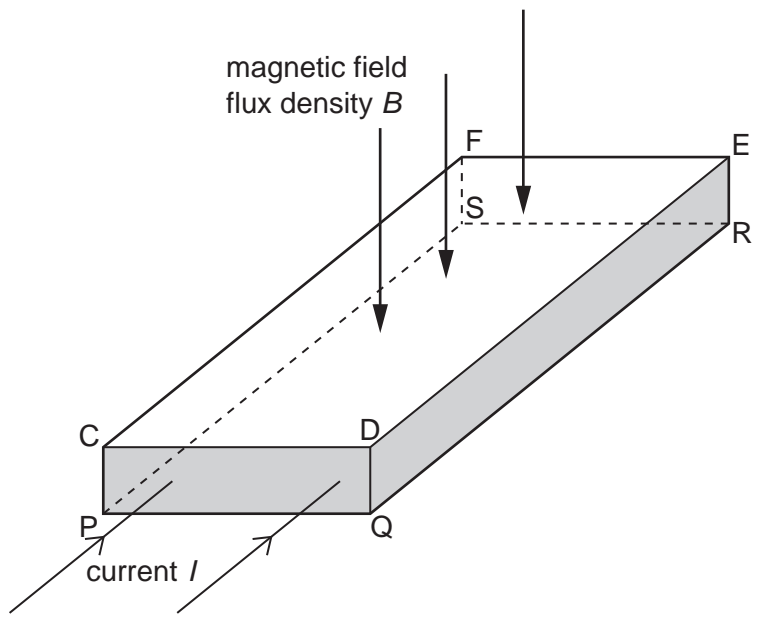


Fig. 8.1

The magnetic field is normal to face CDEF and to face PQRS.

A current  $I$  passes through the slice and is normal to the faces CDQP and FERS.

A potential difference, the Hall voltage  $V_H$ , is developed across the slice.

- (a) State the faces between which the Hall voltage  $V_H$  is developed.  
 ..... and ..... [1]
- (b) The current  $I$  is produced by charge carriers, each of charge  $+q$  moving at speed  $v$  in the direction of the current. The number density of the charge carriers is  $n$ .
  - (i) Derive an expression relating the Hall voltage  $V_H$  to  $v$ ,  $B$  and  $d$ , where  $d$  is one of the dimensions of the slice.

[3]



- (ii) Use your answer in (b)(i) and an expression for the current  $I$  in the slice to derive the expression

$$V_H = \frac{BI}{ntq}$$

Explain your working.

[2]

- (c) Suggest why the Hall voltage is difficult to detect in a thin slice of copper.

.....  
.....  
..... [2]

[Total: 8]

- 9 (a) In computed tomography (CT scanning), it is necessary to take a series of many X-ray images.  
Outline briefly the principles of CT scanning.

.....

.....

.....

.....

.....

.....

.....

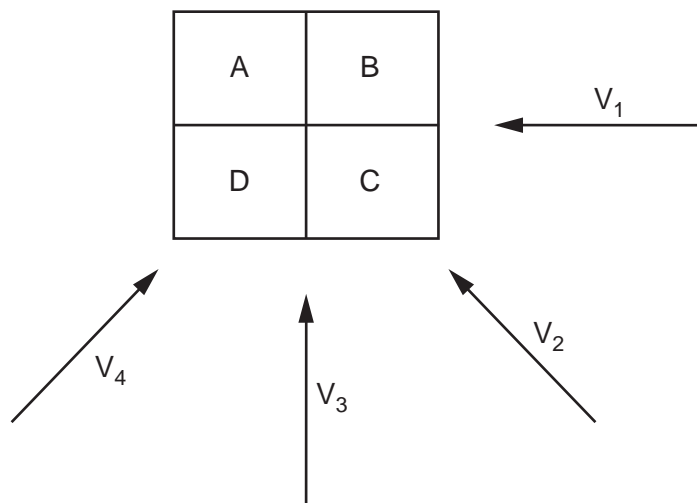
.....

.....

.....

..... [4]

- (b) A student creates a model for CT scanning.  
 A section is divided into four voxels, with pixel numbers A, B, C and D, as shown in Fig. 9.1.



**Fig. 9.1**

The section is viewed from four different directions  $V_1$ ,  $V_2$ ,  $V_3$  and  $V_4$ , as shown in Fig. 9.1.

The detector readings for each direction are noted and then summed. The result is shown in Fig. 9.2.

47	59
44	32

**Fig. 9.2**

The background count is 26.

Determine the pixel numbers A, B, C and D as shown in Fig. 9.1.

A ..... B .....  
 D ..... C .....

[3]

[Total: 7]

10 (a) The mean value of an alternating current is zero.  
Explain why heating occurs when there is an alternating current in a resistor.

.....  
.....  
.....  
..... [2]

(b) Transmission of electrical energy is frequently achieved using alternating high voltages.  
Suggest why

(i) high voltages are used,

.....  
.....  
.....  
..... [2]

(ii) the voltage is alternating.

.....  
.....  
.....  
..... [2]

[Total: 6]

11 (a) State what is meant by a *photon*.

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

(b) Indium-123 ( $^{123}_{49}\text{In}$ ) is radioactive.

A nucleus of indium-123 emits a  $\gamma$ -ray photon of energy 1.1 MeV.

Determine, for this  $\gamma$ -radiation,

(i) the frequency,

frequency = ..... Hz [2]

(ii) the momentum of a photon.

momentum = ..... N s [2]

(c) The indium-123 nucleus is stationary before emission of the  $\gamma$ -ray photon.

Use your answer in (b)(ii) to estimate the recoil speed of the nucleus after emission of the photon.

speed = .....  $\text{ms}^{-1}$  [2]

[Total: 7]

12 (a) A radiation detector is placed close to a radioactive source. The detector does not surround the source.

Radiation is emitted in all directions and, as a result, the activity of the source and the measured count rate are different.

Suggest two other reasons why the activity and the measured count rate may be different.

1. ....
- .....
2. ....
- .....

[2]

(b) The variation with time  $t$  of the measured count rate in (a) is shown in Fig. 12.1.

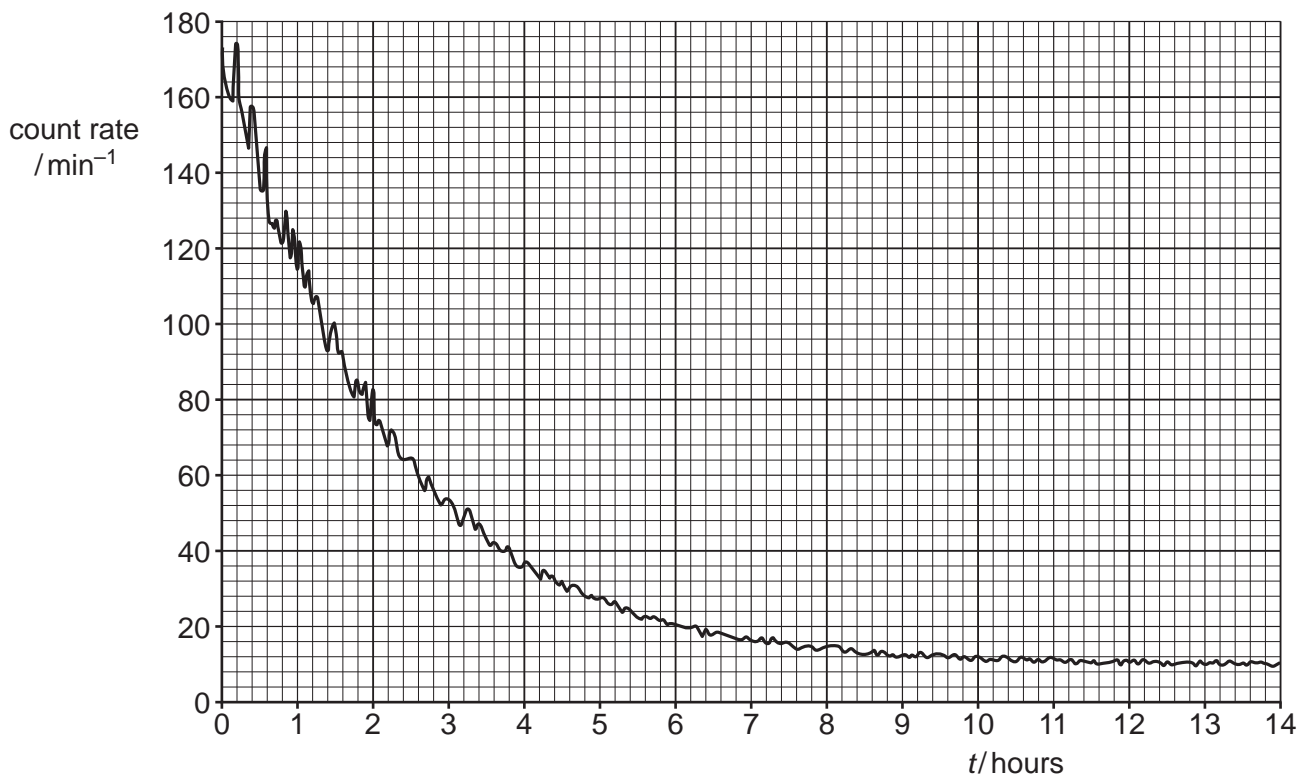


Fig. 12.1

(i) State the feature of Fig. 12.1 that indicates the random nature of radioactive decay.

- .....
- ..... [1]

(ii) Use Fig. 12.1 to determine the half-life of the radioactive isotope in the source.

half-life = ..... hours [4]

(c) The readings in (b) were obtained at room temperature.

A second sample of this isotope is heated to a temperature of 500 °C.

The initial count rate at time  $t = 0$  is the same as that in (b).

The variation with time  $t$  of the measured count rate from the heated source is determined.

State, with a reason, the difference, if any, in

1. the half-life,

.....

.....

.....

2. the measured count rate for any specific time.

.....

.....

.....

[3]

[Total: 10]

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