Cambridge International AS & A Level

Cambridge International Examinations
Cambridge International Advanced Subsidiary and Advanced Level

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PHYSICS **9702/42**

Paper 4 A Level Structured Questions **October/November 2017**

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 **27** printed pages and **1** blank page.

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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	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
gravitational potential	$\phi = -\dfrac{Gm}{r}$
hydrostatic pressure	$p = \rho gh$
pressure of an ideal gas	$p = \frac{1}{3}\dfrac{Nm}{V}\langle c^2\rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0^2 - x^2)}$
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	$R = R_1 + \mathrm{R}_2 + \ldots$
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)** State Newton's law of gravitation.

States that the force between two point masses is proportional to the product of their masses and inversely proportional to the distance b/w the square of their seperation.

[2]

(b) The planet Jupiter and one of its moons, Io, may be considered to be uniform spheres that are isolated in space.
Jupiter has radius R and mean density ρ.
Io has mass m and is in a circular orbit about Jupiter with radius nR, as illustrated in Fig. 1.1.

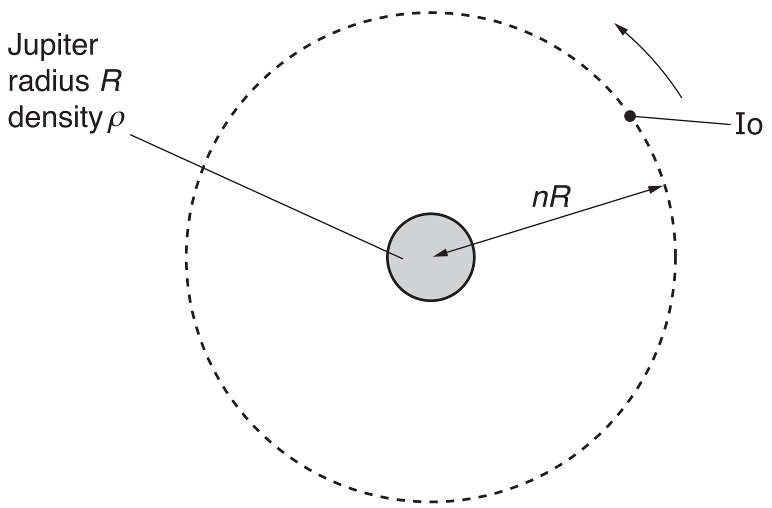

Fig. 1.1

The time for Io to complete one orbit of Jupiter is T.

Show that the time T is related to the mean density ρ of Jupiter by the expression

$$\rho T^2 = \frac{3\pi n^3}{G}$$

where G is the gravitational constant.

$$\frac{GM\cancel{m}}{n^2R^2} = \cancel{m}(nR)\omega^2$$

$$\rho = \frac{M}{\frac{4}{3}\pi r^3}$$

$$\frac{GM}{n^3R^3} = \frac{4\pi^2}{T^2}$$

$$\rho = \frac{3M}{4\pi r^3}$$

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

$$\frac{G \times \cancel{4}\rho\cancel{\pi}\cancel{R^3}}{3} \times \frac{1}{n^3\cancel{R^3}} = \frac{\cancel{4}\pi^{\cancel{2}}}{T^2}$$

$$\frac{G\rho}{3n^3} = \frac{\pi}{T^2}$$

$$\rho T^2 = \frac{3\pi n^3}{G}$$

[4]

(c) **(i)** The radius R of Jupiter is 7.15×10^4 km and the distance between the centres of Jupiter and Io is 4.32×10^5 km.
The period T of the orbit of Io is 42.5 hours.

Calculate the mean density ρ of Jupiter.

$$n = \frac{4.32 \times 10^5}{7.15 \times 10^4} = 6.042$$

$$\rho = \frac{3\pi n^3}{T^2 G}$$

$$= \frac{3\pi (6.042)^3}{(42.5 \times 60^2)^2 \times 6.67 \times 10^{-11}} = 1.775 \times 10^3$$

ρ = ...1.8 × 10³........ kg m^{-3} [3] 1

(ii) The Earth has a mean density of 5.5×10^3 kg m^{-3}. It is said to be a planet made of rock.
By reference to your answer in **(i)**, comment on the possible composition of Jupiter.

It is mostly made up of gas.

.... [1]

[Total: 10]

6

2 (a) State what is meant by *specific latent heat*.

Amount of thermal energy required to change state of 1kg of a substance without a change in temp.

[2]

(b) A beaker of boiling water is placed on the pan of a balance, as illustrated in Fig. 2.1.

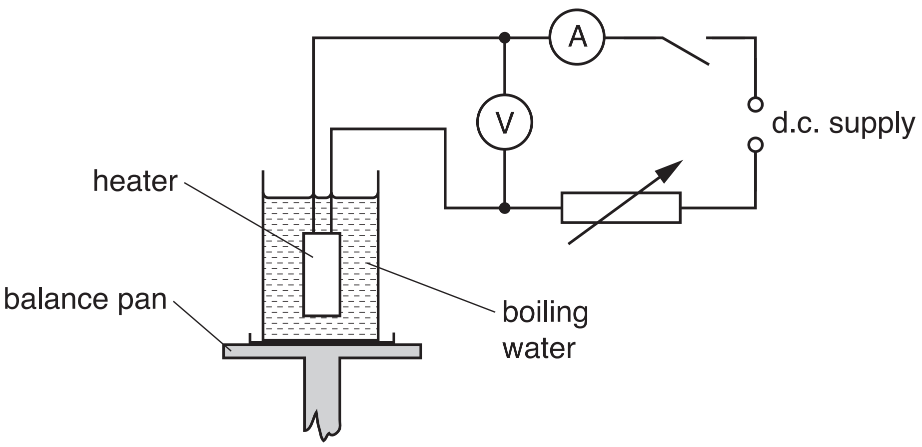

Fig. 2.1

The water is maintained at its boiling point by means of a heater.
The change *M* in the balance reading in 300 s is determined for two different input powers to the heater.
The results are shown in Fig. 2.2.

voltmeter reading / V	ammeter reading / A	*M* / g
11.5	5.2	5.0
14.2	6.4	9.1

Fig. 2.2

(i) Energy is supplied continuously by the heater.
State where, in this experiment,

1. external work is done,

In expansion when the turning the liquid to gas

x

#

2. internal energy increases. Explain your answer.

Internal energy of boiling water increases as the Kinetic energy of the molecules is constant as temp is constant however their potential energy of molecules which requires energy.

[3]

#

1

(ii) Use data in Fig. 2.2 to determine the specific latent heat of vaporisation of water.

$q = mL$

$5.2 \times 11.5 \times 300 = 5L + H \Rightarrow 17940 = 5L + H$

$6.4 \times 14.2 \times 300 = 9.1L + H \Rightarrow 27264 = 9.1L + H$

$27264 = 9.1L + H$

$-\ 17940 = 5L + H$

$9324 = 4.1L$

$L = 2274.146\ \mathrm{J\,g^{-1}}$

specific latent heat = ...2.3×10^3.......... J g^{-1} [3]

[Total: 8]

6

The square of angular frequency is proportional to the acceleration of body and inversely proportional to the displacement at that point.

3 **(a)** **(i)** Define the *radian*.

1 radian is the value for the angle of a sector when its radius is equal to the length of the arc. [2] 1

#

(ii) State, by reference to simple harmonic motion, what is meant by *angular frequency*.

It is the change in displacement per unit time.

[1] 0

#

(b) A thin metal strip, clamped horizontally at one end, has a load of mass M attached to its free end, as shown in Fig. 3.1.

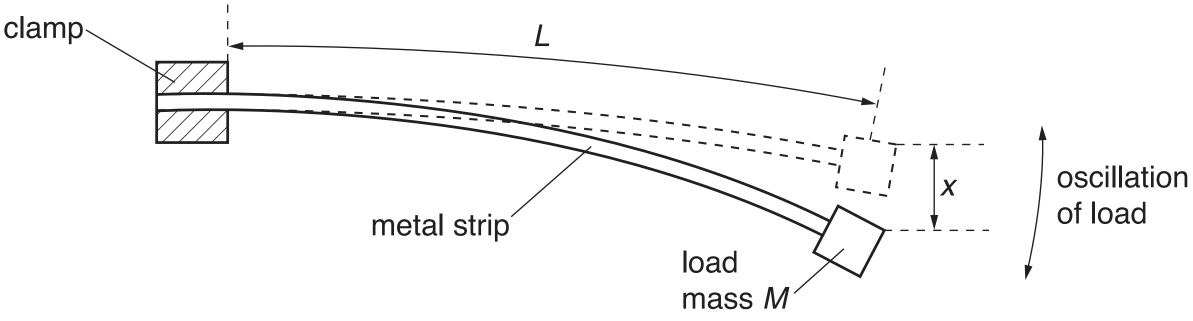

Fig. 3.1

The metal strip bends, as shown in Fig. 3.1.

When the free end of the strip is displaced vertically and then released, the mass oscillates in a vertical plane.
Theory predicts that the variation of the acceleration a of the oscillating load with the displacement x from its equilibrium position is given by

$$a = -\left(\frac{c}{ML^3}\right)x$$

where L is the effective length of the metal strip and c is a positive constant.

anki

(i) Explain how the expression shows that the load is undergoing simple harmonic motion.

acceleration is proportional to displacement and is in the -ve direction of displacement. and acceleration is proportional to the constant

$\frac{c}{ML^3}$ [2] 1

(ii) For a metal strip of length L = 65 cm and a load of mass M = 240 g, the frequency of oscillation is 3.2 Hz.
Calculate the constant c.

$\omega = 2\pi f$
$= 2\pi \times 3.2$
$= 20.10619$

$\omega^2 = \dfrac{c}{mL^3}$

$c = ML^3 \omega^2$
$= .24 \times .65^3 \times 20.10619^2$
$= 26.6447$

c = ... 27 (2 sf) .... kg m^3 s^{-2} [3]

[Total: 8]

4 (a) Explain the principles behind the **generation** of ultrasound waves for diagnosis in medicine.

....

....

....

....

....

....

....

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....

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....

....

....

....

....[5]

(b) Ultrasound frequencies as high as 10 MHz are used in medical diagnosis.
Suggest one advantage of the use of high-frequency ultrasound rather than lower-frequency ultrasound.

....

....

.... [1]

[Total: 6]

5 The analogue signal from a microphone is to be transmitted in digital form.
The variation with time t of part of the signal from the microphone is shown in Fig. 5.1.

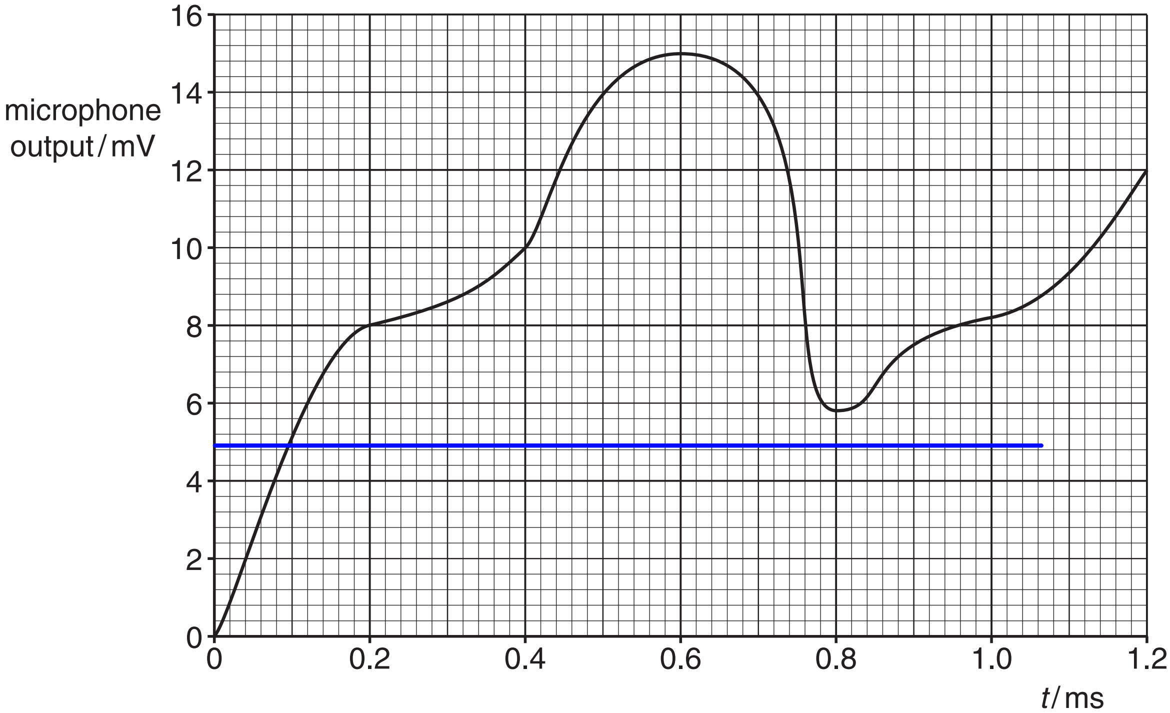


Fig. 5.1

The microphone output is sampled at a frequency of 5.0 kHz by an analogue-to-digital converter (ADC).
The output from the ADC is a series of 4-bit numbers. The smallest bit represents 1.0 mV.
The first sample is taken at time $t = 0$.

$2^3 \; 2^2 \; 2^1 \; 2^0$

8 : 1 0 0 0

5 : 0 1 0 1

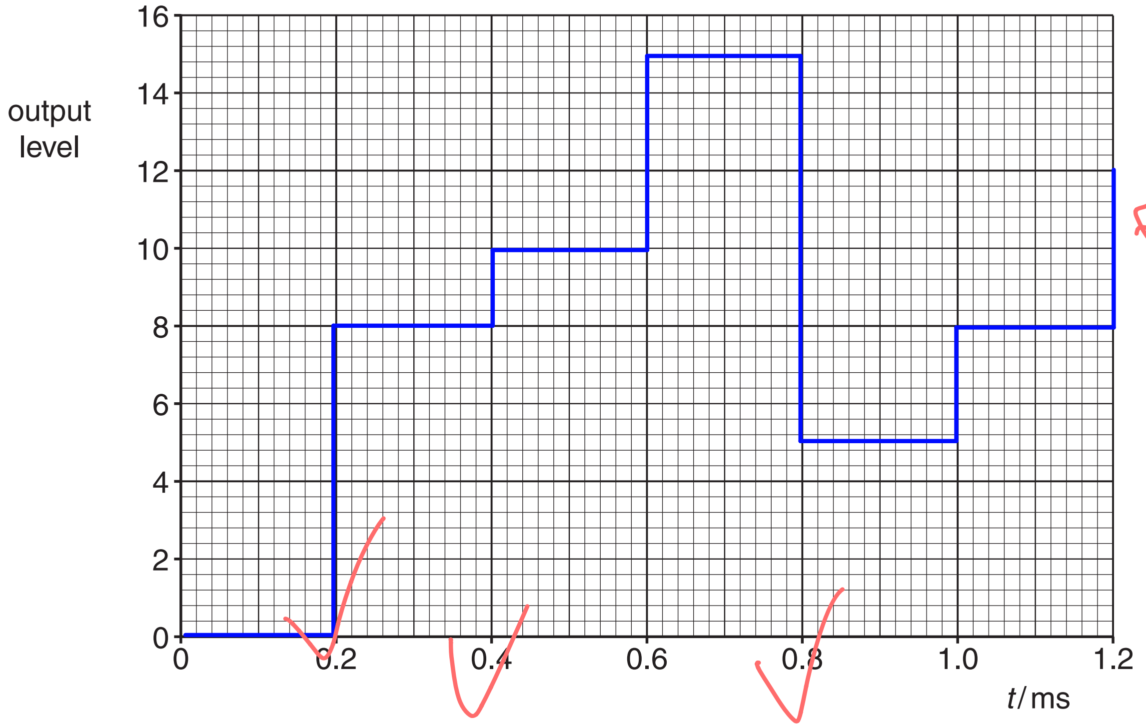
(a) Use Fig. 5.1 to complete Fig. 5.2.

time t/ms	microphone output / mV	ADC output
0.2	8	1000
0.8	5.8	0101

Fig. 5.2

[2] 0

(b) After transmission of the digital signal, it is converted back to an analogue signal using a digital-to-analogue converter (DAC).
Using data from Fig. 5.1, draw, on the axes of Fig. 5.3, the output level from the DAC for the transmitted signal from time $t = 0$ to time $t = 1.2$ ms.



$\frac{1}{5000} =$

Fig. 5.3

[4]

(c) It is usual in modern telecommunication systems for the ADC and the DAC to have more than four bits in each sample.
State and explain the effect on the transmitted analogue signal of such an increase.

step hieght decreases and there is less loss of information

[2]

[Total: 8]

7

6 (a) For any point outside a spherical conductor, the charge on the sphere may be considered to act as a point charge at its centre. By reference to electric field lines, explain this.

Electric field lines are radial, so when you look at the center of the sphere they seem to be coming out of / going into sphere

....[2]

(b) An isolated spherical conductor has charge q, as shown in Fig. 6.1.

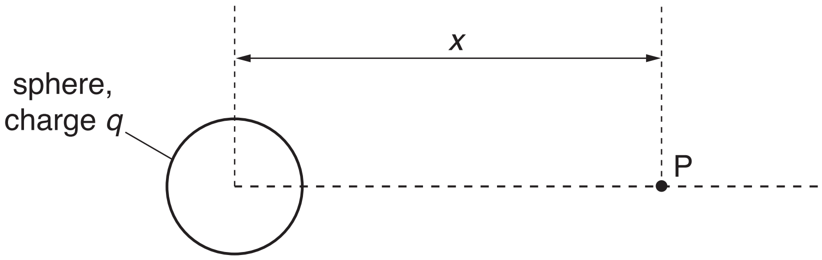


Fig. 6.1

Point P is a movable point that, at any one time, is a distance x from the centre of the sphere.

The variation with distance x of the electric potential V at point P due to the charge on the sphere is shown in Fig. 6.2.

$\frac{5.4\times10^{3}}{6\times10^{-2}} = 9\times10^{4}$ 5.4

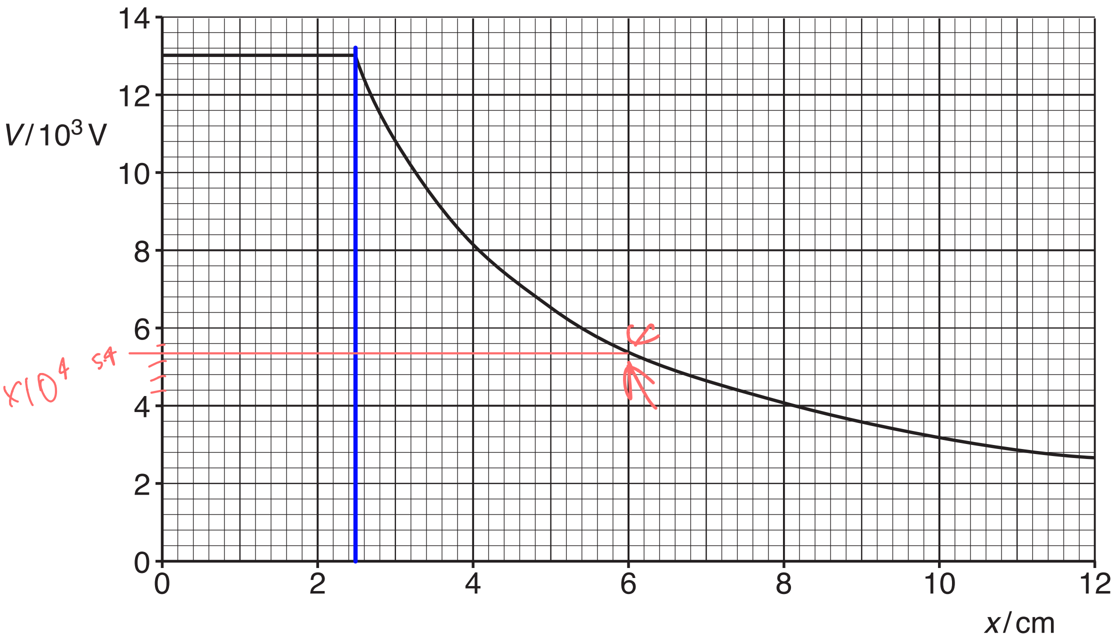


Fig. 6.2

$\dfrac{0.11\times10^{3}}{1.17\times10^{-2}} = 9.4\ 017\times10^{4}$

why not this method 9.4×10^{4}

Use Fig. 6.2 to determine

(i) the electric field strength *E* at point P where $x = 6.0$ cm,

$V = \dfrac{kQ}{r}$

$E = \dfrac{kQ}{r^2} = V \times \dfrac{1}{r} = 5.5\times10^{3} \times \dfrac{1}{6\times10^{-2}}$

$= 9.166\times10^{4}$

$E =$ ....9.2×10^{4}.... NC^{-1} [3]

2

(ii) the radius *R* of the sphere. Explain your answer.

gravitational potential is maximum on the surface of the sphere. ∴ 2.5 cm

$R =$ ....2.5.... cm [2]

[Total: 7]

7 **(a)** Feedback is used frequently in amplifier circuits.

MS had something potential

State

Add to anki

(i) what is meant by *feedback*,

it is the ratio of Vout that is sent back to the inverting input

.... [2]

(ii) two benefits of negative feedback in an amplifier circuit.

1. greater bandwidth

2. lower gain

[2]

(b) An amplifier circuit incorporating an ideal operational amplifier (op-amp) is used to amplify the output of a microphone. The circuit is shown in Fig. 7.1.

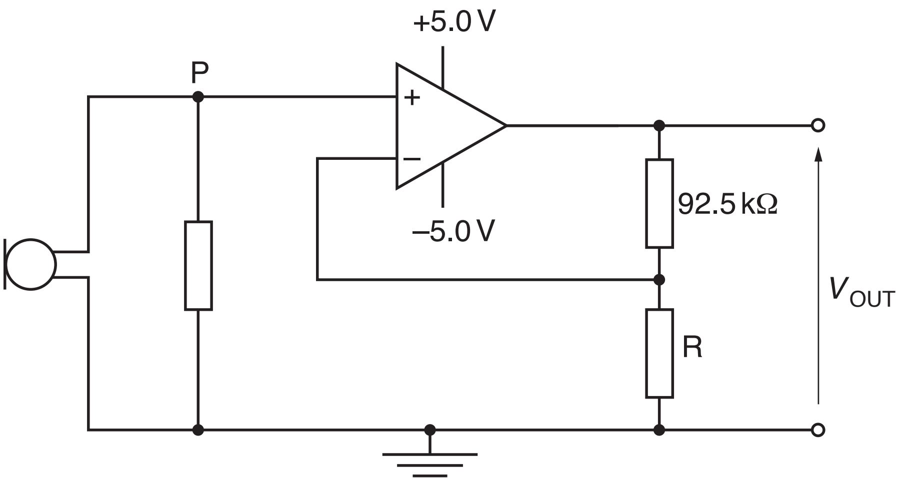


Fig. 7.1

When the potential at point P is 48 mV, the output potential difference V_{OUT} is 3.6 V.

(i) Determine

1. the gain of the amplifier circuit,

$$\text{gain} = \frac{3.6}{48\times10^{-3} - 0} = 75$$

gain = 75 [2]

2. the resistance of resistor R.

$$1 + \frac{R_f}{R_{in}} = 75$$

is 1300 necessary??

$$\frac{92500}{R_{in}} = 74$$

1300Ω?

1250

130

130

resistance = 1250 Ω [2]

(ii) State and explain the effect on the amplifier output when the potential at P exceeds 68 mV.

$V_{out} = 75 \times (68\times10^{-3} - 0) > 5V$ ∴ op amp gets saturated one vout stays constant at 5V

[2]

[Total: 10]

(8)

8 A thin slice of conducting material is placed normal to a uniform magnetic field, as shown in Fig. 8.1.

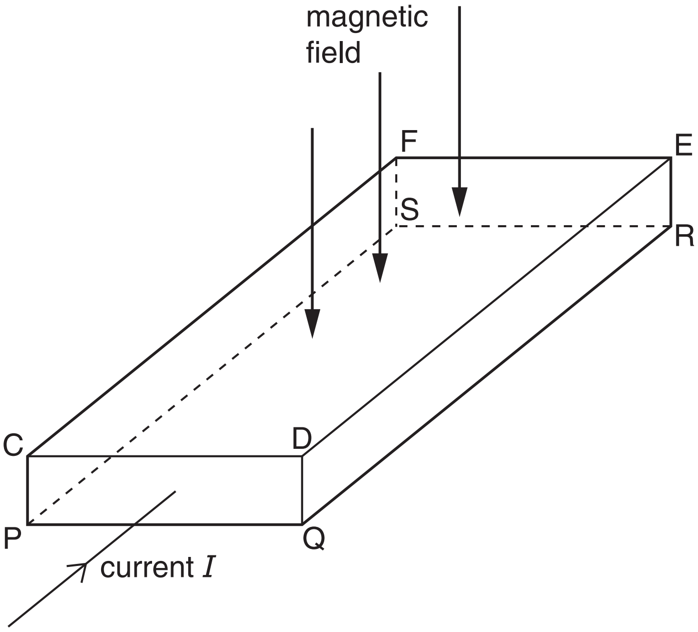


Fig. 8.1

The magnetic field is normal to face CDEF and to face PQRS.

The current I in the slice is normal to the faces CDQP and FERS.

A potential difference, the Hall voltage V_H, is developed across the slice.

(a) **(i)** State the faces between which the Hall voltage V_H is developed.

CFSP and DERQ [1]

1

(ii) Explain why a constant voltage V_H is developed between the faces you have named in **(i)**.

There is magnetic field being directed into the slice. As there is a current in the slice, electrons are moving through it. Magnetic field causes force on moving charged particles. According to Flemings left hand rule, the force on the electrons will be towards DERQ. After some time that face is full of electrons and an equilibrium is achieved where the DERQ face is at a lower potential than the CFSP face ∴ there is a potential difference developed between the two faces. this is Hall voltage. [4]

2

(b) Two slices have similar dimensions. One slice is made of a metal and the other slice is made of a semiconductor material.

For the same values of magnetic flux density and current, state which slice, if either, will give rise to the larger Hall voltage. Explain your reasoning.

$V_H = \frac{BI}{ntq}$, It will be higher with semiconductor as number of charge carriers per unit volume are less ∴ the value of V_H is greater.

[2]

5

[Total: 7]

9 (a) State what is meant by a *field of force*.

#

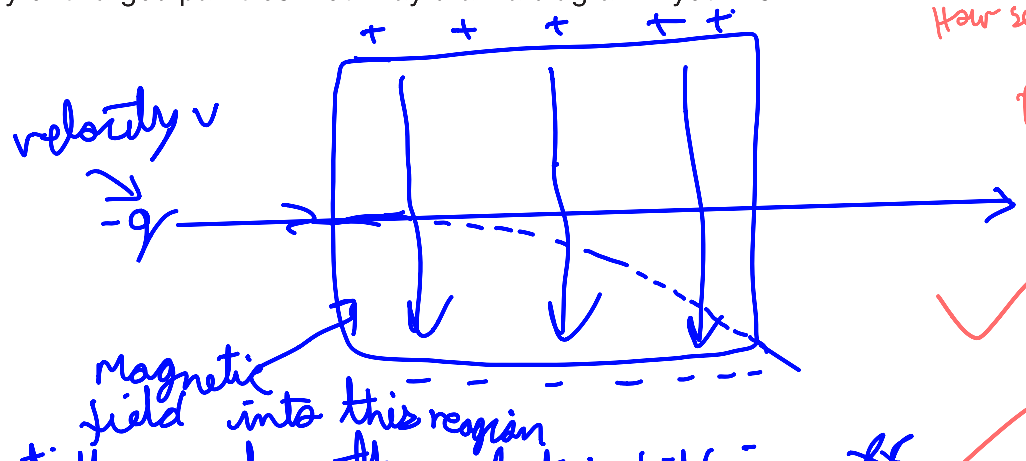
It is an imaginary line representing the direction of force on a particle placed in that field.

x [2]

(b) Explain the use of a uniform magnetic field and a uniform electric field for the selection of the velocity of charged particles. You may draw a diagram if you wish.

How selection?

proper ans with diagram



Initially, when the electric field is off and electrons are directed are perpendicular to this magnetic field, they would be deflected and follow the dotted path. However as soon as the electric field is switched on and its strength slowly increased until a point where electric force and magnetic force on the electrons is equal. They will pass through the field undeflected.

with velocity V,

[4]

3

Marks!

$Eq = Bqv$

$v = E/B$

(c) A beam of charged particles enters a region of uniform magnetic and electric fields, as illustrated in Fig. 9.1.

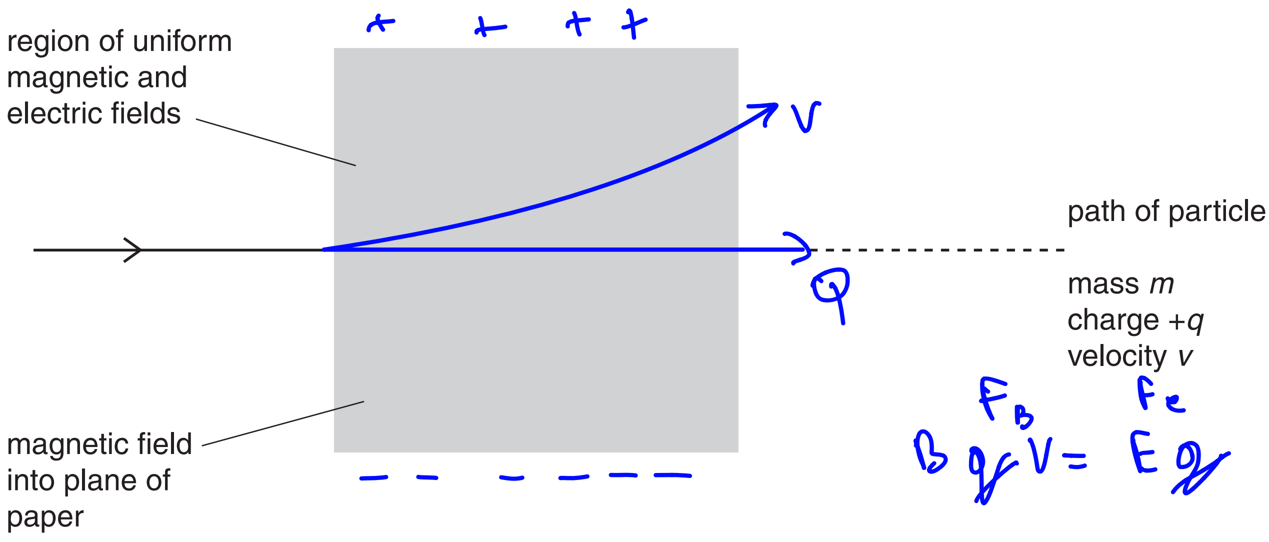


Fig. 9.1

The direction of the magnetic field is into the plane of the paper. The velocity of the charged particles is normal to the magnetic field as the particles enter the field.

A particle in the beam has mass *m*, charge +*q* and velocity *v*. The particle passes undeviated through the region of the two fields.

On Fig. 9.1, sketch the path of a particle that has

(i) mass *m*, charge +2*q* and velocity *v* (label this path Q), [1]

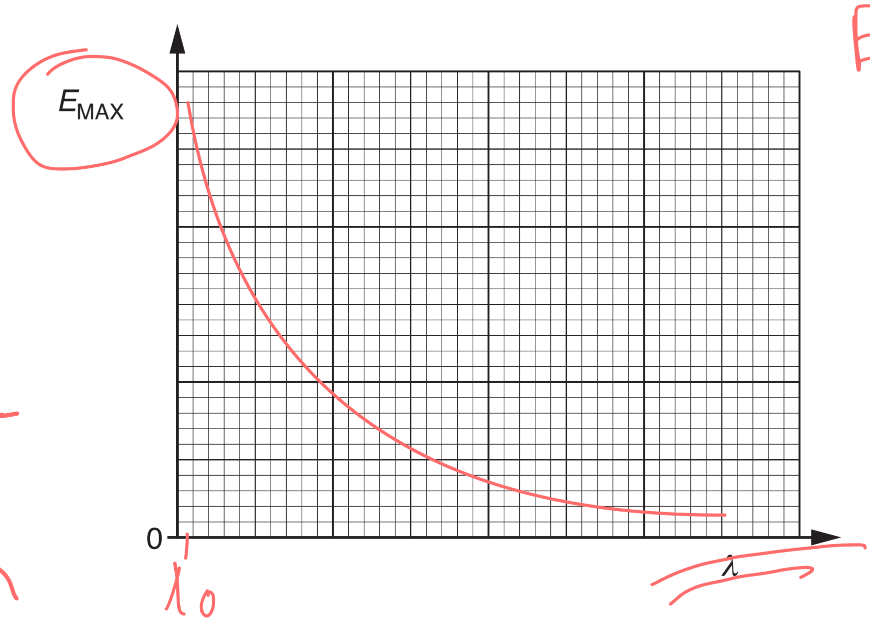
(ii) mass *m*, charge +*q* and velocity slightly larger than *v* (label this path V). [2]

[Total: 9]

6

10 (a) A metal surface is illuminated with light of a single wavelength λ.
On Fig. 10.1, sketch the variation with λ of the maximum kinetic energy E_{MAX} of the electrons emitted from the surface.
On your graph mark, with the symbol λ_0, the threshold wavelength.

$E = hc\left(\frac{1}{\lambda}\right) - \phi$



careful

Fig. 10.1

[3]

(b) A neutron is moving in a straight line with momentum p.
The de Broglie wavelength associated with this neutron is λ.
On Fig. 10.2, sketch the variation with momentum p of the de Broglie wavelength λ.

$\lambda = \frac{h}{p}$

$\lambda \propto \frac{1}{p}$

don't touch

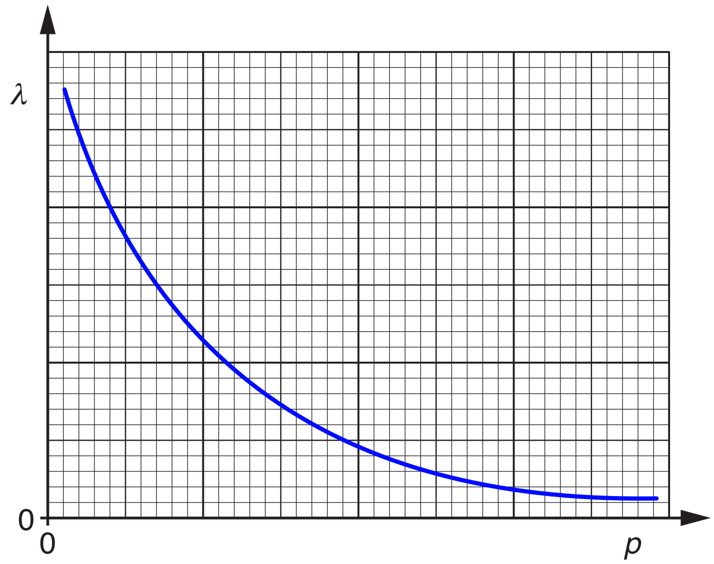


Fig. 10.2

[2]

[Total: 5]

11 The circuit for a full-wave rectifier using four ideal diodes is shown in Fig. 11.1.

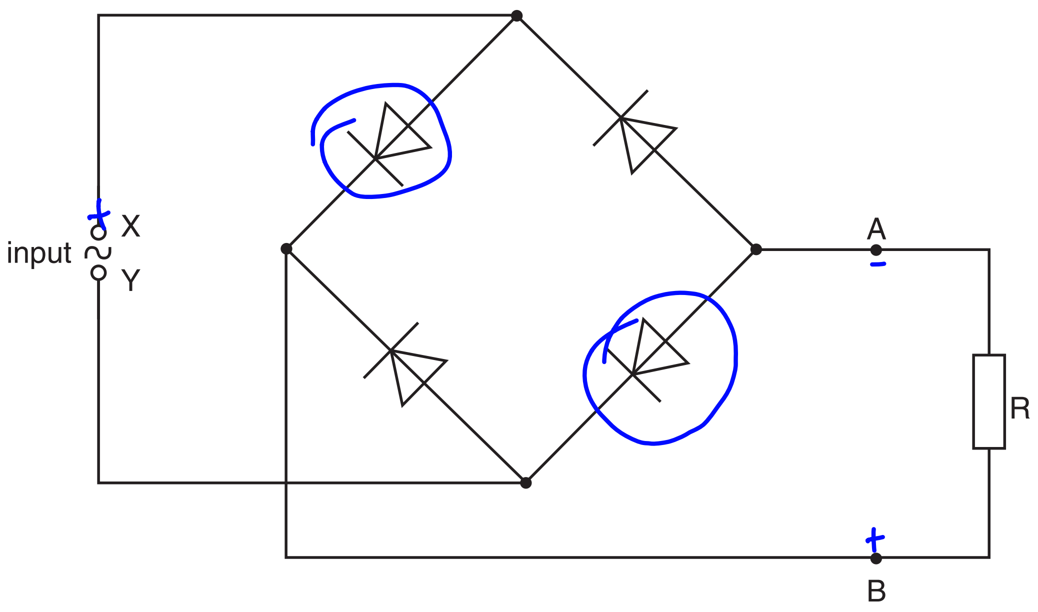


Fig. 11.1

A resistor R is connected across the output AB of the rectifier.

(a) On Fig. 11.1,

(i) draw a circle around any diodes that conduct when the terminal X of the input is positive with respect to terminal Y, [1]

(ii) label the positive (+) and the negative (–) terminals of the output AB. [1]

(b) The variation with time t of the potential difference V across the input XY is given by the expression

$$V = 5.6 \sin 380t$$

where V is measured in volts and t is measured in seconds.

The variation with time t of the rectified potential difference across the resistor R is shown in Fig. 11.2.

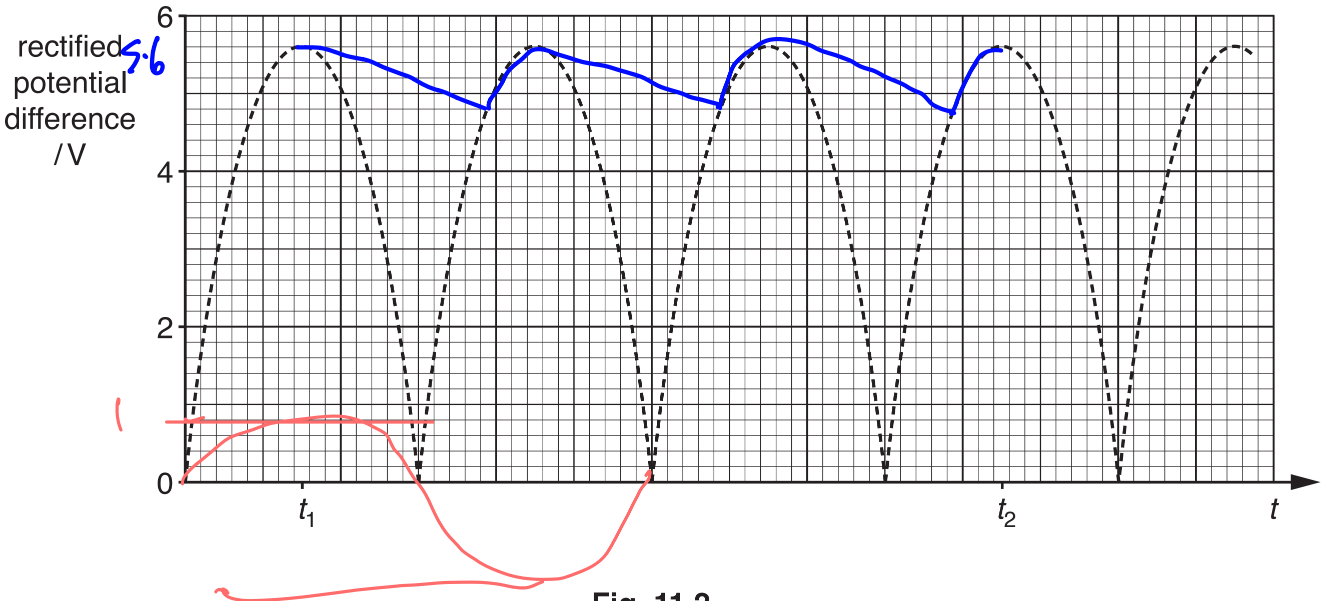


Fig. 11.2

Use the expression for the input potential difference V, or otherwise, to determine

(i) the root-mean-square (r.m.s.) potential difference $V_{\text{r.m.s.}}$ of the input,

$$V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{5.6}{\sqrt{2}} = 3.9598$$

$V_{\text{r.m.s.}}$ = 4.0 .... V [1]

(ii) the number of times per second that the rectified potential difference at the output reaches a peak value.

$\omega = 2\pi f = 380$

$f = 60.4788$

why 2f

number = ...60 × 120...... [2]

(c) A capacitor is now connected between the terminals AB of the output.
The capacitor reduces the variation (the ripple) in the output to 1.6 V.

(i) On Fig. 11.2, sketch the variation with time t of the smoothed output voltage for time $t = t_1$ to time $t = t_2$. [4]

(ii) Suggest and explain the effect, if any, on the mean power dissipation in resistor R when the capacitor is connected between terminals AB.

......Increases as mean voltage increases......

....

.... [2]

[Total: 11]

12 The isotope iodine-131 ($^{131}_{53}\mathrm{I}$) is radioactive with a decay constant of $8.6 \times 10^{-2}\,\mathrm{day}^{-1}$. β^- particles are emitted with a maximum energy of 0.61 MeV.

(a) State what is meant by

(i) *radioactive*,

It is the spontaneous emmission of radiation by unstable nuclei

[2] 2

(ii) *decay constant*.

probability of decay per unit time

[2] 2

(b) Explain why the emitted β^- particles have a range of energies.

As they have a range of masses

Antineutrino

[2]

(c) A sample of blood contains 1.2×10^{-9} g of iodine-131.

Determine, for this sample of blood,

(i) the activity of the iodine-131,

$A = \lambda N$

$= \dfrac{8.6 \times 10^{-2}}{24 \times 60^2} \times 5.5145 \times 10^{12}$

$= 5.48896 \times 10^{6}$

$n \times N_a = N$

$\dfrac{1.2 \times 10^{-9}}{131} \times 6.02 \times 10^{23}$

$= 5.5145 \times 10^{12}$

activity = 5.5×10^{6} Bq [3] 2

in

Per sec?

2 s.f. only?

(ii) the time for the activity of the iodine-131 to be reduced to 1/50 of the activity calculated in **(i)**.

$$\frac{1}{50} = e^{-\lambda t}$$

$$\ln\frac{1}{50} = -\lambda t$$

$$t = \frac{\ln 1/50}{-\lambda} = \frac{\ln 1/50}{8.6\times10^{-2}} = 45.488$$

45.5 days

time = 45 (2sf) days [2]

[Total: 11]

7

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