80

Cambridge International AS & A Level

**Cambridge International Examinations**
Cambridge International Advanced Subsidiary and Advanced Level

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*7622874486*

**PHYSICS** **9702/42**

Paper 4 A Level Structured Questions **May/June 2016**

**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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**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 | $s = ut + \frac{1}{2}at^2$<br>$v^2 = u^2 + 2as$ |
| work done on/by a gas | $W = p\Delta V$ |
| gravitational potential | $\phi = -\dfrac{Gm}{r}$ |
| hydrostatic pressure | $p = \rho g h$ |
| 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. | $v = v_0 \cos \omega t$<br>$v = \pm\, \omega \sqrt{(x_0^{\,2} - x^2)}$ |
| Doppler effect | $f_o = \dfrac{f_s v}{v \pm v_s}$ |
| 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 | $W = \frac{1}{2}QV$ |
| 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 | $V_H = \dfrac{BI}{ntq}$ |
| alternating current/voltage | $x = x_0 \sin \omega t$ |
| radioactive decay | $x = x_0 \exp(-\lambda t)$ |
| decay constant | $\lambda = \dfrac{0.693}{t_{\frac{1}{2}}}$ |

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

1 A binary star consists of two stars A and B that orbit one another, as illustrated in Fig. 1.1.

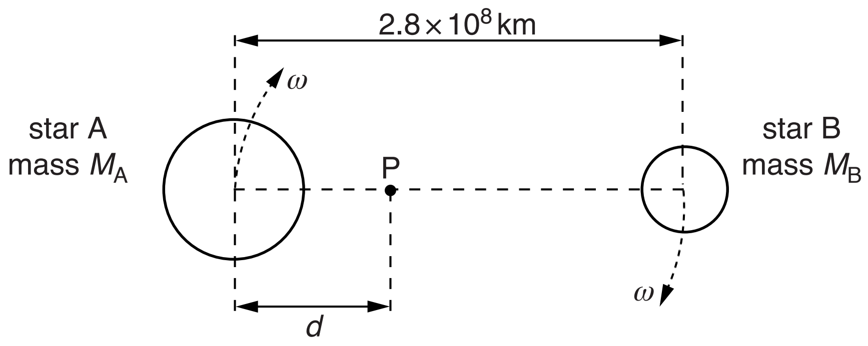


**Fig. 1.1**

The stars are in circular orbits with the centres of both orbits at point P, a distance *d* from the centre of star A.

**(a) (i)** Explain why the centripetal force acting on both stars has the same magnitude.

As the " " is provided by the gravitational force which is proportional to the product of the two masses of the planets and that is always equal

[2]

**(ii)** The period of the orbit of the stars about point P is 4.0 years.

Calculate the angular speed $\omega$ of the stars.

$$\frac{2\pi}{4 \times 365 \times 24 \times 60^2} = 4.98096\ 10^{-8}$$

$\omega$ = $5.0 \times 10^{-8}$ rad s$^{-1}$ [2]

$$\frac{GM_aM_B}{d^2}$$

**(b)** The separation of the centres of the stars is $2.8 \times 10^8$ km.
The mass of star A is $M_A$. The mass of star B is $M_B$.

The ratio $\dfrac{M_A}{M_B}$ is 3.0.

**(i)** Determine the distance *d*.

$$M_a \times d \times \cancel{\omega^2} = M_b \times (r-d) \times \cancel{\omega^2}$$

$$\frac{M_a}{M_B} = 3$$

$$M_a = 3M_B$$

$$\frac{M_a \times d}{M_b} = r-d$$

$$3d = r-d$$

$$4d = r$$

$$d = \frac{r}{4}$$

$$d = \frac{2.8\times10^8}{4} = 7\times10^7$$

$d$ = ....$7\times10^7$.... km [3]

3

**(ii)** Use your answers in **(a)(ii)** and **(b)(i)** to determine the mass $M_B$ of star B.
Explain your working.

$M_a = 3M_B$

gravitational force provides centeripetal force ∴

$F_g = F_c$

$$\frac{G(\cancel{3M_b})M_b}{d^2} = \cancel{(3M_b)} \times d \times \omega^2$$

$$M_b = \frac{d^3\omega^2}{G} = \frac{(7\times10^{10})^3 \times (4.98\times10^{-8})^2}{6.67\times10^{-11}}$$

$M_B$ = ....$1.3\times10^{28}$.... kg [3]

1

$1.275\times10^{28}$

[Total: 10]

8

**2** **(a)** State what is meant by

**(i)** the Avogadro constant $N_A$,

Number of atoms in 1 mole of a substance

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

**(ii)** the mole.

Mass of a an atom relative to carbon 12's

mass. [2]

**(b)** A container has a volume of $1.8 \times 10^4\ cm^3$.

The ideal gas in the container has a pressure of $2.0 \times 10^7$ Pa at a temperature of 17 °C.

Show that the amount of gas in the cylinder is 150 mol.

$$\frac{PV}{RT} = n$$

$$n = \frac{2 \times 10^7 \times \frac{1.8 \times 10^4}{100^3}}{8.31 \times 17 + 273} = 149.38$$

$\approx 150$ mols

$$n = \frac{N}{N_a}$$

[1]

**(c)** Gas molecules leak from the container in **(b)** at a constant rate of $1.5 \times 10^{19}\ s^{-1}$.
The temperature remains at 17 °C.
In a time $t$, the amount of gas in the container is found to be reduced by 5.0%.

Calculate

**(i)** the pressure of the gas after the time $t$,

$$\frac{2.0 \times 10^7 \times 0.95}{1}$$

$$\frac{P_1}{N_1} = \frac{P_2}{N_2}$$

$$P_2 = \frac{P_1 N_2}{N_1}$$

pressure = $1.9 \times 10^7$ Pa [2]

**(ii)** the time *t*.

$149.38 \times 6.02 \times 10^{23} = 8.99212 \times 10^{25}$

$0.05 \times 8.99 \times 25 = 4.496 \times 10^{24}$

$\dfrac{4.496 \times 10^{24}}{1.5 \times 10^{19}} = 2.99755 \times 10^{5}$

*t* = ........ $3 \times 10^{5}$ ........ s [3]

8

[Total: 9]

**3** **(a)** Explain what is meant by the statement that two bodies are in *thermal equilibrium*.

........ Zero net transfer of thermal energy, both at same temp. ........

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

**(b)** Suggest suitable types of thermometer, one in each case, to measure

#

**(i)** the temperature of the flame of a Bunsen burner,

........ IR ........ Appli ........ [1]

**(ii)** the change in temperature of a small crystal when it is exposed to a pulse of ultrasound energy.

#

........ digital thermometer ........ [1]

**(c)** Some water is heated so that its temperature changes from 26.5 °C to a final temperature of 38.0 °C.

State, to an appropriate number of decimal places,

**(i)** the change in temperature in kelvin,

#

change = ........ 11.5 ........ K [1]

**(ii)** the final temperature in kelvin.

273.15 # why 311.2 ??

final temperature = ........ 311 ........ K [1]

[Total: 5]

5

**4** A metal block hangs vertically from one end of a spring. The other end of the spring is tied to a thread that passes over a pulley and is attached to a vibrator, as shown in Fig. 4.1.

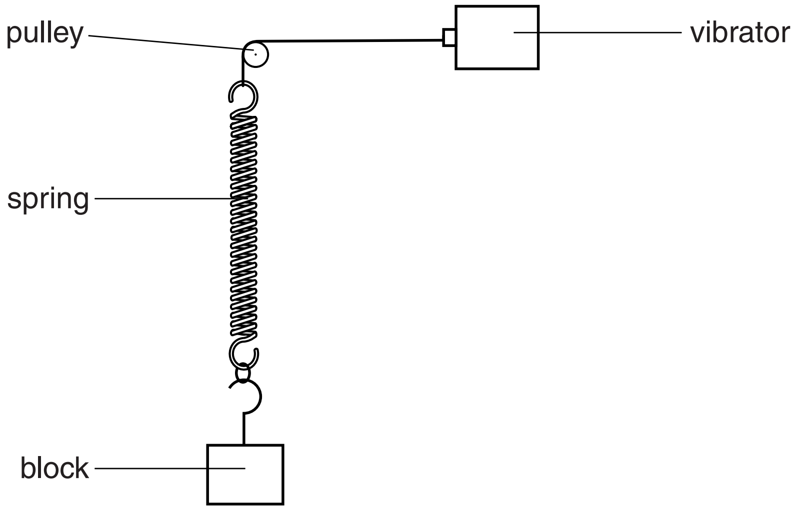


**Fig. 4.1**

**(a)** The vibrator is switched off.
The metal block of mass 120 g is displaced vertically and then released. The variation with time $t$ of the displacement $y$ of the block from its equilibrium position is shown in Fig. 4.2.

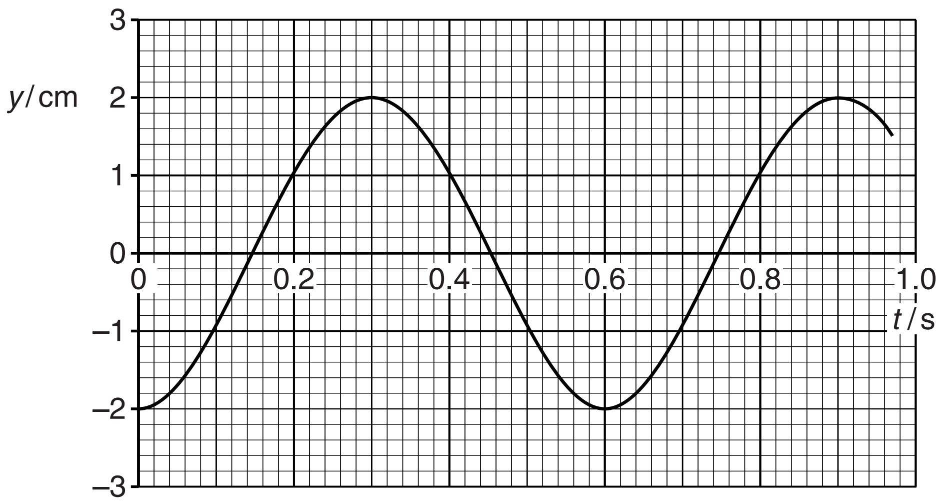


**Fig. 4.2**

For the vibrations of the block, calculate

**(i)** the angular frequency $\omega$,

$\omega = \frac{2\pi}{T}$ $\frac{2\pi}{0.6} = 10.47198$

$\omega$ = ............10.5............................ rad s$^{-1}$ [2]

**(ii)** the energy of the vibrations.

$\frac{1}{2} m \omega^2 x_0^2$

$\frac{1}{2} \times 0.12 \times 10.47198^2 \times 0.02^2$

$2.631897 \times 10^{-3}$

energy = ..... $2.6 \times 10^{-3}$ ..... J [2]

**(b)** The vibrator is now switched on.

The frequency of vibration is varied from 0.7*f* to 1.3*f* where *f* is the frequency of vibration of the block in **(a)**.

For the block, complete Fig. 4.3 to show the variation with frequency of the amplitude of vibration. Label this line A. [3]

2 2

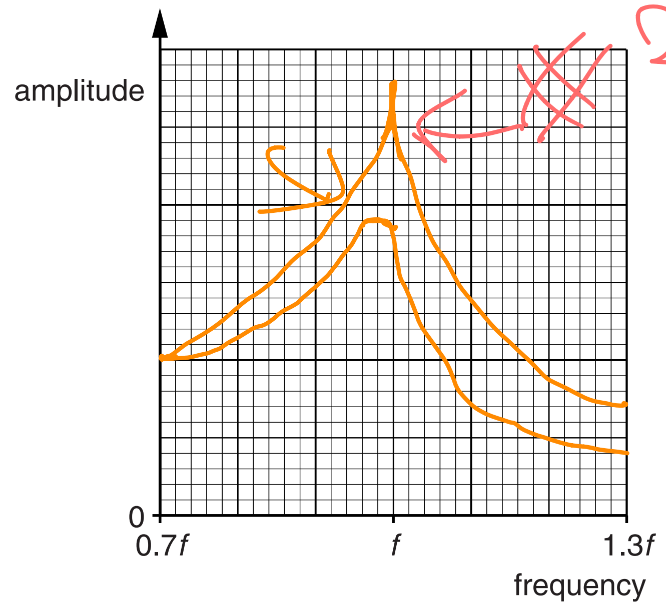


**Fig. 4.3**

**(c)** Some light feathers are now attached to the block in **(b)** to increase air resistance.

The frequency of vibration is once again varied from 0.7*f* to 1.3*f*. The new amplitude of vibration is measured for each frequency.

On Fig. 4.3, draw a line to show the variation with frequency of the amplitude of vibration. Label this line B. [2]

[Total: 9]

9

**5** The signal from a radio station is amplitude modulated.

**(a)** State what is meant by *amplitude modulation* (AM).

amplitude of carrier wave varies in synchrony with the displacement of the information signal, freq of modulated wave stays constant

[2]

**(b)** The variation with frequency of the intensity of the signal from the radio station is shown in Fig. 5.1.

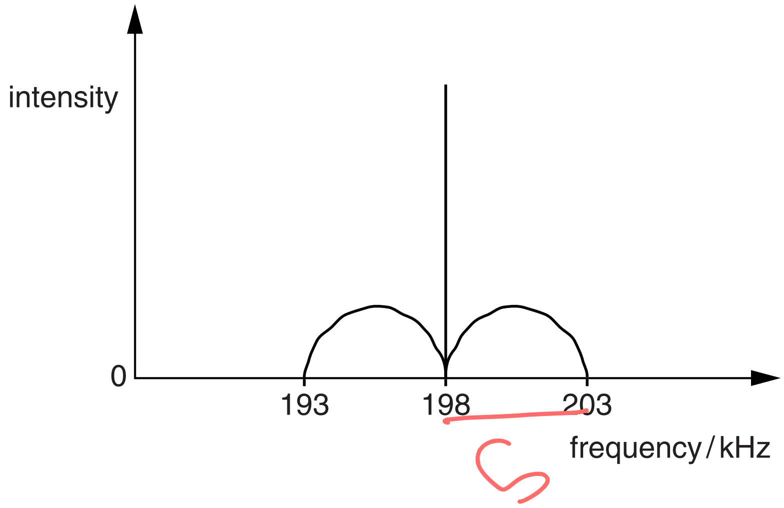


**Fig. 5.1**

State, for this signal,

**(i)** the bandwidth,

bandwidth = 10 kHz [1]

**(ii)** the maximum audio frequency that is broadcast.

maximum frequency = 203 kHz [1]

why?

**(c)** A transmission line of length 45 km has an attenuation per unit length of 2.0 dB km$^{-1}$.

The input power to the transmission line is 500 mW.
The minimum acceptable signal-to-noise ratio is 24 dB for background noise of $5.0 \times 10^{-13}$ W.

**(i)** Calculate the minimum acceptable power output from the transmission line.

$24 = 10 \log\left(\frac{S_{out}}{noise}\right)$

$10^{2.4} \times noise = S_{out}$

$S_{out} = 10^{2.4} \times 5 \times 10^{-13}$

$= 1.2559 \times 10^{-10}$

power = $1.3 \times 10^{-10}$ W [2]

2

**(ii)** Use your answer in **(i)** to determine whether it is possible to transmit the signal along the transmission line.

$-90 = 10 \log \frac{P_{out}}{P_{in}}$

$10^{-9} = \frac{P_{out}}{P_{in}}$

$P_{out} = 10^{-9} \times 500 \times 10^{-3}$

$= 5 \times 10^{-10}$

$5 \times 10^{-10} > 1.3 \times 10^{-10}$

$\therefore$ yes it is possible

[2] 2

[Total: 8]

7

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6 (a) By reference to electric field lines, explain why, for points outside an isolated spherical conductor, the charge on the sphere may be considered to act as a point charge at its centre.

Electric field lines are radial and towards the center of the sphere.

1

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

(b) Two isolated protons are separated in a vacuum by a distance *x*.

(i) Calculate the ratio

$$\frac{\text{electric force between the two protons}}{\text{gravitational force between the two protons}}.$$

$k = \frac{1}{4\pi\varepsilon_0}$

$$\frac{\frac{kQq}{r^2}}{\frac{GMm}{r^2}} = \frac{kQq}{\cancel{r^2}} \times \frac{\cancel{r^2}}{GMm} = \frac{kQq}{GMm} = \frac{9\times10^9 \times (1.6\times10^{-19})^2}{6.67\times10^{-11} \times (1.66\times10^{-27})^2}$$

$$= 1.23858\times10^{36}$$

ratio = $1.2\times10^{36}$ [3]

(ii) By reference to your answer in **(i)**, suggest why gravitational forces are not considered when calculating the force between charged particles.

The gravitational force is very small compared to electric force and is negligible so we dont consider it. [1]

[Total: 6]

5

**7** **(a)** State two uses of capacitors in electrical circuits, other than for the smoothing of direct current.

1. Store of energy ✓

2. To handle surges in voltage blocking DC ✗ (1)

[2]

**(b)** The combined capacitance between terminals A and B of the arrangement shown in Fig. 7.1 is 4.0 μF.

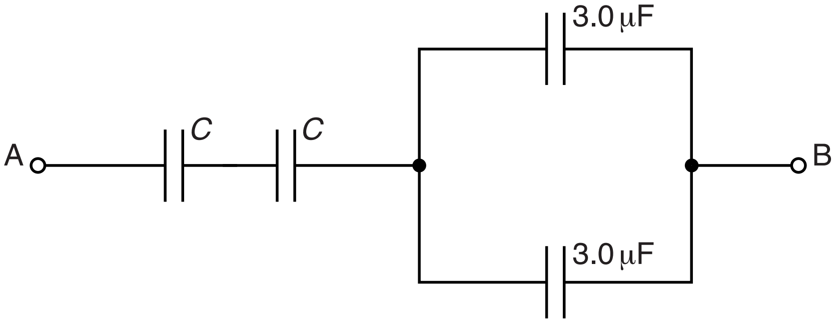



**Fig. 7.1**

Two capacitors each have capacitance $C$ and the remaining capacitors each have capacitance 3.0 μF.

The potential difference (p.d.) between terminals A and B is 12 V.

**(i)** Determine the capacitance $C$.

$3+3=6$

$\left(\frac{1}{6}+\frac{1}{C}+\frac{1}{C}\right)^{-1}=4$

$\left(\frac{1}{6}+\frac{2}{C}\right)^{-1}=4$

$\frac{6C}{C+12}=4$

$6C=4C+48$

$2C=8$

$C=4$

$C$ = ....4.... μF [2] ✗ (1)

**(ii)** Calculate the magnitude of the total positive charge transferred to the arrangement.

$Q=CV$

$=4\times10^{-6}\times12$

$=4.8\times10^{-5}$

charge = ....$4.8\times10^{-5}$.... μC [2] (1)

$Q = CV$ $V = \frac{Q}{C}$



**(iii)** Use your answer in **(ii)** to state the magnitude of the charge on one plate of

**1.** a capacitor of capacitance $C$,

charge = ........ $4.8 \times 10^{-5}$ ........ μC

**2.** a capacitor of capacitance 3.0 μF.

charge = ........ $2.4 \times 10^{-5}$ ........ μC

[2]

[Total: 8]

3

**8** An ideal operational amplifier (op-amp) has infinite voltage gain and infinite slew rate.

**(a)** State what is meant by

**(i)** the *voltage gain*,

signal of a wide range of frequencies are amplified equally

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

**(ii)** *infinite slew rate*.

There is no time delay for the output to change after a change in input.

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

**(b)** A non-inverting amplifier circuit incorporating an ideal op-amp is shown in Fig. 8.1.

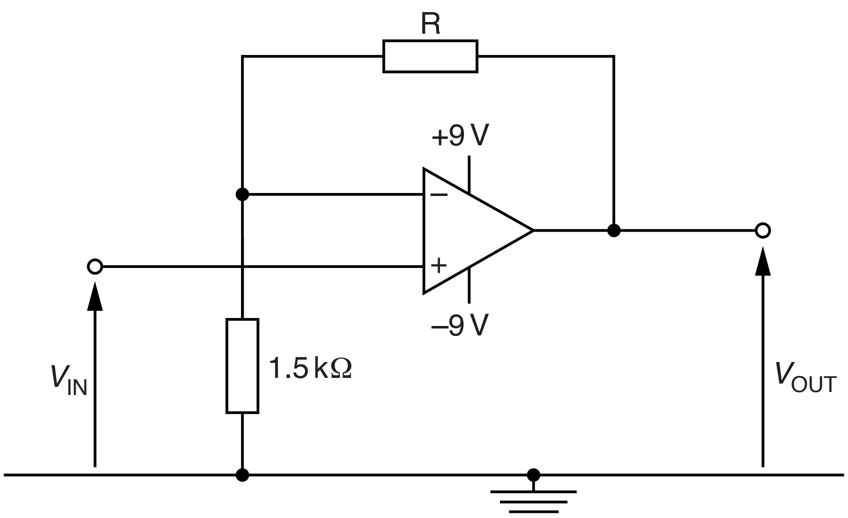



**Fig. 8.1**

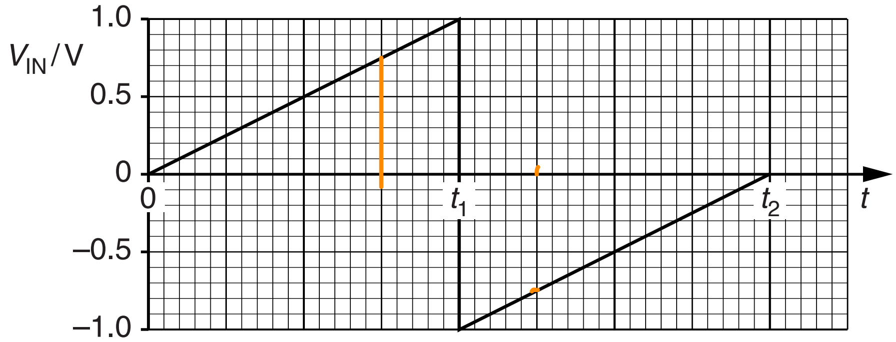
The supply to the op-amp is +9 V / −9 V.
The voltage gain of the amplifier circuit is 12.

Determine the resistance of resistor R.

$$\frac{R}{1500} = 12$$

resistance = 18000 Ω [2]

**(c)** For the circuit of Fig. 8.1, the variation with time $t$ of the input potential $V_{IN}$ to the amplifier is shown in Fig. 8.2.




$9 = 12\,(V^+)$

$V^+ = \frac{9}{12}$

$= 0.75$

**Fig. 8.2**

On Fig. 8.3, show the variation with time $t$ of the output potential $V_{OUT}$ for time $t = 0$ to time $t = t_2$.

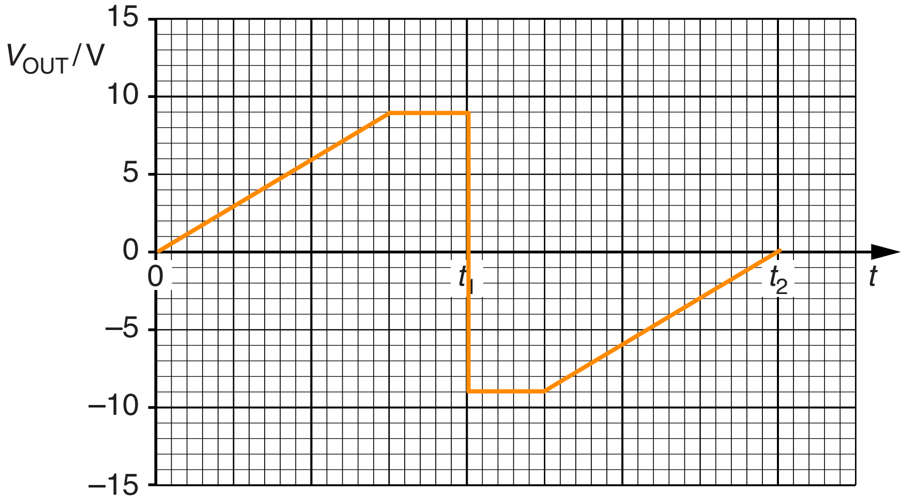



**Fig. 8.3**

[4]

[Total: 9]

**9** A magnetic field of flux density $B$ is normal to face PQRS of a slice of a conducting material, as shown in Fig. 9.1.

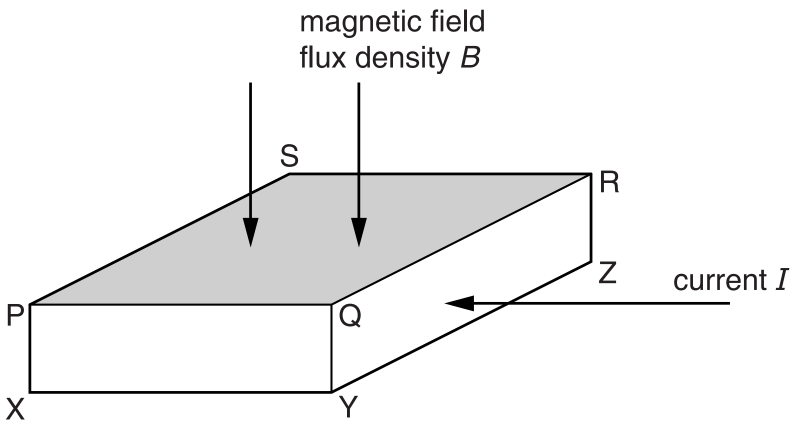



**Fig. 9.1**

A current $I$ in the slice is normal to face QRZY of the slice.

The Hall voltage $V_H$ across the slice is given by the expression

$$V_H = \frac{BI}{ntq}.$$

**(a) (i)** State what is represented by the symbol $n$.

number of charge carriers per unit volume.

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

**(ii)** The symbol $t$ represents the length of one side of the slice. Use letters from Fig. 9.1 to identify $t$.

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

**(b) (i)** In general, the Hall voltage produced in a slice of a metal is very small.
For a slice of the same dimensions with the same current and magnetic flux density, the Hall voltage produced in a semiconductor material is much larger.
Suggest and explain why.

The value of n for a is much smaller compared to a metal so the value of $V_H$ is much larger

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

**(ii)** In some semiconducting materials, electrons are mainly responsible for conduction.
In other semiconducting materials, holes are mainly responsible for conduction.
Suggest and explain the difference, if any, that conduction by electrons or by holes will have on the Hall voltage.

No diff as a hole and charge carrier together form a charge carrier and a hole only forms when an electron jumps to the conduction band, leaving hole behind in the valence band.

#

omkr

[3]

[Total: 7]

4

**10** Two coils P and Q are placed close to one another, as shown in Fig. 10.1.

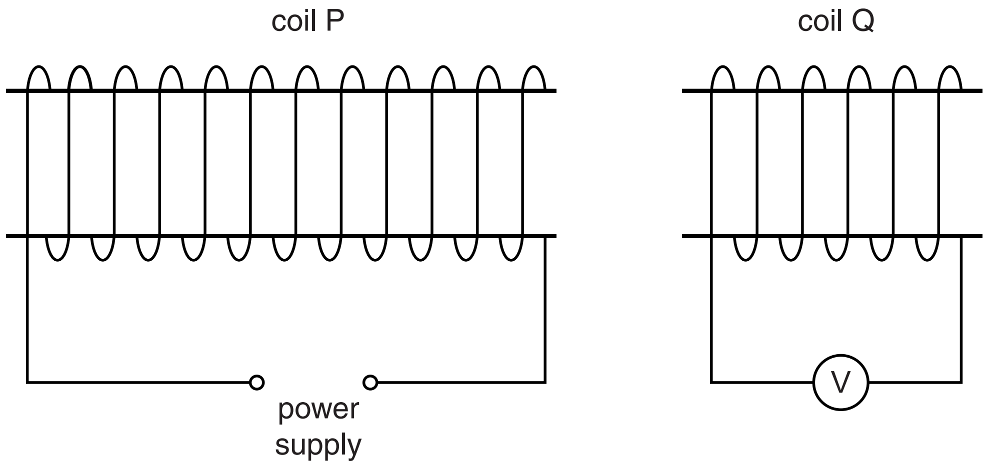



**Fig. 10.1**

**(a)** The current in coil P is constant.

An iron rod is inserted into coil P.

Explain why, during the time that the rod is moving, there is a reading on the voltmeter connected to coil Q.

produces a constant
The coil P magnetic field which cuts the coil Q, however as the rod enters coil P it interferes with that field, changing it. During this change, a constantly varying magnetic flux linkage is formed with coil Q ∴ an emf is induced in Q. [2]

**(b)** The current in coil P is now varied as shown in Fig. 10.2.

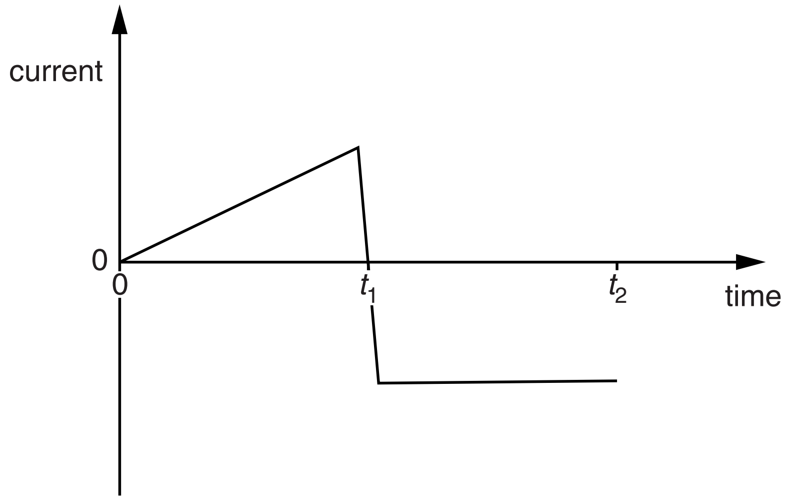



**Fig. 10.2**

On Fig. 10.3, show the variation with time of the reading of the voltmeter connected to coil Q for time $t = 0$ to time $t = t_2$.

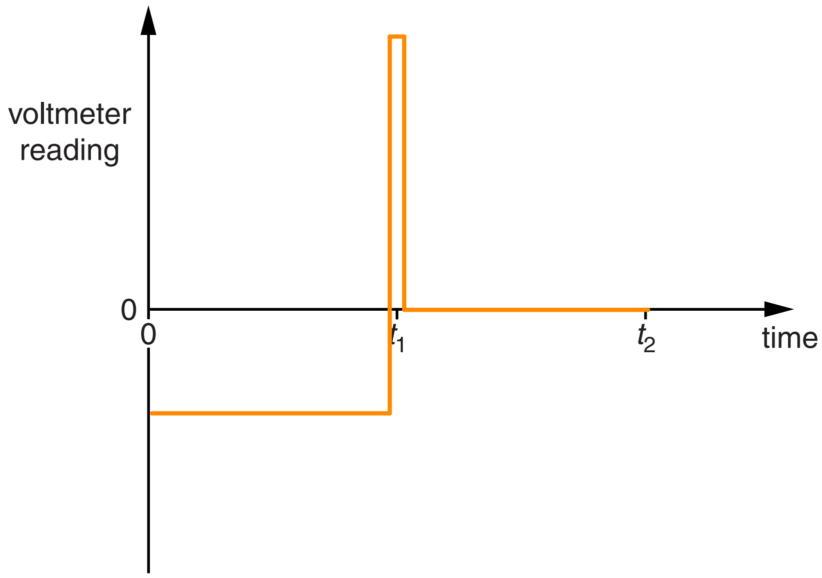



**Fig. 10.3**

2 [4]

[Total: 6]

6

**11** A bridge rectifier contains four ideal diodes A, B, C and D, as shown in Fig. 11.1.

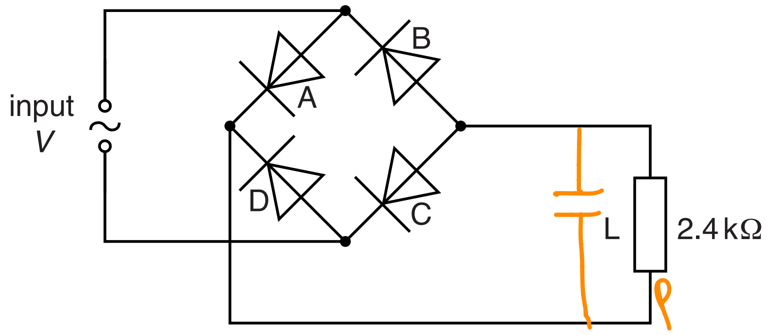



**Fig. 11.1**

The output of the rectifier is connected to a load L of resistance 2.4 kΩ.

**(a)** On Fig. 11.1, mark with the letter P the positive terminal of the load. [1]

1

**(b)** The variation with time *t* of the potential difference *V* across the input to the rectifier is shown in Fig. 11.2.

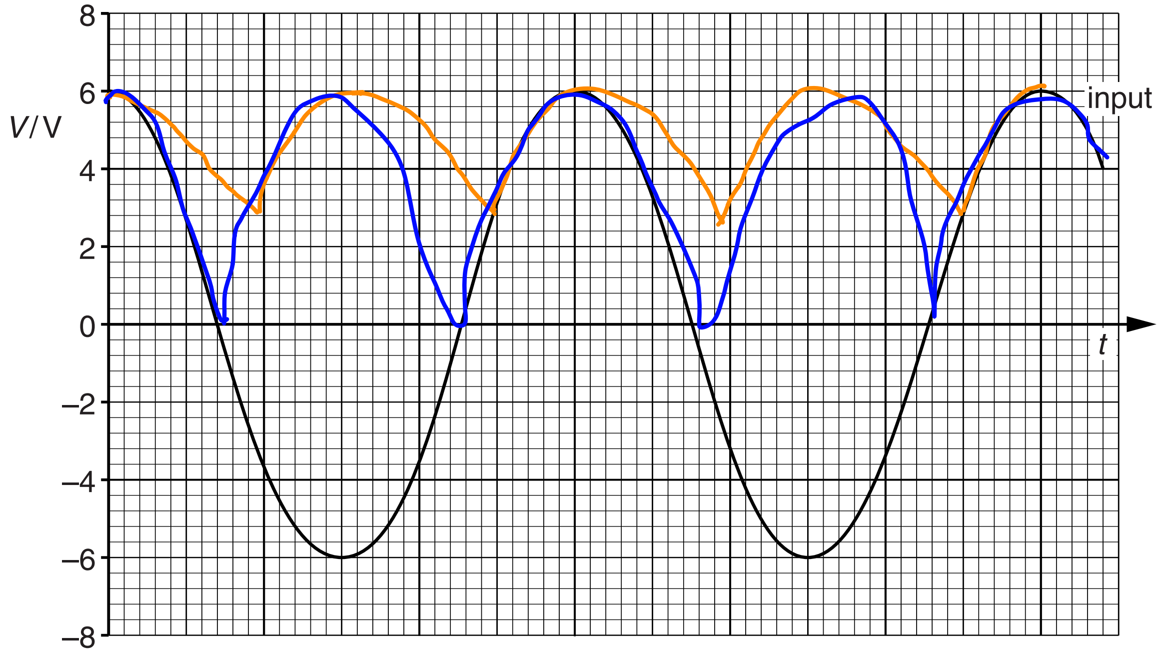



**Fig. 11.2**

Calculate the root-mean-square (r.m.s.) current in the load L.

$V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{6}{\sqrt{2}} = 3\sqrt{2} = 4.2426$

1

r.m.s. current = 4.2 A [2]

**(c)** The potential difference across the load L is to be smoothed using a capacitor.

**(i)** On Fig. 11.1, draw the symbol for a capacitor, connected to produce smoothing. [1]

**(ii)** The minimum potential difference across the load L with the smoothing capacitor connected is 3.0 V.

On Fig. 11.2, sketch the variation with time *t* of the potential difference across the load L. [3]

[Total: 7]

6

**12** High-energy electrons collide with a metal target, producing X-ray photons.

The variation with wavelength of the intensity of the X-ray beam is illustrated in Fig. 12.1.

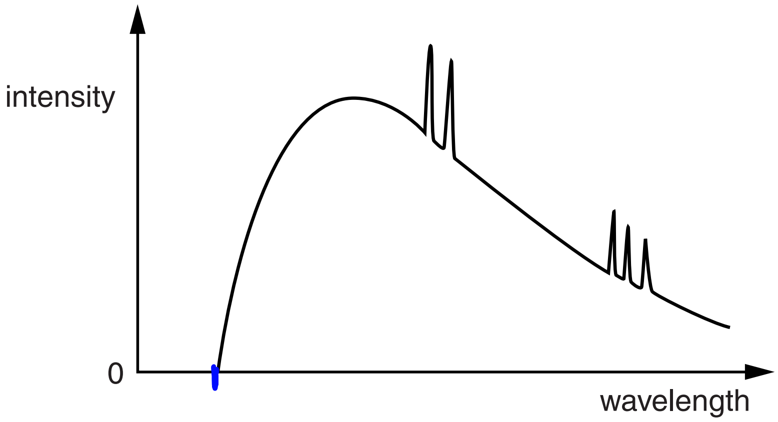



**Fig. 12.1**

**(a)** Explain why there is

**(i)** a continuous distribution of wavelengths,

quick recap

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

**(ii)** a sharp cut-off at short wavelength,

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

**(iii)** a series of peaks superimposed on the continuous distribution of wavelengths.

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

**(b)** In the X-ray imaging of body structures, longer wavelength photons are frequently filtered out of the X-ray beam.

**(i)** State how this filtering is achieved.

Using lead grid × aluminium sheet

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

**(ii)** Suggest the reason for this filtering.

long wavelength x-Rays are less penetrating and do no contribute to the image and cause harm to tissue. [1]

[Total: 8]

**13** **(a)** Explain what is meant by *gamma radiation* (*γ-radiation*).

..........................................................................................................................................

..........................................................................................................................................

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

**(b)** A source of gamma radiation is placed a fixed distance away from a detector and counter, as illustrated in Fig. 13.1.

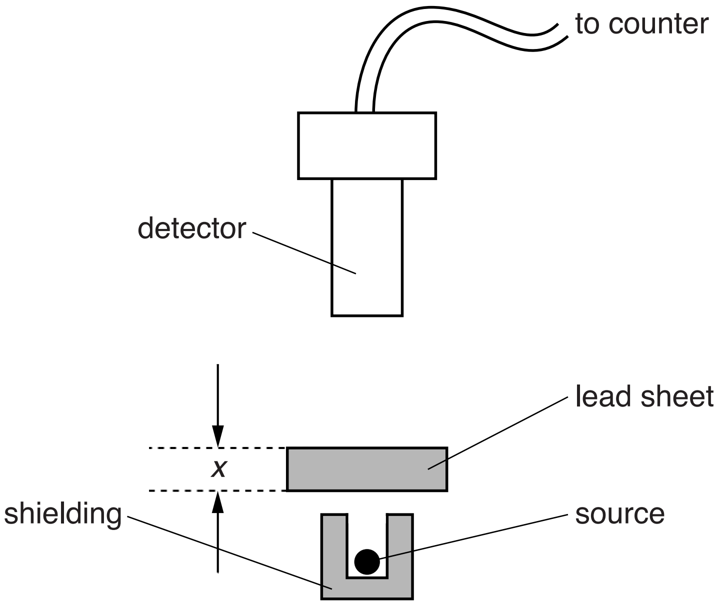



**Fig. 13.1**

A sheet of lead of thickness $x$ is placed between the source and the detector.
The average count rate $C$, corrected for background, is recorded. This is repeated for different values of $x$.
The variation with thickness $x$ of $\ln C$ is shown in Fig. 13.2.

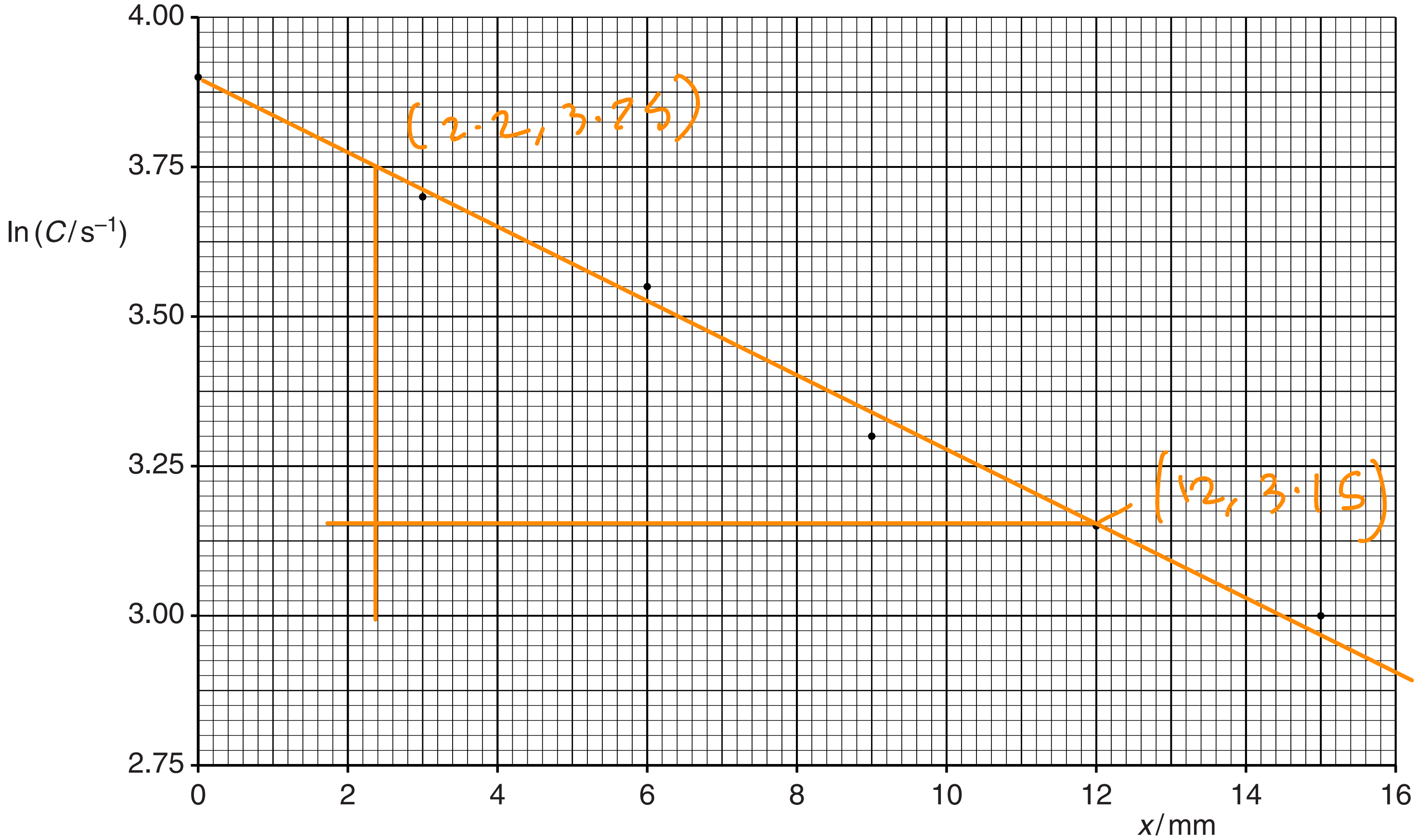



**Fig. 13.2**

The absorption of gamma radiation in lead may be represented by the equation

$$C = C_0 e^{-\mu x}$$ $\ln C = \ln C_0 + -\mu x$

where $C_0$ is the count rate for $x = 0$ and $\mu$ is the linear attenuation (absorption) coefficient.

Use Fig. 13.2 to determine the linear attenuation coefficient $\mu$ for this gamma radiation in lead.

$$\frac{3.75 - 3.15}{2.2 - 12} = -0.06122$$

$$-\mu = -0.06122$$

$\mu$ = ....$\mu = 0.061$.... $mm^{-1}$ [4]

**Question 13 continues on the next page.**

**(c)** The value of $\mu$ calculated in **(b)** is for gamma radiation in lead. lead

Suggest and explain whether the value of $\mu$ for aluminium would be the same, greater or smaller.

less as aluminum is less dense and so speed of sound in it is also slower compared to lead

[2]

1

[Total: 8]

7