RIVER VALLEY HIGH SCHOOL
JC2 PRELIMINARY EXAMINATIONS

H2 PHYSICS 9749
PAPER 3

16 SEP 2021

2 HOURS

CANDIDATE NAME										
CENTRE NUMBER	S					**INDEX NUMBER**				
CLASS	2	0	J							

INSTRUCTIONS TO CANDIDATES

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

Read these notes carefully.
Write your name, centre number, index number and class in the spaces at the top of this page and on all work you hand in.
Candidates answer on the Question Paper.

Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer all questions.

Section B
Answer **one** question only.

You are advised to spend one and half hours on Section A and half an hour on Section B.

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

FOR EXAMINERS' USE	
Section A – do all questions	
1	/ 8
2	/ 7
3	/ 10
4	/ 10
5	/ 15
6	/ 10
Section B – do ONE question only	
7	/ 20
8	/ 20
Deduction	
TOTAL	/ 80

This document consists of **23** printed pages.

Data

speed of light in free space,	c	$= 3.00 \times 10^{8}$ m s^{-1}
permeability of free space,	μ_0	$= 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_0	$= 8.85 \times 10^{-12}$ F m^{-1}
		$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	$= 1.60 \times 10^{-19}$ C
the Planck constant,	h	$= 6.63 \times 10^{-34}$ J s
unified atomic mass constant,	u	$= 1.66 \times 10^{-27}$ kg
rest mass of electron,	m_e	$= 9.11 \times 10^{-31}$ kg
rest mass of proton,	m_p	$= 1.67 \times 10^{-27}$ kg
molar gas constant,	R	$= 8.31$ J K^{-1} mol^{-1}
the Avogadro constant,	N_A	$= 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant,	k	$= 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant,	G	$= 6.67 \times 10^{-11}$ N m^{2} kg^{-2}
acceleration of free fall,	g	$= 9.81$ 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	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -Gm/r$
temperature	$T / \text{K} = T / {}^\circ\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm\omega\sqrt{{x_0}^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

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

1 **(a)** Define *moment of a force*.

....

....

.... [1]

(b) A person supports a load of 20 N in his hand as shown in Fig. 1.1. The system of the hand and load is represented by Fig. 1.2. The rod represents the forearm and T represents the tension exerted in the biceps. The forearm weighs 65 N.

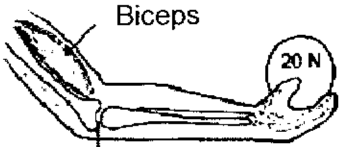


Fig. 1.1

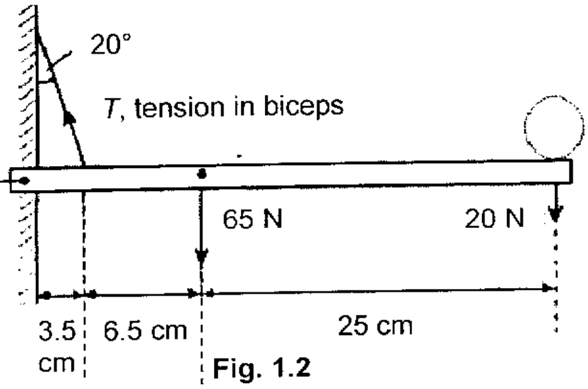


Fig. 1.2

(i) Show that the tension T in the biceps is 410 N.

[3]

(ii) Determine the magnitude and direction of the force acting at the elbow.

force acting at the elbow = ... N

direction of the force: .... [4]

2 Fig. 2.1 shows a skateboarder of mass 55 kg about to descend a curved ramp in a skate park.

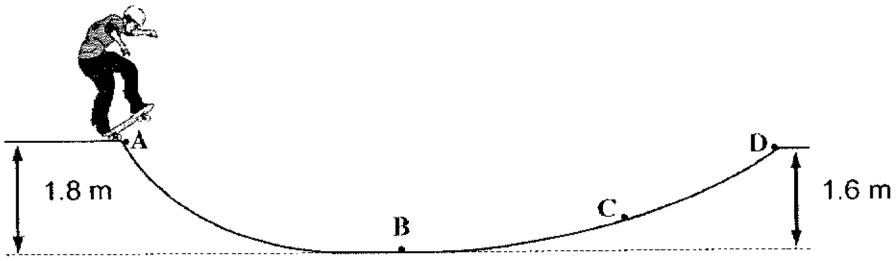


Fig. 2.1

(a) State at which of the points along the track, **A**, **B**, **C** or **D**, the magnitude of the acceleration is the greatest.

.... [1]

(b) The skateboarder is initially at rest. Assuming that there is no frictional force acting from **A** to **B**, calculate the speed the skateboarder would have at **B**.

speed = ... m s^{-1} [2]

(c) The skateboarder has just enough energy to reach **D** because of friction along **B** to **D**. The length of the track between **B** and **D** is 8.5 m.

Calculate

(i) the energy lost due to friction as the skateboarder moves from **A** to **D**,

energy lost = ... J [2]

(ii) the magnitude of the average frictional force from **B** to **D**.

average frictional force = ... N [2]

3 A mass P is attached to the free end of a horizontal spring on a smooth surface. The spring-mass system is set into simple harmonic motion by pulling P to the right of the equilibrium position and is released from rest as shown in Fig. 3.1.

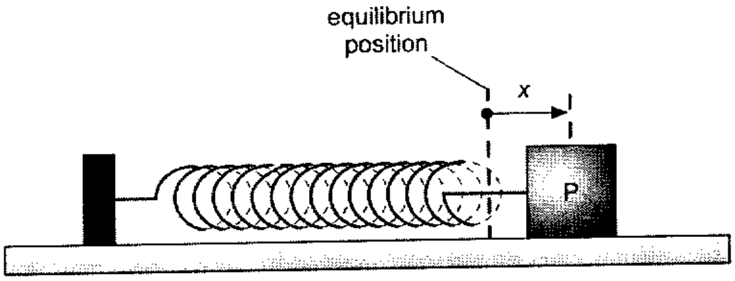


Fig. 3.1

If the air resistance on P is negligible, the variation of the velocity v of P with displacement x is shown in Fig. 3.2. Vectors to the right are taken to be positive.

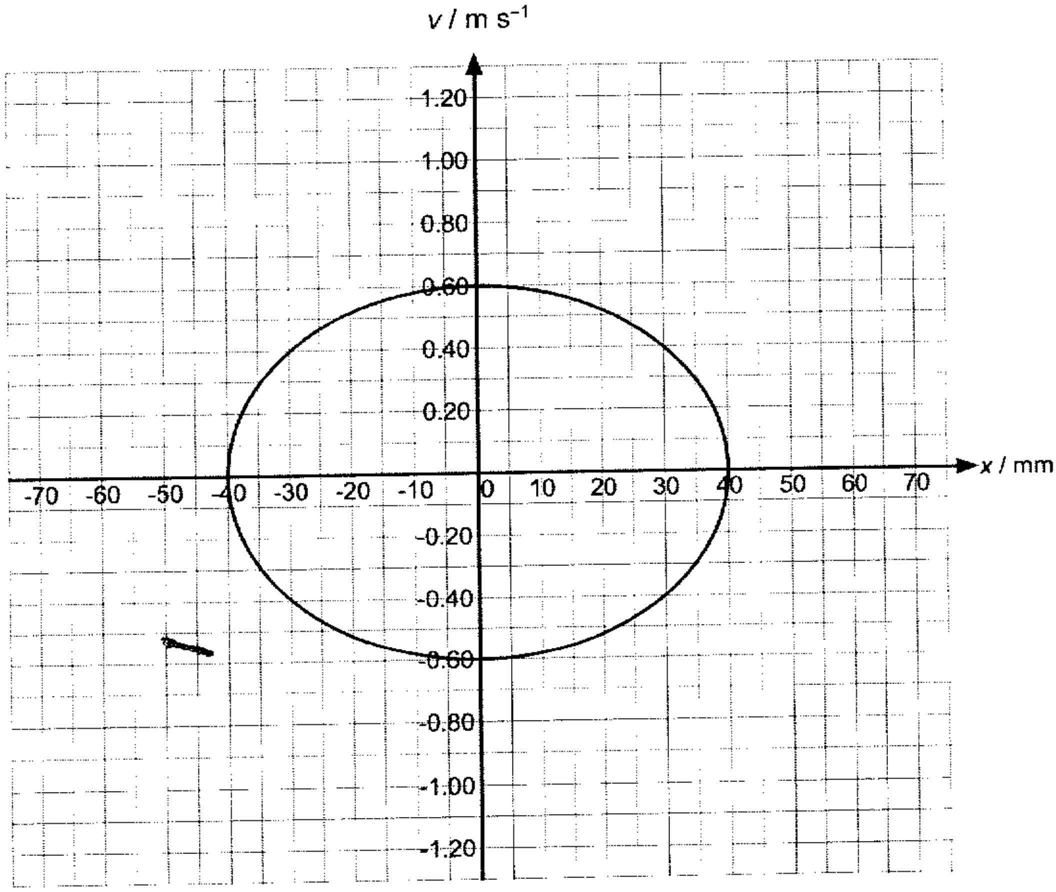


Fig. 3.2

(a) For the motion of P, determine

(i) the amplitude and

amplitude = ... mm [1]

(ii) the frequency.

frequency = ... Hz [2]

(b) If the air resistance on P is not negligible, sketch on Fig. 3.2 the variation of the velocity of P with displacement x. Label it "air resistance". [3]

(c) A periodic force is now exerted on the spring-mass system. When the periodic force is at a certain frequency, P is in resonance.

(i) Given that the total energy of the spring-mass system at steady state is doubled.

Determine the new maximum speed of P.

maximum speed of P = ... m s^{-1} [2]

(ii) On Fig. 3.2, sketch the variation of the velocity of P, at resonance, with displacement x. Label it "resonance".

[2]

4 **(a)** Define the electric potential at a point in an electric field.

....

....

....

.... [2]

(b) Fig. 4.1 shows part of the region between two charges of the same magnitude but opposite sign.

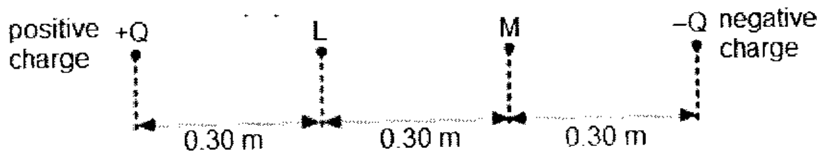


Fig. 4.1

(i) The electric potential at point **L** due to the positive charge **only** is +3.0 V.

Calculate the magnitude Q of the positive charge.

Q = ... nC [1]

(ii) Hence or otherwise, calculate the **net** electric potential at point **L**.

net electric potential = ... V [2]

(iii) Calculate the **resultant** electric field strength at point **M**.

electric field strength at **M** = ... V m^{-1} [2]

(c) R and S are two charged parallel plates, 0.60 m apart, as shown in Fig. 4.2. They are at potentials of + 3.0 V and + 1.0 V respectively.

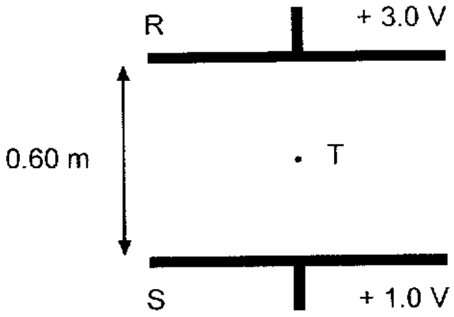


Fig. 4.2

(i) On Fig. 4.2, sketch the electric field between R and S, showing its direction. [1]

(ii) Point **T** is mid-way between R and S.

Calculate the electric field strength at **T**.

electric field strength at **T** = ... V m^{-1} [2]

(iii) A charged oil drop is suspended at point T.
State the sign of the charge and sketch an arrow on Fig. 4.2 showing the direction of the electric force.

sign of charge = ... [1]

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

....

....

.... [2]

(b) A 'bus bar' is a metal bar which can used to conduct a large electric current. In a test, two bus bars, X and Y, of length 0.90 m are clamped at either end parallel to each other on a base board, as shown in Fig. 5.1.

When a constant current of 12 kA is carried by each bus bar, they exert a force of 200 N on each other.

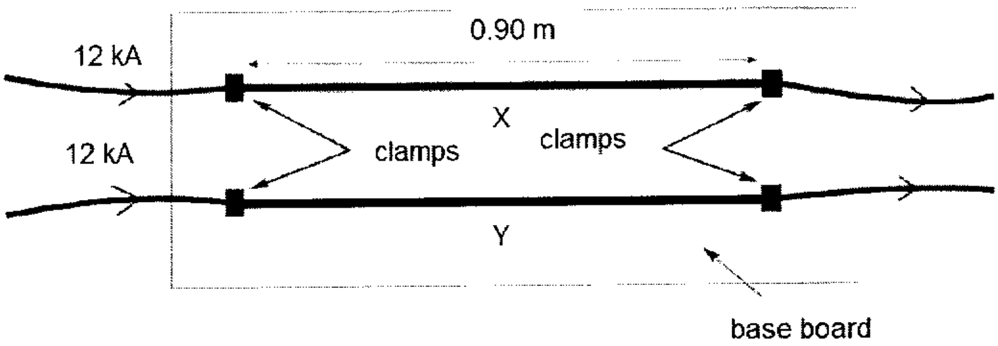


Fig. 5.1

(i) Calculate the magnetic flux density due to the current in one bus bar at the position of the other bus bar.

magnetic flux density = ... T [2]

(ii) Calculate the magnitude of the force on each bus bar if X carried a current of 6.0 kA and Y carried a current of 12 kA in the same direction.

magnetic force on X = ... N

magnetic force on Y = ... N [2]

(c) A small circular coil of cross sectional area 1.7×10^{-4} m^2 contains 250 turns of wire. The plane of the coil is placed parallel to and a distance x from the pole of a magnet as shown in Fig. 5.2.

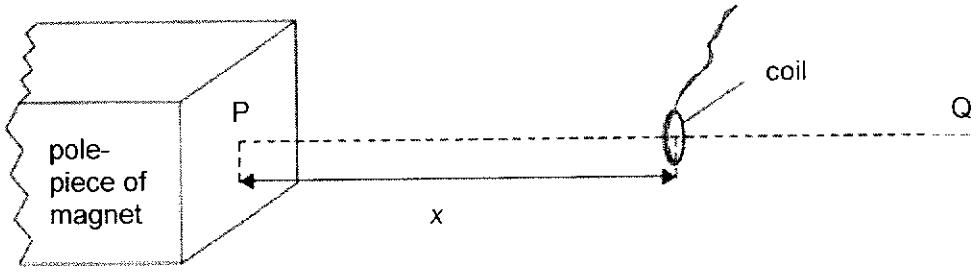


Fig. 5.2

PQ is a line that is normal to the pole piece. The variation with distance x along line PQ of the mean magnetic flux density B in the coil is shown in Fig. 5.3.

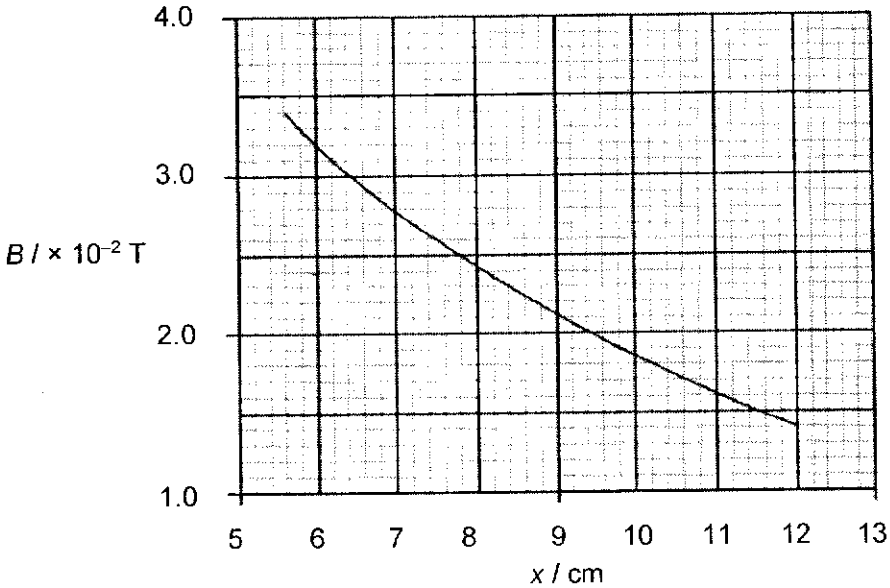


Fig. 5.3

(i) For the coil situated a distance 6.0 cm from the pole piece of the magnet,

1. State the mean magnetic flux density in the coil.

mean magnetic flux density = ... T [1]

2. Calculate the magnetic flux linkage through the coil.

magnetic flux linkage = ... Wb-turns [2]

(ii) The coil is moved along PQ so that the distance x changes from 6.0 cm to 12.0 cm in a time of 0.35 s.

1. Determine the change in magnetic flux linkage through the coil.

change in magnetic flux linkage = ... Wb-turns [2]

2. State Faraday's law of electromagnetic induction and hence calculate the mean e.m.f. induced in the coil.

....

....

....

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

(iii) Use Lenz's law to explain why work has to be done to move the coil along the line PQ.

....

....

....

....

.... [2]

6 The isotope Iron-59 is a β-emitter with a half-life of 45 days. In order to estimate engine wear, an engine component is manufactured from iron throughout which the isotope Iron-59 has been uniformly distributed. The mass of the engine component is 2.4 kg and its initial activity is 8.5×10^7 Bq.

The component is installed in the engine 60 days after manufacture of the component, and then the engine is tested for 30 days. During the testing period, any metal worn off the component is retained in the surrounding oil. Immediately after the test, the oil is found to have a total activity of 880 Bq.

Calculate

(a) **(i)** the decay constant for the isotope Iron-59,

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

(ii) the total activity of the component when it was installed,

activity = ... Bq [2]

(iii) the mass of iron worn off the component during the test.

mass of iron = ... g [4]

(b) State and explain how your results in **(a) (iii)** will change if background radiation is included in the total activity of 880 Bq.

....

....

....

....

....

.... [2]

Section B

Answer **one** question from this Section in the spaces provided.

7 **(a)** A pair of identical speakers, S_1 and S_2, 1.2 m apart makes up a stereo system in a large hall. The voltage input to each speaker is adjustable. The arrangement is shown in Fig. 7.1.

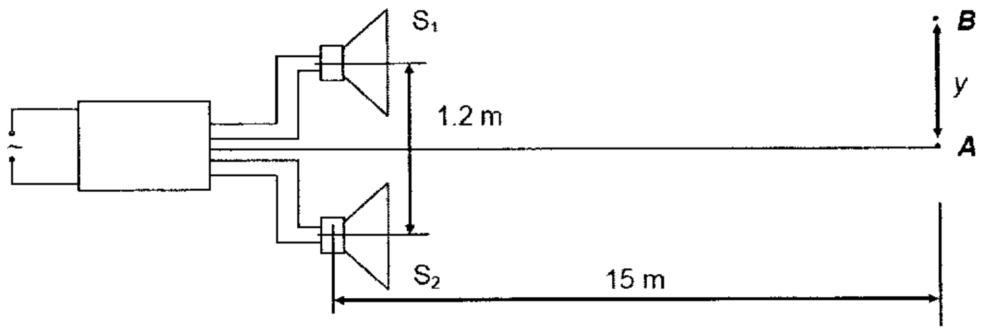


Fig. 7.1

The speakers are initially emitting signals of frequency 1000 Hz which are in phase. Assume that the speed of sound is 330 m s^{-1}. The voltage across each speaker is 6.0 V. An observer holding a sound detector stands on the centre line at point **A**, 15 m away from the point halfway between the speakers and registers a loud sound of intensity I_{max}. As he moves along the line **AB** at right angles to the centre line, the intensity of the sound falls to zero at point **B**, a distance *y* from **A**.

(i) Determine the distance *y*.

distance *y* = ... m [3]

(ii) Calculate the next higher frequency of operation of the speakers such that the point **B** will be a position of maximum intensity.

frequency = ... kHz [2]

(iii) With the speakers emitting the original signal of frequency 1000 Hz, the voltages across S_1 and S_2 are adjusted to 3.0 V and 9.0 V respectively.

Given that the amplitude of the output of each speaker is proportional to the voltage across its terminals, find the new intensity at **A**, expressing your answer in terms of I_{max}.

new intensity at **A** = ... [4]

(b) A *diffraction* grating is to be calibrated by a spectrometer experiment with a source emitting a spectral series of lines of known wavelengths.

(i) Explain what is meant by *diffraction*.

....

.... [1]

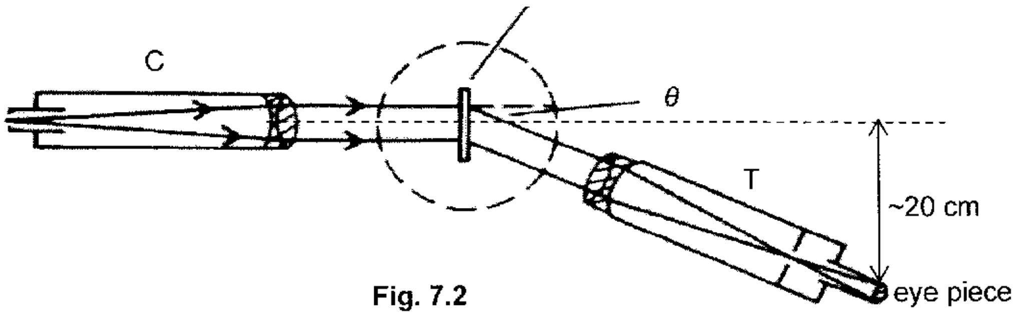


Fig. 7.2

The grating in Fig. 7.2 is set up with light incident normally from a collimator C, with θ, the angle of first order of angular deflections.

(ii) The light from a hydrogen discharge tube contains electromagnetic radiations of wavelengths 660 nm (red) and 490 nm (blue). This light is passed through the grating and observed through a telescope T. The grating has a slit density of 359 lines per mm.

1. The position of the first order blue fringe is observed to be approximately 20 cm from the central maxima.

Estimate the normal distance of the eyepiece in T from the diffraction grating.

normal distance = ... m [3]

2. Determine the angular separation of the red and blue light for hydrogen for the second order diffraction pattern.

angular separation = ... ° [3]

3. Determine the highest order observable for blue light.

highest observable order = ... [2]

4. The diffraction grating may also be used to investigate wavelengths of an unknown source.

Suggest one advantage and one disadvantage of obtaining the wavelength by using observations of the higher order of the diffracted light rather than the first-order diffraction light.

....

....

....

....

....

.... [2]

8 During radioactive decay, which is spontaneous and random, γ-ray (gamma ray) photons may be emitted. When these photons are incident on a sodium iodide crystal, some of the photons may be absorbed in the crystal. The absorption of a γ-ray photon causes the emission of a short pulse of light known as a scintillation. The scintillations may be detected and converted into electrical pulses using *a photomultiplier tube*, which, when connected to a counter, gives the *count rate* and enables γ-ray *activity* to be measured. The arrangement is illustrated in Fig. 8.1.

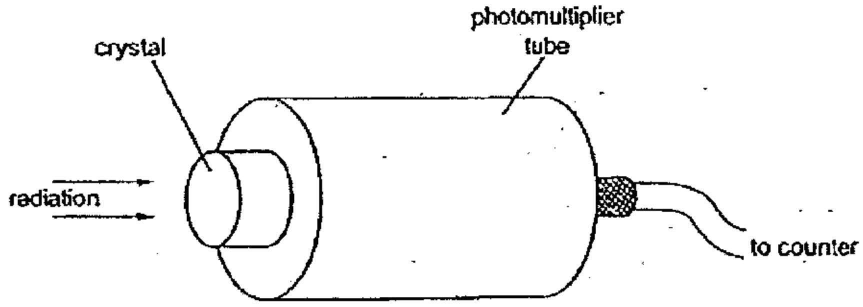


Fig. 8.1

The crystals used in such counters may be of different shapes. Fig. 8.2 shows a solid cylindrical crystal.

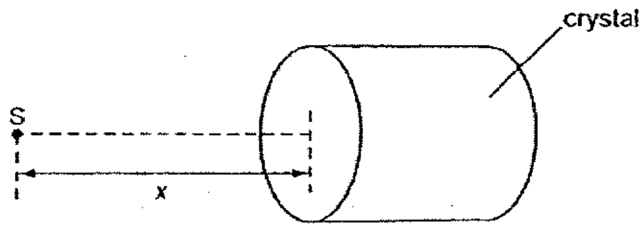


Fig. 8.2

The small γ-ray source S is placed a distance x in front of one face of the crystal. The source is assumed to emit photons uniformly in all directions. Not all of the emitted photons will be absorbed by the crystal. The efficiency Q of detection is defined by the equation

$$Q = \frac{\text{number of photons producing scintillations in the crystal}}{\text{total number of photons emitted by the source}}$$

(a) By reference to the passage, explain what is meant by

(i) *count rate*

....

....

....

.... [1]

(ii) *activity*

....

....

.... [1]

(b) Suggest two reasons why the γ-ray photons emitted by the source are not all absorbed in the crystal.

1. ....

....

....

.... [1]

2. ....

....

....

.... [1]

(c) Fig. 8.3 shows the variation with γ-ray photon energy E of the efficiency Q. Curves are drawn for various values of the distance x of the source S from the face of the crystal.

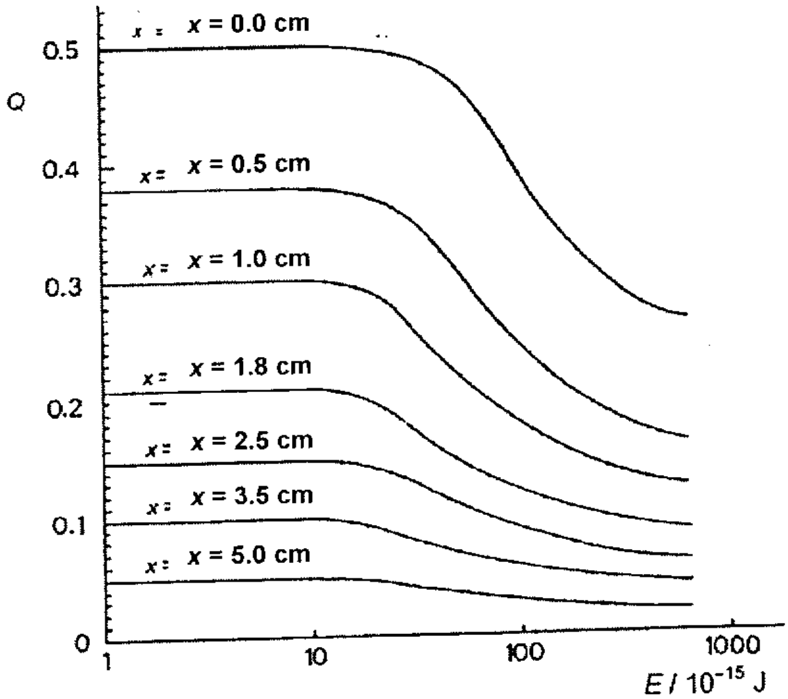


Fig. 8.3

(i) Suggest why at any one particular value of energy, the efficiency Q decreases as x increases.

....

....

....

....

....

....

.... [3]

(ii) With reference to Fig. 8.3 and considering γ-ray photons of energy 8×10^{-15} J, complete Fig. 8.4 with corresponding values of Q with for γ-ray photons of this energy.

Q	x / cm

[2]

Fig. 8.4

(d) **(i)** Use your values in Fig. 8.4 to draw a graph of Q against x in Fig. 8.5.

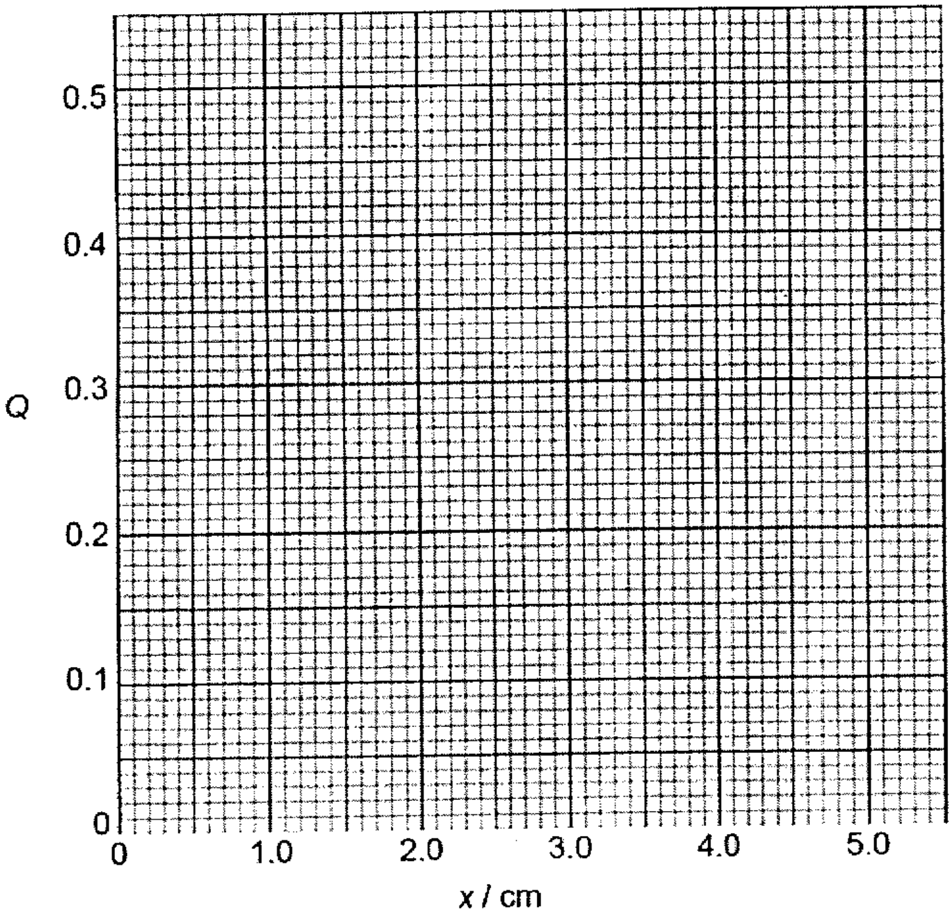


Fig. 8.5

[2]

(ii) Use Fig. 8.5 to determine the rate of change of Q with x when x = 0.5 cm.

rate of change = ... cm^{-1} [4]

(iii) It may be deduced from Fig. 8.5 that Q is related to x by an expression of the form

$$Q = ae^{-bx}$$

where a and b are constants.

Explain how Fig. 8.5 shows this.

....

....

....

....

.... [2]

(e) **(i)** Suggest why the maximum efficiency that can be achieved with low-energy γ-ray photons using the crystal illustrated in Fig. 8.2 is 0.50.

....

....

....

.... [2]

(ii) A second crystal consists of a hollow cylinder, as shown in Fig. 8.6.

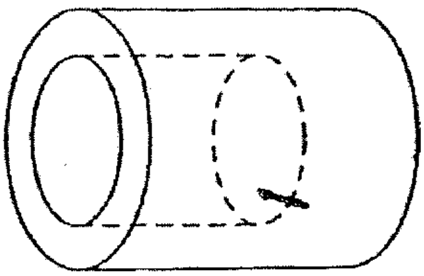


Fig. 8.6

State the effect of this change of shape on the maximum efficiency Q of the detector if the source is placed inside the hollow region.

....

.... [1]

END OF PAPER

RVHS Preliminary Examinations 2021
H2 Physics P3 markscheme

1 **(a)** Define *moment of a force.*

The moment of a force F about an axis is the **product** of that force and

the **perpendicular** distance from the line of action of the force to the axis.

[1]

(b) A person supports a load of 20 N in his hand as shown in Fig 1.1. The system of the hand and load is represented by Fig 1.2. The rod represents the forearm and T represents the tension exerted in the biceps. The forearm weighs 65 N.

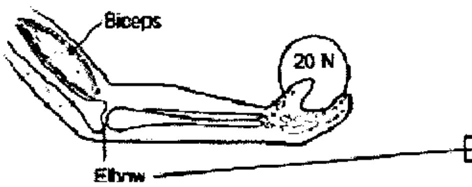


Fig. 1.1

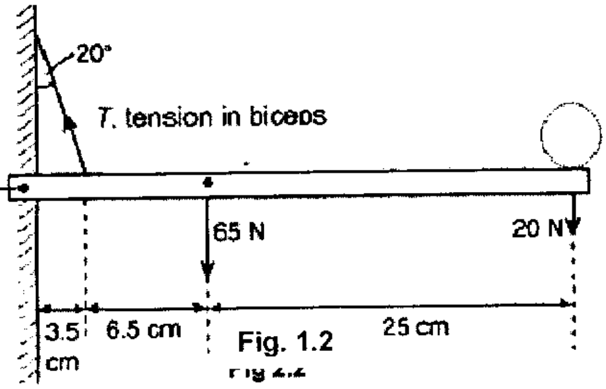


Fig. 1.2

(i) Show that the tension T in the biceps is 410 N.

Taking moments about the elbow,

$T_y \times 3.5 = 65 \times 10 + 20 \times 35$

$T_y = 385.7$ N

$T = T_y / \cos 20^\circ = 410$ N

[3]

(ii) Determine the magnitude and direction of the force acting at the elbow.

$T_x = 385.7 / \tan 20^\circ = 140.4$ N

$\sum F_x = 0$

$T_x = R_x = 140.4$ N

$\sum F_y = 0$

$T_y = R_y + 65 + 20$

$R_y = 385.7 - 65 - 20 = 300.7$ N

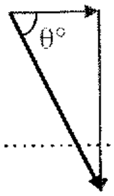
Resultant force acting at elbow (pivot)

$= \sqrt{R_x^2 + R_y^2} = 332$ N

State direction

$\tan \theta^\circ = (300.7 / 140.4)$

$\theta^\circ =$



force acting at the elbow = ... N

direction of the force: .... [4]

2 Fig. 2 shows a skateboarder of mass 55 kg about to descend a curved ramp in a skate park.

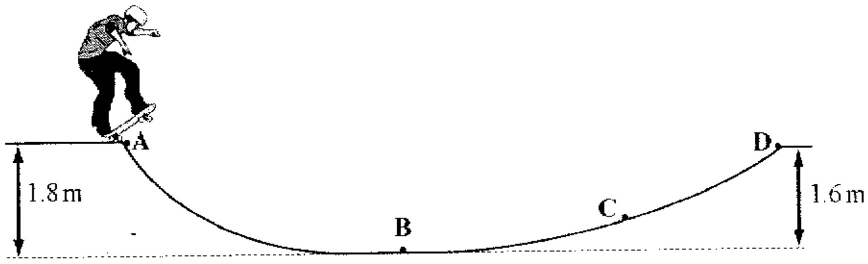


Fig. 2

(a) At which of the points **A**, **B**, **C** or **D** is the magnitude of the acceleration greatest along the track?

A

.... [1]

(b) The skateboarder is initially at rest. Assuming that there is no frictional force acting from **A** to **B**, calculate the speed the skateboarder would have at **B**.

statement that $\Delta Ek = \Delta Ep$

$mgh = \frac{1}{2} mv^2$

$v = 5.9(4)$ m s^{-1}

kinetic energy = ... J [2]

(c) The skateboarder has just enough energy to reach **D** because of friction along **B** to **D**. The length of the track between **B** and **D** is 8.5 m.

Calculate

(i) the energy lost due to friction as the skateboarder moves from **B** to **D**,

energy lost = *mg* × difference in heights

= 107.91 ≈ 110 J

energy lost = ... J [2]

(ii) the magnitude of the average frictional force.

work done = Fs

F = 12.695 ≈ 13 N (ecf from part **(c)(i)**)

average frictional force = ... N [2]

3 A mass P, 80 g, is attached to the free end of a horizontal spring on a smooth surface. The spring-mass system is set into simple harmonic motion by pulling P to the right of the equilibrium position and is released from rest as shown in Fig. 3.1.

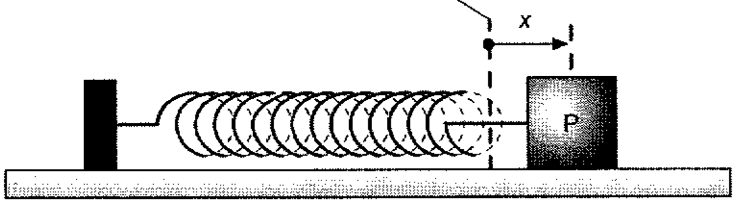


Fig. 3.1

If the air resistance on P is negligible, the variation of the velocity v of P with displacement x is shown in Fig. 3.2. Vectors to the right are taken to be positive.

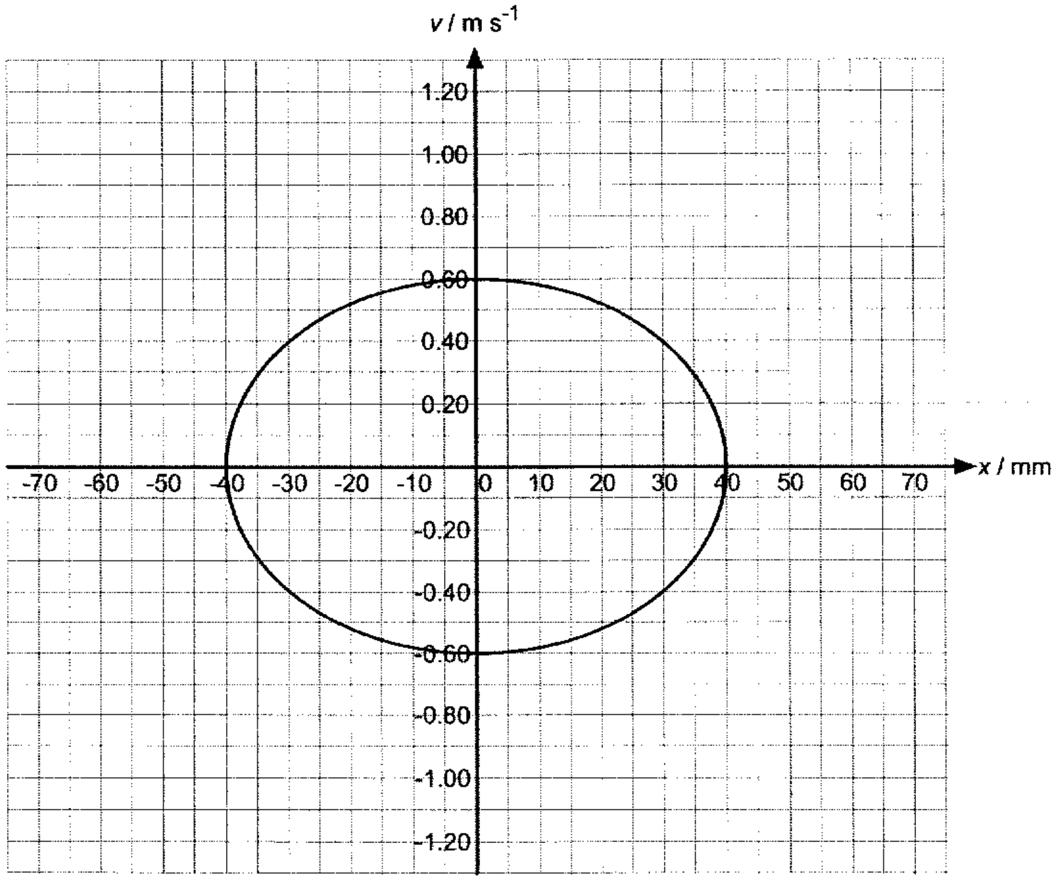


Fig. 3.2

(a) For the motion of P, determine

(i) the amplitude,

40 mm

amplitude = ... mm [1]

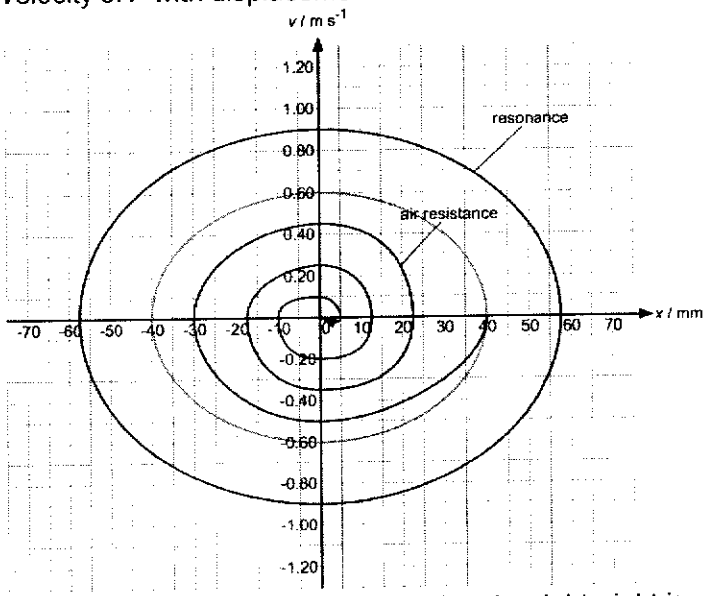
(ii) the frequency.

$v_{max} = \omega x_0 \Rightarrow 0.60 = (2\pi f)(0.040)$

$f = 2.4$ Hz

frequency = ... Hz [2]

(b) If the air resistance on P is not negligible, sketch on Fig. 3.2 the variation of the velocity of P with displacement x. Label it "air resistance". [3]



Must start at (40, 0) [1] (displaced to the right, right is positive)
Clockwise spiral [1] (intially move to left so starting velocity is negative)
Spiral towards origin. [1]

(c) A periodic force is now exerted on the spring-mass system. When the periodic force is at a certain frequency, P is in resonance.

(i) Given that the total energy of the spring-mass system at steady state is doubled. Determine the new maximum speed of P.

$$E_T = \frac{1}{2}mv_0^2 \Rightarrow E_T \propto v_0^2 \Rightarrow \frac{E_T'}{E_T} = \frac{v_0'^2}{v_0^2} \Rightarrow \frac{2E_T}{E_T} = \frac{v_0'^2}{0.6^2}$$

$v_0' = 0.85 \text{ m s}^{-1}$

maximum speed of P = ... m s^{-1} [2]

(ii) On Fig. 3.2, sketch the variation of the velocity of P, at resonance, with displacement x. Label it "resonance". [2]

At resonance, frequency of P is near to its natural frequency of 2.4 Hz.

$v_0 = \omega x_0 \Rightarrow v_0 \propto x_0 \Rightarrow x_0' = \sqrt{2}x_0 = 57$ mm.

Elliptical shape with maximum speed at 0.85 m s^{-1} and amplitude at 57 mm.

4 **(a)** Define the electric potential at a point in an electric field.

the work done per unit positive charge in

bringing a small test charge from infinity to that point .... [1]

(b) Fig. 4.1 shows part of the region between two charges of the same magnitude but opposite sign.

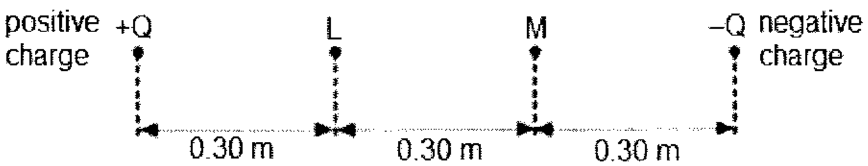


Fig. 4.1

(i) The electric potential at point **L** due to the positive charge **only** is +3.0 V.

Calculate the magnitude Q of the positive charge.

$V = \dfrac{Q}{4\pi\varepsilon_0 r}$ (given on page 3)

$3.0 \times (4\pi\varepsilon_0)(0.30) = Q$

$Q = 1.00 \times 10^{-10}$ C

Q = ... nC [1]

(ii) Hence or otherwise, calculate the **net** electric potential at point **L**.

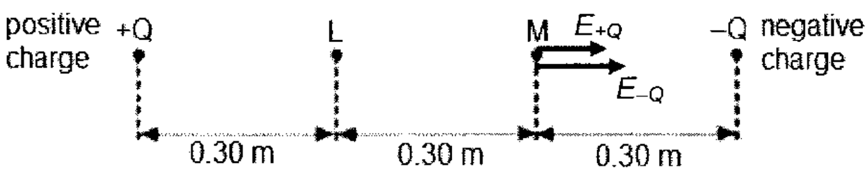
potential due to −Q = −3.0/2 V (double the distance, halve the potential) as $V \propto 1/r$

Sum = +3.0 V + (−3.0/2) = 1.5 V

** potential is a scalar while field strength is a vector. Disregarding direction, simply sum the potentials. Negative charges give negative potentials.

net electric potential = ... V [2]

(iii) Calculate the **resultant** electric field strength at point **M**.



Sum of both

$E = \dfrac{Q}{4\pi\varepsilon_0 r^2}$

$= \dfrac{1.00\times10^{-10}}{4\pi(8.85\times10^{-12})(0.60)^2} + \dfrac{1.00\times10^{-10}}{4\pi(8.85\times10^{-12})(0.30)^2}$

$= 12 \text{ V m}^{-1}$

ecf from **4(b)(i)**

electric field strength at **M** = ... V m^{-1} [2]

(c) R and S are two charged parallel plates, 0.60 m apart, as shown in Fig. 4.2. They are at potentials of + 3.0 V and + 1.0 V respectively.

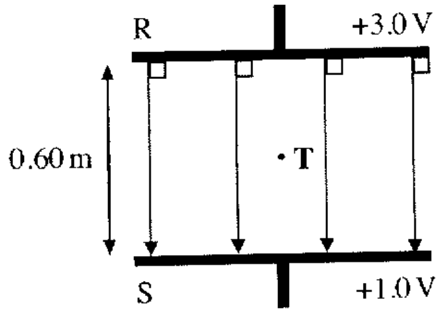


Fig. 4.2

(i) On Fig. 4.2, sketch the electric field between R and S, showing its direction. [1]
uniformly spaced out down arrows

**uniformly spaced out – constant E field between parallel plates contrasting with radial field in previous parts.
**down arrows – direction of E is the same as direction of electric force on a POSITIVE test charge.
**just need minimum 3 lines to show uniform spacing

(ii) Point **T** is mid-way between R and S.

Calculate the electric field strength at **T**.

$$E = \frac{\Delta V}{d} = \frac{3.0 - 1.0}{0.60}$$
$$= 3.3 \text{ V m}^{-1}$$

electric field strength at **T** = ... V m^{-1} [2]

(iii) A point charge is suspended at point T.
State the sign of the charge and sketch an arrow on Fig. 4.2 showing the direction of the electric force.

** downwards weight = upwards electric force
** since electric force is upwards, electric field strength E (defined for postive charge) is downwards, hence charge is negative.

negative and upwards
sign of charge = ... [1]

5	(a)	Define a magnetic field.

A magnetic field is the region of space where a magnetic pole, moving charged particle or current-carrying conductor will experience a magnetic force.

Need all 3 components to award 2 marks
"region of space" and "magnetic force" tied together

...[2]

(a) A 'bus bar' is a metal bar which can used to conduct a large electric current. In a test, two bus bars, X and Y, of length 0.90 m are clamped at either end parallel to each other on a base board, as shown in Fig. 5.1.

When a constant current of 12 kA is carried by each bus bar, they exert a force of 200 N on each other.

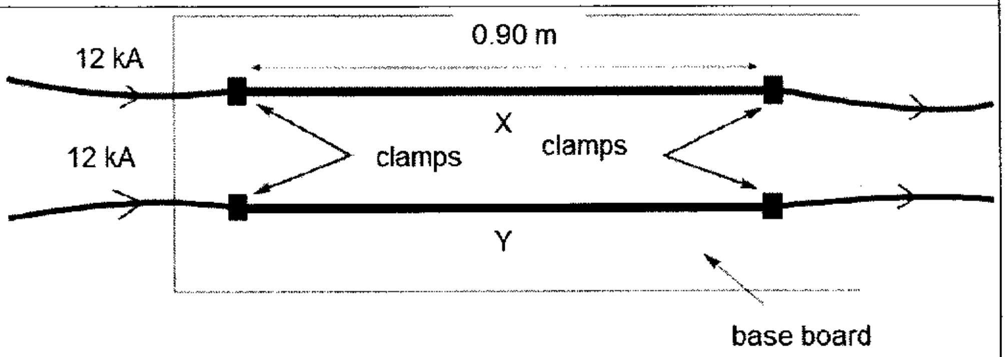


Fig. 5.1

(i) Calculate the magnetic flux density due to the current in one bus bar at the position of the other bus bar.

$B = \frac{F}{IL} = \frac{200}{12\times10^3\times0.90}$
$= 1.85 \times 10^{-2}$ T

magnetic flux density = ... T [2]

(ii) Calculate the magnitude of the force on each bus bar if X carried a current of 6.0 kA and Y carried a current of 12 kA in the same direction.

Force on X due to Y
B at X (due to Y) is unchanged
F_X = BIL and I is reduced to 6 kA
So F_X = 100 N
Force on Y due to X
B at Y (due to X) is reduced to 9.26×10^{-3} T
F_Y = BIL and I is unchanged
So F_Y is reduced to 100 N

magnetic force on X = ... N

magnetic force on Y = ... N [2]

(b) A small circular coil of cross sectional area 1.7×10^{-4} m^2 contains 250 turns of wire. The plane of the coil is placed parallel to and a distance x from the pole of a magnet as shown in Fig. 5.2.

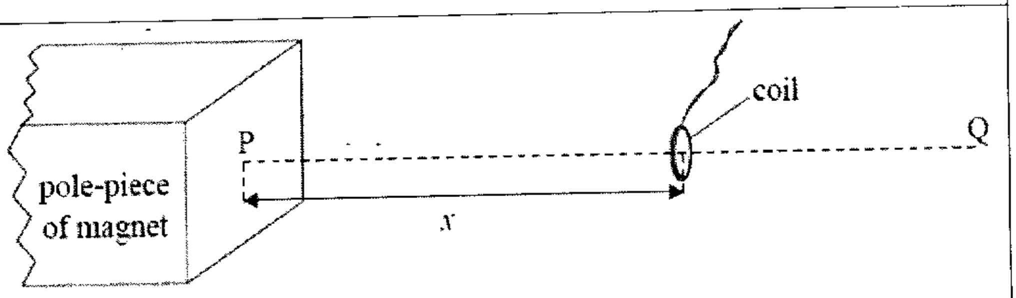


Fig. 5.2

PQ is a line that is normal to the pole piece. The variation with distance x along line PQ of the mean magnetic flux density B in the coil is shown in Fig. 5.3.

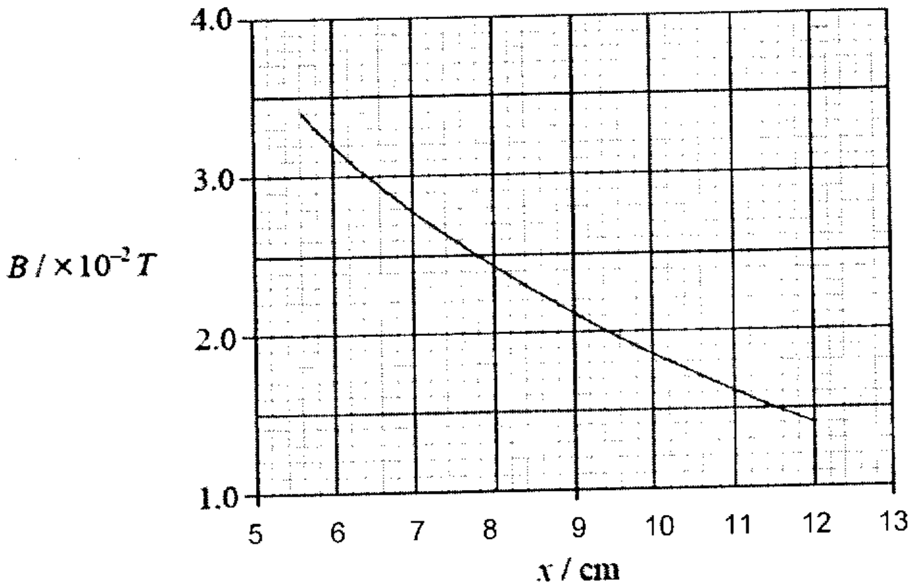


Fig. 5.3

(i) For the coil situated a distance 6.0 cm from the pole piece of the magnet,

1. State the average magnetic flux density in the coil.

average magnetic flux density = 3.2×10^{-2} T .... T [1]

2. Calculate the flux linkage through the coil.

flux linkage = NBA = $250 \times 3.2 \times 10^{-2} \times 1.7 \times 10^{-4}$
= $1.36 \times 10^{-3} \sim 1.4 \times 10^{-3}$ Wb-turns

magnetic flux linkage = ... Wb-turns [2]

(ii) The coil is moved along PQ so that the distance x changes from 6.0 cm to 12.0 cm in a time of 0.35 s.

1. Determine the change in magnetic flux linkage through the coil.

From the graph, $\Delta B = 3.2 \times 10^{-2} - 1.4 \times 10^{-2} = 1.8 \times 10^{-2}$ T
therefore change in flux linkage = NBA = $250 \times 1.8 \times 10^{-2} \times 1.7 \times 10^{-4} = 7.65 \times 10^{-4} \sim 7.7 \times 10^{-4}$ Wb-turns
ecf from (i)

change in magnetic flux linkage = ... Wb-turns [2]

2. State Faraday's law of electromagnetic induction and hence calculate the mean e.m.f. induced in the coil.

e.m.f. is proportional to rate of change of flux linkage

$\varepsilon = \frac{(6.8\times10^{-4})}{0.35} = 2.19 \times 10^{-3}$

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

(iii) Use Lenz's law to explain why work has to be done to move the coil along the line PQ.

Induced current produces a magnetic field in the coil.
This produces a force.
The force acts to oppose the motion of the coil.

.... [2]

6 The isotope Iron-59 is a β-emitter with a half-life of 45 days. In order to estimate engine wear, an engine component is manufactured from iron throughout which the isotope Iron-59 has been uniformly distributed. The mass of the engine component is 2.4 kg and its initial activity is 8.5×10^7 Bq.
The component is installed in the engine 60 days after manufacture of the component, and then the engine is tested for 30 days. During the testing period, any metal worn off the component is retained in the surrounding oil. Immediately after the test, the oil is found to have a total activity of 880 Bq.
Calculate

(a) **(i)** the decay constant for the isotope Iron-59,

Decay constant $\lambda = \dfrac{\ln 2}{t_{1/2}}$

$= 0.0154 \text{ day}^{-1}$
$= 1.78 \times 10^{-7} \text{ s}^{-1}$

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

(ii) the total activity of the component when it was installed,

$A = A_o e^{-\lambda t} = 8.5 \times 10^7 e^{-0.0154(60)}$
$A = 3.37 \times 10^7$ Bq

activity = ... Bq [2]

(iii) the mass of iron worn off the component during the test.

Activity after 90 days,

$A = 8.5 \times 10^7 e^{-0.0154(90)}$
$= 2.1256 \times 10^7$ Bq

Mass of iron worn off $= \dfrac{880}{2.1256 \times 10^7} \times 2.4$ kg

$= 9.94 \times 10^{-5}$ kg

mass of iron = ... g [4]

(b) State and explain how your results in **(a) (iii)** will change if background radiation is included in the total activity of 880 Bq.

The mass of iron worn off the component in (a) (iii) will be less.

As background radiation is included in the total activity of 880 Bq, the actual activity due to Iron-59 in the oil is less than 880 Bq which means lesser mass of iron is worn off the component.

....

....

....

....

....

.... [2]

Section B

Answer **one** question from this Section in the spaces provided.

7 **(a)** A pair of identical speakers, S_1 and S_2, 1.2 m apart makes up a stereo system in a large hall. The voltage input to each speaker is adjustable. The arrangement is shown in Fig. 7.1.

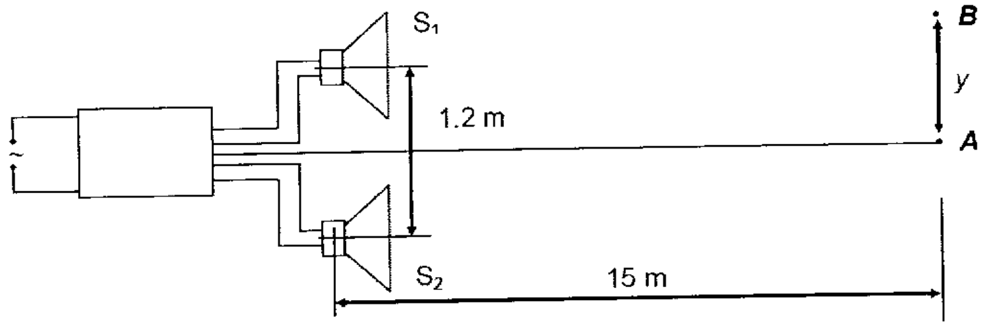


Fig. 7.1

The speakers are initially emitting signals of frequency 1000 Hz, which are in phase. Assume that the speed of sound is 330 m s^{-1}. The voltage across each speaker is 6.0 V. An observer holding a sound detector stands on the centre line at point **A**, 15 m away from the point halfway between the speakers and registers a loud sound of intensity I_{max}. As he moves along the line **AB** at right angles to the centre line, the intensity of the sound falls to zero at point **B**, a distance y from **A**.

(i) Determine the distance y.

B is location of 1st minima.
Since both speakers are in phase, a λ/2 path difference is needed for destructive interference at B.
y = (λ/2)(D)/d
= ½ (330/1000)(15)/1.2 = 2.1 m

[3]

(ii) Calculate the next higher frequency of operation of the speakers such that the point **B** will be a position of maximum intensity.

y = λD/d
= vD/df
f = vD/df = (330)(15)/(1.2)(2.06)
= 2002 ~ 2.0 (2.00) kHz (2 or 3 s.f.)

frequency = ... kHz [2]

(iii) With the speakers emitting the original signal of frequency 1000 Hz, the voltages across S_1 and S_2 are adjusted to 3.0 V and 9.0 V respectively.

Given that the amplitude of the output of each speaker is proportional to the voltage across its terminals, find the new intensity at **A**, expressing your answer in terms of I_{max}.

> A α V → A = kV
> I α A^2
> $I_{max,\ original} = (6k + 6k)^2 = 144\ k^2$
> $I_{max,\ new} = (3k + 9k)^2 = 144\ k^2$
> The new intensity at A = I_{max}

new intensity at **A** = ... [4]

(b) A *diffraction* grating is to be calibrated by a spectrometer experiment with a source emitting a spectral series of lines of known wavelengths.

(i) Explain what is meant by *diffraction*. [1]

....

....

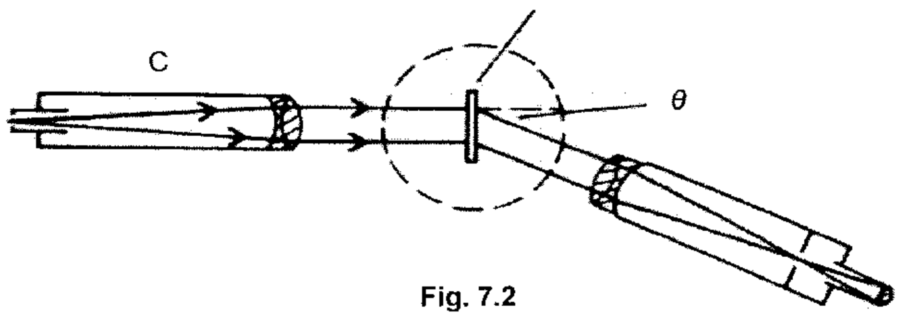


Fig. 7.2

The grating in Fig. 7.2 is set up with light incident normally from a collimator C, with θ, the angle of first order of angular deflections.

(ii) The light from a hydrogen discharge tube contains electromagnetic radiations of wavelengths 660 nm (red) and 490 nm (blue). This light is passed through the grating and and observed through a telescope T. The grating has a slit density of 359 lines per mm.

(A) The position of the first order blue fringe is observed to be approximately 20 cm from the central maxima.

> *estimate, because of use of small angle approximation
> making use of path difference: λ = dy/L
> $L = dy/\lambda = d\frac{y}{\lambda} = \frac{1}{3.59 \times 10^5}\frac{20 \times 10^{-2}}{490 \times 10^{-9}}$
> = 1.14 m ≈ 1 m

e

normal distance = ... m [2]

(B) Determine the angular separation of the red and blue light for hydrogen for the second order diffraction pattern.

dsinθ = 2 λ

angular separation

= θr − θb = $sin^{-1}\left(\frac{2\lambda_r}{d}\right) - sin^{-1}\left(\frac{2\lambda_b}{d}\right)$

= $sin^{-1}(2 \times 660 \times 10^{-9} \times 3.59 \times 10^{5}) - sin^{-1}(3.59 \times 10^{5} \times 2 \times 490 \times 10^{-9})$

= 28.4° − 20.6° = 7.8°

angular separation = ... ° [3]

(C) Determine the highest order observable for blue light.

dsinθ = n λ

use θ = 90 or directly uses d(1) = n λ

n < d/ λ = 1/(3.59 × 10^5)(490 × 10^{-9})

= 5.68

therefore highest observable order = 5

value of n before rounding down must be shown

highest observable order = ... [3]

(D) The diffraction grating may also be used to investigate wavelengths of an unknown source.

Suggest one advantage and one disadvantage of obtaining the wavelength by using observations of the higher order of the diffracted light rather than the first-order diffraction light. [2]

Advantage:

- Able to distinguish between the emission lines easily as the angle of deviation is larger/larger angular separation
- larger angle of deviation → smaller % uncertainty

Disadvantage:

- Intensity of the pattern is weaker. May be difficult to detect/differentiate the fringes on the screen.
- With larger angular separation, λ = dy/L, which is based on small angle approximation, is no longer valid.

8 **(a)** When monochromatic light is shone on a clean metal surface, electrons are emitted from the surface due to the photoelectric effect.

(i) State what is meant by the threshold frequency of the incident light.

below a certain frequency (called the threshold frequency) no electrons emitted

....

.... [1]

(ii) Explain why the photoelectric effect is not observed below the threshold frequency.

(light travels as photons) energy of a photon depends on frequency

....

below threshold frequency (photon) does not have enough energy

....

to liberate an electron / (to allow the electron) to overcome the work function

....

or minimum frequency of the photon that will give the electrons enough energy to overcome work function

.... [2]

(b) Monochromatic light of wavelength 5.40×10^{-7} m is incident on a metal surface which has a work function of 1.40×10^{-19} J.

(i) Calculate the threshold frequency of this incident light.

$\phi = hf_0$

$f_0 = \phi / h = 1.40 \times 10^{-19} / 6.63 \times 10^{-34}$

$= 2.11 \times 10^{14}$ Hz

threshold frequency = ... Hz [2]

(ii) Calculate the energy of a single photon of this light.

$E = hf = hc/\lambda$

$E = 6.63 \times 10^{-34} \times 3.00 \times 10^{8}/5.40 \times 10^{-7}$

$E = 3.68 \times 10^{-19}$ J

energy of photon = ... J [2]

(iii) Calculate the maximum speed of the emitted electron.

$hf = E_k + \phi$

$3.68 \times 10^{-19} = E_{k,max} + 1.40 \times 10^{-19}$

$E_{k,max} = 2.28 \times 10^{-19}$ J

$E_{k,max} = \frac{1}{2} m v_{max}^2$

$v_{max}^2 = 2 \times 2.28 \times 10^{-19} / 9.11 \times 10^{-31}$

$v_{max} = 7.1 \times 10^{5}$ m s^{-1}

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

(iv) Calculate the de Broglie wavelength of the fastest electrons.

$\lambda = h / p = h / mv$

$\lambda = 6.63 \times 10^{-34}$ $(9.11 \times 10^{-31} \times 7.1 \times 10^{5})$

$\lambda = 1.03 \times 10^{-9} = 1.03$ nm

de Broglie wavelength = ... nm [2]

(c) Fig. 8.1 below represents the energy levels of the four lowest states of the hydrogen atom.

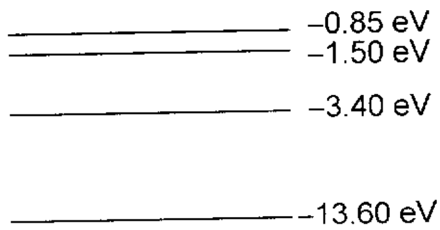


Fig. 8.1

(i) State what happens in the atom when line spectra are produced.

electrons are excited or de-excited from one energy level (or orbit) to another

....

emitting or absorbing a definite frequency/wavelength/colour or photon energy (of electromagnetic radiation)

....

.... [1]

(ii) State the transition and determine the wavelength of one possible **visible** spectral line detected in the **emission** spectrum of atomic hydrogen, due to transitions between these states.

loss in energy by atom = energy of photon emitted

$$\Delta E = hf = \frac{hc}{\lambda}$$

$$\lambda = \frac{hc}{\Delta E}$$

Either 4 → 2: 488 nm = 0.488 μm

Or 3 → 2: 654 nm = 0.654 μm

transition = level .... to ....

wavelength = ... μm [3]

(d) Fig. 8.2 below represents a typical X-ray spectrum.

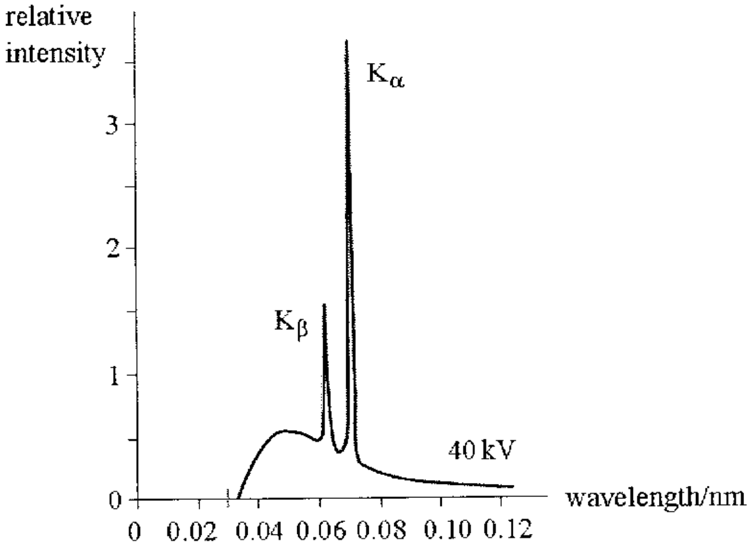


Fig. 8.2

(i) Distinguish between the mechanisms that produce **characteristic** X-ray spectra in Fig. 8.2 and the line spectra in part **(c)(i)**.

In (c)(i): electrons are excited to higher levels by incoming electrons and subsequently decay to lower levels, emitting photons

....

in Fig. 8.2: inner electrons ejected by incoming electrons and (outer) electrons fall to unoccupied level

.... [2]

(ii) Estimate the maximum velocity of the electrons

loss in E_K = X-ray photon emitted

$$\frac{1}{2}mv^2 = hf = h\frac{c}{\lambda}$$

$$v_{max} = \sqrt{\frac{2hc}{m\lambda_{min}}} = \sqrt{\frac{2(6.63\times10^{-34})(3.00\times10^{8})}{(9.11\times10^{-31})(\approx 0.034\times10^{-9})}}$$

$$\approx 1\times10^{8}\ \text{m s}^{-1}$$

maximum velocity ≈ .... m s^{-1} [2]

END OF PAPER