

Centre Number	Candidate Number	Name
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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS  
General Certificate of Education Advanced Level

**PHYSICS**

**9702/04**

Paper 4

Specimen Paper

**1 hour 45 minutes**

Candidates answer on the Question Paper.  
No Additional Materials are required.

**READ THESE INSTRUCTIONS FIRST**

Write your Centre number, candidate number and name on all the work you hand in.  
Write in dark blue or black pen in the spaces provided on the Question Paper.  
You may use a pencil for any diagrams, graphs or rough working.  
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.  
The number of marks is given in brackets [ ] at the end of each question or part question.  
You may lose marks if you do not show your working or if you do not use appropriate units.

For Examiner's Use	
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<b>Total</b>	

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

**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,	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$
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

$$W = p \Delta V$$

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.

$$v = v_0 \cos \omega t$$

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

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

$$W = \frac{1}{2} QV$$

resistors in series

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

resistors in parallel

$$1/R = 1/R_1 + 1/R_2 + \dots$$

alternating current/voltage

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

radioactive decay

$$x = x_0 \exp(-\lambda t)$$

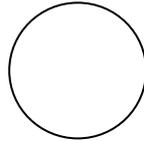
decay constant

$$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$$

**Section A**

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

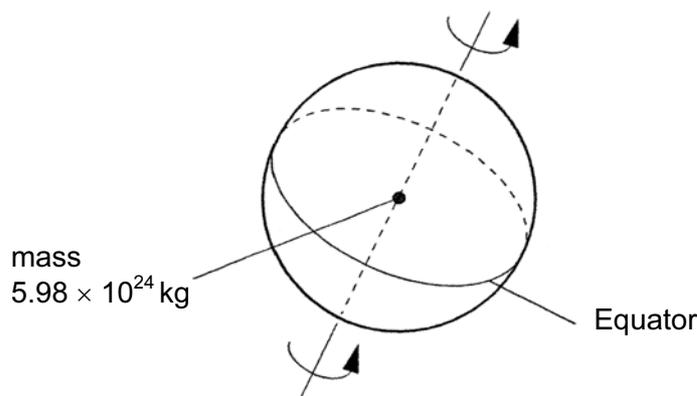
- 1 (a) (i) On Fig. 1.1, draw lines to represent the gravitational field outside an isolated uniform sphere.

**Fig. 1.1**

- (ii) A second sphere has the same mass but a smaller radius. Suggest what difference, if any, there is between the patterns of field lines for the two spheres.

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

- (b) The Earth may be considered to be a uniform sphere of radius 6380 km with its mass of  $5.98 \times 10^{24}$  kg concentrated at its centre, as illustrated in Fig. 1.2.

**Fig. 1.2**

A mass of 1.00 kg on the Equator rotates about the axis of the Earth with a period of 1.00 day ( $8.64 \times 10^4$  s).

Calculate, to three significant figures,

- (i) the gravitational force  $F_G$  of attraction between the mass and the Earth,

$$F_G = \text{.....} \quad \text{N}$$

- (ii) the centripetal force  $F_C$  on the 1.00 kg mass,

$$F_C = \text{.....} \quad \text{N}$$

- (iii) the difference in magnitude of the forces.

$$\text{difference} = \text{.....} \quad \text{N}$$

[6]

- (c) By reference to your answers in (b), suggest, with a reason, a value for the acceleration of free fall at the Equator.

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

- 2 (a) The defining equation of simple harmonic motion is

$$a = -\omega^2 x.$$

- (i) State the relation between  $\omega$  and the frequency  $f$ .

.....

- (ii) State the significance of the negative (-) sign in the equation.

.....

..... [2]

- (b) A frictionless trolley of mass  $m$  is held on a horizontal surface by means of two similar springs, each of spring constant  $k$ . The springs are attached to fixed points as illustrated in Fig. 2.1.

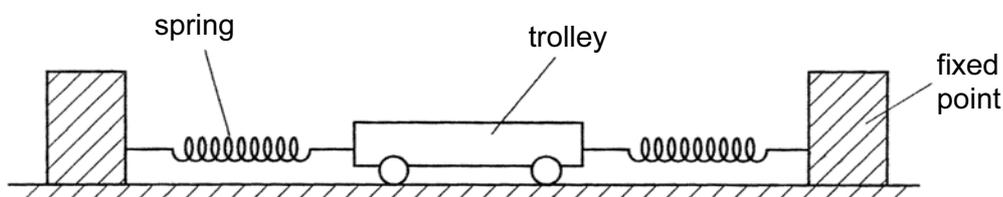


Fig. 2.1

When the trolley is in equilibrium, the extension of each spring is  $e$ . The trolley is then displaced a small distance  $x$  to the right along the axis of the springs. Both springs remain extended.

- (i) Show that the magnitude  $F$  of the restoring force acting on the trolley is given by

$$F = 2kx.$$

[2]

- (ii) The trolley is then released. Show that the acceleration  $a$  of the trolley is given by

$$a = \frac{-2kx}{m}$$

[2]

- (iii) The mass  $m$  of the trolley is 900 g and the spring constant  $k$  is  $120 \text{ N m}^{-1}$ . By comparing the equations in (a) and (b)(ii), determine the frequency of oscillation of the trolley.

frequency = ..... Hz [3]

- 3 The rectified output of a sinusoidal signal generator is connected across a resistor  $R$  of resistance  $1.5\text{ k}\Omega$  as shown in Fig. 4.1.



Fig 4.1

The variation with time  $t$  of the potential difference  $V$  across  $R$  is shown in Fig. 4.2.

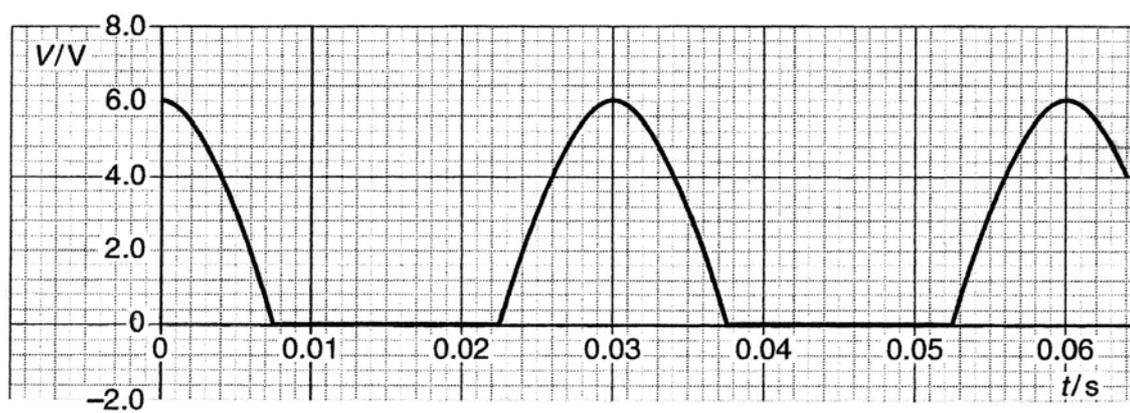


Fig. 4.2

- (a) State how the rectification shown in Fig. 4.2 may be achieved.

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

- (b) A capacitor is now connected in parallel with the resistor  $R$ . The resulting variation with time  $t$  of the potential difference  $V$  across  $R$  is shown in Fig. 4.3.

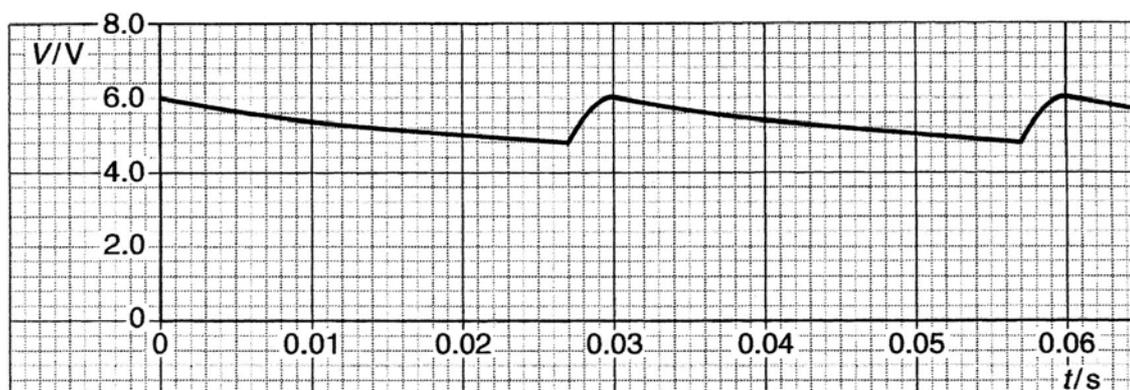


Fig. 4.3

(i) Using Fig. 4.3, determine

1. the mean potential difference across the resistor **R**,

potential difference = ..... V

2. the mean current in the resistor,

mean current = ..... A

3. the time in each cycle during which the capacitor discharges through the resistor.

time = ..... s

[4]

(ii) Using your answers in (i), calculate

1. the charge passing through the resistor during one discharge of the capacitor,

charge = ..... C

2. the capacitance of the capacitor.

capacitance = ..... F

[4]

(c) A second capacitor is now connected in parallel with the resistor **R** and the first capacitor. On Fig. 4.3, draw a line to show the variation with time  $t$  of the potential difference  $V$  across the resistor. [1]

- 4 A small coil is positioned so that its axis lies along the axis of a large bar magnet, as shown in Fig. 5.1.

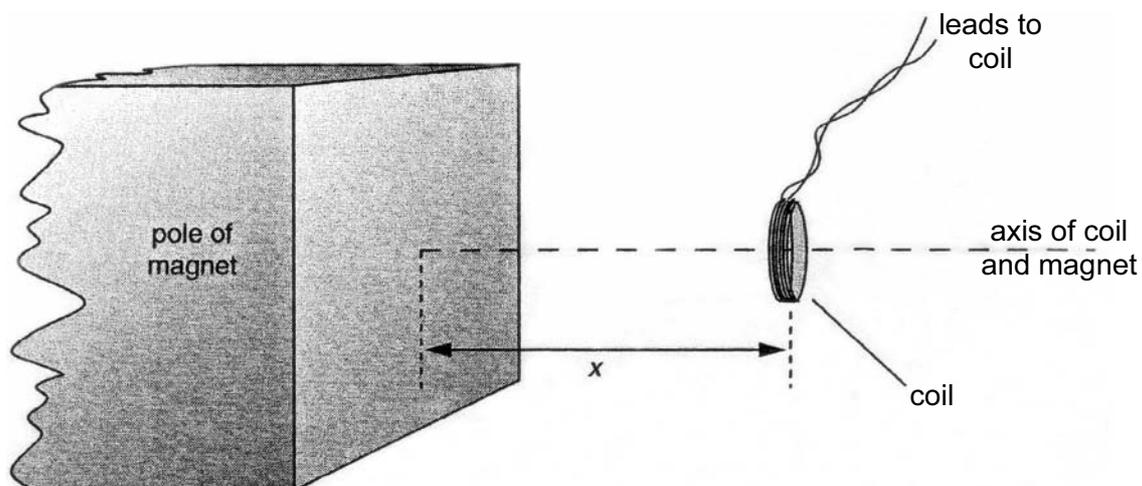


Fig. 5.1

The coil has a cross-sectional area of  $0.40 \text{ cm}^2$  and contains 150 turns of wire.

The average magnetic flux density  $B$  through the coil varies with the distance  $x$  between the face of the magnet and the plane of the coil, as shown in Fig. 5.2.

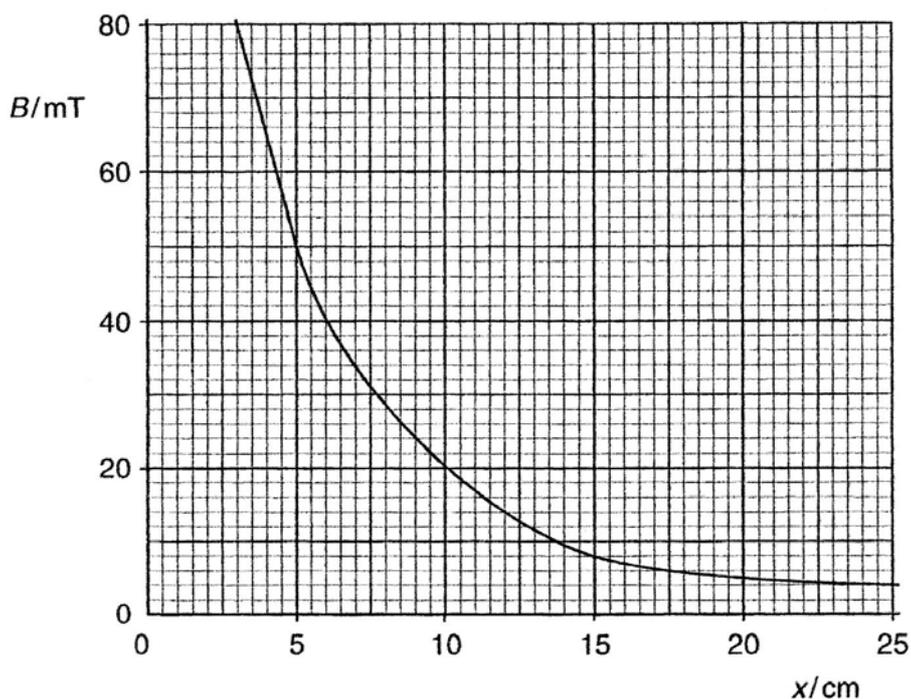


Fig. 5.2

- (a) (i) The coil is 5.0 cm from the face of the magnet. Use Fig. 5.2 to determine the magnetic flux density in the coil.

magnetic flux density = ..... T

- (ii) Hence show that the magnetic flux linkage of the coil is  $3.0 \times 10^{-4}$  Wb.

[3]

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

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

- (c) The coil is moved along the axis of the magnet so that the distance  $x$  changes from  $x = 5.0$  cm to  $x = 15.0$  cm in a time of 0.30 s. Calculate

- (i) the change in flux linkage of the coil,

change = ..... Wb [2]

- (ii) the average e.m.f. induced in the coil.

e.m.f. = ..... V [2]

- (d) State and explain the variation, if any, of the speed of the coil so that the induced e.m.f. remains constant during the movement in (c).

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

- 5 A charged particle passes through a region of uniform magnetic field of flux density 0.74 T, as shown in Fig. 6.1.

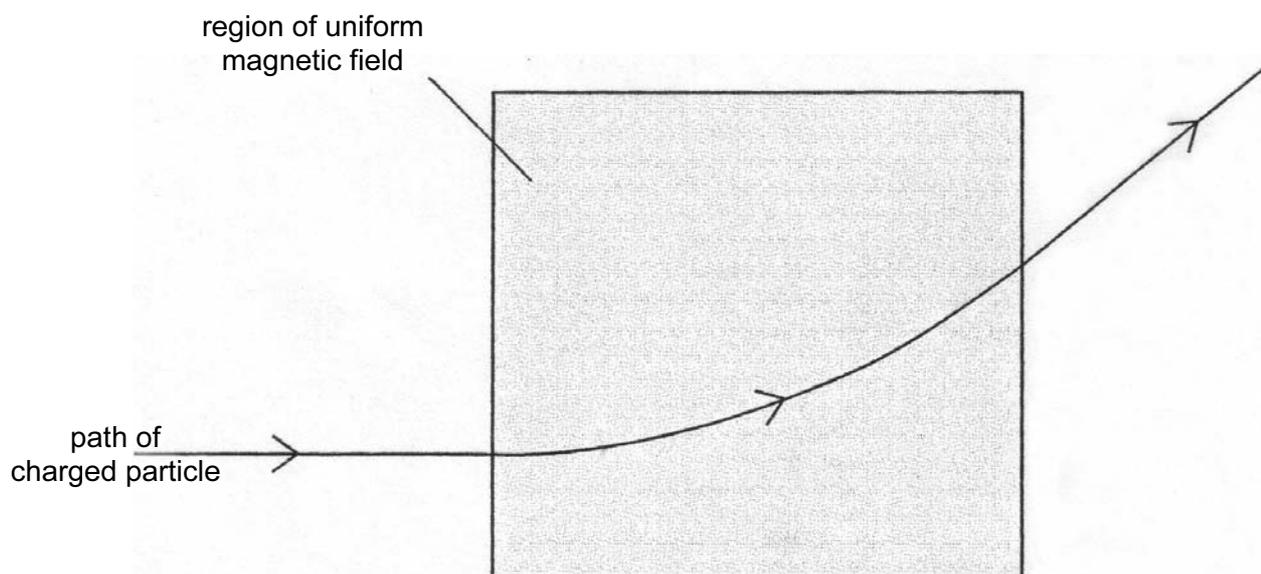


Fig. 6.1

The radius  $r$  of the path of the particle in the magnetic field is 23 cm.

- (a) The particle is positively charged. State the direction of the magnetic field.

..... [1]

- (b) (i) Show that the specific charge of the particle (the ratio  $\frac{q}{m}$  of its charge to its mass) is given by the expression

$$\frac{q}{m} = \frac{v}{rB},$$

where  $v$  is the speed of the particle and  $B$  is the flux density of the field.

- (ii) The speed  $v$  of the particle is  $8.2 \times 10^6 \text{ m s}^{-1}$ . Calculate the specific charge of the particle. [2]

specific charge = ..... C kg<sup>-1</sup> [2]

- (c) (i) The particle in (b) has charge  $1.6 \times 10^{-19}$  C. Using your answer to (b)(ii), determine the mass of the particle in terms of the unified mass constant  $u$ .

mass = .....  $u$  [2]

- (ii) The particle is the nucleus of an atom. Suggest the composition of this nucleus.

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

6 The volume of some air, assumed to be an ideal gas, in the cylinder of a car engine is  $540 \text{ cm}^3$  at a pressure of  $1.1 \times 10^5 \text{ Pa}$  and a temperature of  $27 \text{ }^\circ\text{C}$ . The air is suddenly compressed, so that no thermal energy enters or leaves the gas, to a volume of  $30 \text{ cm}^3$ . The pressure rises to  $6.5 \times 10^6 \text{ Pa}$ .

(a) Determine the temperature of the gas after the compression.

temperature = ..... K [3]

(b) (i) State and explain the first law of thermodynamics.

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

(ii) Use the law to explain why the temperature of the air changed during the compression.

.....  
.....  
.....  
.....  
..... [4]

7 The isotopes Radium-224 ( $^{224}_{88}\text{Ra}$ ) and Radium-226 ( $^{226}_{88}\text{Ra}$ ) both undergo spontaneous  $\alpha$ -particle decay. The energy of the  $\alpha$ -particles emitted from Radium-224 is 5.68 MeV and from Radium-226, 4.78 MeV.

(a) (i) State what is meant by the *decay constant* of a radioactive nucleus.

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

(ii) Suggest, with a reason, which of the two isotopes has the larger decay constant.

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

(b) Radium-224 has a half-life of 3.6 days.

(i) Calculate the decay constant of Radium-224, stating the unit in which it is measured.

decay constant = ..... [2]

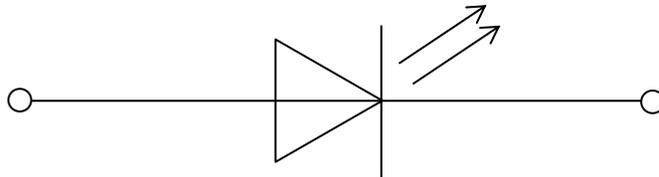
(ii) Determine the activity of a sample of Radium-224 of mass 2.24 mg.

activity = ..... Bq [4]

**Section B**

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

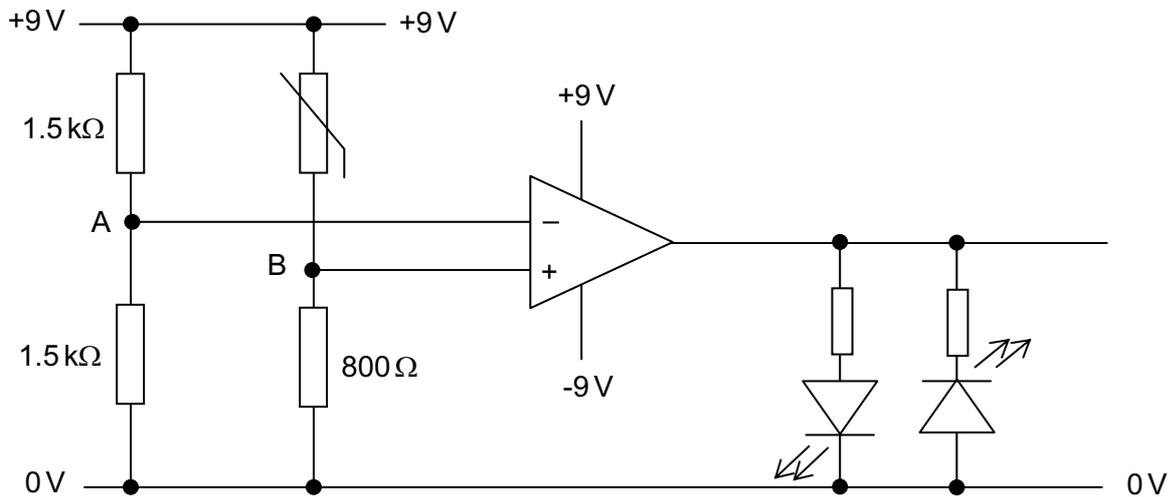
- 8 (a) Fig. 8.1 is the symbol for a light-emitting diode (LED).



**Fig. 8.1**

On Fig. 8.1, mark the polarity of the diode such that the diode is emitting light. [1]

- (b) Fig. 8.2 is a circuit diagram for a temperature-sensing device.



**Fig. 8.2**

The operational amplifier (op-amp) is ideal.  
Some values for the resistance of the thermistor at different temperatures are given in Fig. 8.3.

temperature / °C	resistance / $\Omega$
15	2200
30	1200
60	800
100	680

**Fig. 8.3**

The thermistor is held in a water bath at a temperature of 15 °C.

(i) Determine the voltage

1. at A,

voltage = ..... V

2. at B,

voltage = ..... V

3. at the output of the operational amplifier.

voltage = ..... V

[4]

(ii) State which LED is emitting light.

..... [1]

(c) Describe and explain what is observed as the temperature of the thermistor is raised from 15 °C to 100 °C.

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

9 (a) The quality of an image produced using X-rays depends on sharpness and contrast. State what is meant by

(i) *sharpness*,

.....  
.....

(ii) *contrast*.

.....  
.....

[2]

(b) A parallel beam of X-ray photons is produced by an X-ray tube with 80 keV between the anode and cathode. The beam has its intensity reduced to one half of its original value when it passes through a thickness of 1.0 mm of copper.

(i) Determine the linear absorption coefficient  $\mu$  of the X-ray photons in copper.

$\mu = \dots\dots\dots \text{mm}^{-1}$  [2]

(ii) Suggest, with a reason, the effect on the linear absorption coefficient if the beam is comprised of 100 keV photons.

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

10 A sinusoidal wave of frequency 75 kHz is to be amplitude modulated by a wave of frequency 5.0 kHz.

(a) Explain what is meant by *amplitude modulation*.

.....

.....

..... [2]

(b) On the axes of Fig. 10.1, sketch a graph to show the variation with frequency  $f$  of the power  $P$  of the modulated wave. Give labelled values on the frequency axis. [3]



Fig. 10.1

(c) State the bandwidth of the modulated wave.

bandwidth = ..... kHz [1]

11 Fig. 11.1 shows a microphone connected directly to an amplifier having a gain of 63 dB.

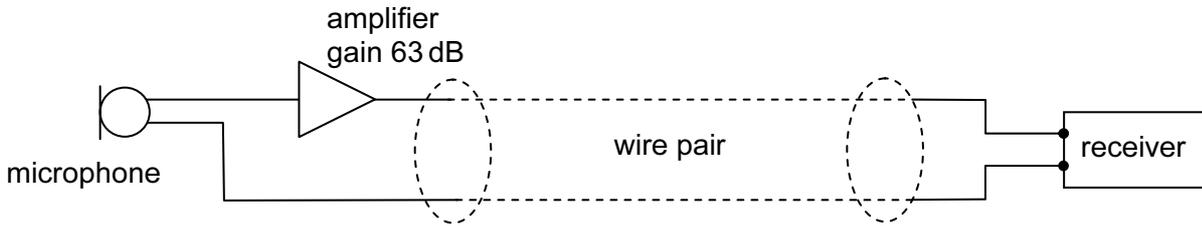


Fig. 11.1

The microphone and amplifier are connected to a receiver by means of a wire pair having an attenuation of 12 dB per kilometre length. The output signal from the microphone is  $2.5 \mu\text{W}$  and there is a constant noise power in the wire pair of  $0.035 \mu\text{W}$ .

(a) Explain what is meant by *noise*.

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

(b) Calculate the power output of the amplifier.

power output = ..... W [3]

- (c) Calculate the length of the wire pair for the signal power to be reduced to the level of the noise power.

length = ..... km [2]

12 Fig. 12.1 illustrates part of a mobile phone network.

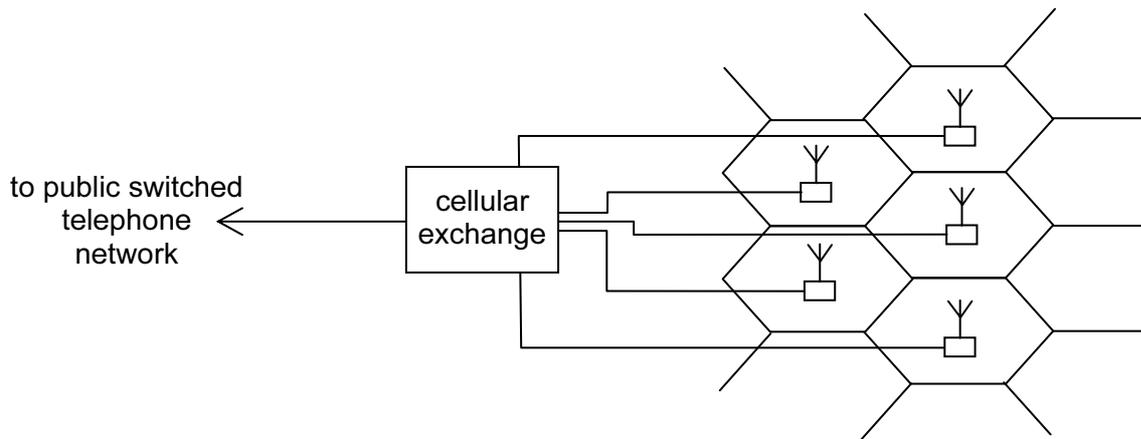


Fig. 12.1

State four functions of the cellular exchange.

- 1. ....
- 2. ....
- 3. ....
- 4. .... [4]

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