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## 9702/41

**May/June 2010**

**1 hour 45 minutes**

No Additional Materials are required.

Write your Centre number, candidate number and name on all the work you hand in.  
Write in dark blue or black pen.  
You may use a soft pencil for any diagrams, graphs or rough working.  
Do not use staples, paper clips, highlighters, glue or correction fluid.  
**DO NOT WRITE IN ANY BARCODES.**

Answer **all** questions.

You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.  
The number of marks is given in brackets [ ] at the end of each question or part question.

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| Total              |  |

This document consists of **21** printed pages and **3** 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.

For  
Examiner's  
Use

- 1 (a) Define the *radian*.

.....

.....

..... [2]

- (b) A stone of weight 3.0 N is fixed, using glue, to one end P of a rigid rod CP, as shown in Fig. 1.1.

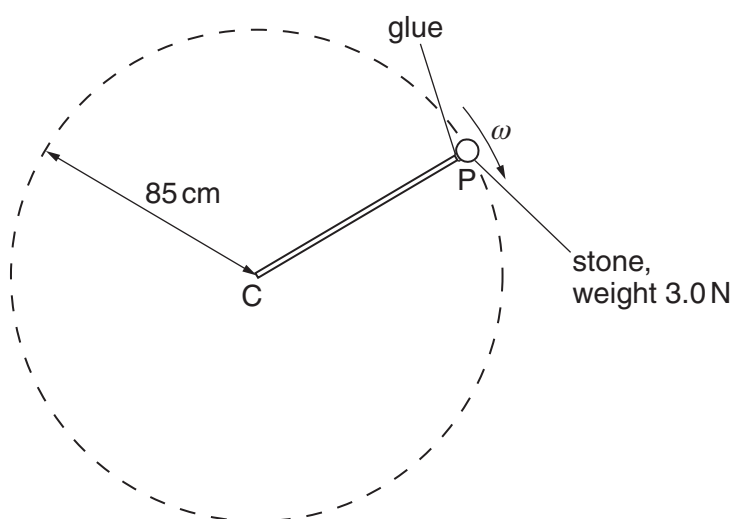


Fig. 1.1

The rod is rotated about end C so that the stone moves in a vertical circle of radius 85 cm.

The angular speed  $\omega$  of the rod and stone is gradually increased from zero until the glue snaps. The glue fixing the stone snaps when the tension in it is 18 N.

For the position of the stone at which the glue snaps,

- (i) on the dotted circle of Fig. 1.1, mark with the letter S the position of the stone, [1]
- (ii) calculate the angular speed  $\omega$  of the stone.

angular speed = ..... rad s<sup>-1</sup> [4]

- 2 (a) Some gas, initially at a temperature of  $27.2^{\circ}\text{C}$ , is heated so that its temperature rises to  $38.8^{\circ}\text{C}$ .

Calculate, in kelvin, to an appropriate number of decimal places,

- (i) the initial temperature of the gas,

initial temperature = ..... K [2]

- (ii) the rise in temperature.

rise in temperature = ..... K [1]

- (b) The pressure  $p$  of an ideal gas is given by the expression

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

where  $\rho$  is the density of the gas.

- (i) State the meaning of the symbol  $\langle c^2 \rangle$ .

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

- (ii) Use the expression to show that the mean kinetic energy  $\langle E_K \rangle$  of the atoms of an ideal gas is given by the expression

$$\langle E_K \rangle = \frac{3}{2} kT.$$

Explain any symbols that you use.

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

For  
Examiner's  
Use

- (c) Helium-4 may be assumed to behave as an ideal gas.  
A cylinder has a constant volume of  $7.8 \times 10^3 \text{ cm}^3$  and contains helium-4 gas at a pressure of  $2.1 \times 10^7 \text{ Pa}$  and at a temperature of  $290 \text{ K}$ .

For  
Examiner's  
Use

Calculate, for the helium gas,

- (i) the amount of gas,

amount = ..... mol [2]

- (ii) the mean kinetic energy of the atoms,

mean kinetic energy = ..... J [2]

- (iii) the total internal energy.

internal energy = ..... J [3]

3 (a) State what is meant by

(i) *oscillations*,

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

(ii) *free oscillations*,

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

(iii) *simple harmonic motion*.

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

(b) Two inclined planes RA and LA each have the same constant gradient. They meet at their lower edges, as shown in Fig. 3.1.

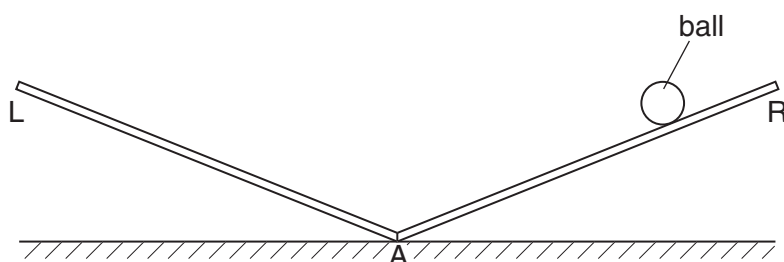


Fig. 3.1

A small ball moves from rest down plane RA and then rises up plane LA. It then moves down plane LA and rises up plane RA to its original height. The motion repeats itself.

State and explain whether the motion of the ball is simple harmonic.

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

- 4 (a) Explain what is meant by the *potential energy* of a body.

For  
Examiner's  
Use

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

- (b) Two deuterium ( ${}^2_1\text{H}$ ) nuclei each have initial kinetic energy  $E_K$  and are initially separated by a large distance.  
 The nuclei may be considered to be spheres of diameter  $3.8 \times 10^{-15} \text{ m}$  with their masses and charges concentrated at their centres.  
 The nuclei move from their initial positions to their final position of just touching, as illustrated in Fig. 4.1.

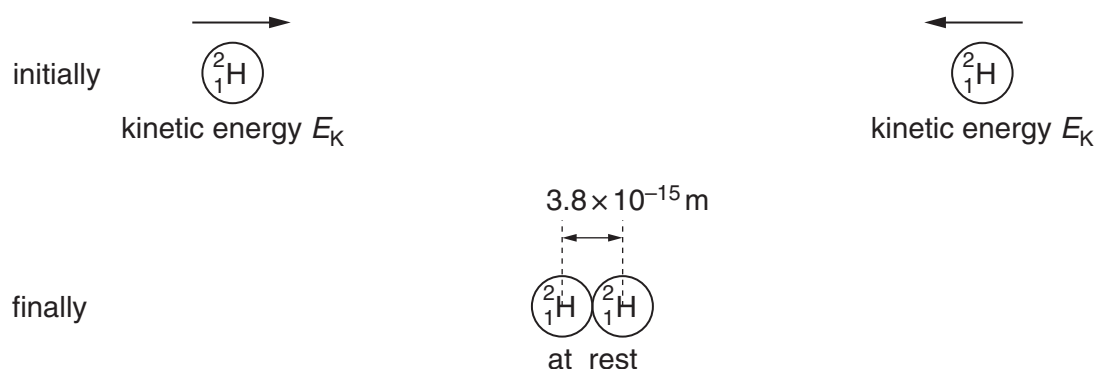


Fig. 4.1

- (i) For the two nuclei approaching each other, calculate the total change in

1. gravitational potential energy,

energy = ..... J [3]

2. electric potential energy.

energy = ..... J [3]

- (ii) Use your answers in (i) to show that the initial kinetic energy  $E_K$  of each nucleus is 0.19 MeV.

For  
Examiner's  
Use

[2]

- (iii) The two nuclei may rebound from each other. Suggest one other effect that could happen to the two nuclei if the initial kinetic energy of each nucleus is greater than that calculated in (ii).

.....

.....[1]

- 5 (a) A constant current is maintained in a long straight vertical wire. A Hall probe is positioned a distance  $r$  from the centre of the wire, as shown in Fig. 5.1.

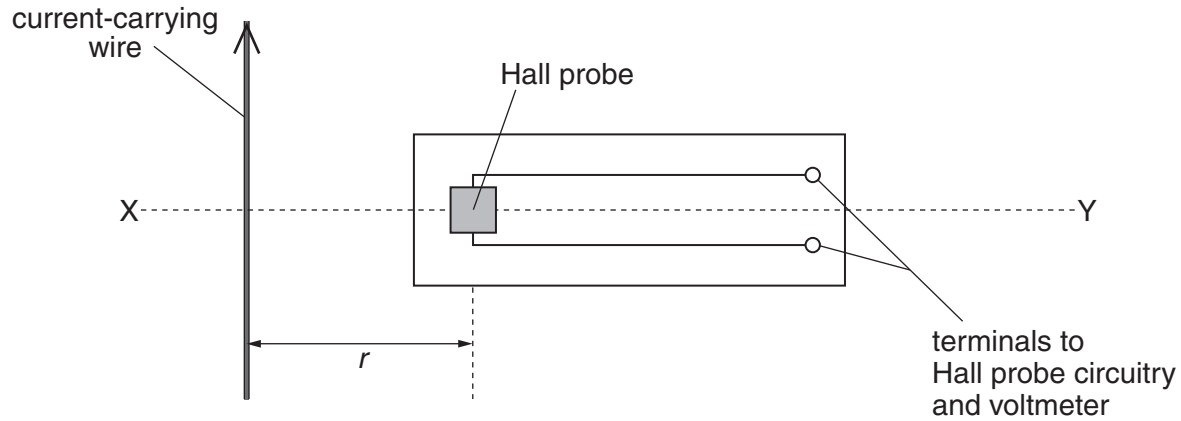


Fig. 5.1

- (i) Explain why, when the Hall probe is rotated about the horizontal axis XY, the Hall voltage varies between a maximum positive value and a maximum negative value.

.....

.....

..... [2]

- (ii) The maximum Hall voltage  $V_H$  is measured at different distances  $r$ . Data for  $V_H$  and the corresponding values of  $r$  are shown in Fig. 5.2.

| $V_H / \text{V}$ | $r / \text{cm}$ |
|------------------|-----------------|
| 0.290            | 1.0             |
| 0.190            | 1.5             |
| 0.140            | 2.0             |
| 0.097            | 3.0             |
| 0.073            | 4.0             |
| 0.060            | 5.0             |

Fig. 5.2

It is thought that  $V_H$  and  $r$  are related by an expression of the form

$$V_H = \frac{k}{r}$$

where  $k$  is a constant.

1. Without drawing a graph, use data from Fig.5.2 to suggest whether the expression is valid.

[2]

2. A graph showing the variation with  $\frac{1}{r}$  of  $V_H$  is plotted.

State the features of the graph that suggest that the expression is valid.

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

- (b) The Hall probe in (a) is now replaced with a small coil of wire connected to a sensitive voltmeter. The coil is arranged so that its plane is normal to the magnetic field of the wire.

- (i) State Faraday's law of electromagnetic induction and hence explain why the voltmeter indicates a zero reading.

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

- (ii) State three different ways in which an e.m.f. may be induced in the coil.

1. ....  
 .....  
 2. ....  
 .....  
 3. ....  
 .....  
 .....[3]

- 6 A student is asked to design a circuit by which a direct voltage of peak value 9.0V is obtained from a 240V alternating supply. The student uses a transformer that may be considered to be ideal and a bridge rectifier incorporating four ideal diodes. The partially completed circuit diagram is shown in Fig. 6.1.

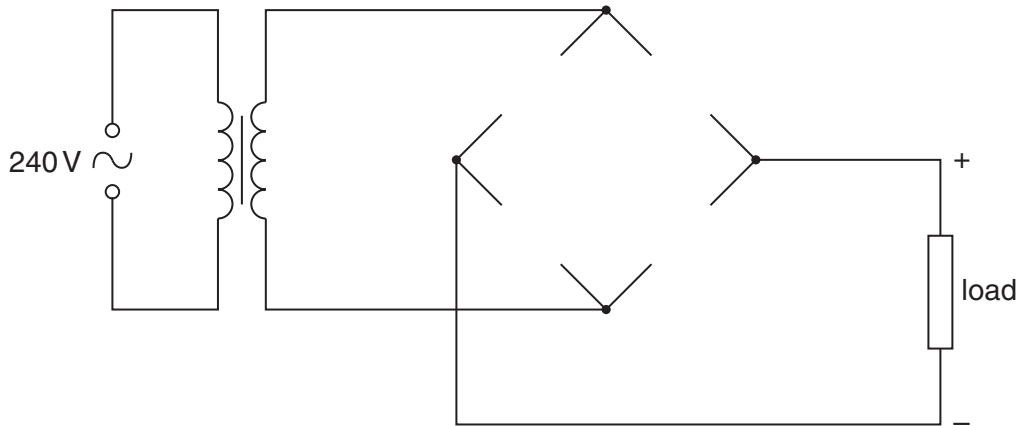


Fig. 6.1

- (a) On Fig. 6.1, draw symbols for the four diodes so as to produce the polarity across the load as shown on the diagram. [2]
- (b) Calculate the ratio

$$\frac{\text{number of turns on the secondary coil}}{\text{number of turns on the primary coil}}$$

ratio = ..... [3]

- 7 Negatively-charged particles are moving through a vacuum in a parallel beam. The particles have speed  $v$ . The particles enter a region of uniform magnetic field of flux density  $930\ \mu\text{T}$ . Initially, the particles are travelling at right-angles to the magnetic field. The path of a single particle is shown in Fig. 7.1.

For  
Examiner's  
Use

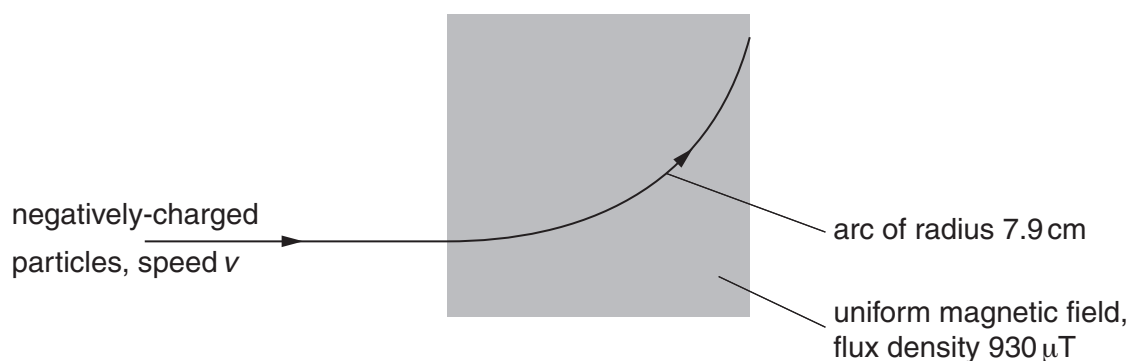


**Fig. 7.1**

The negatively-charged particles follow a curved path of radius  $7.9\text{ cm}$  in the magnetic field.

A uniform electric field is then applied in the same region as the magnetic field. For an electric field strength of  $12\text{ kV m}^{-1}$ , the particles are undeviated as they pass through the region of the fields.

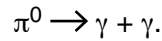
- (a) On Fig. 7.1, mark with an arrow the direction of the electric field. [1]
- (b) Calculate, for the negatively-charged particles,
- (i) the speed  $v$ ,

$$v = \dots\dots\dots \text{ m s}^{-1} \quad [3]$$

- (ii) the ratio  $\frac{\text{charge}}{\text{mass}}$ .

$$\text{ratio} = \dots\dots\dots \text{ C kg}^{-1} \quad [3]$$

- 8** A  $\pi^0$  meson is a sub-atomic particle.  
 A stationary  $\pi^0$  meson, which has mass  $2.4 \times 10^{-28}$  kg, decays to form two  $\gamma$ -ray photons.  
 The nuclear equation for this decay is



- (a)** Explain why the two  $\gamma$ -ray photons have the same energy.

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

- (b)** Determine, for each  $\gamma$ -ray photon,

- (i)** the energy, in joule,

energy = ..... J [2]

- (ii)** the wavelength,

wavelength = ..... m [2]

For  
Examiner's  
Use

(iii) the momentum.

*For  
Examiner's  
Use*

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

## Section B

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

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Examiner's  
Use

- 9 The circuit diagram of Fig. 9.1 is an amplifier circuit incorporating an operational amplifier (op-amp).

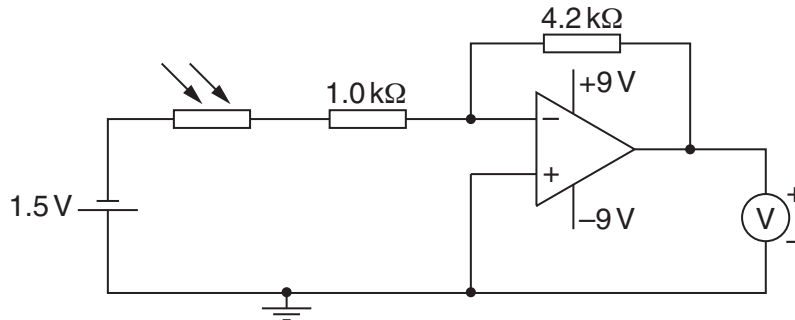


Fig. 9.1

- (a) (i) On Fig. 9.1, mark, with the letter X, the virtual earth. [1]

- (ii) Explain what is meant by a *virtual earth*.

.....

.....

.....

..... [3]

- (b) In bright sunlight, the light-dependent resistor (LDR) has resistance  $200\ \Omega$ .

- (i) Calculate, for the LDR in bright sunlight, the voltmeter reading.

reading = ..... V [3]

- (ii) The sunlight incident on the LDR becomes less bright.  
State and explain the effect on the voltmeter reading of this decrease in brightness.

*For  
Examiner's  
Use*

.....

.....

.....

.....[3]

10 (a) Briefly explain the principles of CT scanning.

For  
Examiner's  
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.....[6]

- (b) A simple section through a body consists of four voxels, as illustrated in Fig. 10.1.

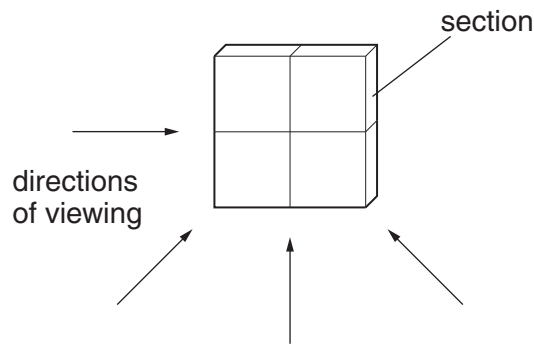


**Fig. 10.1**

An X-ray image of the section is obtained by viewing along each of the directions shown in Fig. 10.1.

The detector readings for each direction of viewing are summed to give the pattern of readings shown in Fig. 10.2.

|    |    |
|----|----|
| 25 | 22 |
| 34 | 31 |

**Fig. 10.2**

For any one direction, the total of the detector readings is 16.

- (i) For the pattern of readings of Fig. 10.2, state the magnitude of the background reading.

background reading = ..... [1]

- (ii) On Fig. 10.1, mark the pattern of pixels for the four-voxel section. [2]

- 11** Many radio stations now broadcast on FM rather than on AM. In general, FM is broadcast at much higher frequencies than AM.

**(a)** Explain what is meant by *FM* (*frequency modulation*).

.....

.....

.....

..... [2]

**(b)** State two advantages and two disadvantages of FM transmissions when compared with AM transmissions.

advantages of FM transmissions

1. ....

.....

2. ....

.....

disadvantages of FM transmissions

1. ....

.....

2. ....

.....

[4]

- 12 A ground station on Earth transmits a signal of frequency 14 GHz and power 18 kW towards a communications satellite orbiting the Earth, as illustrated in Fig. 12.1.

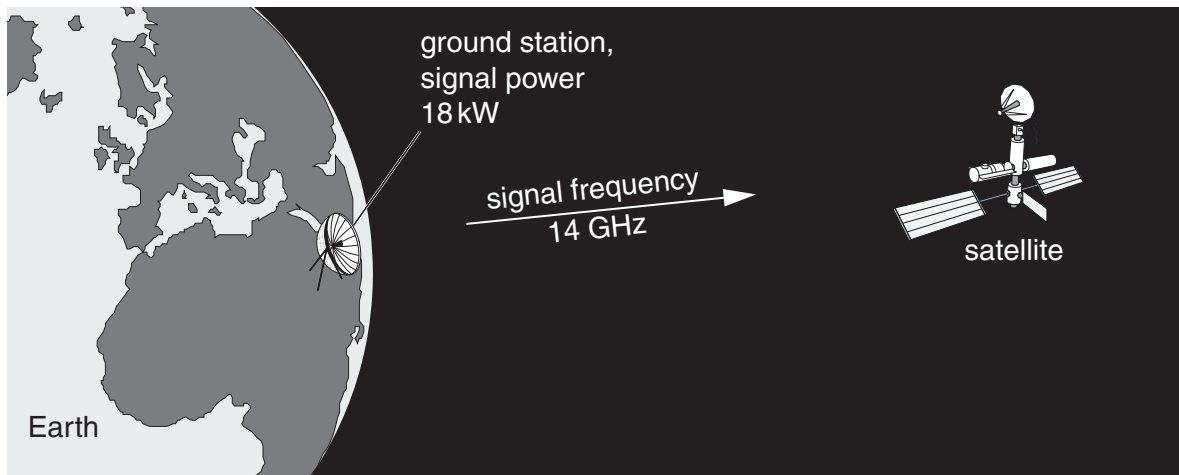


**Fig. 12.1**

The loss in signal power between the ground station and the satellite is 190 dB.

- (a) Calculate the power of the signal received by the satellite.

power = ..... W [3]

- (b) The signal received by the satellite is amplified and transmitted back to Earth.

- (i) Suggest a frequency for the signal that is sent back to Earth.

frequency = ..... GHz [1]

- (ii) Give a reason for your answer in (i).

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

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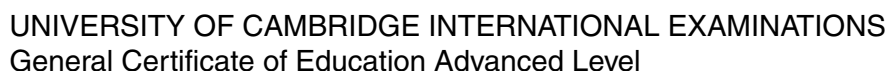
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**9702/42**

**May/June 2010**

**1 hour 45 minutes**

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This document consists of **20** printed pages.

**Data**

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|-------------------------------|----------------------------------------------------------|
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| acceleration of free fall,    | $g = 9.81 \text{ m s}^{-2}$                              |

**Formulae**

|                                 |                                                               |
|---------------------------------|---------------------------------------------------------------|
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| 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.

For  
Examiner's  
Use

- 1 (a) Define *gravitational potential* at a point.

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

- (b) The Earth may be considered to be an isolated sphere of radius  $R$  with its mass concentrated at its centre.  
 The variation of the gravitational potential  $\phi$  with distance  $x$  from the centre of the Earth is shown in Fig. 1.1.

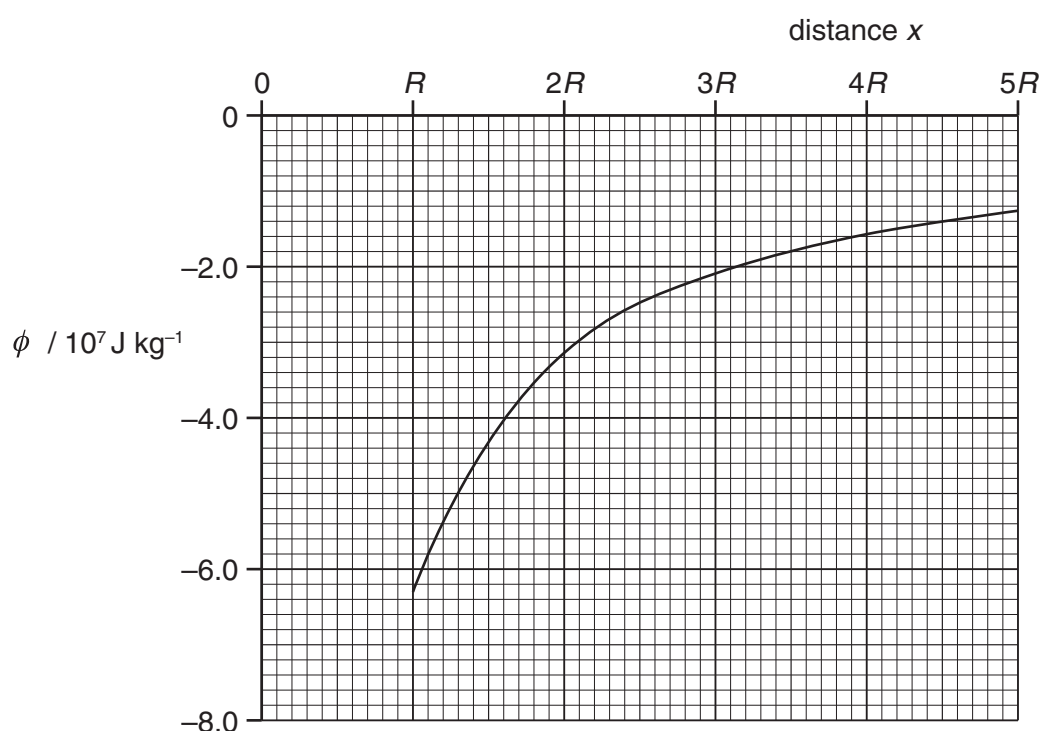


Fig. 1.1

The radius  $R$  of the Earth is  $6.4 \times 10^6$  m.

- (i) By considering the gravitational potential at the Earth's surface, determine a value for the mass of the Earth.

mass = ..... kg [3]

- (ii) A meteorite is at rest at infinity. The meteorite travels from infinity towards the Earth.

Calculate the speed of the meteorite when it is at a distance of  $2R$  above the Earth's surface. Explain your working.

speed = .....  $\text{ms}^{-1}$  [4]

- (iii) In practice, the Earth is not an isolated sphere because it is orbited by the Moon, as illustrated in Fig. 1.2.



**Fig. 1.2** (not to scale)

The initial path of the meteorite is also shown.

Suggest two changes to the motion of the meteorite caused by the Moon.

1. ....
2. ....

[2]

- 2 A long strip of springy steel is clamped at one end so that the strip is vertical. A mass of 65 g is attached to the free end of the strip, as shown in Fig. 2.1.

For  
Examiner's  
Use

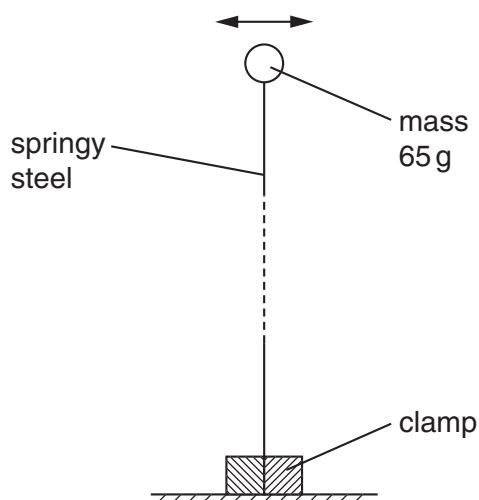


Fig. 2.1

The mass is pulled to one side and then released. The variation with time  $t$  of the horizontal displacement of the mass is shown in Fig. 2.2.

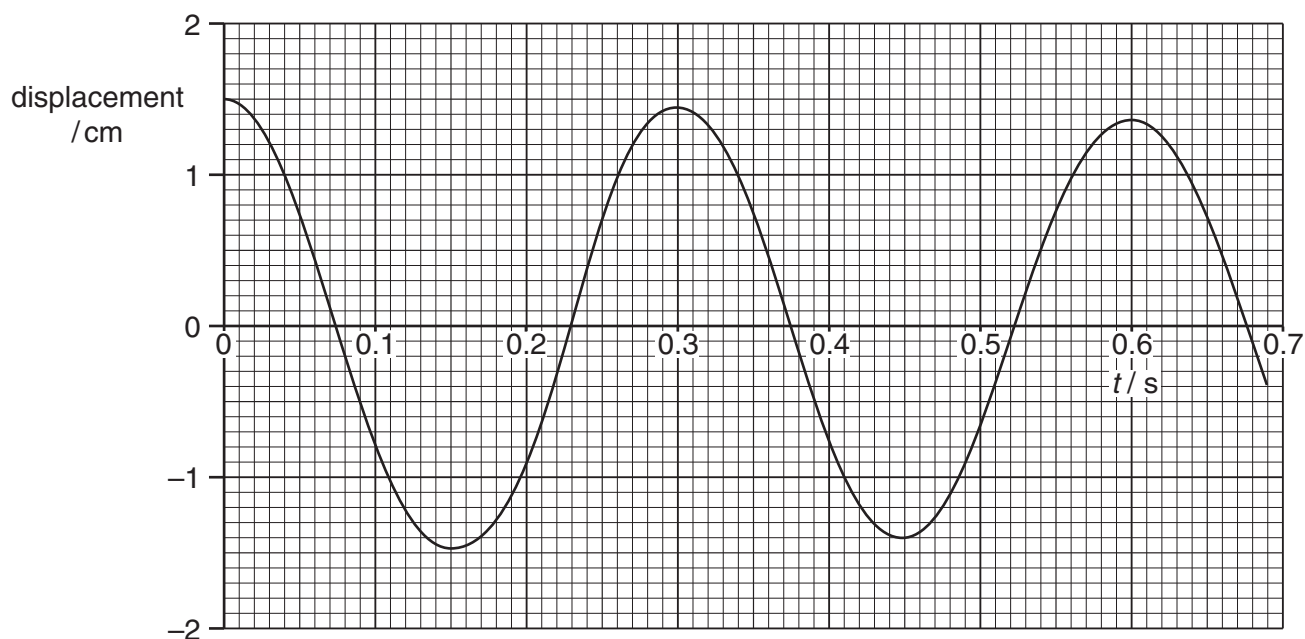


Fig. 2.2

The mass undergoes damped simple harmonic motion.

- (a) (i) Explain what is meant by *damping*.

.....

.....

..... [2]

- (ii) Suggest, with a reason, whether the damping is light, critical or heavy.

.....

.....

..... [2]

- (b) (i) Use Fig. 2.2 to determine the frequency of vibration of the mass.

frequency = ..... Hz [1]

- (ii) Hence show that the initial energy stored in the steel strip before the mass is released is approximately 3.2 mJ.

[2]

- (c) After eight complete oscillations of the mass, the amplitude of vibration is reduced from 1.5 cm to 1.1 cm. State and explain whether, after a further eight complete oscillations, the amplitude will be 0.7 cm.

.....

.....

..... [2]

- 3 (a) The resistance of a thermistor at  $0^{\circ}\text{C}$  is  $3840\ \Omega$ . At  $100^{\circ}\text{C}$  the resistance is  $190\ \Omega$ . When the thermistor is placed in water at a particular constant temperature, its resistance is  $2300\ \Omega$ .

For  
Examiner's  
Use

- (i) Assuming that the resistance of the thermistor varies linearly with temperature, calculate the temperature of the water.

temperature = .....  $^{\circ}\text{C}$  [2]

- (ii) The temperature of the water, as measured on the thermodynamic scale of temperature, is  $286\text{ K}$ .

By reference to what is meant by the thermodynamic scale of temperature, comment on your answer in (i).

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

- (b) A polystyrene cup contains a mass of  $95\text{ g}$  of water at  $28^{\circ}\text{C}$ .

A cube of ice of mass  $12\text{ g}$  is put into the water. Initially, the ice is at  $0^{\circ}\text{C}$ . The water, of specific heat capacity  $4.2 \times 10^3\text{ J kg}^{-1}\text{ K}^{-1}$ , is stirred until all the ice melts.

Assuming that the cup has negligible mass and that there is no heat exchange with the atmosphere, calculate the final temperature of the water.

The specific latent heat of fusion of ice is  $3.3 \times 10^5\text{ J kg}^{-1}$ .

temperature = .....  $^{\circ}\text{C}$  [4]

- 4 Two point charges A and B each have a charge of  $+6.4 \times 10^{-19} \text{ C}$ . They are separated in a vacuum by a distance of  $12.0 \mu\text{m}$ , as shown in Fig. 4.1.

For  
Examiner's  
Use

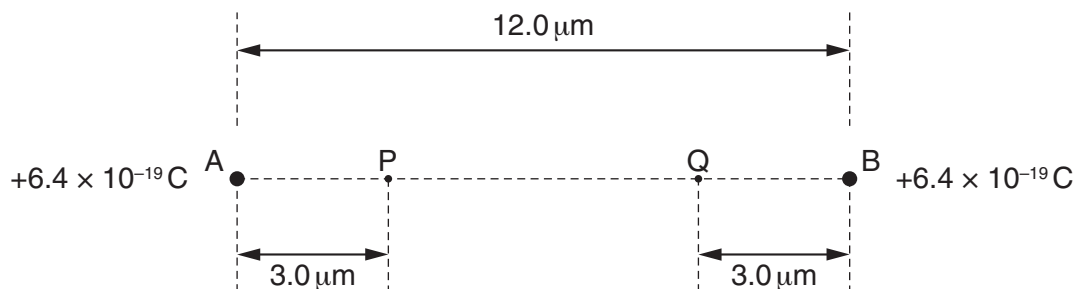


**Fig. 4.1**

Points P and Q are situated on the line AB. Point P is  $3.0 \mu\text{m}$  from charge A and point Q is  $3.0 \mu\text{m}$  from charge B.

- (a) Calculate the force of repulsion between the charges A and B.

force = ..... N [3]

- (b) Explain why, without any calculation, when a small test charge is moved from point P to point Q, the net work done is zero.

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

- (c) Calculate the work done by an electron in moving from the midpoint of line AB to point P.

work done = ..... J [4]

- 5 (a) State two functions of capacitors in electrical circuits.

1. ....

2. ....

[2]

- (b) Three capacitors, each marked ' $30\ \mu\text{F}$ ,  $6\text{V max}$ ', are arranged as shown in Fig. 5.1.

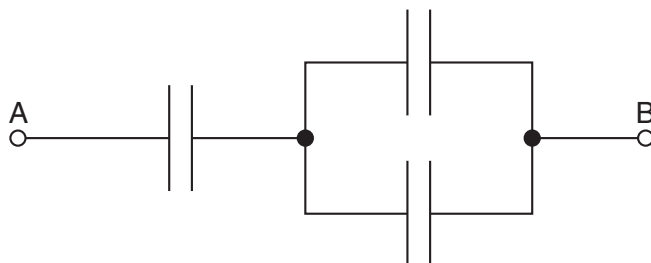


**Fig. 5.1**

Determine, for the arrangement shown in Fig. 5.1,

- (i) the total capacitance,

capacitance = .....  $\mu\text{F}$  [2]

- (ii) the maximum potential difference that can safely be applied between points A and B.

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

For  
Examiner's  
Use

- (c) A capacitor of capacitance  $4700\ \mu\text{F}$  is charged to a potential difference of  $18\text{V}$ . It is then partially discharged through a resistor. The potential difference is reduced to  $12\text{V}$ . Calculate the energy dissipated in the resistor during the discharge.

For  
Examiner's  
Use

energy = ..... J [3]

- 6 (a) A uniform magnetic field has constant flux density  $B$ . A straight wire of fixed length carries a current  $I$  at an angle  $\theta$  to the magnetic field, as shown in Fig. 6.1.

For  
Examiner's  
Use

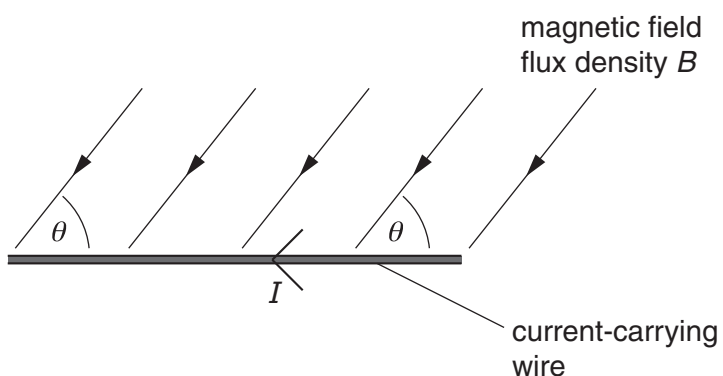


Fig. 6.1

- (i) The current  $I$  in the wire is changed, keeping the angle  $\theta$  constant. On Fig. 6.2, sketch a graph to show the variation with current  $I$  of the force  $F$  on the wire.

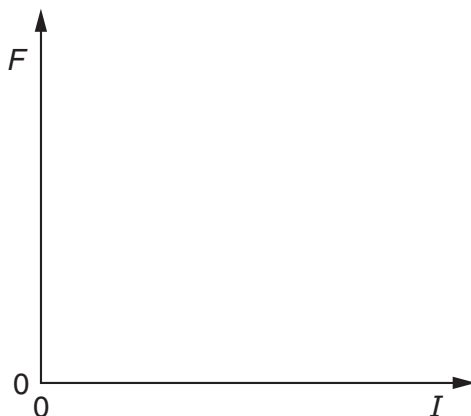


Fig. 6.2

[2]

- (ii) The angle  $\theta$  between the wire and the magnetic field is now varied. The current  $I$  is kept constant.  
On Fig. 6.3, sketch a graph to show the variation with angle  $\theta$  of the force  $F$  on the wire.

For  
Examiner's  
Use

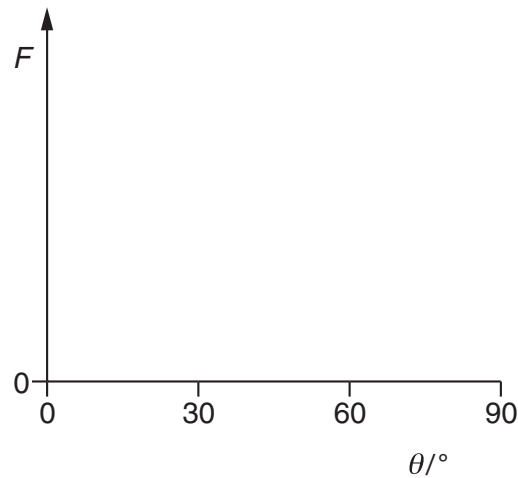


**Fig. 6.3**

[3]

- (b) A uniform magnetic field is directed at right-angles to the rectangular surface PQRS of a slice of a conducting material, as shown in Fig. 6.4.

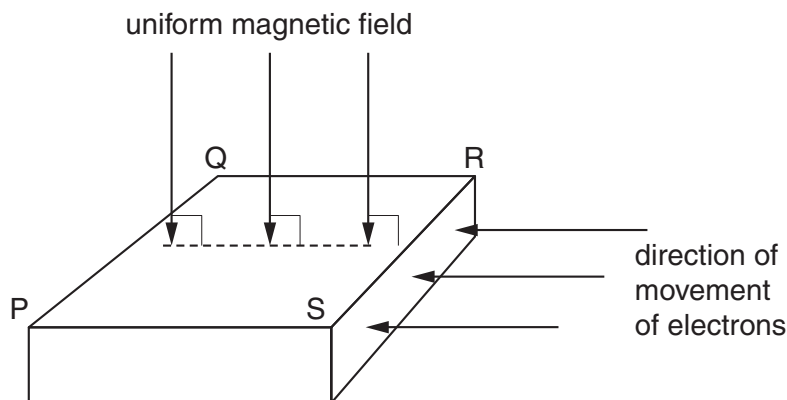


**Fig. 6.4**

Electrons, moving towards the side SR, enter the slice of conducting material. The electrons enter the slice at right-angles to side SR.

- (i) Explain why, initially, the electrons do not travel in straight lines across the slice from side SR to side PQ.

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

- (ii) Explain to which side, PS or QR, the electrons tend to move.

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

- 7 (a) Explain what is meant by the *root-mean-square* (r.m.s.) value of an alternating voltage.

.....

.....

..... [2]

- (b) An alternating voltage  $V$  is represented by the equation

$$V = 220 \sin(120\pi t),$$

where  $V$  is measured in volts and  $t$  is in seconds.

For this alternating voltage, determine

- (i) the peak voltage,

peak voltage = ..... V [1]

- (ii) the r.m.s. voltage,

r.m.s. voltage = ..... V [1]

- (iii) the frequency.

frequency = ..... Hz [1]

- (c) The alternating voltage in (b) is applied across a resistor such that the mean power output from the resistor is 1.5 kW.

Calculate the resistance of the resistor.

resistance = .....  $\Omega$  [2]

- 8** Americium-241 is an artificially produced radioactive element that emits  $\alpha$ -particles. A sample of americium-241 of mass  $5.1 \mu\text{g}$  is found to have an activity of  $5.9 \times 10^5 \text{ Bq}$ .

For  
Examiner's  
Use

**(a)** Determine, for this sample of americium-241,

**(i)** the number of nuclei,

number = ..... [2]

**(ii)** the decay constant,

decay constant = .....  $\text{s}^{-1}$  [2]

**(iii)** the half-life, in years.

half-life = ..... years [2]

- (b)** Another radioactive element has a half-life of approximately 4 hours. Suggest why measurement of the mass and activity of a sample of this element is not appropriate for the determination of its half-life.

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

## Section B

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

For  
Examiner's  
Use

9 (a) Negative feedback may be used in amplifier circuits. State

(i) what is meant by *negative feedback*,

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

(ii) two effects of negative feedback on an amplifier incorporating an operational amplifier (op-amp).

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

(b) Fig. 9.1 is a circuit for an amplifier that is used with a microphone.

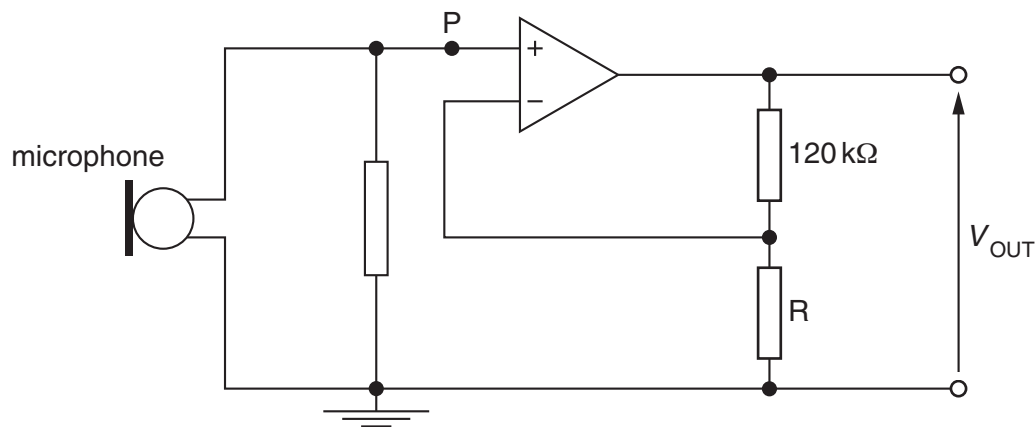


Fig. 9.1

The output potential difference  $V_{\text{OUT}}$  is  $4.4\text{ V}$  when the potential at point P is  $62\text{ mV}$ .

Determine

(i) the gain of the amplifier,

gain = ..... [1]

- (ii) the resistance of the resistor R.

resistance = .....  $\Omega$  [2]

- (c) The maximum potential produced by the microphone at point P on Fig. 9.1 is 95 mV.  
The power supply for the operational amplifier may be either  $\pm 5$  V or  $\pm 9$  V.

State which power supply should be used. Justify your answer quantitatively.

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

**10 (a)** State the name of an electrical sensing device that will respond to changes in

(i) length,

..... [1]

(ii) pressure.

..... [1]

**(b)** A relay is sometimes used as the output of a sensing circuit.

The output of a particular sensing circuit is either  $+2\text{V}$  or  $-2\text{V}$ .

On Fig. 10.1, draw symbols for a relay and any other necessary component so that the external circuit is switched on only when the output from the sensing circuit is  $+2\text{V}$ .



**Fig. 10.1**

[4]

- ..... [6

- 12** A telephone link between two towns is to be provided using an optic fibre. The length of the optic fibre between the two towns is 75 km.

**(a)** State two changes that occur in a signal as it is transmitted along an optic fibre.

1. ....

.....

2. ....

.....

[2]

**(b)** The optic fibre has an attenuation per unit length of  $1.6 \text{ dB km}^{-1}$ . The minimum permissible signal-to-noise power ratio in the fibre is 25 dB. The average noise power in the optic fibre is  $6.1 \times 10^{-19} \text{ W}$ .

**(i)** Suggest one reason why power ratios are expressed in dB.

.....

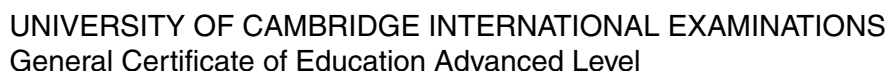
..... [1]

**(ii)** The signal input power to the optic fibre is designed to be 6.5 mW. Determine whether repeater amplifiers are necessary in the optic fibre between the two towns.

[5]

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**9702/43**

**May/June 2010**

**1 hour 45 minutes**

No Additional Materials are required.

## READ THESE INSTRUCTIONS FIRST

DO **NOT** WRITE IN ANY BARCODES.

The number of marks is given in brackets [ ] at the end of each question or part question.

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| 1                  |  |
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| Total              |  |

This document consists of **20** printed 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.

For  
Examiner's  
Use

- 1 (a) Define *gravitational potential* at a point.

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

- (b) The Earth may be considered to be an isolated sphere of radius  $R$  with its mass concentrated at its centre.  
 The variation of the gravitational potential  $\phi$  with distance  $x$  from the centre of the Earth is shown in Fig. 1.1.

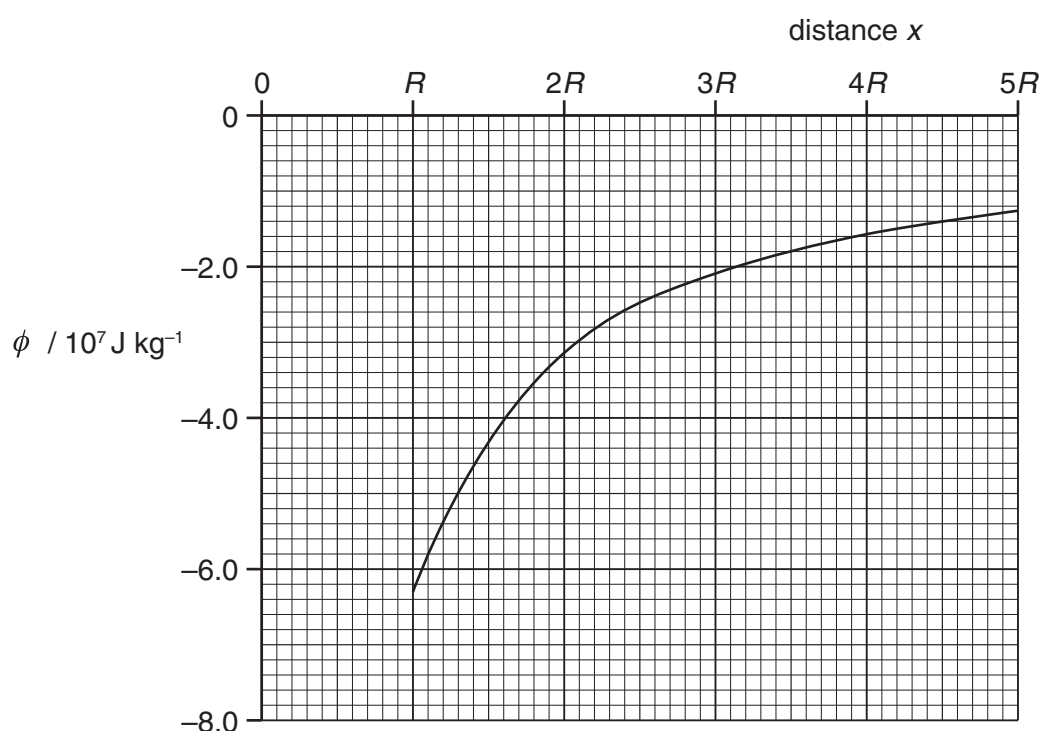


Fig. 1.1

The radius  $R$  of the Earth is  $6.4 \times 10^6 \text{ m}$ .

- (i) By considering the gravitational potential at the Earth's surface, determine a value for the mass of the Earth.

mass = ..... kg [3]

- (ii) A meteorite is at rest at infinity. The meteorite travels from infinity towards the Earth.

For  
Examiner's  
Use

Calculate the speed of the meteorite when it is at a distance of  $2R$  above the Earth's surface. Explain your working.

speed = .....  $\text{ms}^{-1}$  [4]

- (iii) In practice, the Earth is not an isolated sphere because it is orbited by the Moon, as illustrated in Fig. 1.2.



**Fig. 1.2** (not to scale)

The initial path of the meteorite is also shown.

Suggest two changes to the motion of the meteorite caused by the Moon.

1. ....
2. ....

[2]

- 2 A long strip of springy steel is clamped at one end so that the strip is vertical. A mass of 65 g is attached to the free end of the strip, as shown in Fig. 2.1.

For  
Examiner's  
Use

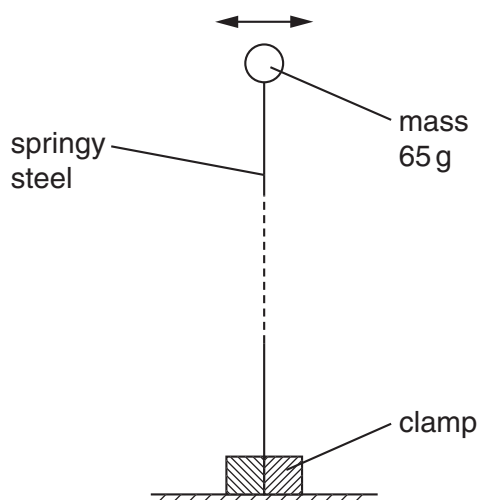


Fig. 2.1

The mass is pulled to one side and then released. The variation with time  $t$  of the horizontal displacement of the mass is shown in Fig. 2.2.

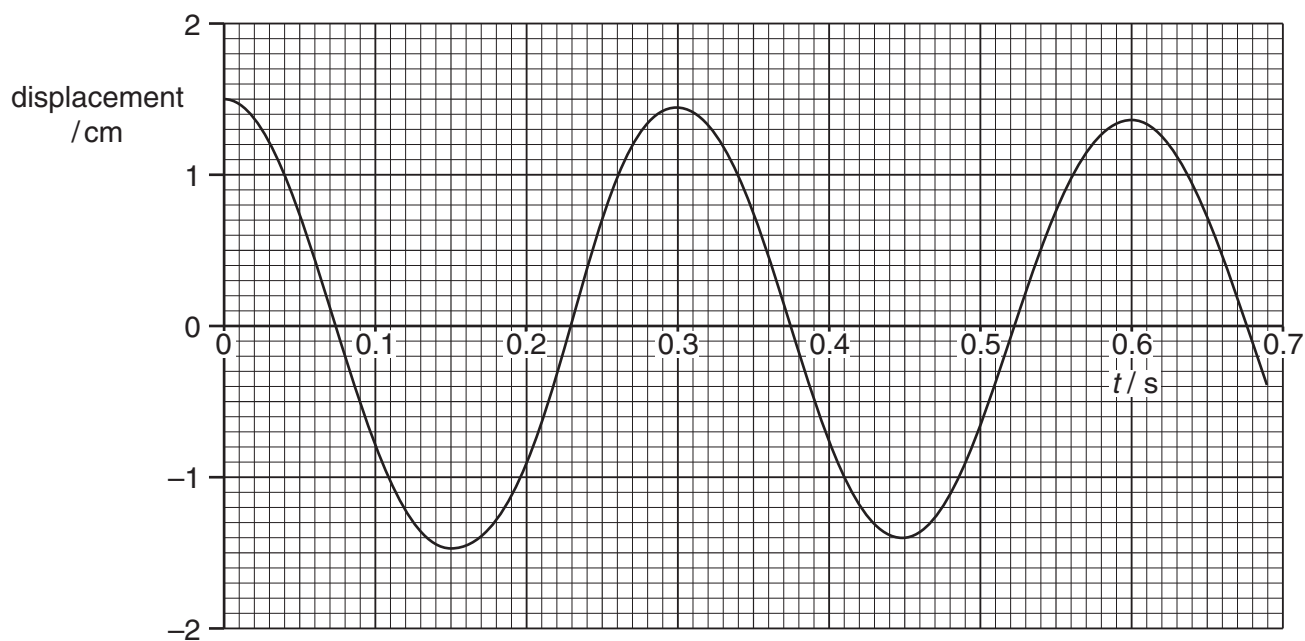


Fig. 2.2

The mass undergoes damped simple harmonic motion.

- (a) (i) Explain what is meant by *damping*.

.....

.....

..... [2]

- (ii) Suggest, with a reason, whether the damping is light, critical or heavy.

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

- (b) (i) Use Fig. 2.2 to determine the frequency of vibration of the mass.

frequency = ..... Hz [1]

- (ii) Hence show that the initial energy stored in the steel strip before the mass is released is approximately 3.2 mJ.

[2]

- (c) After eight complete oscillations of the mass, the amplitude of vibration is reduced from 1.5 cm to 1.1 cm. State and explain whether, after a further eight complete oscillations, the amplitude will be 0.7 cm.

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

- 3 (a)** The resistance of a thermistor at  $0^{\circ}\text{C}$  is  $3840\ \Omega$ . At  $100^{\circ}\text{C}$  the resistance is  $190\ \Omega$ . When the thermistor is placed in water at a particular constant temperature, its resistance is  $2300\ \Omega$ .

For  
Examiner's  
Use

- (i)** Assuming that the resistance of the thermistor varies linearly with temperature, calculate the temperature of the water.

temperature = .....  $^{\circ}\text{C}$  [2]

- (ii)** The temperature of the water, as measured on the thermodynamic scale of temperature, is  $286\text{ K}$ .

By reference to what is meant by the thermodynamic scale of temperature, comment on your answer in **(i)**.

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

- (b)** A polystyrene cup contains a mass of  $95\text{ g}$  of water at  $28^{\circ}\text{C}$ .

A cube of ice of mass  $12\text{ g}$  is put into the water. Initially, the ice is at  $0^{\circ}\text{C}$ . The water, of specific heat capacity  $4.2 \times 10^3\text{ J kg}^{-1}\text{ K}^{-1}$ , is stirred until all the ice melts.

Assuming that the cup has negligible mass and that there is no heat exchange with the atmosphere, calculate the final temperature of the water.

The specific latent heat of fusion of ice is  $3.3 \times 10^5\text{ J kg}^{-1}$ .

temperature = .....  $^{\circ}\text{C}$  [4]

- 4 Two point charges A and B each have a charge of  $+6.4 \times 10^{-19} \text{ C}$ . They are separated in a vacuum by a distance of  $12.0 \mu\text{m}$ , as shown in Fig. 4.1.

For  
Examiner's  
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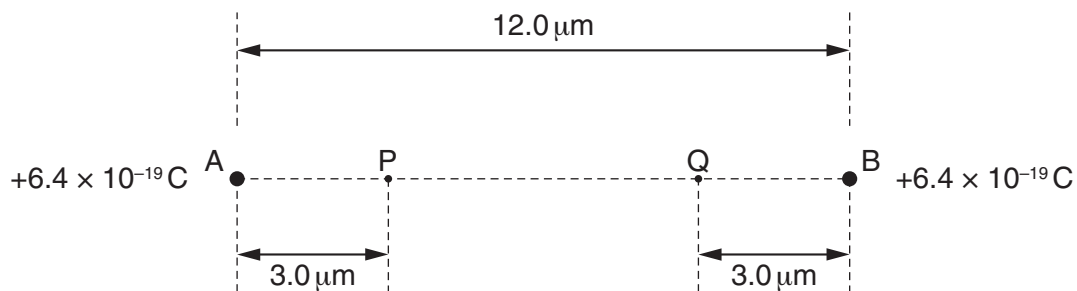


**Fig. 4.1**

Points P and Q are situated on the line AB. Point P is  $3.0 \mu\text{m}$  from charge A and point Q is  $3.0 \mu\text{m}$  from charge B.

- (a) Calculate the force of repulsion between the charges A and B.

force = ..... N [3]

- (b) Explain why, without any calculation, when a small test charge is moved from point P to point Q, the net work done is zero.

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

- (c) Calculate the work done by an electron in moving from the midpoint of line AB to point P.

work done = ..... J [4]

- 5 (a) State two functions of capacitors in electrical circuits.

1. ....

2. ....

[2]

- (b) Three capacitors, each marked ' $30\ \mu\text{F}$ ,  $6\text{V max}$ ', are arranged as shown in Fig. 5.1.

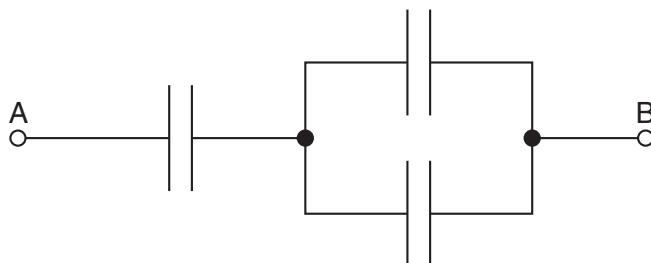


**Fig. 5.1**

Determine, for the arrangement shown in Fig. 5.1,

- (i) the total capacitance,

capacitance = .....  $\mu\text{F}$  [2]

- (ii) the maximum potential difference that can safely be applied between points A and B.

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

For  
Examiner's  
Use

- (c) A capacitor of capacitance  $4700\ \mu\text{F}$  is charged to a potential difference of  $18\text{V}$ . It is then partially discharged through a resistor. The potential difference is reduced to  $12\text{V}$ . Calculate the energy dissipated in the resistor during the discharge.

For  
Examiner's  
Use

energy = ..... J [3]

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For  
Examiner's  
Use

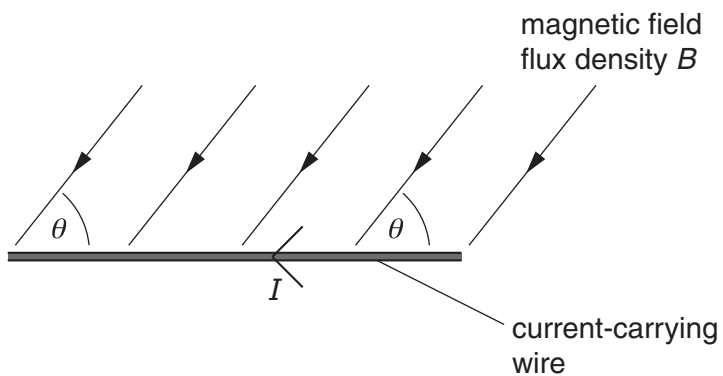


Fig. 6.1

- (i) The current  $I$  in the wire is changed, keeping the angle  $\theta$  constant. On Fig. 6.2, sketch a graph to show the variation with current  $I$  of the force  $F$  on the wire.

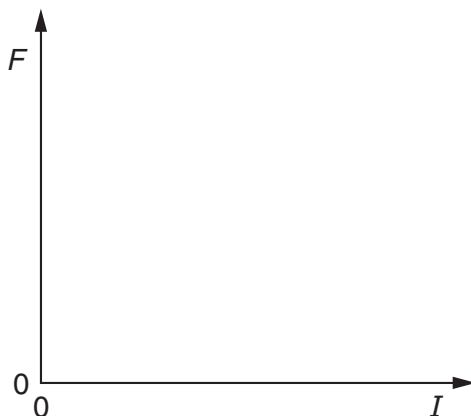


Fig. 6.2

[2]

- (ii) The angle  $\theta$  between the wire and the magnetic field is now varied. The current  $I$  is kept constant.  
On Fig. 6.3, sketch a graph to show the variation with angle  $\theta$  of the force  $F$  on the wire.

For  
Examiner's  
Use

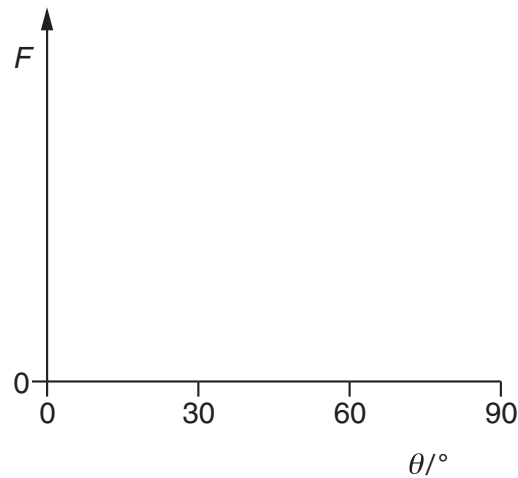


**Fig. 6.3**

[3]

- (b) A uniform magnetic field is directed at right-angles to the rectangular surface PQRS of a slice of a conducting material, as shown in Fig. 6.4.

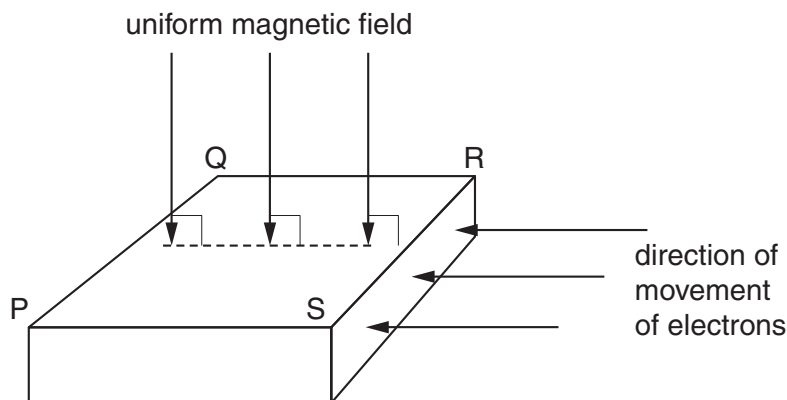


**Fig. 6.4**

Electrons, moving towards the side SR, enter the slice of conducting material. The electrons enter the slice at right-angles to side SR.

- (i) Explain why, initially, the electrons do not travel in straight lines across the slice from side SR to side PQ.

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

- (ii) Explain to which side, PS or QR, the electrons tend to move.

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

- 7 (a) Explain what is meant by the *root-mean-square* (r.m.s.) value of an alternating voltage.

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

- (b) An alternating voltage  $V$  is represented by the equation

$$V = 220 \sin(120\pi t),$$

where  $V$  is measured in volts and  $t$  is in seconds.

For this alternating voltage, determine

- (i) the peak voltage,

peak voltage = ..... V [1]

- (ii) the r.m.s. voltage,

r.m.s. voltage = ..... V [1]

- (iii) the frequency.

frequency = ..... Hz [1]

- (c) The alternating voltage in (b) is applied across a resistor such that the mean power output from the resistor is 1.5 kW.

Calculate the resistance of the resistor.

resistance = .....  $\Omega$  [2]

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For  
Examiner's  
Use

(a) Determine, for this sample of americium-241,

(i) the number of nuclei,

number = ..... [2]

(ii) the decay constant,

decay constant = .....  $\text{s}^{-1}$  [2]

(iii) the half-life, in years.

half-life = ..... years [2]

- (b) Another radioactive element has a half-life of approximately 4 hours. Suggest why measurement of the mass and activity of a sample of this element is not appropriate for the determination of its half-life.

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

## Section B

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

For  
Examiner's  
Use

9 (a) Negative feedback may be used in amplifier circuits. State

(i) what is meant by *negative feedback*,

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

(ii) two effects of negative feedback on an amplifier incorporating an operational amplifier (op-amp).

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

(b) Fig. 9.1 is a circuit for an amplifier that is used with a microphone.

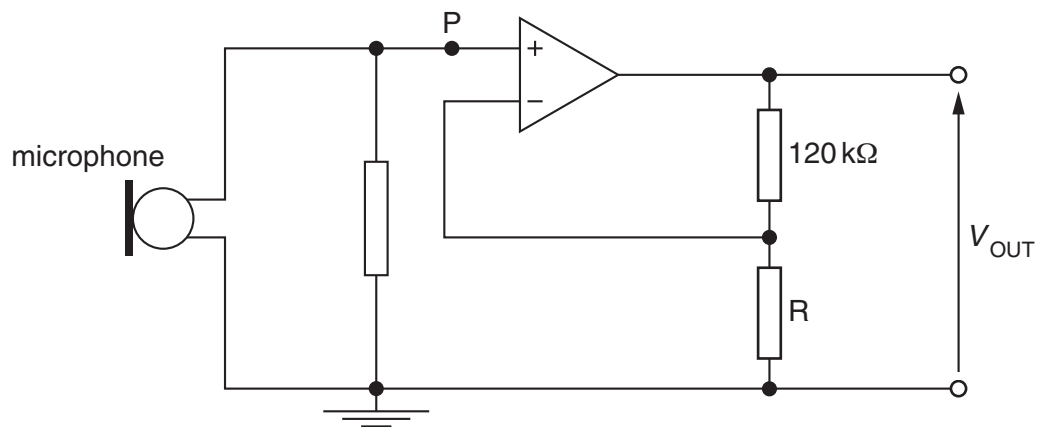


Fig. 9.1

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Determine

(i) the gain of the amplifier,

gain = ..... [1]

- (ii) the resistance of the resistor R.

resistance = .....  $\Omega$  [2]

- (c) The maximum potential produced by the microphone at point P on Fig. 9.1 is 95 mV.  
The power supply for the operational amplifier may be either  $\pm 5$  V or  $\pm 9$  V.

State which power supply should be used. Justify your answer quantitatively.

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

**10 (a)** State the name of an electrical sensing device that will respond to changes in

(i) length,

..... [1]

(ii) pressure.

..... [1]

**(b)** A relay is sometimes used as the output of a sensing circuit.

The output of a particular sensing circuit is either  $+2\text{V}$  or  $-2\text{V}$ .

On Fig. 10.1, draw symbols for a relay and any other necessary component so that the external circuit is switched on only when the output from the sensing circuit is  $+2\text{V}$ .



**Fig. 10.1**

[4]

- ..... [6

- 12** A telephone link between two towns is to be provided using an optic fibre. The length of the optic fibre between the two towns is 75 km.

**(a)** State two changes that occur in a signal as it is transmitted along an optic fibre.

1. ....

.....

2. ....

.....

[2]

**(b)** The optic fibre has an attenuation per unit length of  $1.6 \text{ dB km}^{-1}$ . The minimum permissible signal-to-noise power ratio in the fibre is 25 dB. The average noise power in the optic fibre is  $6.1 \times 10^{-19} \text{ W}$ .

**(i)** Suggest one reason why power ratios are expressed in dB.

.....

..... [1]

**(ii)** The signal input power to the optic fibre is designed to be 6.5 mW.  
Determine whether repeater amplifiers are necessary in the optic fibre between the two towns.

[5]

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