Cambridge International A Level

Cambridge International Examinations
Cambridge International Advanced Level

CANDIDATE NAME

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2203241344

PHYSICS **9702/42**

Paper 4 A2 Structured Questions **May/June 2015**

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.

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Total	

This document consists of **23** printed pages and **1** blank page.

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

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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, $V = \frac{Q}{4\pi\varepsilon_0 r}$

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

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[Turn over

Section A

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

1 **(a)** The Earth may be considered to be a uniform sphere of radius 6.37×10^3 km with its mass of 5.98×10^{24} kg concentrated at its centre. The Earth spins on its axis with a period of 24.0 hours.

(i) A stone of mass 2.50 kg rests on the Earth's surface at the Equator.

1. Calculate, using Newton's law of gravitation, the gravitational force on the stone.

gravitational force = ... N [2]

2. Determine the force required to maintain the stone in its circular path.

force = ... N [2]

(ii) The stone is now hung from a newton-meter.

Use your answers in **(i)** to determine the reading on the meter. Give your answer to three significant figures.

reading = ... N [2]

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(b) A satellite is orbiting the Earth. For an astronaut in the satellite, his sensation of weight is caused by the contact force from his surroundings.

The astronaut reports that he is 'weightless', despite being in the Earth's gravitational field.

Suggest what is meant by the astronaut reporting that he is 'weightless'.

.....

.....

.....

.....[3]

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2 In a sample of gas at room temperature, five atoms have the following speeds:

$1.32 \times 10^3\,\text{m s}^{-1}$
$1.50 \times 10^3\,\text{m s}^{-1}$
$1.46 \times 10^3\,\text{m s}^{-1}$
$1.28 \times 10^3\,\text{m s}^{-1}$
$1.64 \times 10^3\,\text{m s}^{-1}$.

For these five atoms, calculate, to three significant figures,

(a) the mean speed,

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

(b) the mean-square speed,

mean-square speed = ... $\text{m}^2\,\text{s}^{-2}$ [2]

(c) the root-mean-square speed.

root-mean-square speed = ... m s^{-1} [1]

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3 **(a)** Define *specific latent heat*.

.....

.....

.....[2]

(b) A beaker containing a liquid is placed on a balance, as shown in Fig. 3.1.

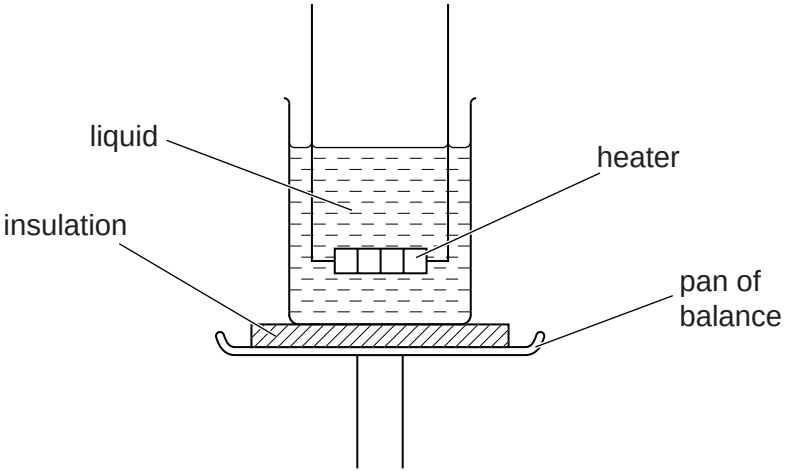


Fig. 3.1

A heater of power 110W is immersed in the liquid. The heater is switched on and, when the liquid is boiling, balance readings *m* are taken at corresponding times *t*.

A graph of the variation with time *t* of the balance reading *m* is shown in Fig. 3.2.

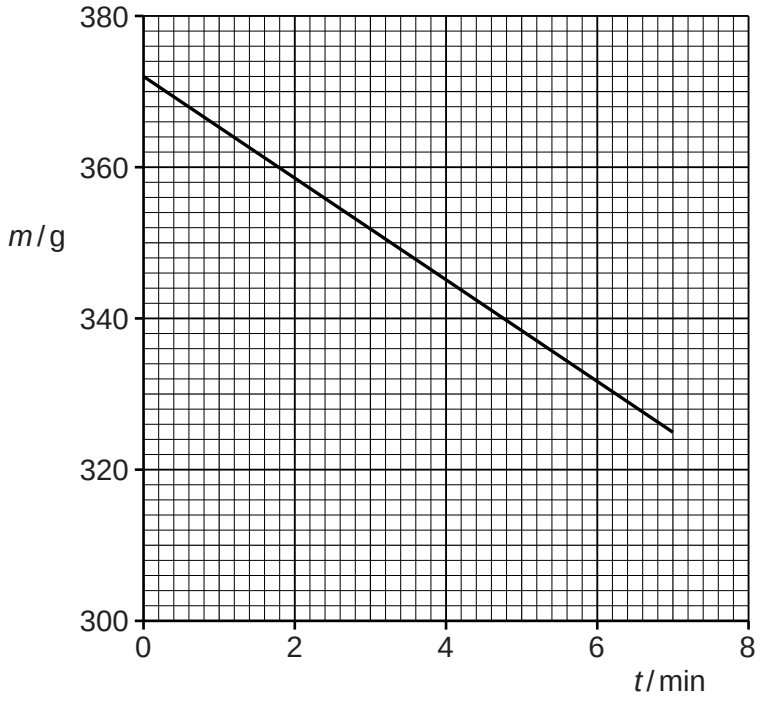


Fig. 3.2

(i) State the feature of Fig. 3.2 which suggests that the liquid is boiling at a steady rate.

.....

.....[1]

(ii) Use data from Fig. 3.2 to determine a value for the specific latent heat *L* of vaporisation of the liquid.

L = ... $J kg^{-1}$ [3]

(iii) State, with a reason, whether the value determined in **(ii)** is likely to be an overestimate or an underestimate of the normally accepted value for the specific latent heat of vaporisation of the liquid.

.....

.....

.....[2]

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

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.....

.....[2]

(b) The variation with time t of the displacement x of two oscillators P and Q is shown in Fig. 4.1.

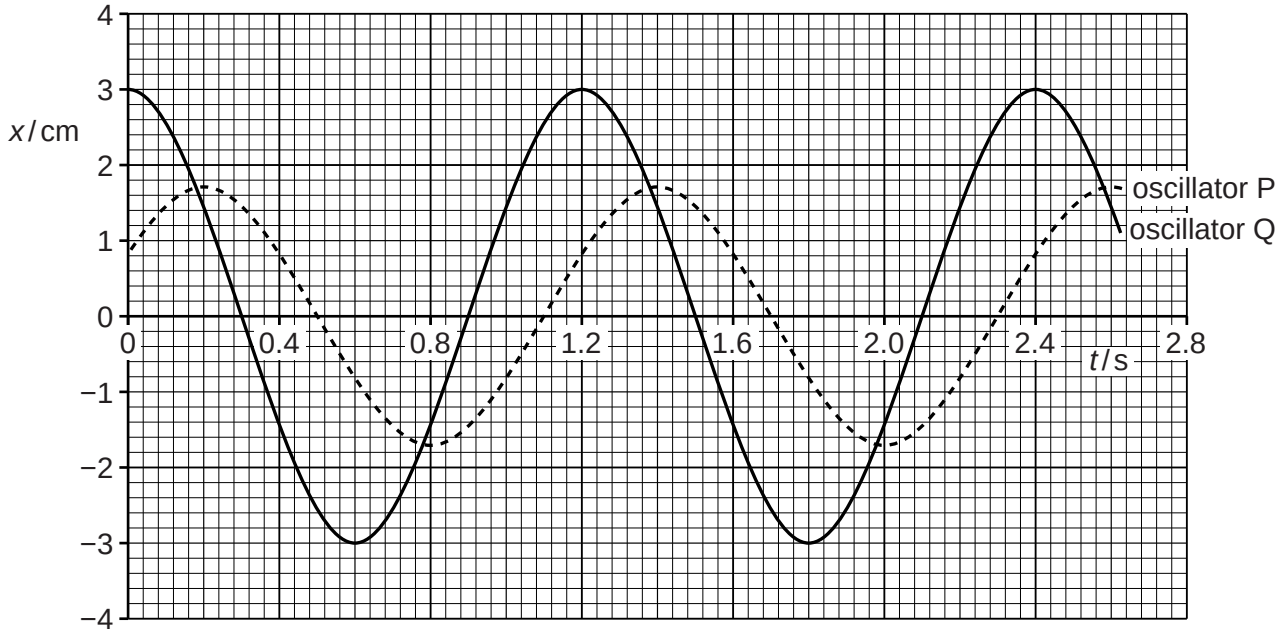


Fig. 4.1

The two oscillators each have the same mass.

Use Fig. 4.1 to determine

(i) the phase difference between the two oscillators,

phase difference = ... rad [1]

(ii) the maximum acceleration of oscillator Q,

maximum acceleration = ... $m\,s^{-2}$ [2]

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(iii) the ratio

$$\frac{\text{maximum kinetic energy of oscillations of Q}}{\text{maximum kinetic energy of oscillations of P}}.$$

ratio = ... [2]

(c) Use data from **(b)** to sketch, on the axes of Fig. 4.2, the variation with displacement *x* of the acceleration *a* of oscillator Q.

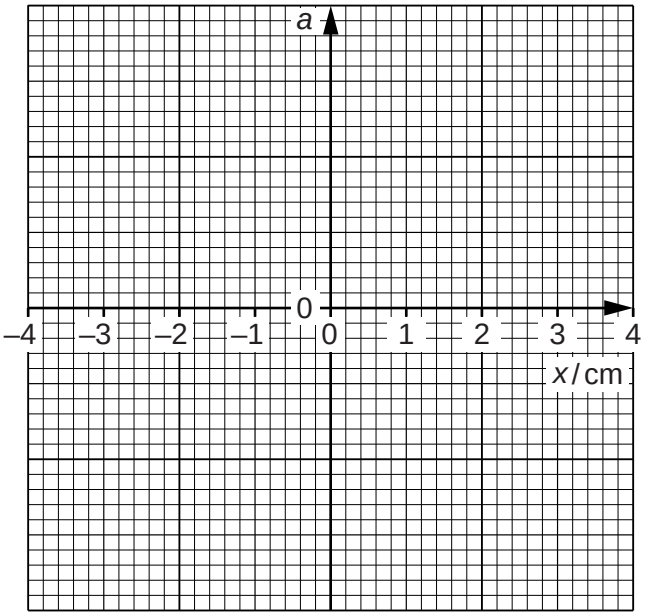


Fig. 4.2

[2]

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

.....

.....

.....[2]

(b) Two positively charged metal spheres A and B are situated in a vacuum, as shown in Fig. 5.1.

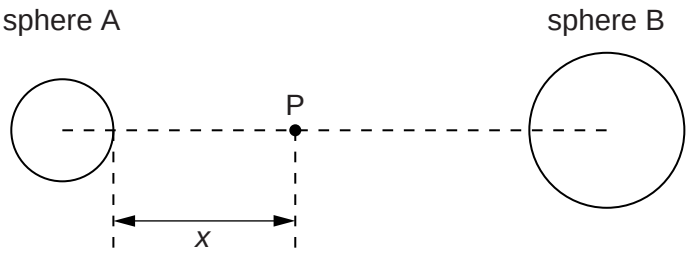


Fig. 5.1

A point P lies on the line joining the centres of the two spheres and is a distance *x* from the surface of sphere A.

The variation with *x* of the electric potential *V* due to the two charged spheres is shown in Fig. 5.2.

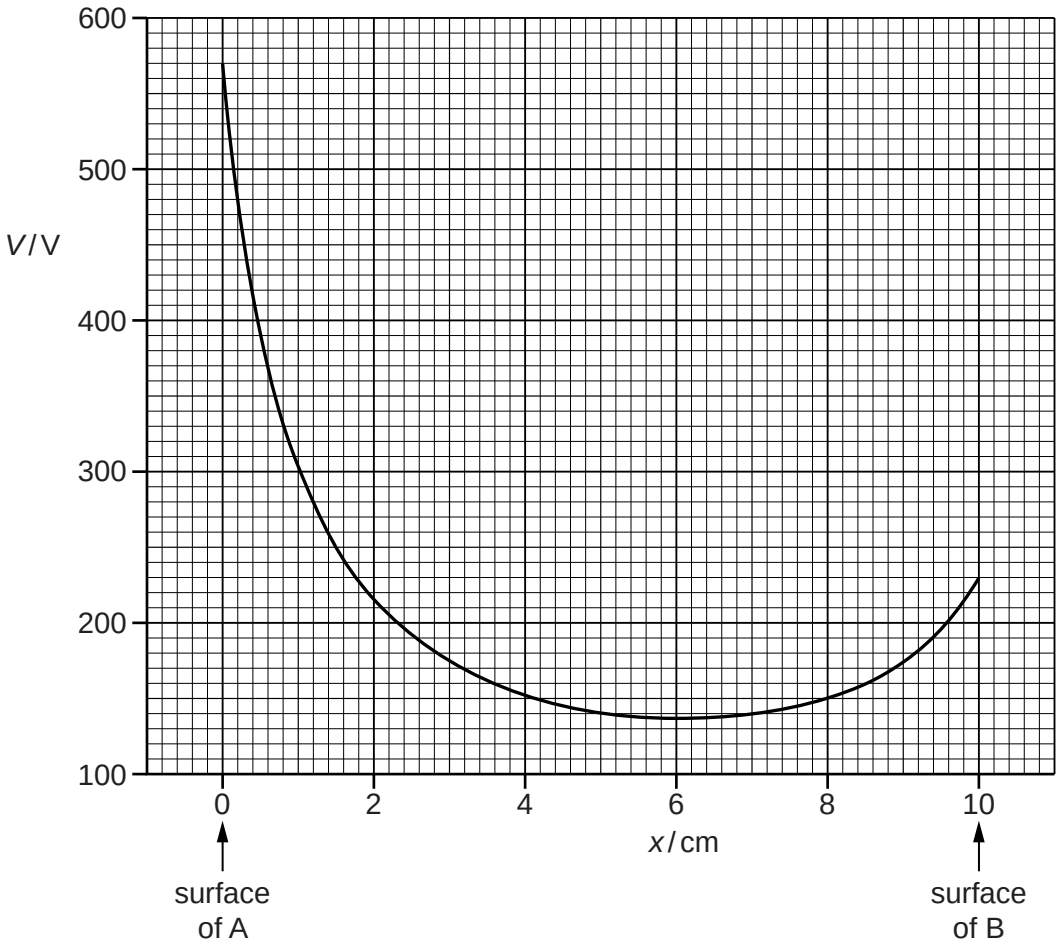


Fig. 5.2

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(i) State how the magnitude of the electric field strength at any point P may be determined from the graph of Fig. 5.2.

.....

.....[1]

(ii) Without any calculation, describe the force acting on a positively charged particle placed at point P for values of x from $x = 0$ to $x = 10\,\text{cm}$.

.....

.....

.....

.....[3]

(c) The positively charged particle in **(b)(ii)** has charge q and mass m given by the expression

$$\frac{q}{m} = 4.8 \times 10^{7}\,\text{C kg}^{-1}.$$

Initially, the particle is at rest on the surface of sphere A where $x = 0$. It then moves freely along the line joining the centres of the spheres until it reaches the surface of sphere B.

(i) On Fig. 5.2, mark with the letter M the point where the charged particle has its maximum speed. [1]

(ii) **1.** Use Fig. 5.2 to determine the potential difference between the spheres.

potential difference = ... V [1]

2. Use your answer in **(ii) part 1** to calculate the speed of the particle as it reaches the surface of sphere B.
Explain your working.

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

6 **(a)** Explain what is meant by a *photon*.

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.....[2]

(b) An X-ray photon of energy 3.06×10^{-14} J is incident on an isolated stationary electron, as illustrated in Fig. 6.1.

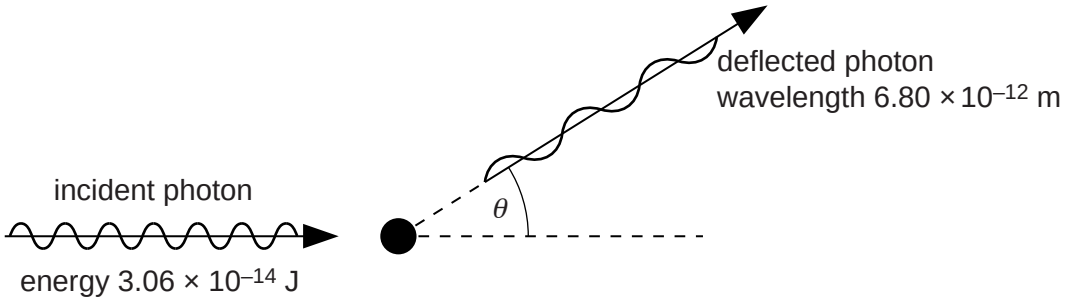


Fig. 6.1

The photon is deflected elastically by the electron through angle θ. The deflected photon has a wavelength of 6.80×10^{-12} m.

(i) On Fig. 6.1, draw an arrow to indicate a possible initial direction of motion of the electron after the photon has been deflected. [1]

(ii) Calculate

1. the energy of the deflected photon,

photon energy = ... J [2]

2. the speed of the electron after the photon has been deflected.

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

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(c) Explain why the magnitude of the final momentum of the electron is not equal to the change in magnitude of the momentum of the photon.

.....

.....

..... [2]

7 **(a)** A solenoid is connected in series with a resistor, as shown in Fig. 7.1.

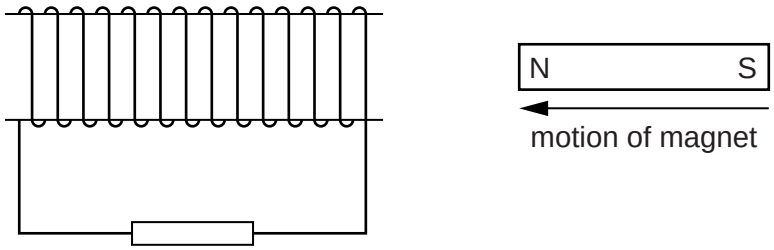


Fig. 7.1

As the magnet is being moved into the solenoid, thermal energy is transferred in the resistor. Use laws of electromagnetic induction to explain the origin of this thermal energy.

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.....[4]

(b) Explain why the alternating current in the primary coil of a transformer is not in phase with the alternating e.m.f. induced in the secondary coil.

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.....[4]

8 The power for a space probe is to be supplied by the energy released when plutonium-236 decays by the emission of α-particles.

The α-particles, each of energy 5.75 MeV, are captured and their energy is converted into electrical energy with an efficiency of 24%.

(a) Calculate

(i) the energy, in joules, equal to 5.75 MeV,

energy = ... J [1]

(ii) the number of α-particles per second required to generate 1.9 kW of electrical power.

number per second = ... s^{-1} [2]

(b) Each plutonium-236 nucleus, on disintegration, produces one α-particle.
Plutonium-236 has a half-life of 2.8 years.

(i) Calculate the decay constant, in s^{-1}, of plutonium-236.

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

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(ii) Use your answers in **(a)(ii)** and **(b)(i)** to determine the mass of plutonium-236 required for the generation of 1.9 kW of electrical power.

mass = ... g [4]

(c) The minimum electrical power required for the space probe is 0.84 kW.

Calculate the time, in years, for which the sample of plutonium-236 in **(b)(ii)** will provide sufficient power.

time = ... years [2]

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Section B

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

9 **(a)** The strain in a beam is to be monitored using a strain gauge.
The strain gauge is included in the potential divider circuit shown in Fig. 9.1.

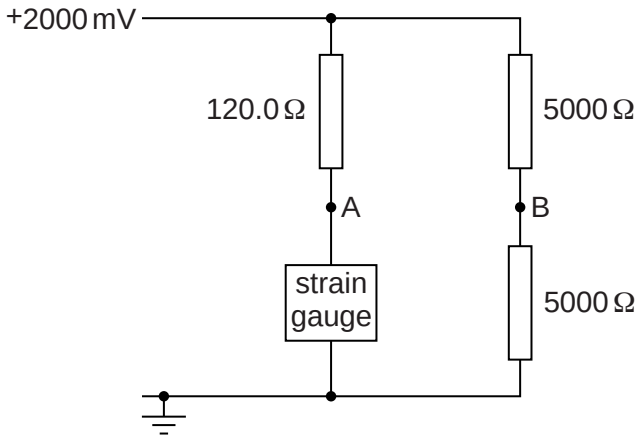


Fig. 9.1

The strain gauge has a resistance of 120.0 Ω when it is not strained. The resistance increases to 121.5 Ω when the strain is ε.

Calculate the potential difference between points A and B on Fig. 9.1 when the strain in the gauge is ε.

potential difference = ... mV [3]

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(b) An inverting amplifier, incorporating an operational amplifier (op-amp), uses a high-resistance voltmeter to display the output. A partially completed circuit for the amplifier is shown in Fig. 9.2.

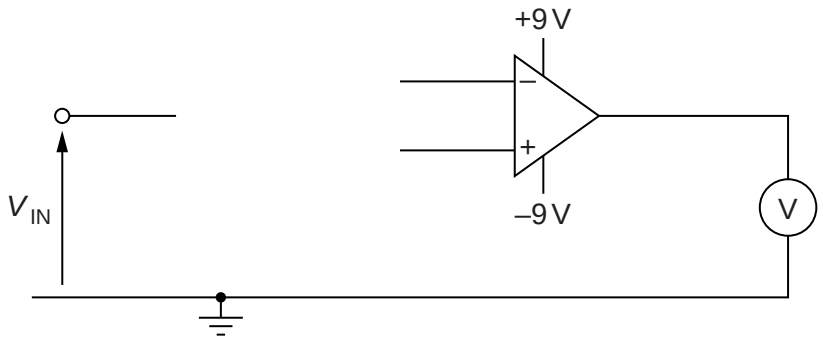


Fig. 9.2

The voltmeter is to indicate a full-scale deflection of +6.0V for an input potential V_{IN} of 0.15V.

(i) On Fig. 9.2,

1. complete the circuit for the inverting amplifier, [2]

2. mark, with the letter P, the positive terminal of the voltmeter. [1]

(ii) Suggest appropriate values for the resistors you have shown in Fig. 9.2.
Label the resistors in Fig. 9.2 with these values. [2]

10 **(a)** State what is meant by the *specific acoustic impedance* of a medium.

.....

.....

.....[2]

(b) The specific acoustic impedances Z of some media are given in Fig. 10.1.

	Z / kg m^{-2} s^{-1}
air	4.3×10^{2}
gel	1.5×10^{6}
soft tissue	1.6×10^{6}
bone	7.0×10^{6}

Fig. 10.1

(i) The density of a sample of bone is 1.7×10^{3} kg m^{-3}.

Determine the wavelength, in mm, of ultrasound of frequency 9.0×10^{5} Hz in the bone.

wavelength = ... mm [3]

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(ii) Ultrasound of intensity I is incident normally on the boundary between two media of specific acoustic impedances Z_1 and Z_2, as shown in Fig. 10.2.

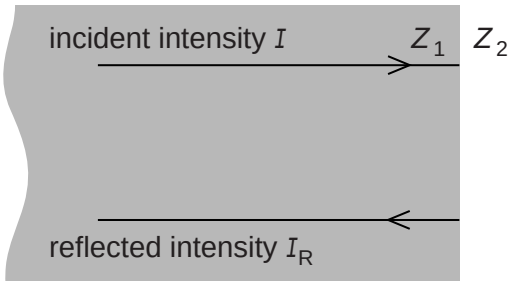


Fig. 10.2

The intensity of the ultrasound reflected from the boundary is I_R.

The ratio $\frac{I_R}{I}$ is given by the expression

$$\frac{I_R}{I} = \frac{(Z_1 - Z_2)^2}{(Z_1 + Z_2)^2}.$$

By making reference to the data for air, gel and soft tissue, explain quantitatively why, during medical diagnosis using ultrasound, a gel is usually put on the skin.

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.....[4]

11 One channel of communication is by the use of a coaxial cable. Such a cable is illustrated in Fig. 11.1.

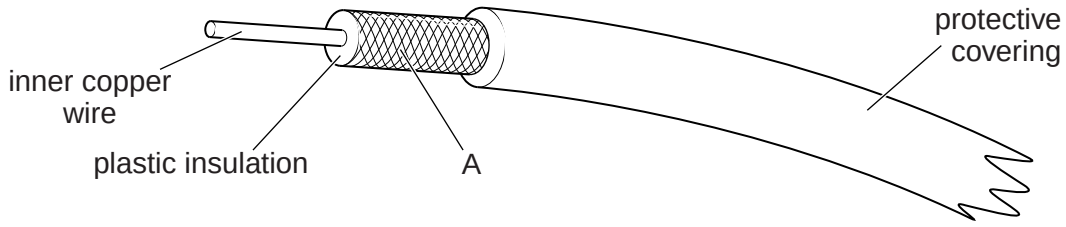


Fig. 11.1

(a) (i) Suggest the material from which the component labelled A on Fig. 11.1 is made.

.....[1]

(ii) Suggest two functions of the component labelled A.

1. .....

.....

2. .....

.....

[2]

(b) When a signal travels along the coaxial cable, it is attenuated.

(i) State the meaning of *attenuation*.

.....

.....[1]

(ii) State and explain why attenuation is frequently measured in decibels (dB).

.....

.....

.....[2]

(c) A television aerial is connected to a receiver using a coaxial cable of length 11 m. The attenuation per unit length of the cable is 190 dB km^{-1}.

Calculate the ratio

$$\frac{\text{output signal from coaxial cable}}{\text{input signal to coaxial cable}}.$$

ratio = ...[3]

Please turn over for Question 12.

12 A mobile phone handset is, at its simplest, a radio transmitter and receiver.

Outline the role of base stations and the cellular exchange when a mobile phone is switched on and before a call is made.

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.....[4]

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