Cambridge International AS & A Level

Cambridge Assessment International Education
Cambridge International Advanced Subsidiary and Advanced Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

4651206235

PHYSICS **9702/42**

Paper 4 A Level Structured Questions **February/March 2019**

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.

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

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[Turn over

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	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\,\mathrm{m\,F^{-1}})$
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 unit	$1\,\mathrm{u} = 1.66 \times 10^{-27}\,\mathrm{kg}$
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	$\phi = -\frac{Gm}{r}$
hydrostatic pressure	$p = \rho gh$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0^{\,2} - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
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	$W = \frac{1}{2}QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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

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

....

....

.... [2]

(ii) Use your answer in **(i)** to explain why the gravitational potential near an isolated mass is always negative.

....

....

....

....

....

.... [3]

(b) A spherical planet has mass 6.00×10^{24} kg and radius 6.40×10^{6} m.
The planet may be assumed to be isolated in space with its mass concentrated at its centre.

A satellite of mass 340 kg is in a circular orbit about the planet at a height 9.00×10^{5} m above its surface.

For the satellite:

(i) show that its orbital speed is $7.4 \times 10^{3}\,\mathrm{m\,s^{-1}}$

[2]

(ii) calculate its gravitational potential energy.

energy = ... J [3]

(c) Rockets on the satellite are fired for a short time. The satellite's orbit is now closer to the surface of the planet.

State and explain the change, if any, in the kinetic energy of the satellite.

....

....

....

.... [2]

[Total: 12]

2 The pressure p of an ideal gas having density ρ is given by the expression

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

(a) State what is meant by:

(i) an ideal gas

....

....

.... [2]

(ii) the symbol $\langle c^2\rangle$.

....

.... [1]

(b) A cylinder contains a fixed mass of a gas at a temperature of 120 °C. The gas has a volume of $6.8 \times 10^{-3}\,m^3$ at a pressure $2.4 \times 10^5\,Pa$.

(i) Assuming the gas acts like an ideal gas, show that the number of atoms of gas in the cylinder is 3.0×10^{23}.

[3]

(ii) Each atom of the gas, assumed to be a sphere, has a radius of $3.2 \times 10^{-11}\,m$.

Use the answer in **(i)** to estimate the actual volume occupied by the gas atoms.

volume = ... m^3 [2]

(iii) One of the assumptions of the kinetic theory of gases is related to the volume of the atoms.
State this assumption. Explain whether your answer in **(ii)** is consistent with this assumption.

....

....

....

.... [2]

[Total: 10]

3 A cylindrical tube, sealed at one end, has cross-sectional area A and contains some sand. The total mass of the tube and the sand is M.

The tube floats upright in a liquid of density ρ, as illustrated in Fig. 3.1.

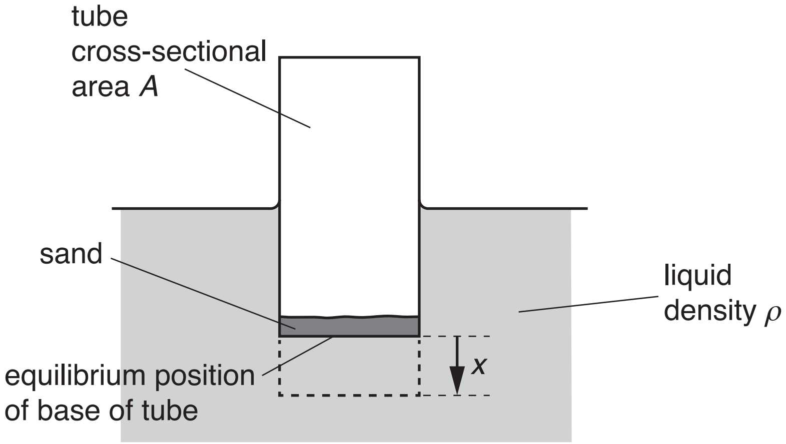

Fig. 3.1

The tube is pushed a short distance into the liquid and then released.

(a) **(i)** State the two forces that act on the tube immediately after its release.

....

.... [1]

(ii) State and explain the direction of the resultant force acting on the tube immediately after its release.

....

....

.... [2]

(b) The acceleration a of the tube is given by the expression

$$a = -\left(\frac{A\rho g}{M}\right)x$$

where x is the vertical displacement of the tube from its equilibrium position.

Use the expression to explain why the tube undergoes simple harmonic oscillations in the liquid.

....

....

.... [2]

(c) For a tube having cross-sectional area A of 4.5 cm^2 and a total mass M of 0.17 kg, the period of oscillation of the tube is 1.3 s.

(i) Determine the angular frequency ω of the oscillations.

ω = ... rad s^{-1} [2]

(ii) Use your answer in **(i)** and the expression in **(b)** to determine the density ρ of the liquid in which the tube is floating.

ρ = ... kg m^{-3} [3]

[Total: 10]

4 **(a)** State **three** features of the orbit of a geostationary satellite.

1. ....

....

2. ....

....

3. ....

.... [3]

(b) A signal is transmitted from Earth to a geostationary satellite. Initially, the signal has power 3.2 kW. The signal is attenuated by 194 dB.

Calculate the signal power received by the satellite.

power = ... W [2]

(c) Suggest one advantage and one disadvantage of the use of geostationary satellites compared with polar-orbiting satellites for communication between points on the Earth's surface.

advantage: ....

....

disadvantage: ....

.... [2]

[Total: 7]

5 **(a)** State what is meant by an *electric field*.

....

.... [1]

(b) An isolated solid metal sphere has radius R. The charge on the sphere is $+Q$ and the electric field strength at its surface is E.

On Fig. 5.1, draw a line to show the variation of the electric field strength with distance x from the centre of the solid sphere for values of x from $x = 0$ to $x = 3R$.

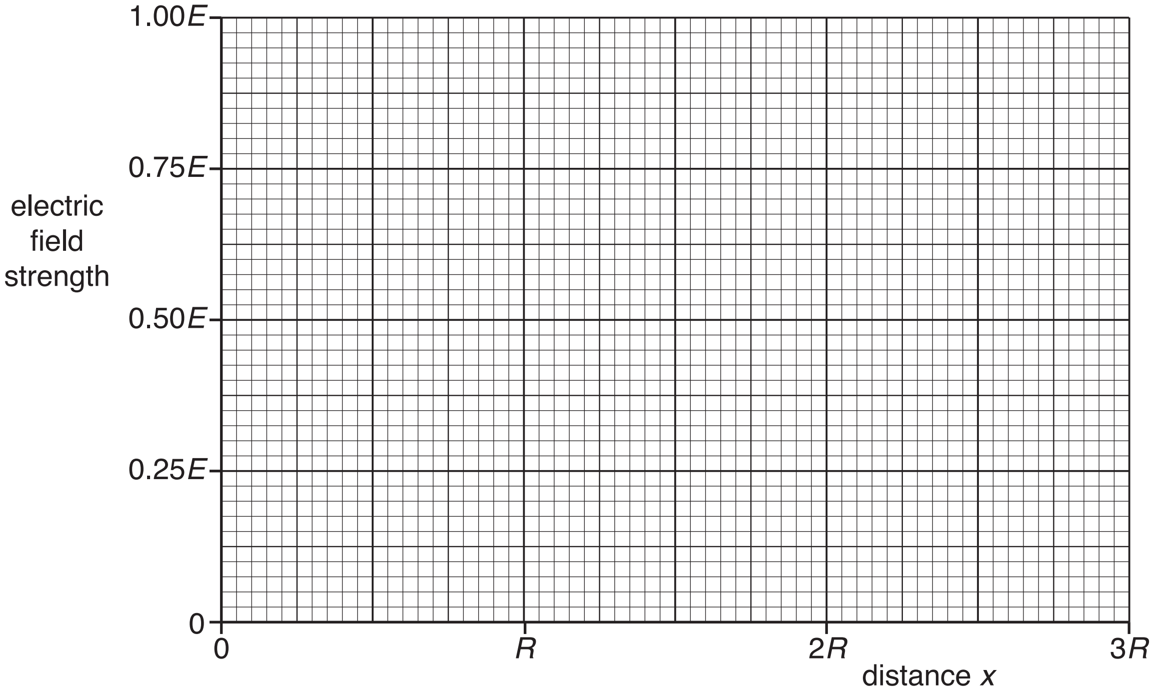

Fig. 5.1

[4]

(c) The sphere in **(b)** has radius $R = 0.26\,\text{m}$.

Electrical breakdown (a spark) occurs when the electric field strength at the surface of the sphere exceeds $2.0 \times 10^{6}\,\text{V}\,\text{m}^{-1}$.

Determine the maximum charge that can be stored on the sphere before electrical breakdown occurs.

charge = ... C [3]

[Total: 8]

6 **(a)** Define the *capacitance* of a parallel-plate capacitor.

....

....

.... [2]

(b) A student has three capacitors. Two of the capacitors have a capacitance of 4.0 μF and one has a capacitance of 8.0 μF.

Draw labelled circuit diagrams, one in each case, to show how the three capacitors may be connected to give a total capacitance of:

(i) 1.6 μF

[1]

(ii) 10 μF.

[1]

(c) A capacitor C of capacitance 47 μF is connected across the output terminals of a bridge rectifier, as shown in Fig. 6.1.

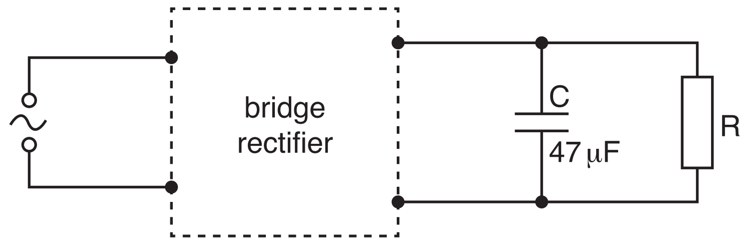

Fig. 6.1

The variation with time *t* of the potential difference *V* across the resistor R is shown in Fig. 6.2.

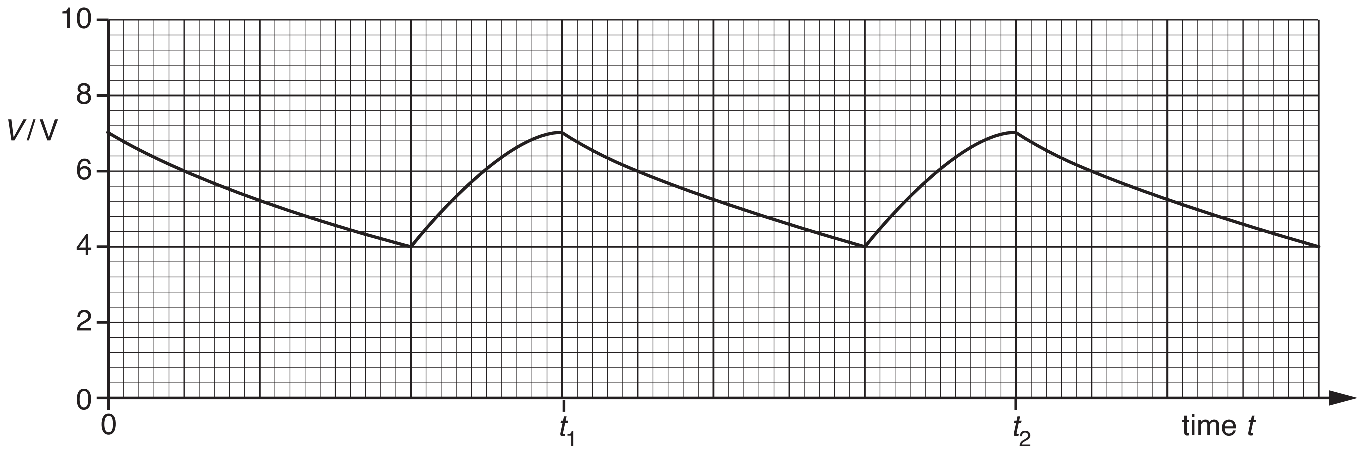

Fig. 6.2

Use data from Fig. 6.2 to determine the energy transfer from the capacitor C to the resistor R between time t_1 and time t_2.

energy = ... J [3]

[Total: 7]

7 **(a)** Two properties that an ideal operational amplifier (op-amp) would have are constant voltage gain and infinite slew rate.

State what is meant by:

(i) *gain* of an amplifier

....

.... [1]

(ii) *infinite slew rate*.

....

....

.... [2]

(b) The partially completed circuit of a non-inverting amplifier, incorporating an ideal op-amp, is shown in Fig. 7.1.

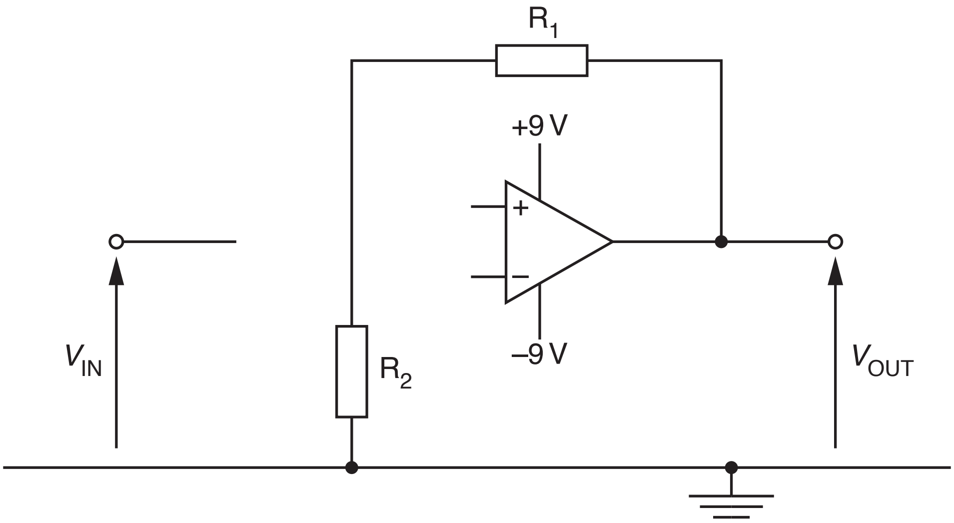

Fig. 7.1

(i) On Fig. 7.1, complete the circuit for the non-inverting amplifier. [2]

(ii) For the completed circuit of Fig. 7.1, the gain of the amplifier is 25. The resistance of resistor R_1 is 12 kΩ.

Calculate the resistance of resistor R_2.

resistance = ... Ω [2]

(iii) Calculate, for the amplifier gain of 25, the range of values of V_{IN} for which the amplifier does not saturate.

range from .... V to .... V [2]

[Total: 9]

8 A horseshoe magnet is placed on a top pan balance. A rigid copper wire is fixed between the poles of the magnet, as illustrated in Fig. 8.1.

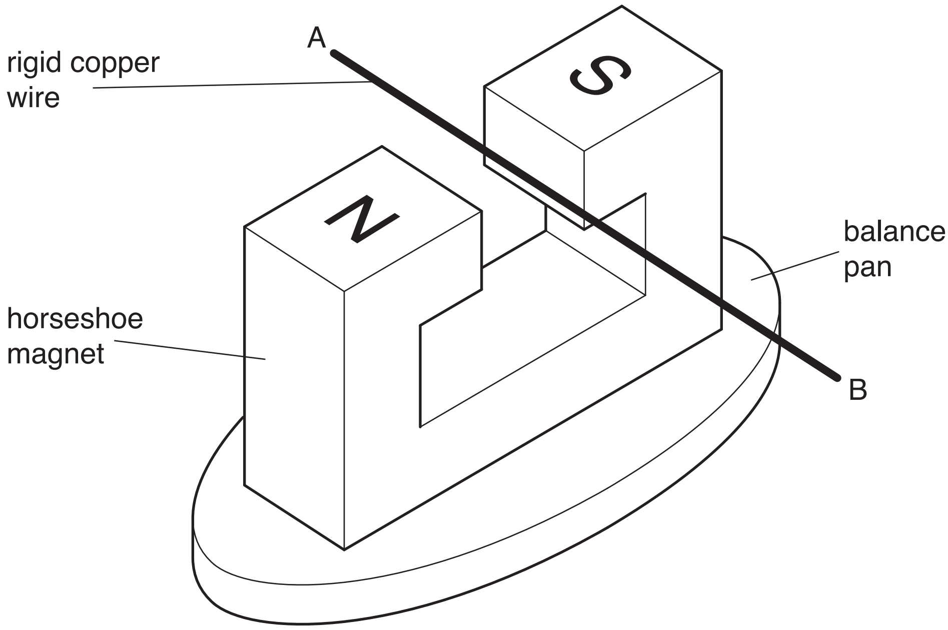

Fig. 8.1

The wire is clamped at ends A and B.

(a) When a direct current is switched on in the wire, the reading on the balance is seen to **decrease**.

State and explain the direction of:

(i) the force acting on the wire

....

....

....

.... [3]

(ii) the current in the wire.

....

....

.... [2]

(b) A direct current of 4.6A in the wire causes the reading on the balance to change by 4.5×10^{-3} N.

The direct current is now replaced by an alternating current of frequency 40 Hz and root-mean-square (r.m.s.) value 4.6 A.

On the axes of Fig. 8.2, sketch a graph to show the change in balance reading over a time of 50 ms.

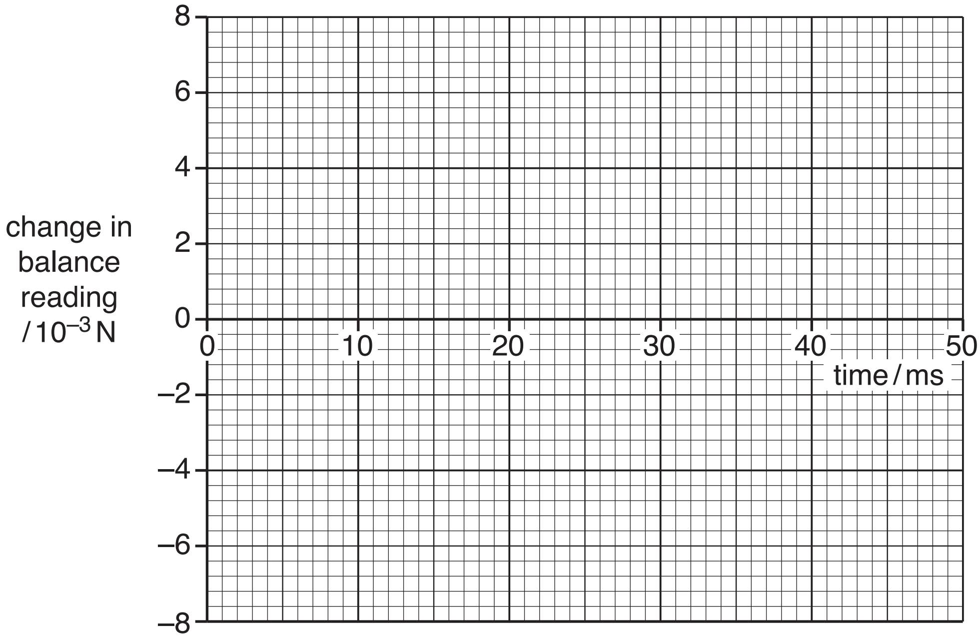

Fig. 8.2

[3]

[Total: 8]

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9 Outline the principles of computed tomography (CT) scanning.

....

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....

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.... [5]

[Total: 5]

10 **(a)** A cross-section through a current-carrying solenoid is shown in Fig. 10.1.

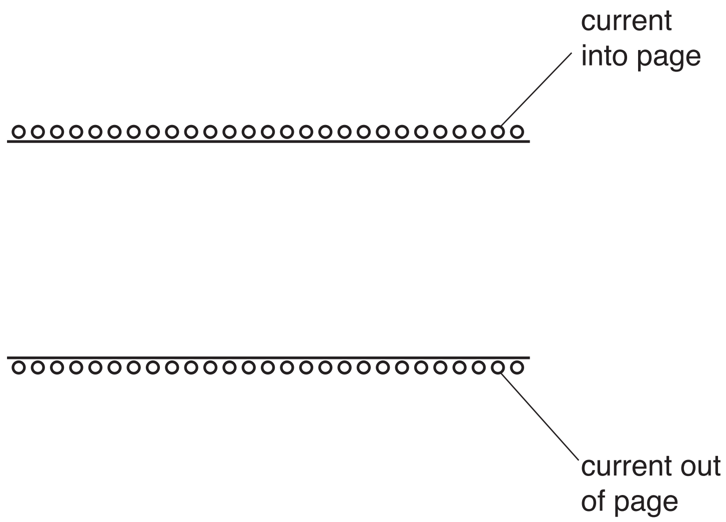

Fig. 10.1

On Fig. 10.1, draw field lines to represent the magnetic field inside the solenoid. [3]

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

....

....

.... [2]

(c) A coil of insulated wire is wound on to a soft-iron core.

The coil is connected in series with a battery, a switch and an ammeter, as shown in Fig. 10.2.

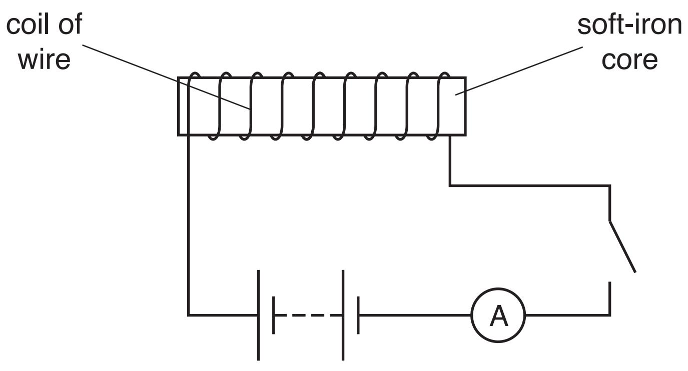

Fig. 10.2

Use laws of electromagnetic induction to explain why, when the switch is closed, the current increases **gradually** to its maximum value.

....

....

....

....

.... [3]

[Total: 8]

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

....

....

.... [2]

(b) Calculate the energy, in eV, of a photon of light of wavelength 540 nm.

energy = ... eV [3]

(c) The outermost electron energy bands of a semiconductor material are illustrated in Fig. 11.1.

Fig. 11.1

The width of the forbidden band is 1.1 eV.

Explain why, when photons of light, each of energy 2.1 eV, are incident on the semiconductor material, its resistance decreases.

....

....

....

....

....

.... [4]

[Total: 9]

12 The incomplete nuclear equation for one possible reaction that takes place in the core of a nuclear reactor is

$$^{235}_{92}\text{U} + ^{1}_{0}\text{n} \rightarrow ^{139}_{57}\text{La} + ^{95}_{42}\text{Mo} + 2^{1}_{0}\text{n} + \ldots\ldots\ldots\ldots$$

(a) **(i)** State the name given to this type of nuclear reaction.

.... [1]

(ii) Complete the nuclear equation. [2]

(b) The mass defect for the reaction is 0.223 u.

(i) Calculate the energy, in J, equivalent to 0.223 u.

energy = ... J [2]

(ii) Suggest **two** forms of the energy released in this reaction.

1. ....

....

2. ....

.... [2]

[Total: 7]

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