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9702/41

May/June 2013

2 hours

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

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.

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

For Examiner's Use	
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11	
12	
Total	

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

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,	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$
	$(\frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \text{ m F}^{-1})$
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) State what is meant by a *gravitational field*.

.....

.....

..... [2]

- (b) In the Solar System, the planets may be assumed to be in circular orbits about the Sun. Data for the radii of the orbits of the Earth and Jupiter about the Sun are given in Fig. 1.1.

	radius of orbit / km
Earth	1.50×10^8
Jupiter	7.78×10^8

Fig. 1.1

- (i) State Newton's law of gravitation.

.....

.....

.....

..... [3]

- (ii) Use Newton's law to determine the ratio

$$\frac{\text{gravitational field strength due to the Sun at orbit of Earth}}{\text{gravitational field strength due to the Sun at orbit of Jupiter}}$$

ratio = ... [3]

(c) The orbital period of the Earth about the Sun is T .

- (i) Use ideas about circular motion to show that the mass M of the Sun is given by

$$M = \frac{4\pi^2 R^3}{GT^2}$$

where R is the radius of the Earth's orbit about the Sun and G is the gravitational constant.

Explain your working.

For
Examiner's
Use

[3]

- (ii) The orbital period T of the Earth about the Sun is 3.16×10^7 s.
The radius of the Earth's orbit is given in Fig. 1.1.
Use the expression in (i) to determine the mass of the Sun.

mass = ... kg [2]

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

For
Examiner's
Use

.....

.....

.....

.....[3]

- (b) Two cylinders A and B are connected by a tube of negligible volume, as shown in Fig. 2.1.

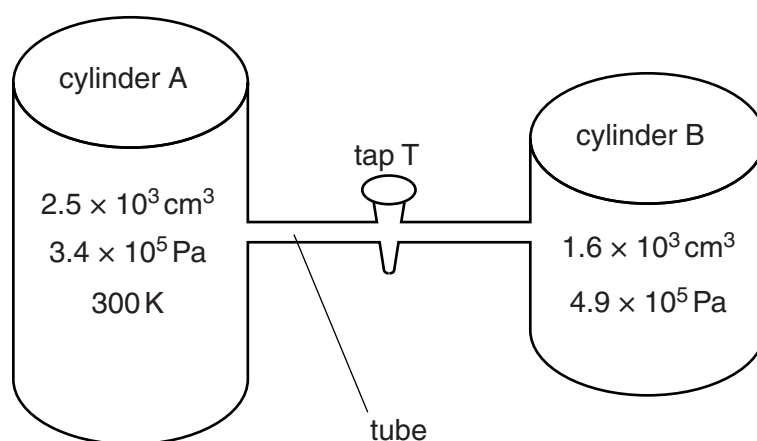


Fig. 2.1

Initially, tap T is closed. The cylinders contain an ideal gas at different pressures.

- (i) Cylinder A has a constant volume of $2.5 \times 10^3 \text{ cm}^3$ and contains gas at pressure $3.4 \times 10^5 \text{ Pa}$ and temperature 300 K .

Show that cylinder A contains 0.34 mol of gas.

[1]

- (ii) Cylinder B has a constant volume of $1.6 \times 10^3 \text{ cm}^3$ and contains 0.20 mol of gas. When tap T is opened, the pressure of the gas in both cylinders is $3.9 \times 10^5 \text{ Pa}$. No thermal energy enters or leaves the gas.

Determine the final temperature of the gas.

For
Examiner's
Use

temperature = ... K [2]

- (c) By reference to work done and change in internal energy, suggest why the temperature of the gas in cylinder A has changed.

.....

.....

.....

..... [3]

- 3 A ball is held between two fixed points A and B by means of two stretched springs, as shown in Fig. 3.1.

For
Examiner's
Use

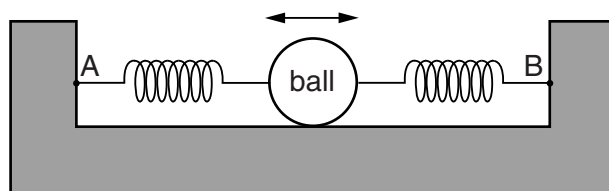


Fig. 3.1

The ball is free to oscillate along the straight line AB. The springs remain stretched and the motion of the ball is simple harmonic.

The variation with time t of the displacement x of the ball from its equilibrium position is shown in Fig. 3.2.

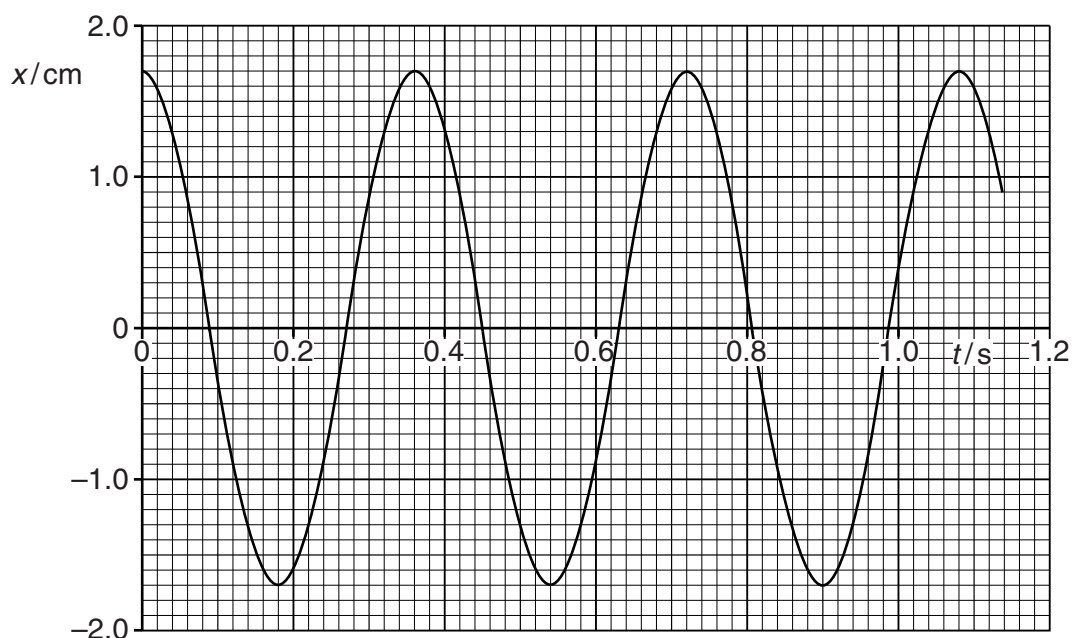


Fig. 3.2

- (a) (i) Use Fig. 3.2 to determine, for the oscillations of the ball,

1. the amplitude,

amplitude = ... cm [1]

2. the frequency.

frequency = ... Hz [2]

- (ii) Show that the maximum acceleration of the ball is 5.2 m s^{-2} .

For
Examiner's
Use

[2]

- (b) Use your answers in (a) to plot, on the axes of Fig. 3.3, the variation with displacement x of the acceleration a of the ball.

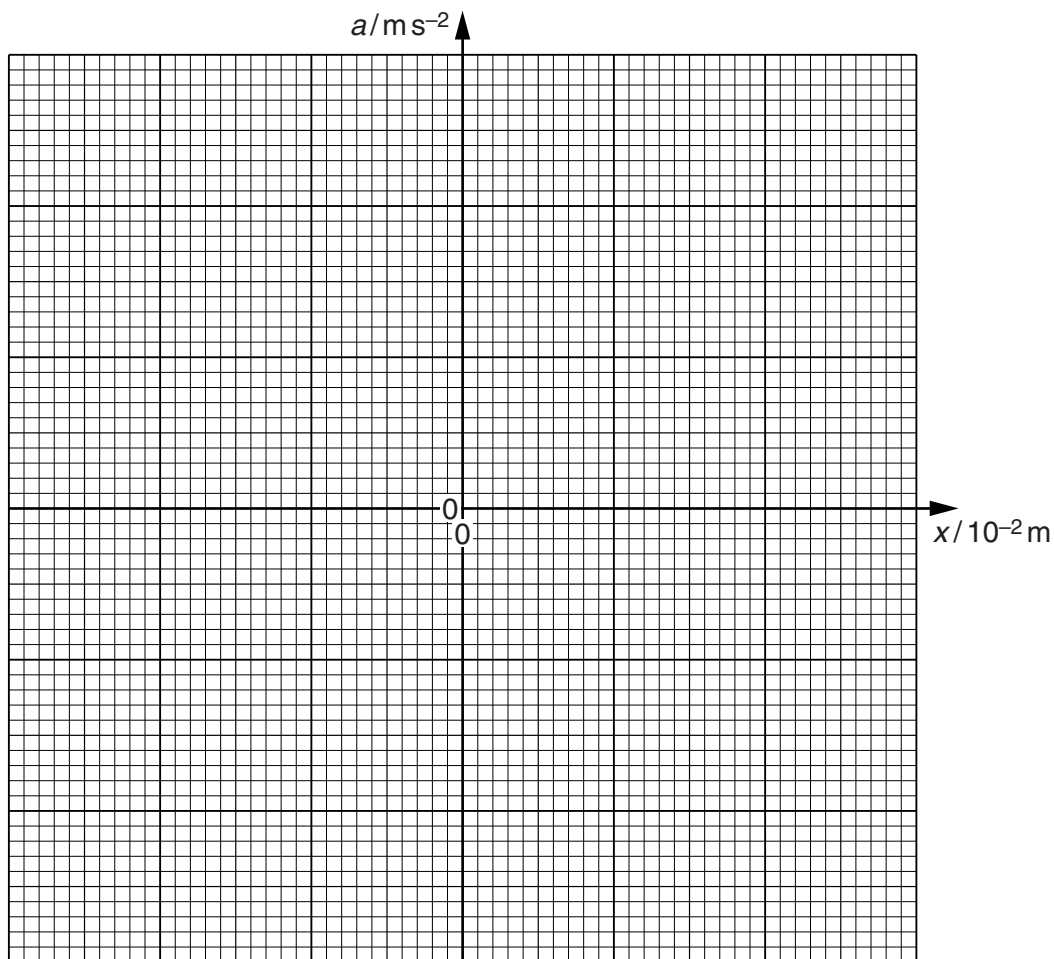


Fig. 3.3

[2]

- (c) Calculate the displacement of the ball at which its kinetic energy is equal to one half of the maximum kinetic energy.

*For
Examiner's
Use*

displacement = ... cm [3]

- 4 (a) Define *electric potential* at a point.

.....

.....

.....[2]

- (b) A charged particle is accelerated from rest in a vacuum through a potential difference V . Show that the final speed v of the particle is given by the expression

$$v = \sqrt{\frac{2Vq}{m}}$$

where $\frac{q}{m}$ is the ratio of the charge to the mass (the specific charge) of the particle.

[2]

- (c) A particle with specific charge $+9.58 \times 10^7 \text{ C kg}^{-1}$ is moving in a vacuum towards a fixed metal sphere, as illustrated in Fig. 4.1.



Fig. 4.1

The initial speed of the particle is $2.5 \times 10^5 \text{ m s}^{-1}$ when it is a long distance from the sphere.

The sphere is positively charged and has a potential of $+470 \text{ V}$.

Use the expression in (b) to determine whether the particle will reach the surface of the sphere.

[3]

- 5 (a) Define the *tesla*.

For
Examiner's
Use

.....

.....

.....[2]

- (b) A long solenoid has an area of cross-section of 28 cm^2 , as shown in Fig. 5.1.

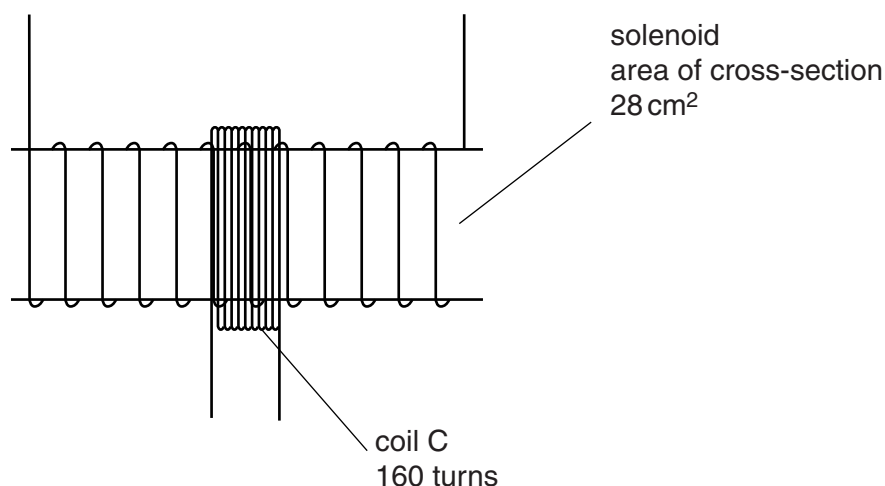


Fig. 5.1

A coil C consisting of 160 turns of insulated wire is wound tightly around the centre of the solenoid.

The magnetic flux density B at the centre of the solenoid is given by the expression

$$B = \mu_0 n I$$

where I is the current in the solenoid, n is a constant equal to $1.5 \times 10^3 \text{ m}^{-1}$ and μ_0 is the permeability of free space.

Calculate, for a current of 3.5 A in the solenoid,

- (i) the magnetic flux density at the centre of the solenoid,

flux density = ... T [2]

- (ii) the flux linkage in the coil C.

flux linkage = ... Wb [2]

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

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

- (ii) The current in the solenoid in (b) is reversed in direction in a time of 0.80 s.
Calculate the average e.m.f. induced in coil C.

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

- 6 A simple transformer is illustrated in Fig. 6.1.

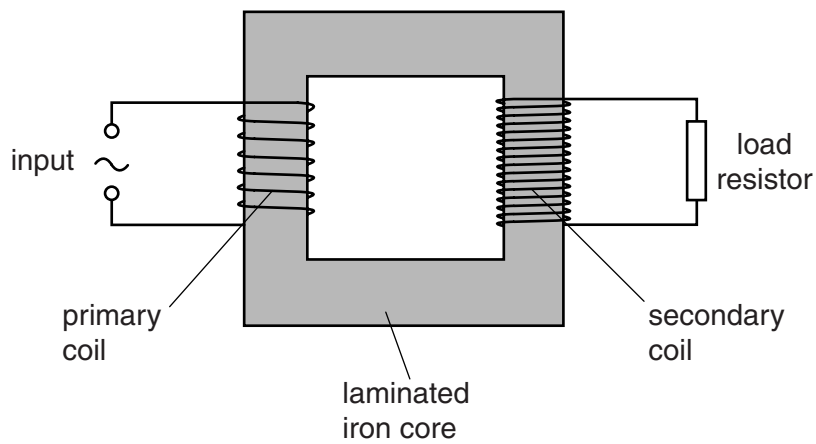


Fig. 6.1

- (a)** State

- (i)** why the iron core is laminated,

.....

 [2]

- (ii)** what is meant by an *ideal* transformer.

.....
 [1]

- (b)** An ideal transformer has 300 turns on the primary coil and 8100 turns on the secondary coil.

The root-mean-square input voltage to the primary coil is 9.0V.

Calculate the peak voltage across the load resistor connected to the secondary coil.

peak voltage = ... V [2]

- 7 Some data for the work function energy Φ and the threshold frequency f_0 of some metal surfaces are given in Fig. 7.1.

For
Examiner's
Use

metal	$\Phi / 10^{-19} \text{ J}$	$f_0 / 10^{14} \text{ Hz}$
sodium	3.8	5.8
zinc	5.8	8.8
platinum	9.0	

Fig. 7.1

- (a) (i) State what is meant by the *threshold frequency*.

.....

 [2]

- (ii) Calculate the threshold frequency for platinum.

threshold frequency = ... Hz [2]

- (b) Electromagnetic radiation having a continuous spectrum of wavelengths between 300 nm and 600 nm is incident, in turn, on each of the metals listed in Fig. 7.1. Determine which metals, if any, will give rise to the emission of electrons.

.....

 [2]

- (c) When light of a particular intensity and frequency is incident on a metal surface, electrons are emitted. State and explain the effect, if any, on the rate of emission of electrons from this surface for light of the same intensity and higher frequency.

.....

 [3]

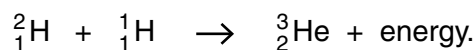
- 8 (a) State what is meant by a *nuclear fusion reaction*.

For
Examiner's
Use

.....

[2]

- (b) One nuclear reaction that takes place in the core of the Sun is represented by the equation



Data for the nuclei are given in Fig. 8.1.

	mass/u
proton ${}^1_1\text{H}$	1.00728
deuterium ${}^2_1\text{H}$	2.01410
helium ${}^3_2\text{He}$	3.01605

Fig. 8.1

- (i) Calculate the energy, in joules, released in this reaction.

energy = ... J [3]

- (ii) The temperature in the core of the Sun is approximately 1.6×10^7 K.
Suggest why such a high temperature is necessary for this reaction to take place.

.....

[2]

Section B

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

*For
Examiner's
Use*

- 9 (a)** Suggest electrical sensing devices, one in each case, that may be used to monitor changes in

(i) light intensity,

.....[1]

(ii) the width of a crack in a welded joint,

.....[1]

(iii) the intensity of an ultrasound beam.

.....[1]

- (b) A student designs the circuit of Fig. 9.1 to detect changes in temperature in the range 0°C to 100°C .

For
Examiner's
Use

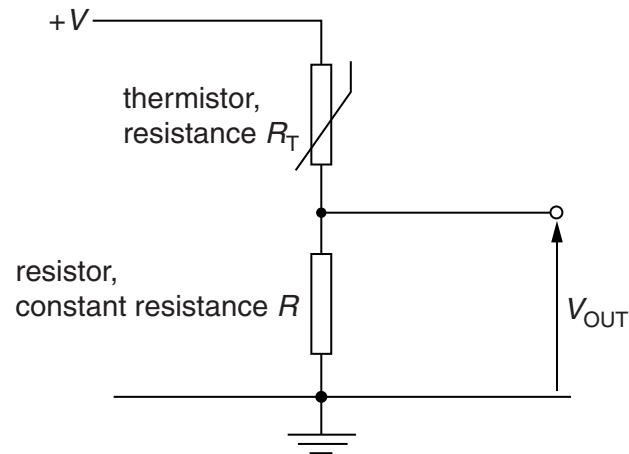


Fig. 9.1

The resistance of the thermistor is R_T and that of the resistor is R .
The student monitors the potential difference V_{OUT} .

State and explain

- (i) whether V_{OUT} increases or decreases as the temperature of the thermistor increases,

.....

 [3]

- (ii) whether the change in V_{OUT} varies linearly with the change in temperature of the thermistor.

.....

 [2]

- 10 (a) Distinguish between sharpness and contrast in X-ray imaging.

sharpness:

.....

contrast:

.....

[2]

- (b) State two causes of loss of sharpness of an X-ray image.

1.

.....

2.

.....

[2]

- (c) Data for the linear attenuation (absorption) coefficient μ of X-ray photons are given in Fig. 10.1.

	μ/cm^{-1}
bone	2.85
muscle	0.95

Fig. 10.1

A parallel beam of X-rays is incident, separately, on a thickness of 3.5 cm of bone and on a muscle of thickness 8.0 cm.

- (i) Calculate the ratio

$$\frac{\text{intensity of X-ray beam transmitted through bone}}{\text{intensity of X-ray beam transmitted through muscle}}$$

ratio = ... [3]

- (ii) Use your answer in (i) to suggest whether an X-ray image of the bone and muscle would show good or poor contrast.

*For
Examiner's
Use*

.....

.....

.....[2]

11 A radio station emits an amplitude-modulated wave for the transmission of music.

(a) (i) State what is meant by an *amplitude-modulated* (AM) wave.

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

(ii) Give two reasons why the transmitted wave is modulated, rather than transmitting the information signal directly as a radio wave.

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

- (b) The variation with frequency f of the amplitude A of the transmitted wave is shown in Fig. 11.1.

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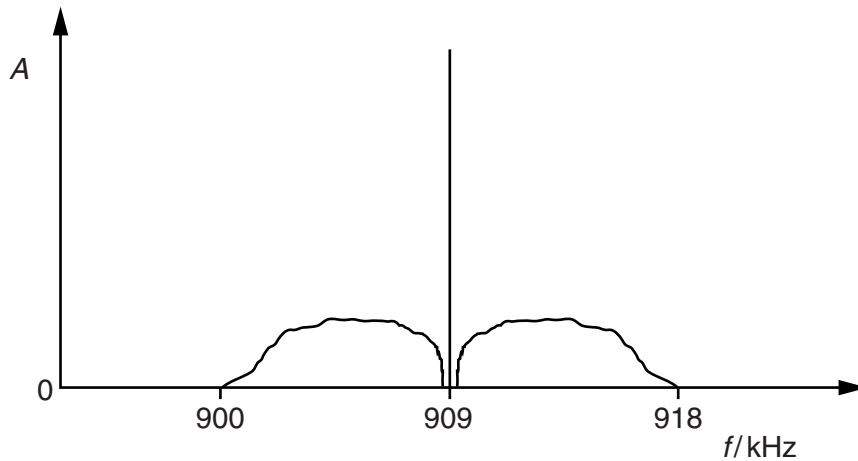


Fig. 11.1

For this transmission, determine

- (i) the wavelength of the carrier wave,

wavelength = ... m [2]

- (ii) the bandwidth,

bandwidth = ... kHz [1]

- (iii) the maximum frequency, in Hz, of the transmitted audio signal.

frequency = ... Hz [1]

- 12 An optic fibre is used for the transmission of digital telephone signals. The power input to the optic fibre is 9.8 mW . The effective noise level in the receiver circuit is $0.36 \mu\text{W}$, as illustrated in Fig. 12.1.

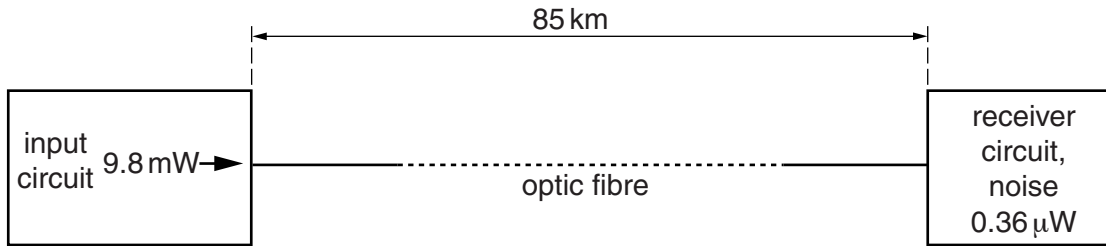


Fig. 12.1

The signal-to-noise ratio at the receiver must not fall below 28 dB.
For this transmission without any repeater amplifiers, the maximum length of the optic fibre is 85 km.

- (a) Calculate the minimum input signal power to the receiver.

power = ... W [2]

- (b) Use your answer in (a) to calculate the attenuation in the fibre.

attenuation = ... dB [2]

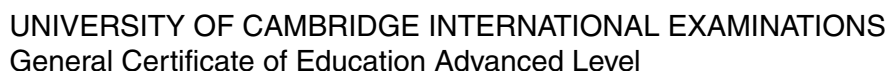
- (c) Determine the attenuation per unit length of the fibre.

attenuation per unit length = ... dB km^{-1} [1]

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9702/42

May/June 2013

2 hours

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 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.

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.
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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) Explain what is meant by a *geostationary orbit*.

.....

.....

.....

..... [3]

- (b) A satellite of mass m is in a circular orbit about a planet.
The mass M of the planet may be considered to be concentrated at its centre.
Show that the radius R of the orbit of the satellite is given by the expression

$$R^3 = \left(\frac{GMT^2}{4\pi^2} \right)$$

where T is the period of the orbit of the satellite and G is the gravitational constant.
Explain your working.

[4]

- (c) The Earth has mass 6.0×10^{24} kg. Use the expression given in (b) to determine the radius of the geostationary orbit about the Earth.

radius = ... m [3]

- 2 (a) The volume of an ideal gas in a cylinder is $1.80 \times 10^{-3} \text{ m}^3$ at a pressure of $2.60 \times 10^5 \text{ Pa}$ and a temperature of 297 K , as illustrated in Fig. 2.1.

For
Examiner's
Use

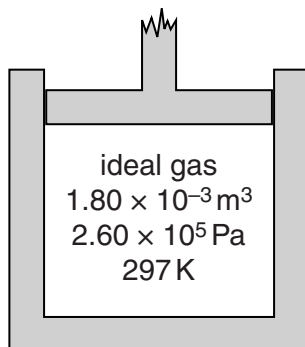


Fig. 2.1

The thermal energy required to raise the temperature by 1.00 K of 1.00 mol of the gas at constant volume is 12.5 J .

The gas is heated at constant volume such that the internal energy of the gas increases by 95.0 J .

- (i) Calculate

1. the amount of gas, in mol, in the cylinder,

amount = ... mol [2]

2. the rise in temperature of the gas.

temperature rise = ... K [2]

- (ii) Use your answer in (i) **part 2** to show that the final pressure of the gas in the cylinder is $2.95 \times 10^5 \text{ Pa}$.

For
Examiner's
Use

[1]

- (b) The gas is now allowed to expand. No thermal energy enters or leaves the gas. The gas does 120 J of work when expanding against the external pressure.

State and explain whether the final temperature of the gas is above or below 297 K.

.....

.....

.....

..... [3]

- 3 A mass of 78 g is suspended from a fixed point by means of a spring, as illustrated in Fig. 3.1.

For
Examiner's
Use

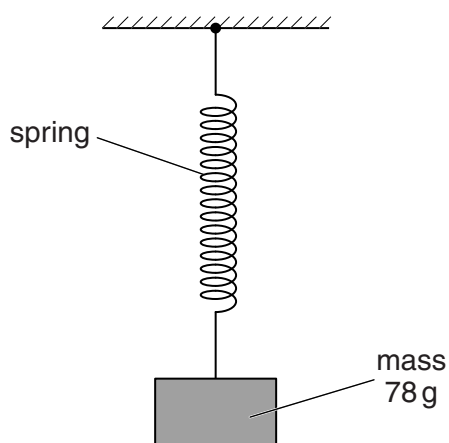


Fig. 3.1

The stationary mass is pulled vertically downwards through a distance of 2.1 cm and then released.

The mass is observed to perform simple harmonic motion with a period of 0.69 s.

- (a) The mass is released at time $t = 0$.

For the oscillations of the mass,

- (i) calculate the angular frequency ω ,

$$\omega = \dots\dots\dots \text{rad s}^{-1} \quad [2]$$

- (ii) determine numerical equations for the variation with time t of

1. the displacement x in cm,

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

2. the speed v in m s^{-1} .

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

(b) Calculate the total energy of oscillation of the mass.

*For
Examiner's
Use*

energy = ... J [2]

- 4 (a) An insulated metal sphere of radius R is situated in a vacuum. The charge q on the sphere may be considered to be a point charge at the centre of the sphere.

- (i) State a formula, in terms of R and q , for the potential V on the surface of the sphere.

..... [1]

- (ii) Define capacitance and hence show that the capacitance C of the sphere is given by the expression

$$C = 4\pi\epsilon_0 R.$$

[1]

- (b) An isolated metal sphere has radius 45 cm.

- (i) Use the expression in (a)(ii) to calculate the capacitance, in picofarad, of the sphere.

capacitance = ... pF [2]

- (ii) The sphere is charged to a potential of $9.0 \times 10^5 \text{ V}$.
A spark occurs, partially discharging the sphere so that its potential is reduced to $3.6 \times 10^5 \text{ V}$.

Determine the energy of the spark.

energy = ... J [3]

- 5 (a) Define the *tesla*.

For
Examiner's
Use

.....

 [2]

- (b) Two long straight vertical wires X and Y are separated by a distance of 4.5 cm, as illustrated in Fig. 5.1.

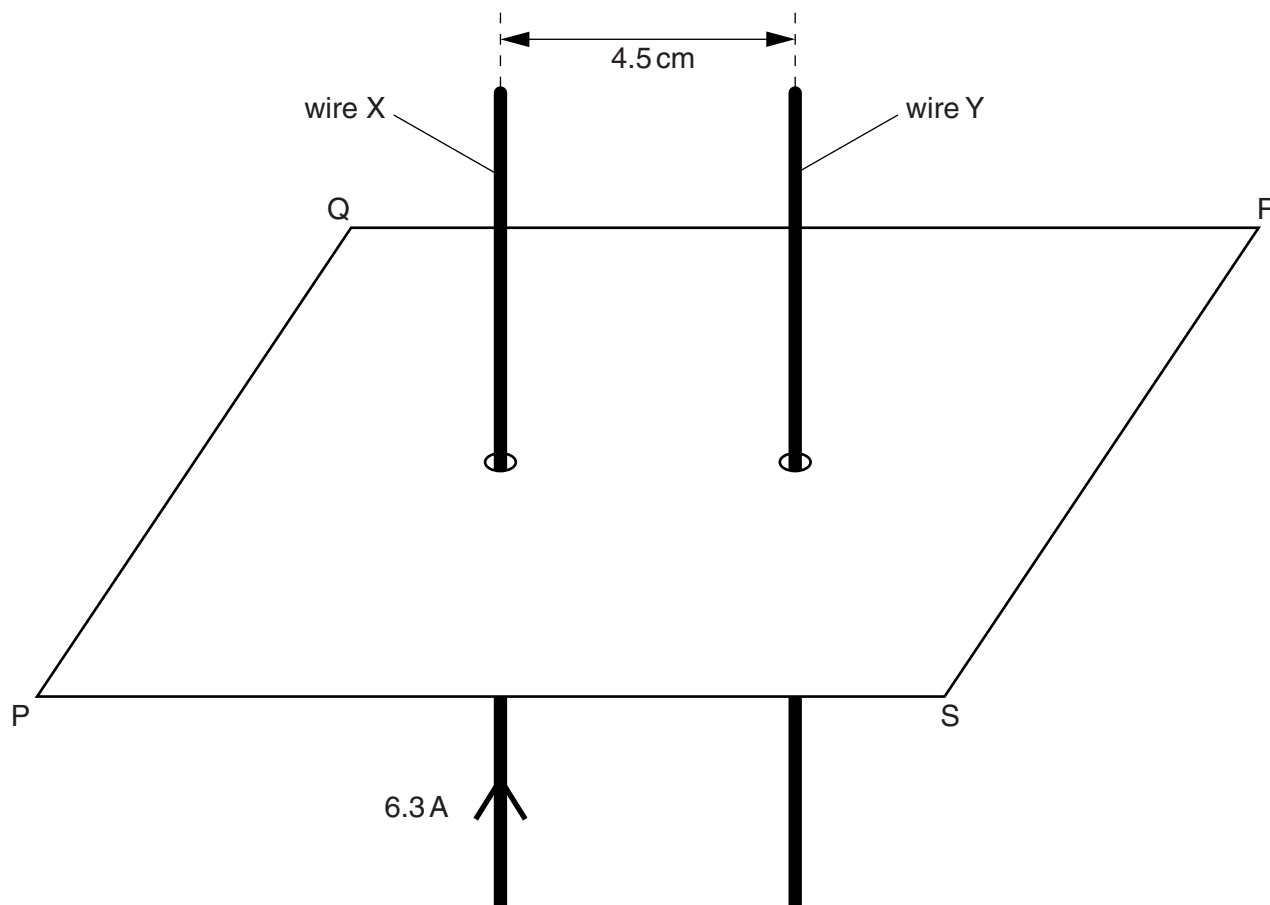


Fig. 5.1

The wires pass through a horizontal card PQRS.

The current in wire X is 6.3 A in the upward direction. Initially, there is no current in wire Y.

- (i) On Fig. 5.1, sketch, in the plane PQRS, the magnetic flux pattern due to the current in wire X. Show at least four flux lines. [3]

- (ii) The magnetic flux density B at a distance x from a long straight current-carrying wire is given by the expression

$$B = \frac{\mu_0 I}{2\pi x}$$

where I is the current in the wire and μ_0 is the permeability of free space.

Calculate the magnetic flux density at wire Y due to the current in wire X.

flux density = ... T [2]

- (iii) A current of 9.3A is now switched on in wire Y. Use your answer in (ii) to calculate the force per unit length on wire Y.

force per unit length = ... Nm^{-1} [2]

- (c) The currents in the two wires in (b)(iii) are not equal.
Explain whether the force per unit length on the two wires will be the same, or different.

.....

 [2]

For
Examiner's
Use

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

.....

.....

..... [2]

- (b) The output of an ideal transformer is connected to a bridge rectifier, as shown in Fig. 6.1.

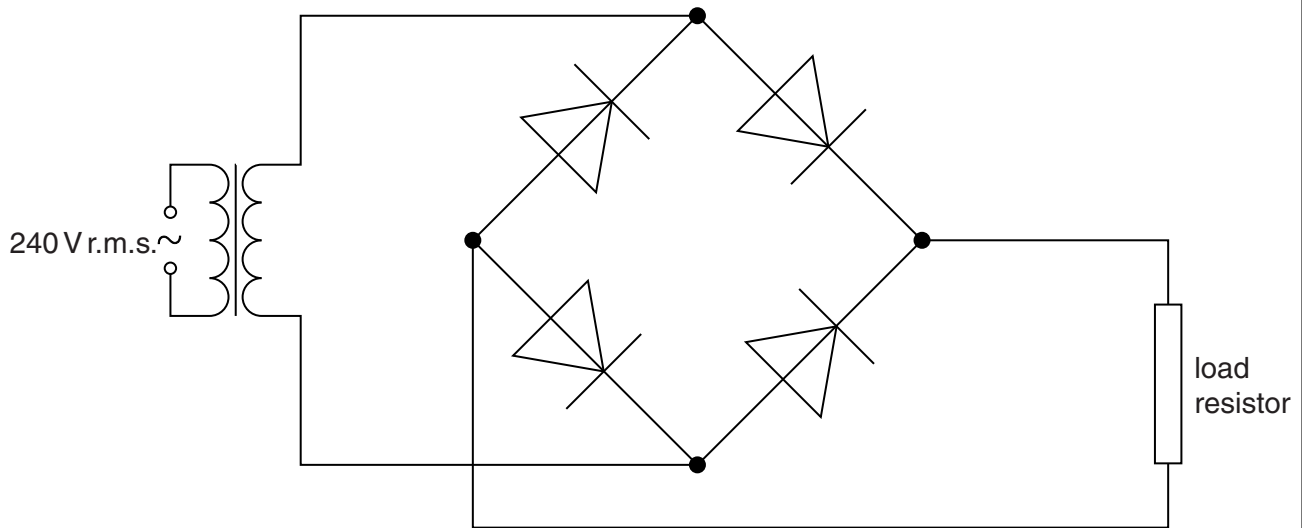


Fig. 6.1

The input to the transformer is 240 V r.m.s. and the **maximum** potential difference across the load resistor is 9.0 V.

- (i) On Fig. 6.1, mark with the letter P the positive output from the rectifier. [1]
- (ii) Calculate the ratio

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

ratio = ... [3]

- (c) The variation with time t of the potential difference V across the load resistor in (b) is shown in Fig. 6.2.

For
Examiner's
Use

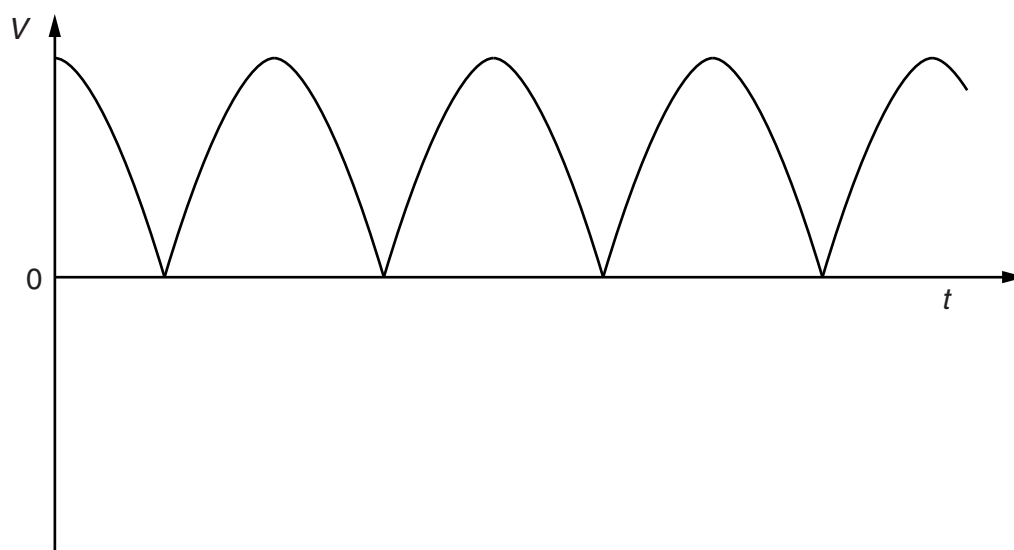


Fig. 6.2

A capacitor is now connected in parallel with the load resistor to produce some smoothing.

- (i) Explain what is meant by *smoothing*.

.....
 [1]

- (ii) On Fig. 6.2, draw the variation with time t of the smoothed output potential difference. [2]

- 7 (a) The emission spectrum of atomic hydrogen consists of a number of discrete wavelengths. Explain how this observation leads to an understanding that there are discrete electron energy levels in atoms.

For
Examiner's
Use

.....

.....

.....

..... [2]

- (b) Some electron energy levels in atomic hydrogen are illustrated in Fig. 7.1.

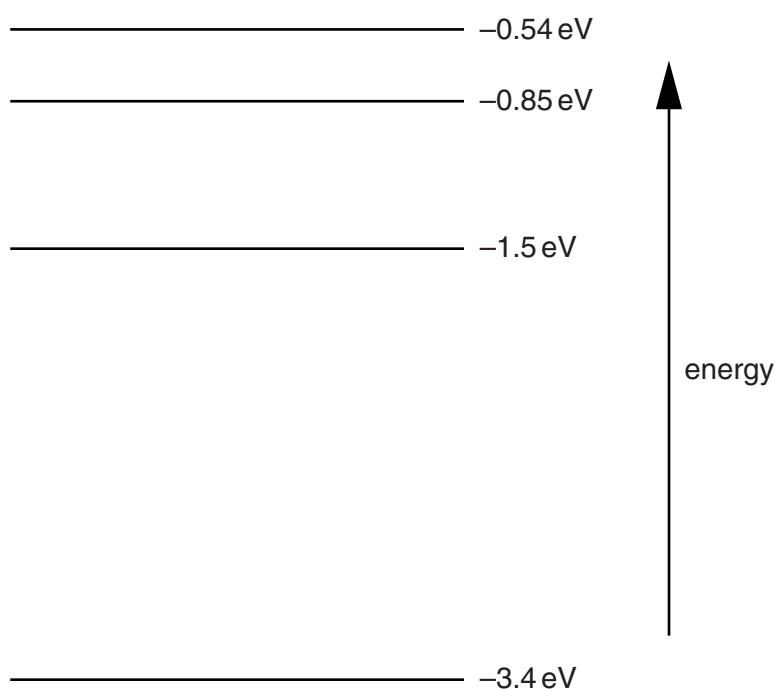


Fig. 7.1

The longest wavelength produced as a result of electron transitions between two of the energy levels shown in Fig. 7.1 is $4.0 \times 10^{-6} \text{ m}$.

For
Examiner's
Use

(i) On Fig. 7.1,

1. draw, and mark with the letter L, the transition giving rise to the wavelength of $4.0 \times 10^{-6} \text{ m}$, [1]

2. draw, and mark with the letter S, the transition giving rise to the shortest wavelength. [1]

(ii) Calculate the wavelength for the transition you have shown in (i) part 2.

wavelength = ... m [3]

(c) Photon energies in the visible spectrum vary between approximately 3.66 eV and 1.83 eV.

Determine the energies, in eV, of photons in the visible spectrum that are produced by transitions between the energy levels shown in Fig. 7.1.

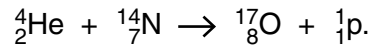
photon energies eV [2]

- 8 (a) Explain why the mass of an α -particle is less than the total mass of two individual protons and two individual neutrons.

.....

 [2]

- (b) An equation for one possible nuclear reaction is



Data for the masses of the nuclei are given in Fig. 8.1.

		mass/u
proton	${}^1_1\text{p}$	1.00728
helium-4	${}^4_2\text{He}$	4.00260
nitrogen-14	${}^{14}_7\text{N}$	14.00307
oxygen-17	${}^{17}_8\text{O}$	16.99913

Fig. 8.1

- (i) Calculate the mass change, in u, associated with this reaction.

mass change = ... u [2]

- (ii) Calculate the energy, in J, associated with the mass change in (i).

energy = ... J [2]

- (iii) Suggest and explain why, for this reaction to occur, the helium-4 nucleus must have a minimum speed.

*For
Examiner's
Use*

.....

.....

..... [2]

Section B

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

For
Examiner's
Use

- 9 The volume of fuel in the fuel tank of a car is monitored using a sensing device. The device gives a voltage output that is measured using a voltmeter. The variation of voltmeter reading with the volume of fuel in the tank is shown in Fig. 9.1.

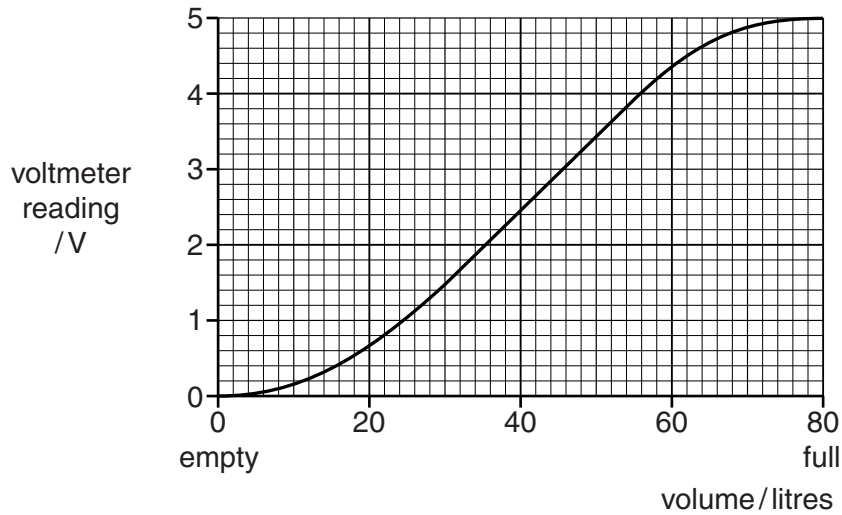


Fig. 9.1

- (a) Use Fig. 9.1 to determine the range of volume over which the volume has a linear relationship to the voltmeter reading.

from litres to litres [1]

- (b) Suggest why, comparing values from Fig. 9.1,

- (i) when the tank is nearly full, the voltmeter readings give the impression that fuel consumption is low,

.....

 [2]

- (ii) when the voltmeter first indicates that the tank is nearly empty, there is more fuel remaining than is expected.

.....

 [2]

- 10 (a) By reference to ultrasound waves, state what is meant by *acoustic impedance*.

.....

.....

..... [2]

- (b) An ultrasound wave is incident on the boundary between two media. The acoustic impedances of the two media are Z_1 and Z_2 , as illustrated in Fig. 10.1.

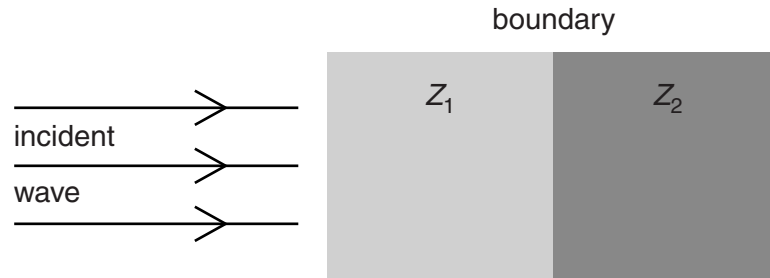


Fig. 10.1

Explain the importance of the difference between Z_1 and Z_2 for the transmission of ultrasound across the boundary.

.....

.....

.....

..... [3]

- (c) Ultrasound frequencies as high as 10 MHz are used in medical diagnosis. State and explain one advantage of the use of high-frequency ultrasound compared with lower-frequency ultrasound.

.....

.....

..... [2]

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- 11 (a) Explain how the hardness of an X-ray beam is controlled by the accelerating voltage in the X-ray tube.

For
Examiner's
Use

.....

.....

..... [2]

- (b) The attenuation of a parallel beam of X-ray radiation is given by the expression

$$\frac{I}{I_0} = e^{-\mu x}$$

where μ is the linear attenuation (absorption) coefficient and x is the thickness of the material through which the beam passes.

- (i) State

1. what is meant by *attenuation*,

.....

..... [1]

2. why the expression applies only to a parallel beam.

.....

.....

..... [2]

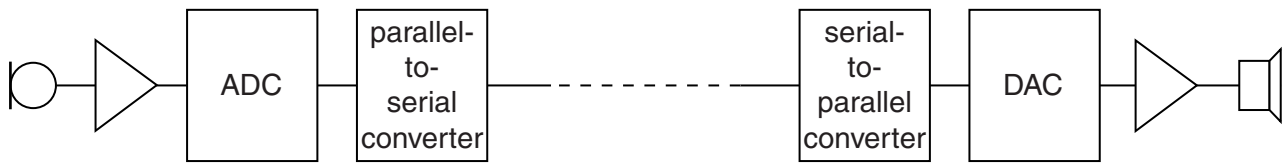
- (ii) The linear attenuation coefficients for X-rays in bone and in soft tissue are 2.9 cm^{-1} and 0.95 cm^{-1} respectively.

Calculate, for a parallel X-ray beam, the ratio

$$\frac{\text{fraction } \frac{I}{I_0} \text{ of intensity transmitted through bone of thickness } 2.5 \text{ cm}}{\text{fraction } \frac{I}{I_0} \text{ of intensity transmitted through soft tissue of thickness } 6.0 \text{ cm}}.$$

ratio = ... [2]

12 The digital transmission of speech may be represented by the block diagram of Fig. 12.1.



For
Examiner's
Use

Fig. 12.1

(a) State the purpose of the parallel-to-serial converter.

.....

.....

..... [2]

(b) Part of the signal from the microphone is shown in Fig. 12.2.

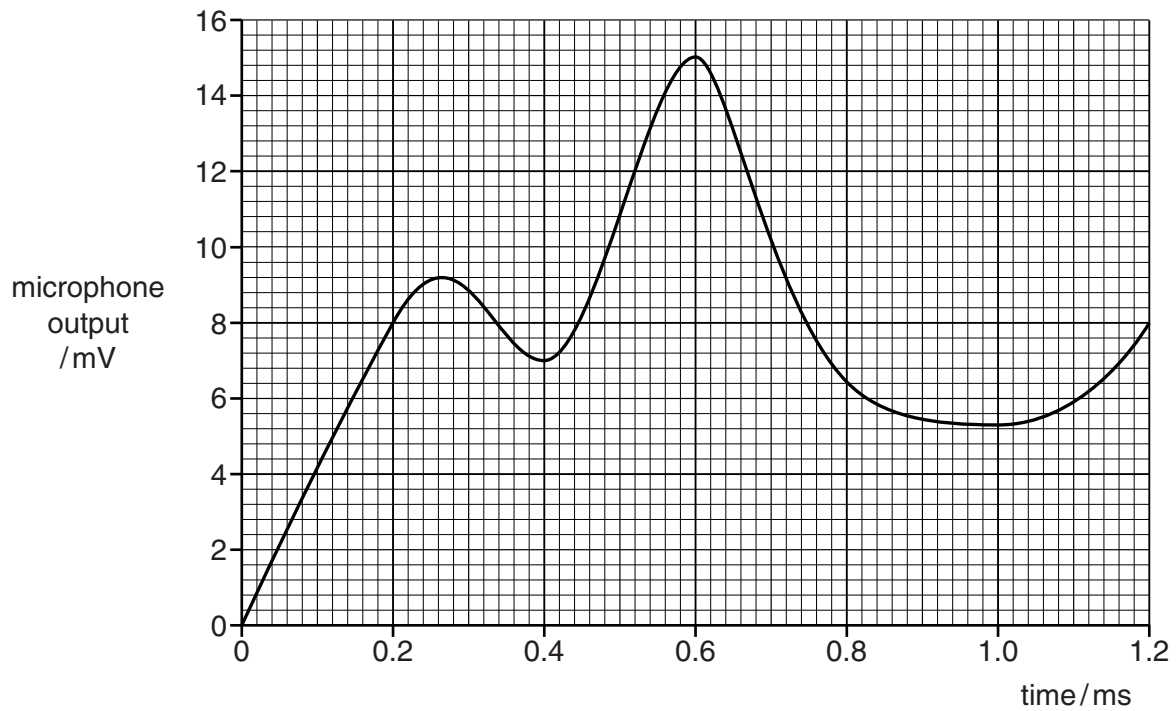


Fig. 12.2

The ADC (analogue-to-digital converter) samples the analogue signal at a frequency of 5.0 kHz.

Each sample from the ADC is a four-bit digital number where the smallest bit represents 1.0 mV.

The first sample is taken at time zero.

Use Fig. 12.2 to determine the four-bit digital number produced by the ADC at times

(i) 0.4 ms,

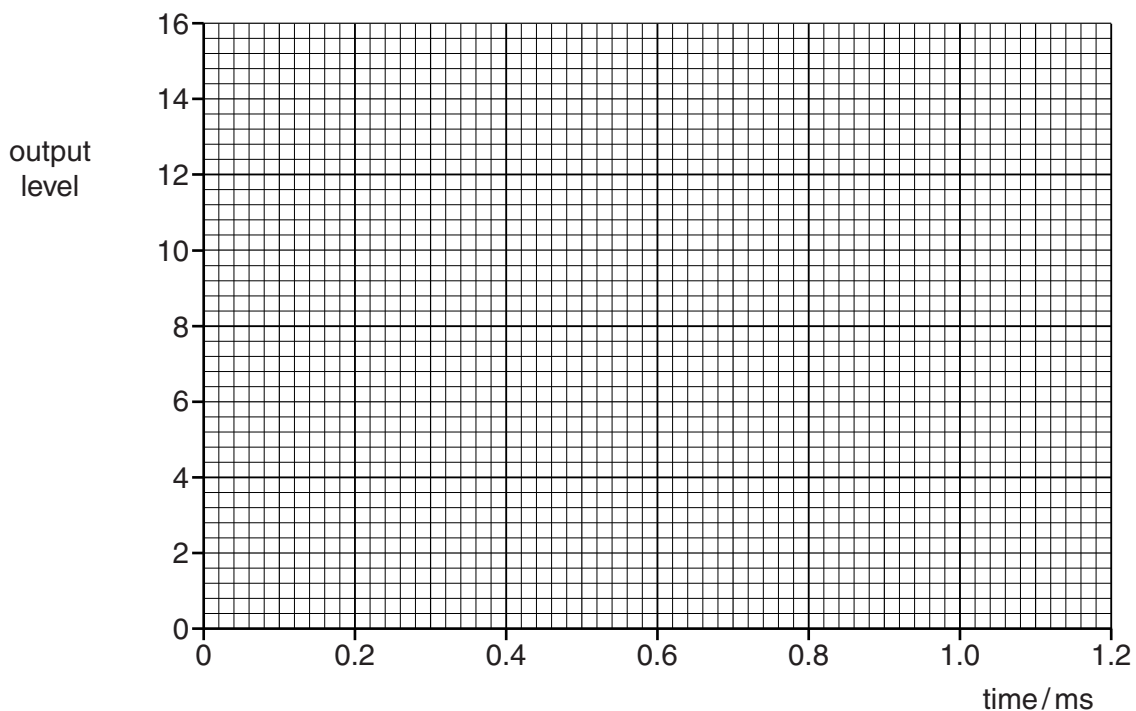
..... [1]

(ii) 0.8 ms.

..... [1]

(c) The digital signal is transmitted and then converted to an analogue form by the DAC (digital-to-analogue converter).

Using data from Fig. 12.2, draw, on the axes of Fig. 12.3, the output level of the transmitted analogue signal for time zero to time 1.2 ms.



[4]

Fig. 12.3

(d) State and explain the effect on the transmitted analogue waveform of increasing, for the ADC and the DAC, both the sampling frequency and the number of bits in each sample.

.....

.....

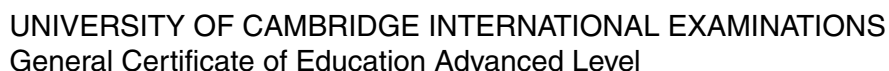
.....

..... [3]

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9702/43

May/June 2013

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 a 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.

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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1	
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11	
12	
Total	

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

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,	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$
	$(\frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \text{ m F}^{-1})$
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) State what is meant by a *gravitational field*.

.....

.....

..... [2]

- (b) In the Solar System, the planets may be assumed to be in circular orbits about the Sun. Data for the radii of the orbits of the Earth and Jupiter about the Sun are given in Fig. 1.1.

	radius of orbit / km
Earth	1.50×10^8
Jupiter	7.78×10^8

Fig. 1.1

- (i) State Newton's law of gravitation.

.....

.....

.....

..... [3]

- (ii) Use Newton's law to determine the ratio

$$\frac{\text{gravitational field strength due to the Sun at orbit of Earth}}{\text{gravitational field strength due to the Sun at orbit of Jupiter}}$$

ratio = ... [3]

(c) The orbital period of the Earth about the Sun is T .

- (i) Use ideas about circular motion to show that the mass M of the Sun is given by

$$M = \frac{4\pi^2 R^3}{GT^2}$$

where R is the radius of the Earth's orbit about the Sun and G is the gravitational constant.

Explain your working.

For
Examiner's
Use

[3]

- (ii) The orbital period T of the Earth about the Sun is 3.16×10^7 s.
The radius of the Earth's orbit is given in Fig. 1.1.
Use the expression in (i) to determine the mass of the Sun.

mass = ... kg [2]

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

.....

.....

.....

.....[3]

- (b) Two cylinders A and B are connected by a tube of negligible volume, as shown in Fig. 2.1.

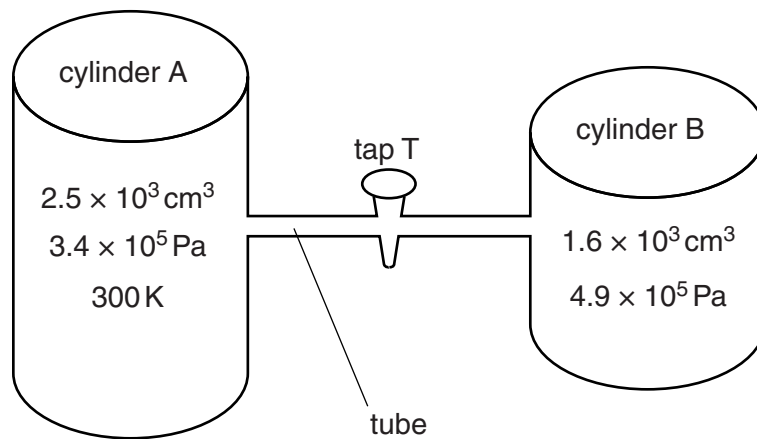


Fig. 2.1

Initially, tap T is closed. The cylinders contain an ideal gas at different pressures.

- (i) Cylinder A has a constant volume of $2.5 \times 10^3 \text{ cm}^3$ and contains gas at pressure $3.4 \times 10^5 \text{ Pa}$ and temperature 300 K .

Show that cylinder A contains 0.34 mol of gas.

[1]

- (ii) Cylinder B has a constant volume of $1.6 \times 10^3 \text{ cm}^3$ and contains 0.20 mol of gas. When tap T is opened, the pressure of the gas in both cylinders is $3.9 \times 10^5 \text{ Pa}$. No thermal energy enters or leaves the gas.

Determine the final temperature of the gas.

For
Examiner's
Use

temperature = ... K [2]

- (c) By reference to work done and change in internal energy, suggest why the temperature of the gas in cylinder A has changed.

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

- 3 A ball is held between two fixed points A and B by means of two stretched springs, as shown in Fig. 3.1.

For
Examiner's
Use

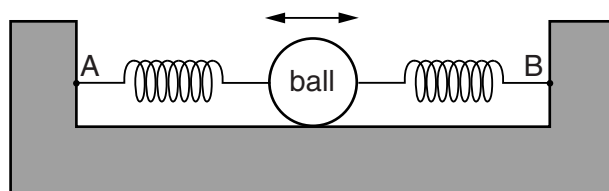


Fig. 3.1

The ball is free to oscillate along the straight line AB. The springs remain stretched and the motion of the ball is simple harmonic.

The variation with time t of the displacement x of the ball from its equilibrium position is shown in Fig. 3.2.

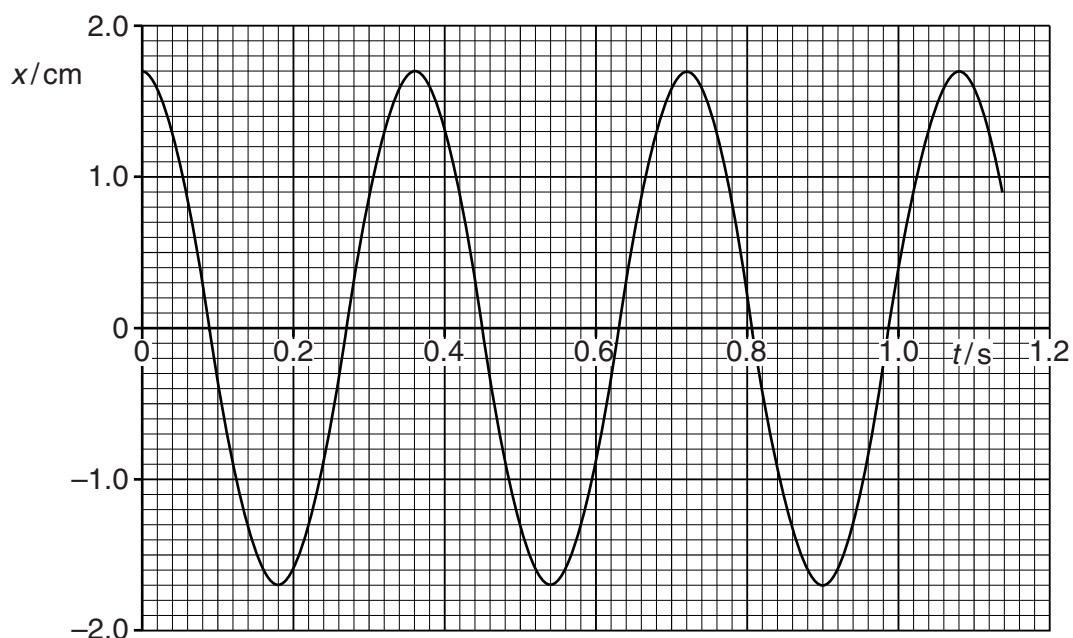


Fig. 3.2

- (a) (i) Use Fig. 3.2 to determine, for the oscillations of the ball,

1. the amplitude,

amplitude = ... cm [1]

2. the frequency.

frequency = ... Hz [2]

- (ii) Show that the maximum acceleration of the ball is 5.2 m s^{-2} .

For
Examiner's
Use

[2]

- (b) Use your answers in (a) to plot, on the axes of Fig. 3.3, the variation with displacement x of the acceleration a of the ball.

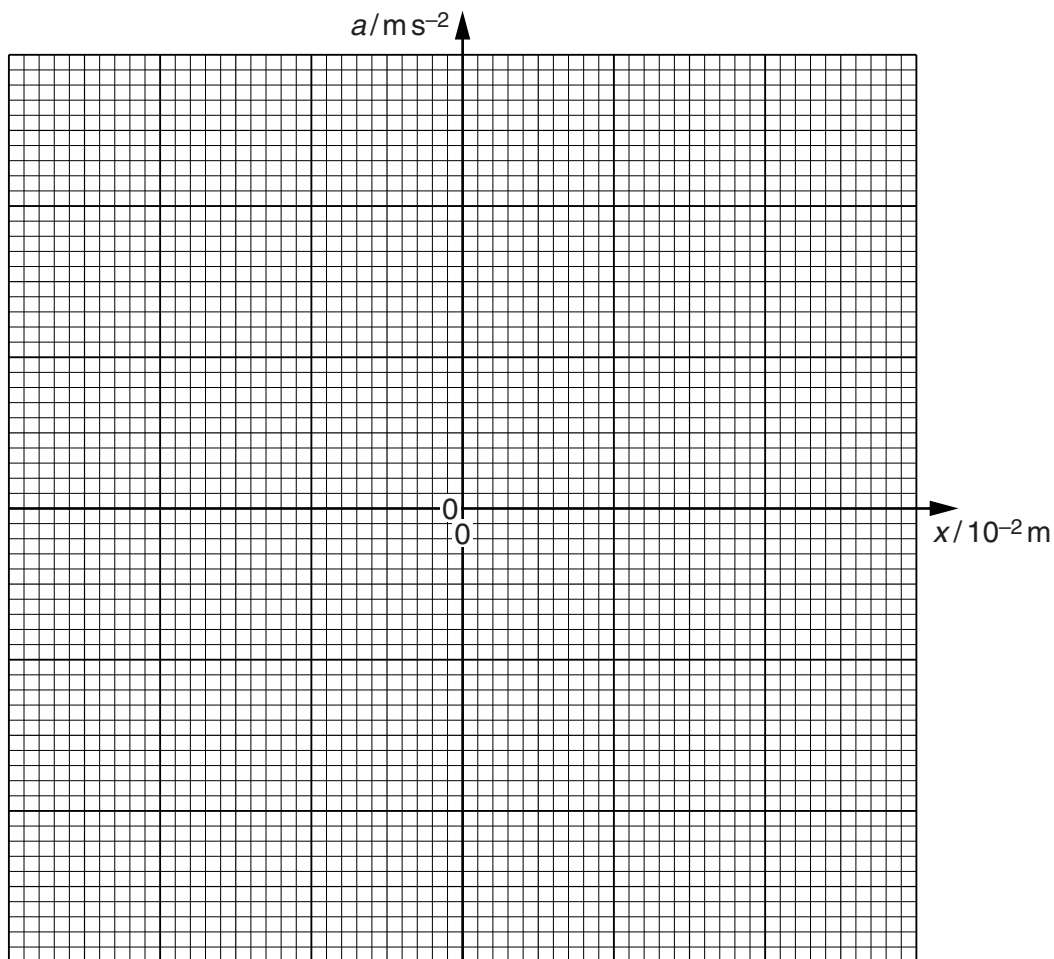


Fig. 3.3

[2]

- (c) Calculate the displacement of the ball at which its kinetic energy is equal to one half of the maximum kinetic energy.

*For
Examiner's
Use*

displacement = ... cm [3]

- 4 (a) Define *electric potential* at a point.

.....

.....

.....[2]

- (b) A charged particle is accelerated from rest in a vacuum through a potential difference V . Show that the final speed v of the particle is given by the expression

$$v = \sqrt{\frac{2Vq}{m}}$$

where $\frac{q}{m}$ is the ratio of the charge to the mass (the specific charge) of the particle.

[2]

- (c) A particle with specific charge $+9.58 \times 10^7 \text{ C kg}^{-1}$ is moving in a vacuum towards a fixed metal sphere, as illustrated in Fig. 4.1.



Fig. 4.1

The initial speed of the particle is $2.5 \times 10^5 \text{ m s}^{-1}$ when it is a long distance from the sphere.

The sphere is positively charged and has a potential of $+470 \text{ V}$.

Use the expression in (b) to determine whether the particle will reach the surface of the sphere.

[3]

- 5 (a) Define the *tesla*.

For
Examiner's
Use

.....

.....

.....[2]

- (b) A long solenoid has an area of cross-section of 28 cm^2 , as shown in Fig. 5.1.

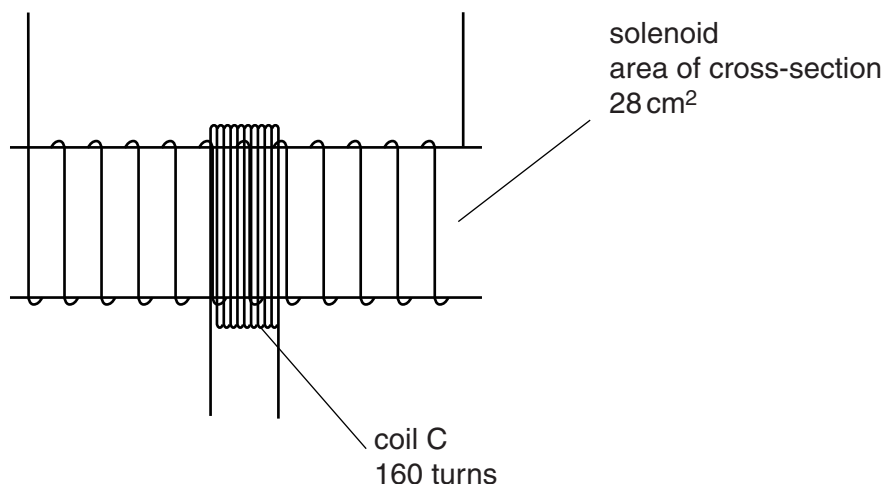


Fig. 5.1

A coil C consisting of 160 turns of insulated wire is wound tightly around the centre of the solenoid.

The magnetic flux density B at the centre of the solenoid is given by the expression

$$B = \mu_0 n I$$

where I is the current in the solenoid, n is a constant equal to $1.5 \times 10^3 \text{ m}^{-1}$ and μ_0 is the permeability of free space.

Calculate, for a current of 3.5 A in the solenoid,

- (i) the magnetic flux density at the centre of the solenoid,

flux density = ... T [2]

- (ii) the flux linkage in the coil C.

flux linkage = ... Wb [2]

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

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

- (ii) The current in the solenoid in (b) is reversed in direction in a time of 0.80 s.
Calculate the average e.m.f. induced in coil C.

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

- 6 A simple transformer is illustrated in Fig. 6.1.

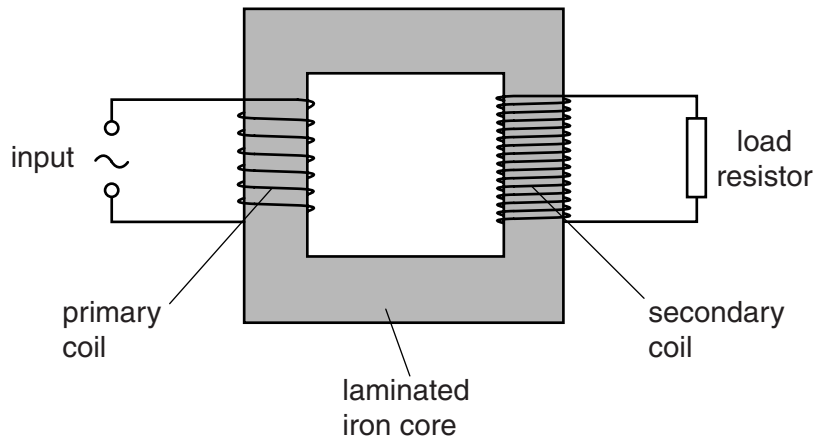


Fig. 6.1

- (a)** State

- (i)** why the iron core is laminated,

.....

 [2]

- (ii)** what is meant by an *ideal* transformer.

.....
 [1]

- (b)** An ideal transformer has 300 turns on the primary coil and 8100 turns on the secondary coil.

The root-mean-square input voltage to the primary coil is 9.0V.

Calculate the peak voltage across the load resistor connected to the secondary coil.

peak voltage = ... V [2]

- 7 Some data for the work function energy Φ and the threshold frequency f_0 of some metal surfaces are given in Fig. 7.1.

For
Examiner's
Use

metal	$\Phi / 10^{-19} \text{ J}$	$f_0 / 10^{14} \text{ Hz}$
sodium	3.8	5.8
zinc	5.8	8.8
platinum	9.0	

Fig. 7.1

- (a) (i) State what is meant by the *threshold frequency*.

.....

 [2]

- (ii) Calculate the threshold frequency for platinum.

threshold frequency = ... Hz [2]

- (b) Electromagnetic radiation having a continuous spectrum of wavelengths between 300 nm and 600 nm is incident, in turn, on each of the metals listed in Fig. 7.1. Determine which metals, if any, will give rise to the emission of electrons.

.....

 [2]

- (c) When light of a particular intensity and frequency is incident on a metal surface, electrons are emitted. State and explain the effect, if any, on the rate of emission of electrons from this surface for light of the same intensity and higher frequency.

.....

 [3]

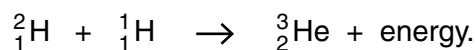
- 8 (a) State what is meant by a *nuclear fusion reaction*.

For
Examiner's
Use

.....

[2]

- (b) One nuclear reaction that takes place in the core of the Sun is represented by the equation



Data for the nuclei are given in Fig. 8.1.

	mass/u
proton ${}^1_1\text{H}$	1.00728
deuterium ${}^2_1\text{H}$	2.01410
helium ${}^3_2\text{He}$	3.01605

Fig. 8.1

- (i) Calculate the energy, in joules, released in this reaction.

energy = ... J [3]

- (ii) The temperature in the core of the Sun is approximately 1.6×10^7 K.
Suggest why such a high temperature is necessary for this reaction to take place.

.....

[2]

Section B

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

*For
Examiner's
Use*

- 9 (a)** Suggest electrical sensing devices, one in each case, that may be used to monitor changes in

(i) light intensity,

.....[1]

(ii) the width of a crack in a welded joint,

.....[1]

(iii) the intensity of an ultrasound beam.

.....[1]

- (b) A student designs the circuit of Fig. 9.1 to detect changes in temperature in the range 0°C to 100°C .

For
Examiner's
Use

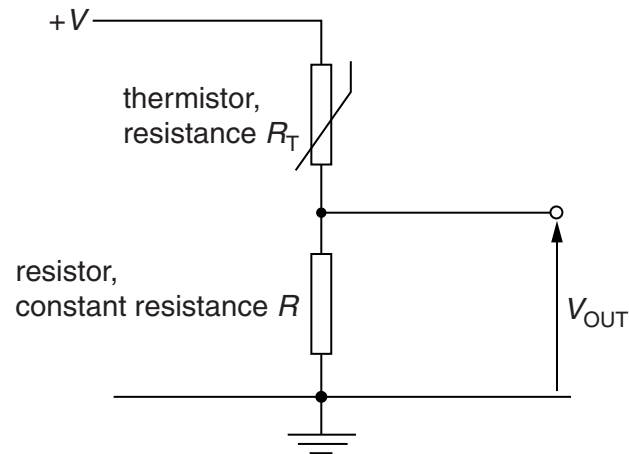


Fig. 9.1

The resistance of the thermistor is R_T and that of the resistor is R .
The student monitors the potential difference V_{OUT} .

State and explain

- (i) whether V_{OUT} increases or decreases as the temperature of the thermistor increases,

.....

 [3]

- (ii) whether the change in V_{OUT} varies linearly with the change in temperature of the thermistor.

.....

 [2]

- 10 (a) Distinguish between sharpness and contrast in X-ray imaging.

sharpness:

.....

contrast:

.....

[2]

- (b) State two causes of loss of sharpness of an X-ray image.

1.

.....

2.

.....

[2]

- (c) Data for the linear attenuation (absorption) coefficient μ of X-ray photons are given in Fig. 10.1.

	μ/cm^{-1}
bone	2.85
muscle	0.95

Fig. 10.1

A parallel beam of X-rays is incident, separately, on a thickness of 3.5 cm of bone and on a muscle of thickness 8.0 cm.

- (i) Calculate the ratio

$$\frac{\text{intensity of X-ray beam transmitted through bone}}{\text{intensity of X-ray beam transmitted through muscle}}$$

ratio = ... [3]

- (ii) Use your answer in (i) to suggest whether an X-ray image of the bone and muscle would show good or poor contrast.

*For
Examiner's
Use*

.....

.....

.....[2]

11 A radio station emits an amplitude-modulated wave for the transmission of music.

(a) (i) State what is meant by an *amplitude-modulated* (AM) wave.

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

(ii) Give two reasons why the transmitted wave is modulated, rather than transmitting the information signal directly as a radio wave.

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

- (b) The variation with frequency f of the amplitude A of the transmitted wave is shown in Fig. 11.1.

For
Examiner's
Use

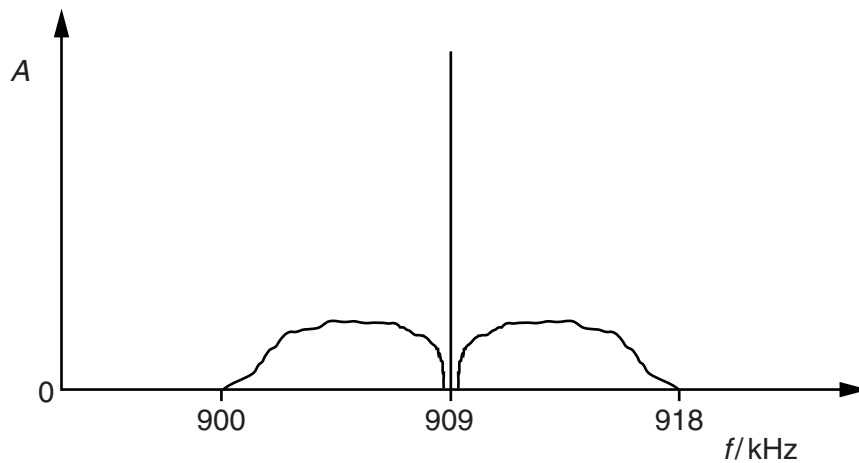


Fig. 11.1

For this transmission, determine

- (i) the wavelength of the carrier wave,

wavelength = ... m [2]

- (ii) the bandwidth,

bandwidth = ... kHz [1]

- (iii) the maximum frequency, in Hz, of the transmitted audio signal.

frequency = ... Hz [1]

- 12 An optic fibre is used for the transmission of digital telephone signals. The power input to the optic fibre is 9.8 mW . The effective noise level in the receiver circuit is $0.36 \mu\text{W}$, as illustrated in Fig. 12.1.

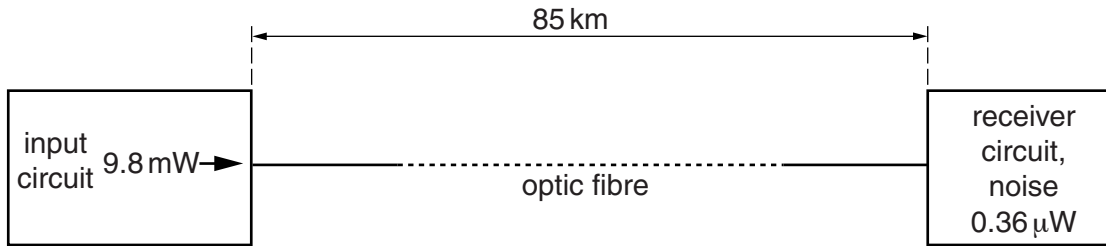


Fig. 12.1

The signal-to-noise ratio at the receiver must not fall below 28 dB.
For this transmission without any repeater amplifiers, the maximum length of the optic fibre is 85 km.

- (a) Calculate the minimum input signal power to the receiver.

power = ... W [2]

- (b) Use your answer in (a) to calculate the attenuation in the fibre.

attenuation = ... dB [2]

- (c) Determine the attenuation per unit length of the fibre.

attenuation per unit length = ... dB km^{-1} [1]

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