Cambridge International A Level

Cambridge International Examinations
Cambridge International Advanced Level

CANDIDATE NAME			
CENTRE NUMBER		CANDIDATE NUMBER	

6143367755

PHYSICS **9702/42**

Paper 4 A2 Structured Questions **October/November 2014**

2 hours

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.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

Electronic calculators may be used.
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.

For Examiner's Use	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
Total	

This document consists of **25** printed pages and **3** blank pages.

DC (NF/SW) 98838

CAMBRIDGE International Examinations

Data

speed of light in free space,	$c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$
permittivity of free space,	$\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
	$(\dfrac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ \mathrm{m\,F^{-1}})$
elementary charge,	$e = 1.60 \times 10^{-19}\ \mathrm{C}$
the Planck constant,	$h = 6.63 \times 10^{-34}\ \mathrm{J\,s}$
unified atomic mass constant,	$u = 1.66 \times 10^{-27}\ \mathrm{kg}$
rest mass of electron,	$m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$
rest mass of proton,	$m_p = 1.67 \times 10^{-27}\ \mathrm{kg}$
molar gas constant,	$R = 8.31\ \mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant,	$N_A = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
the Boltzmann constant,	$k = 1.38 \times 10^{-23}\ \mathrm{J\,K^{-1}}$
gravitational constant,	$G = 6.67 \times 10^{-11}\ \mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall,	$g = 9.81\ \mathrm{m\,s^{-2}}$

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,	$\phi = -\dfrac{Gm}{r}$
hydrostatic pressure,	$p = \rho gh$
pressure of an ideal gas,	$p = \frac{1}{3}\dfrac{Nm}{V}\langle c^2 \rangle$
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,	$V = \dfrac{Q}{4\pi\varepsilon_0 r}$
capacitors in series,	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel,	$C = C_1 + C_2 + \ldots$
energy of charged capacitor,	$W = \frac{1}{2}QV$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
alternating current/voltage,	$x = x_0 \sin \omega t$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \dfrac{0.693}{t_{\frac{1}{2}}}$

Section A

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

1 An isolated spherical planet has a diameter of 6.8×10^6 m. Its mass of 6.4×10^{23} kg may be assumed to be a point mass at the centre of the planet.

(a) Show that the gravitational field strength at the surface of the planet is $3.7\,\mathrm{N\,kg^{-1}}$.

[2]

(b) A stone of mass 2.4 kg is raised from the surface of the planet through a vertical height of 1800 m.
Use the value of field strength given in **(a)** to determine the change in gravitational potential energy of the stone.
Explain your working.

change in energy = ... J [3]

(c) A rock, initially at rest at infinity, moves towards the planet. At point P, its height above the surface of the planet is 3.5 *D*, where *D* is the diameter of the planet, as shown in Fig. 1.1.

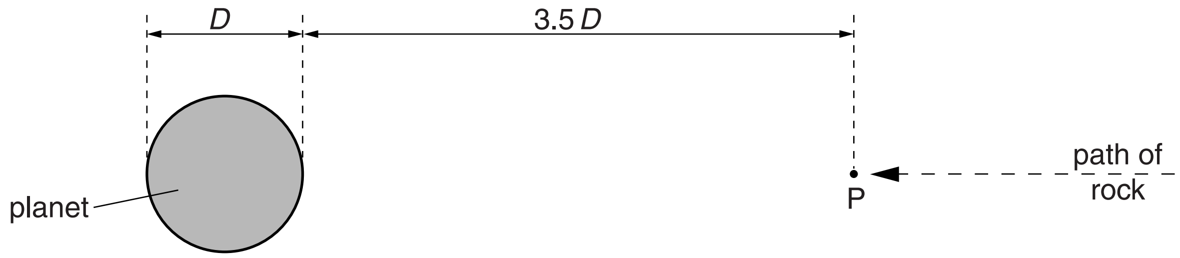

Fig. 1.1

Calculate the speed of the rock at point P, assuming that the change in gravitational potential energy is all transferred to kinetic energy.

speed = ... $m\,s^{-1}$ [4]

2 A large bowl is made from part of a hollow sphere.

A small spherical ball is placed inside the bowl and is given a horizontal speed. The ball follows a horizontal circular path of constant radius, as shown in Fig. 2.1.

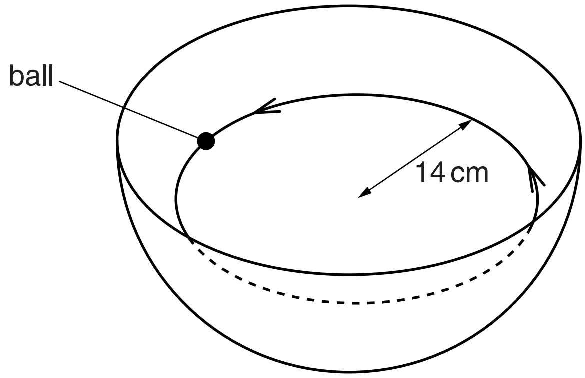

Fig. 2.1

The forces acting on the ball are its weight W and the normal reaction force R of the bowl on the ball, as shown in Fig. 2.2.

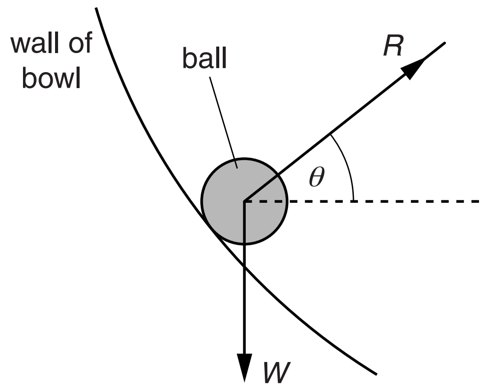

Fig. 2.2

The normal reaction force R is at an angle θ to the horizontal.

(a) (i) By resolving the reaction force R into two perpendicular components, show that the resultant force F acting on the ball is given by the expression

$$W = F \tan\theta.$$

[2]

(ii) State the significance of the force F for the motion of the ball in the bowl.

....

.... [1]

(b) The ball moves in a circular path of radius 14 cm. For this radius, the angle θ is 28°.

Calculate the speed of the ball.

speed = ... $m\,s^{-1}$ [3]

BLANK PAGE

3 **(a)** State what is meant by an *ideal* gas.

....

.... [1]

(b) A storage cylinder for an ideal gas has a volume of $3.0 \times 10^{-4}\,m^3$. The gas is at a temperature of 23 °C and a pressure of 5.0×10^7 Pa.

(i) Show that the amount of gas in the cylinder is 6.1 mol.

[2]

(ii) The gas leaks slowly from the cylinder so that, after a time of 35 days, the pressure has reduced by 0.40%. The temperature remains constant.
Calculate the average rate, in atoms per second, at which gas atoms escape from the cylinder.

rate = ... s^{-1} [4]

4 **(a)** State what is meant by *simple harmonic motion*.

....

....

.... [2]

(b) A small ball rests at point P on a curved track of radius r, as shown in Fig. 4.1.

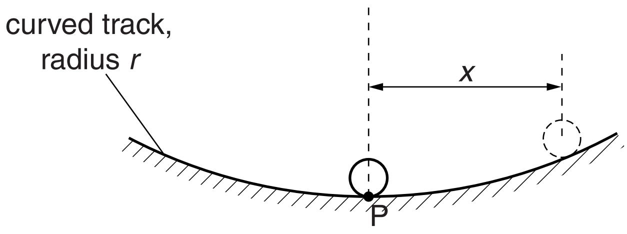

Fig. 4.1

The ball is moved a small distance to one side and is then released. The horizontal displacement x of the ball is related to its acceleration a towards P by the expression

$$a = -\frac{gx}{r}$$

where g is the acceleration of free fall.

(i) Show that the ball undergoes simple harmonic motion.

....

....

....

.... [2]

(ii) The radius r of curvature of the track is 28 cm.

Determine the time interval τ between the ball passing point P and then returning to point P.

τ = ... s [3]

(c) The variation with time t of the displacement x of the ball in **(b)** is shown in Fig. 4.2.

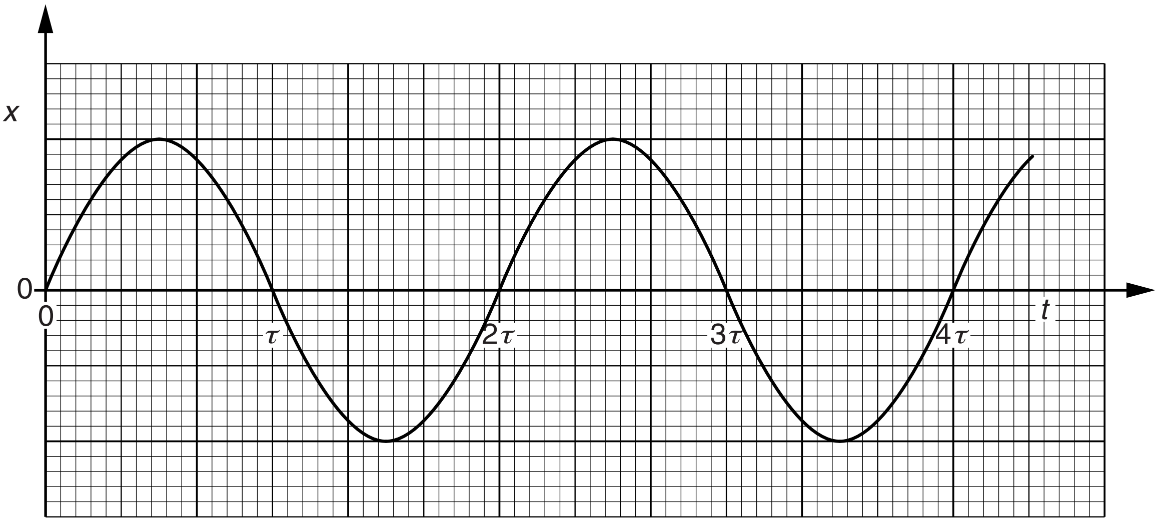

Fig. 4.2

Some moisture now forms on the track, causing the ball to come to rest after approximately 15 oscillations.

On the axes of Fig. 4.2, sketch the variation with time t of the displacement x of the ball for the first two periods after the moisture has formed. Assume the moisture forms at time t = 0. [3]

5 **(a)** Define *electric potential* at a point.

....

....

.... [2]

(b) An isolated solid metal sphere is positively charged.

The variation of the potential V with distance x from the centre of the sphere is shown in Fig. 5.1.

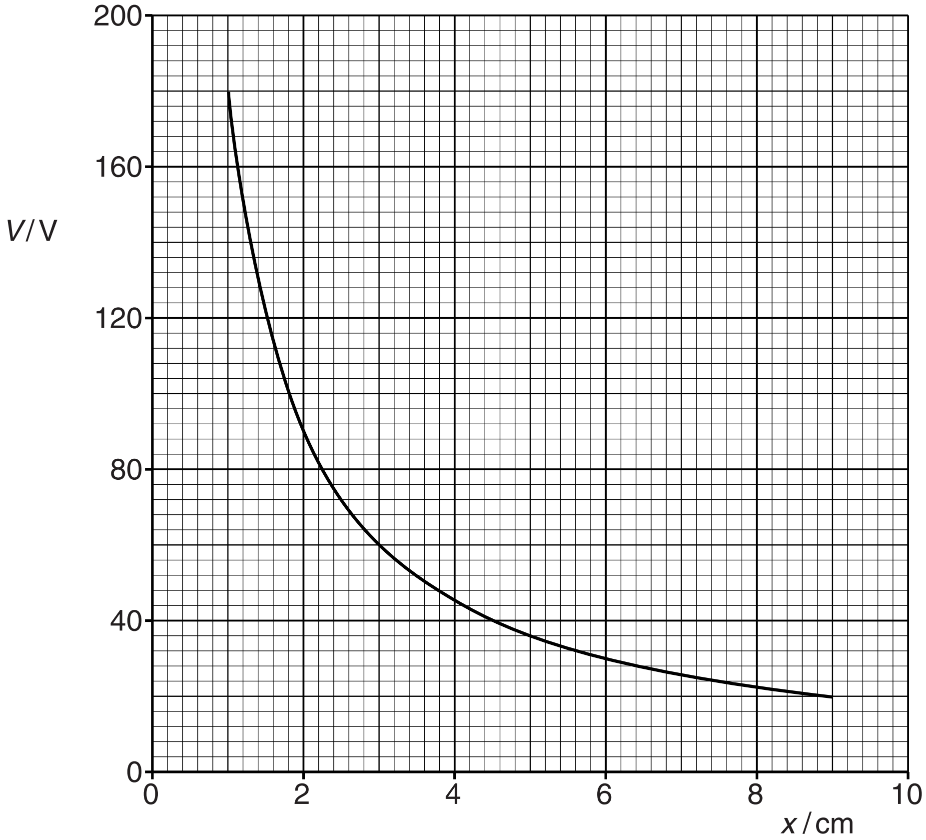

Fig. 5.1

Use Fig. 5.1 to suggest

(i) why the radius of the sphere cannot be greater than 1.0 cm,

....

.... [1]

(ii) that the charge on the sphere behaves as if it were a point charge.

[3]

(c) Assuming that the charge on the sphere does behave as a point charge, use data from Fig. 5.1 to determine the charge on the sphere.

charge = ... C [2]

BLANK PAGE

6 A stiff straight copper wire XY is held fixed in a uniform magnetic field of flux density 2.6×10^{-3} T, as shown in Fig. 6.1.

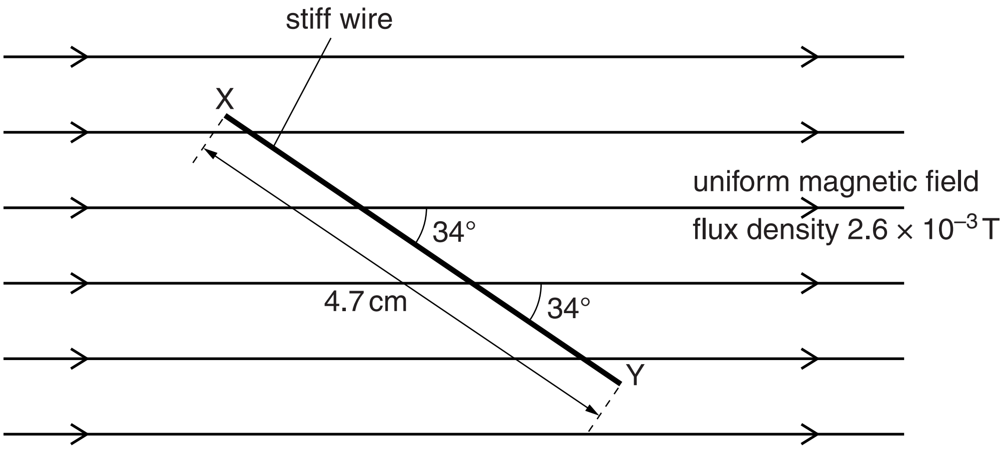

Fig. 6.1

The wire XY has length 4.7 cm and makes an angle of 34° with the magnetic field.

(a) Calculate the force on the wire due to a constant current of 5.4 A in the wire.

force = ... N [2]

(b) The current in the wire is now changed to an alternating current of r.m.s. value 1.7 A.

Determine the total variation in the force on the wire due to the alternating current.

variation in force = ... N [3]

7 **(a)** The mean value of an alternating current is zero.

Explain

(i) why an alternating current gives rise to a heating effect in a resistor,

....

....

.... [2]

(ii) by reference to heating effect, what is meant by the root-mean-square (r.m.s.) value of an alternating current.

....

....

....

.... [2]

(b) A simple iron-cored transformer is illustrated in Fig. 7.1.

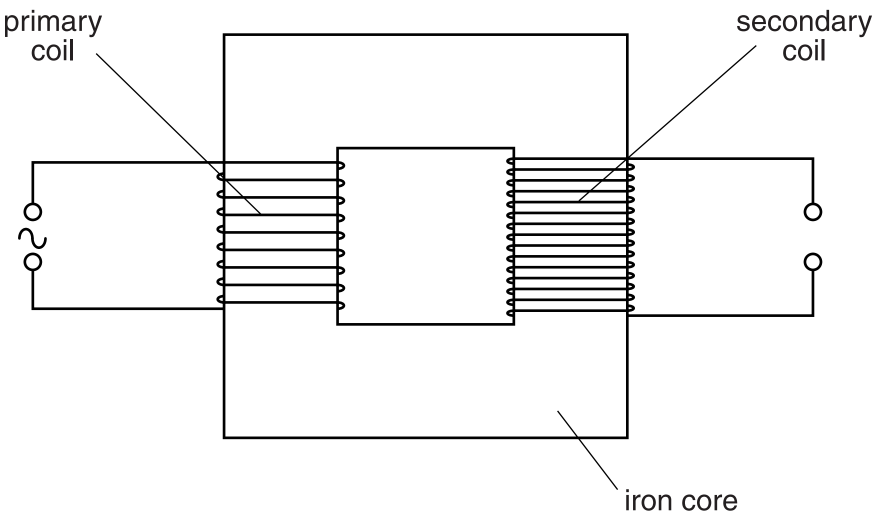

Fig. 7.1

(i) State Faraday's law of electromagnetic induction.

....

....

.... [2]

(ii) Use Faraday's law to explain why the current in the primary coil is not in phase with the e.m.f. induced in the secondary coil.

....

....

....

....

.... [3]

8 White light is incident on a cloud of cool hydrogen gas, as illustrated in Fig. 8.1.

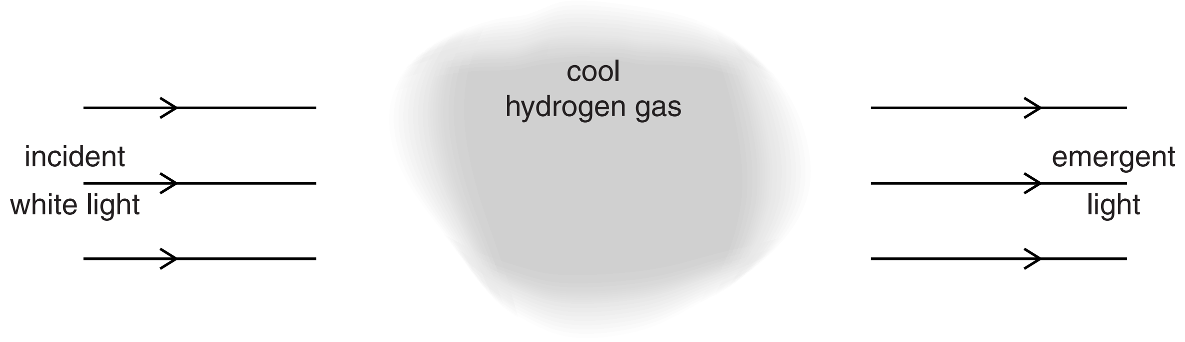

Fig. 8.1

The spectrum of the light emerging from the gas cloud is found to contain a number of dark lines.

(a) Explain why these dark lines occur.

....

....

....

....

.... [3]

(b) Some electron energy levels in a hydrogen atom are illustrated in Fig. 8.2.

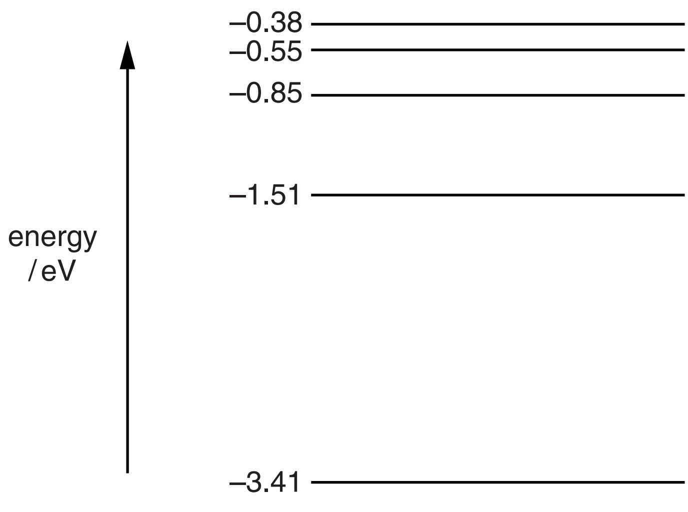

Fig. 8.2

One dark line is observed at a wavelength of 435 nm.

(i) Calculate the energy, in eV, of a photon of light of wavelength 435 nm.

energy = ... eV [4]

(ii) On Fig. 8.2, draw an arrow to indicate the energy change that gives rise to this dark line. [1]

9 One likely means by which nuclear fusion may be achieved on a practical scale is the D-T reaction.

(a) State what is meant by *nuclear fusion*.

....

.... [1]

(b) In the D-T reaction, a deuterium ($^{2}_{1}H$) nucleus fuses with a tritium ($^{3}_{1}H$) nucleus to form a helium-4 ($^{4}_{2}He$) nucleus. The nuclear equation for the reaction is

$$^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n + \text{energy}$$

Some data for this reaction are given in Fig. 9.1.

	mass / u
deuterium ($^{2}_{1}H$)	2.01356
tritium ($^{3}_{1}H$)	3.01551
helium-4 ($^{4}_{2}He$)	4.00151
neutron ($^{1}_{0}n$)	1.00867

Fig. 9.1

(i) Calculate the energy, in MeV, equivalent to 1.00 u. Explain your working.

energy = ... MeV [3]

(ii) Use data from Fig. 9.1 and your answer in **(i)** to determine the energy released in this D-T reaction.

energy = ... MeV [2]

(iii) Suggest why, for the D-T reaction to take place, the temperature of the deuterium and the tritium must be high.

....

....

.... [2]

Section B

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

10 **(a)** An ideal operational amplifier (op-amp) has infinite open-loop gain and infinite input resistance (impedance).

State three further properties of an ideal op-amp.

1. ....

....

2. ....

....

3. ....

....
[3]

(b) The circuit of Fig. 10.1 is used to detect changes in temperature.

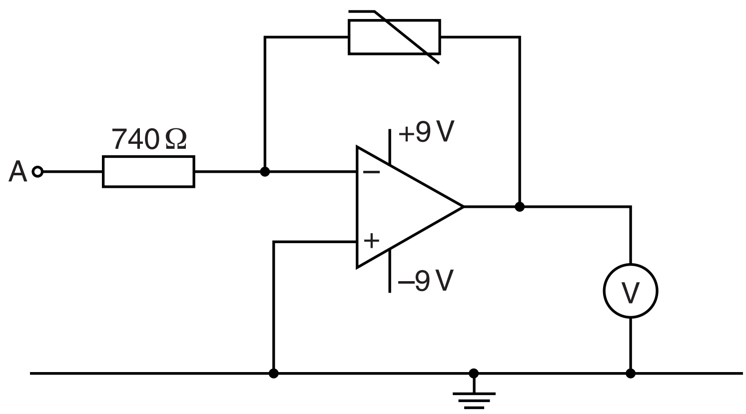

Fig. 10.1

The voltmeter has infinite resistance.

The variation with temperature θ of the resistance R of the thermistor is shown in Fig. 10.2.

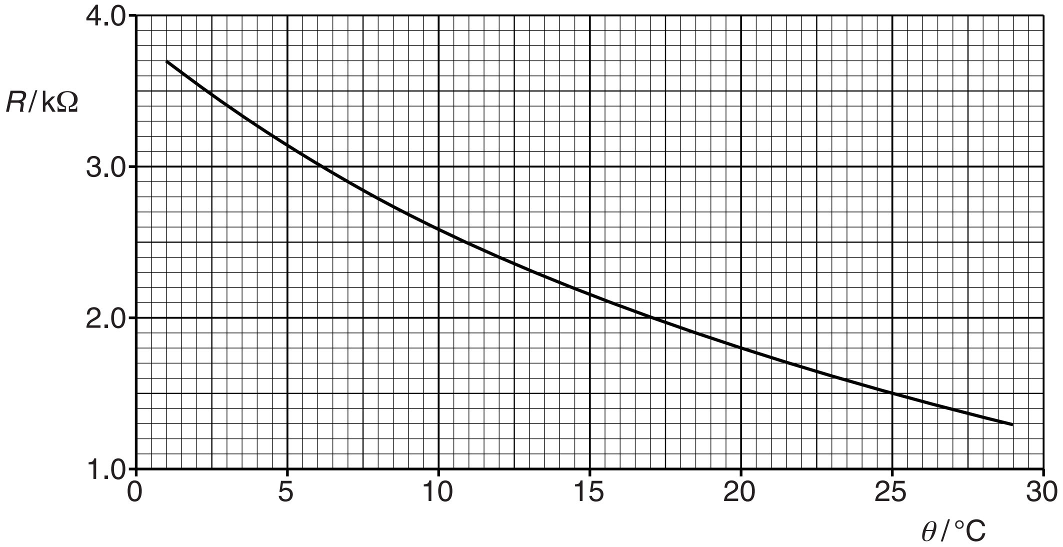

Fig. 10.2

(i) When the thermistor is at a temperature of 1.0 °C, the voltmeter reads +1.0 V.

Show that, for the thermistor at 1.0 °C, the potential at A is −0.20 V.

[4]

(ii) The potential at A remains at −0.20 V.

Determine the voltmeter reading for a thermistor temperature of 15 °C.

voltmeter reading = ... V [2]

(c) The voltmeter reading for a thermistor temperature of 29 °C is 0.35 V.

(i) Assuming a linear change of voltmeter reading with change of temperature over the range 1 °C to 29 °C, calculate the voltmeter reading at 15 °C.

voltmeter reading = ... V [1]

(ii) Suggest why your answers in **(b)(ii)** and **(c)(i)** are not the same.

....

.... [1]

11 The use of X-rays in medical diagnosis gives rise to an increased exposure of the patient to radiation.

Explain why

(a) an aluminium filter may be placed in the X-ray beam when producing an X-ray image of a patient,

....

....

....

....

.... [3]

(b) the radiation dose received by a patient is different for a CT scan from that for a simple X-ray image.

....

....

....

....

....

.... [4]

12 **(a)** Information may be carried by different channels of communication.

State one application, in each case, where information is carried using

(i) microwaves,

....

.... [1]

(ii) coaxial cables,

....

.... [1]

(iii) wire pairs.

....

.... [1]

(b) A station on Earth transmits a signal of initial power 3.1 kW to a geostationary satellite. The attenuation of the signal received by the satellite is 190 dB.

(i) Calculate the power of the signal received by the satellite.

power = ... kW [2]

(ii) By reference to your answer in **(i)**, state and explain the changes made to the signal before transmission back to Earth.

....

....

....

....

.... [3]

13 A simplified block diagram of a mobile phone handset is shown in Fig. 13.1.

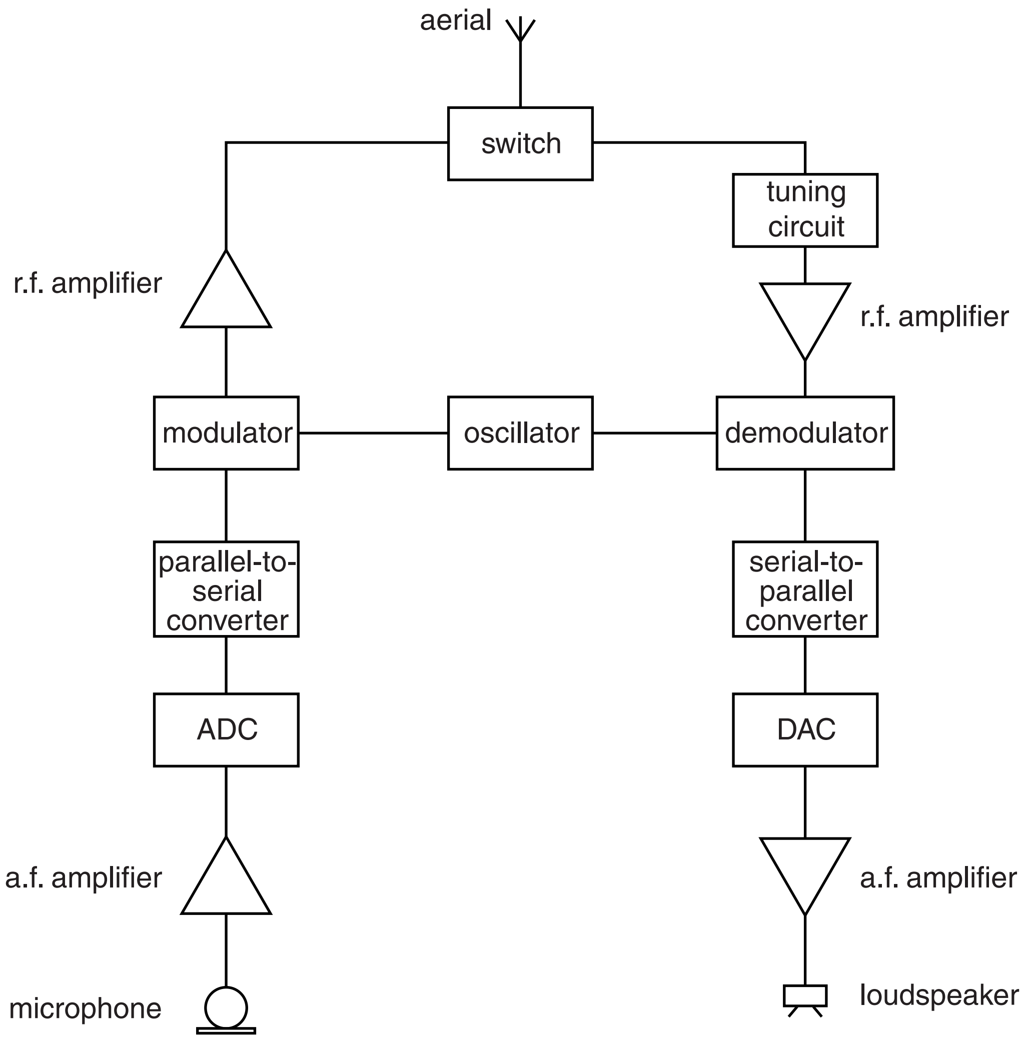

Fig. 13.1

State the purpose of

(a) the switch,

....

....

....

.... [2]

(b) the tuning circuit.

....

....

....

.... [2]

BLANK PAGE