NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2 PRELIMINARY EXAMINATION

Higher 2

CANDIDATE NAME

SUBJECT CLASS | REGISTRATION NUMBER

PHYSICS **9749/01**

Paper 1 Multiple Choice

14 September 2022
1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THE INSTRUCTION FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, subject class and registration number on the Answer Sheet in the spaces provided unless this has been done for you.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

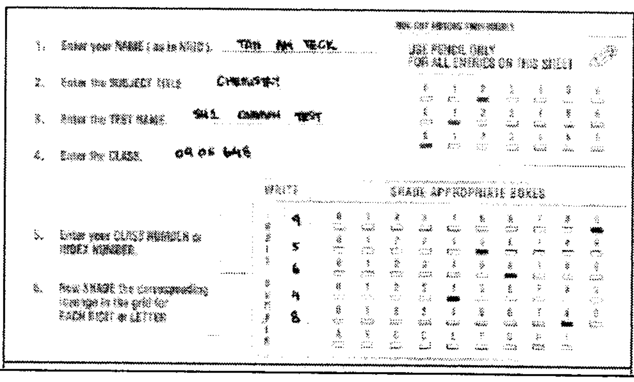
Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

The OAS index number is in a 5-digit format.

The 5-digit format is as follows: **2nd digit** and the **last four digits** of the Reg Number.

e.g. 2005011 becomes **05011**

INSTRUCTIONS ON SHADING OF REGISTRATION NUMBER



This document contains **15** printed pages and **1** blank pages.

[Turn over

Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(1/(36\pi)) \times 10^{-9}\,\mathrm{F\,m^{-1}}$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
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unified atomic mass constant	$u = 1.66 \times 10^{-27}\,\mathrm{kg}$
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	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -Gm/r$
temperature	$T/\text{K} = T/°\text{C} + 273.15$
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	$B = \frac{\mu_0 I}{2\pi d}$
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radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

[Turn over

1 Which of the following is the best estimate of the kinetic energy of an average National Junior College sprinter?

A 25 J **B** 1500 J **C** 3500 J **D** 11000 J

2 A student makes measurements from which he calculates the speed of sound as 327.66 m s^{-1}. He estimates that his result is accurate to $\pm$ 3%. Which of the following gives his results reduced to the appropriate number of significant figures?

A 300 m s^{-1}

B 320 m s^{-1}

C 328 m s^{-1}

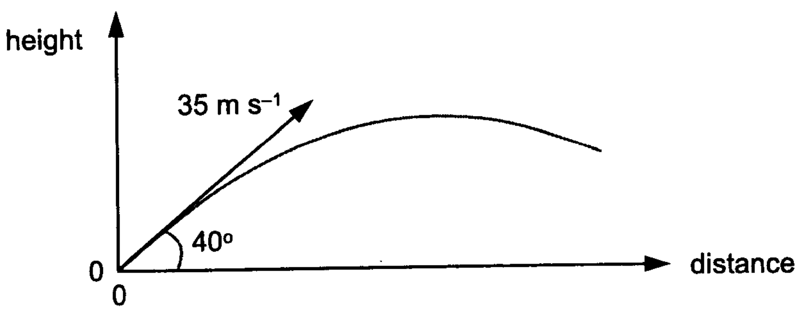
D 330 m s^{-1}

3 A car accelerates uniformly from rest for 16 s along a straight track.

What is the ratio $\frac{\text{distance travelled between 8 s and 16 s}}{\text{distance travelled between 0 s and 8 s}}$?

A 1 **B** 2 **C** 3 **D** 4

4 An object is projected with velocity 35 m s^{-1} at an angle of 40° to the horizontal. Air resistance is negligible.



What is the speed of the object after 4.0 s?

A 26 m s^{-1} **B** 32 m s^{-1} **C** 67 m s^{-1} **D** 70 m s^{-1}

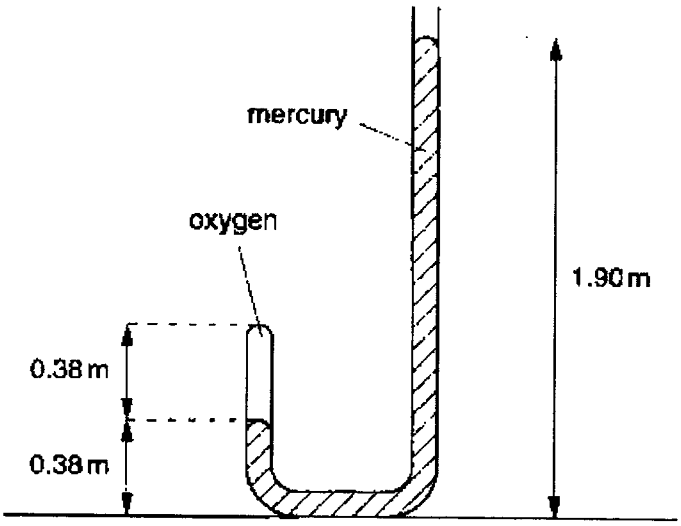
5 A trolley of mass 0.50 kg moves with a certain acceleration down a runway which is inclined to the horizontal at 15°. If the angle of inclination is increased to 20°, the acceleration of the trolley would be doubled. What is the frictional force, assumed to be the same in both cases, acting on the trolley?

A 0.12 N **B** 0.41 N **C** 0.86 N **D** 4.9 N

6 A 5.00 kg object moves at 15.0 m s^{-1} makes a head-on collision with a 10.0 kg object which was at rest. Both the objects coalesce and move off with a common velocity. How much kinetic energy is lost in the collision?

A 188 J **B** 375 J **C** 563 J **D** 702 J

7 Oxygen is compressed in the sealed end of a long J-tube by means of a column of mercury open to the atmosphere, as shown.



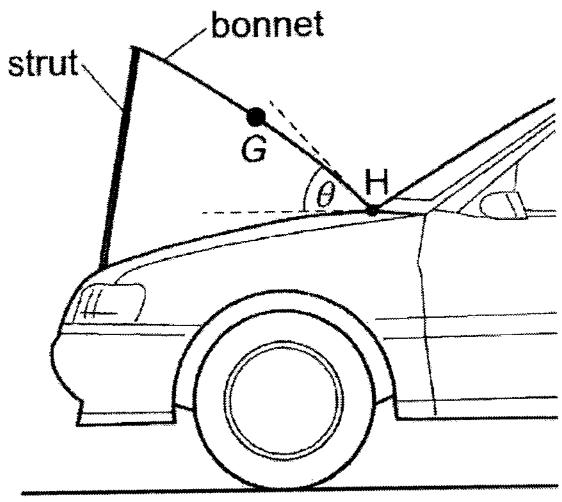
Mercury has density 13.6×10^3 kg m^{-3} and atmospheric pressure 1.01×10^5 Pa.

What is approximate value of $\dfrac{\text{pressure of oxygen}}{\text{pressure of atmosphere}}$?

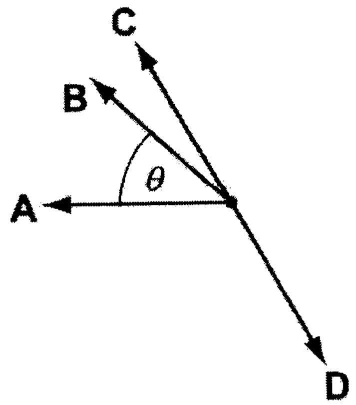
A 1.5 **B** 2.0 **C** 2.5 **D** 3.0

[Turn over

8 To inspect the engine of a car, the bonnet, hinged at H, is held open by a strut. The weight of the bonnet acts through its centre of gravity *G*.



Which arrow best represent the approximate direction of the force on the bonnet at the hinge H?



9 A body of mass m moves at constant speed v for a distance s against a constant F. What is the power required to sustain this motion?

A mv **B** $\frac{1}{2} mv^2$ **C** $\frac{1}{2} F s$ **D** Fv

10 A mass of 2 kg rotates at a constant speed in a horizontal circle of radius 5 m and the time for one complete revolution is 3 s. The force acting on the mass is

A $\frac{20\pi^2}{3}$ N **B** $\frac{20\pi^2}{9}$ N **C** $\frac{40\pi^2}{9}$ N **D** $\frac{100\pi^2}{9}$ N

11 Two stationary particles of masses M_1 and M_2 are a distance d apart. A third particle of mass m, lying on the line joining the particles, experiences no resultant gravitational force.

What is the distance of this particle of this mass from M_1?

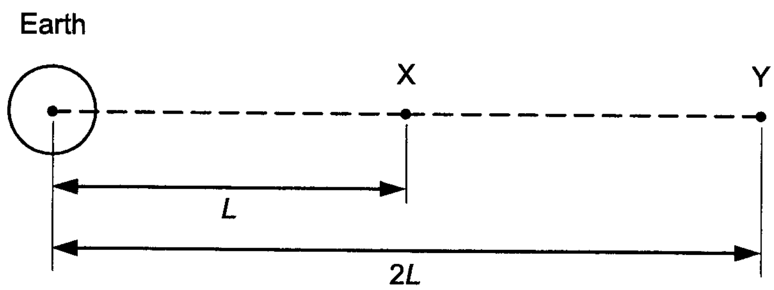
A $d\sqrt{\frac{M_1}{M_2}}$

B $d\left(\frac{M_1}{M_1+M_2}\right)$

C $d\left(\frac{\sqrt{M_1}}{\sqrt{M_1}+\sqrt{M_2}}\right)$

D $d\sqrt{\frac{M_1}{M_1+M_2}}$

12 The diagram shows two points X and Y at distance L and $2L$, respectively, from the centre of the Earth. The gravitational potential at X is – 8 kJ kg^{-1}.



What is the gain in gravitational potential energy of a 2 kg mass when it is moved from X to Y?

A – 8 kJ **B** – 4 kJ **C** + 4 kJ **D** + 8 kJ

13 Which of the following statements is not correct?

A The microscopic potential energy of an ideal gas is zero.

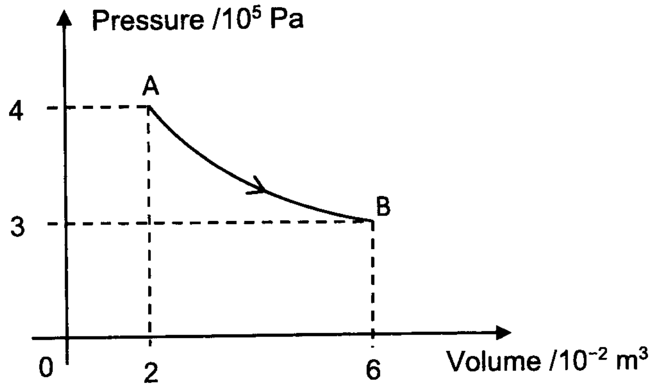
B Two bodies in thermal equilibrium have no heat flow between them.

C During the melting of ice, there is no increase in temperature.

D The average kinetic energy of a gas molecule is proportional to its thermodynamic temperature.

[Turn over

14 An ideal gas is enclosed in a cylinder by a gas-tight, frictionless piston. The gas then undergoes changes along the path as shown in the figure below (not to scale).



Which of the following statement is valid?

A There is no change in the internal energy of the gas.

B Work is done on the gas.

C The average kinetic energy of the gas molecules is the same at both states A and B.

D Heat is gained by the gas.

15 Which statements about internal energy is correct?

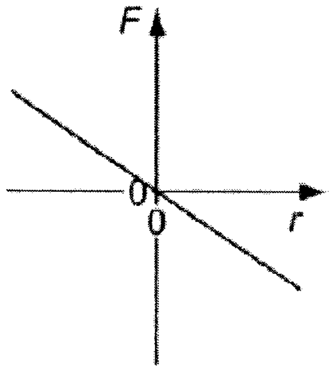
A The internal energy of a system depends only on its temperature.

B The internal energy of a system can be increased without heating.

C When the internal energy of a system is increased, its temperature always rises.

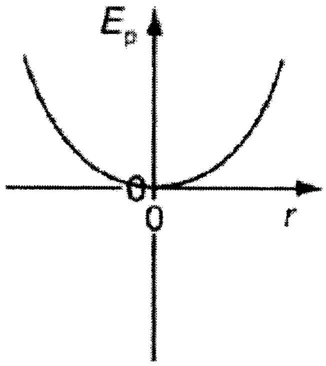
D When two systems have the same internal energy, they must be at the same temperature.

16 A particle is moving such that the force F on it changes with the distance r from a fixed point as shown.

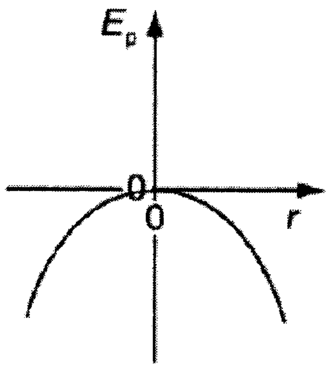


Which graph best shows the relationship between the potential energy E_p of the particle and the distance r?

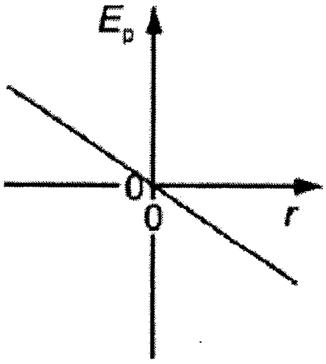
A



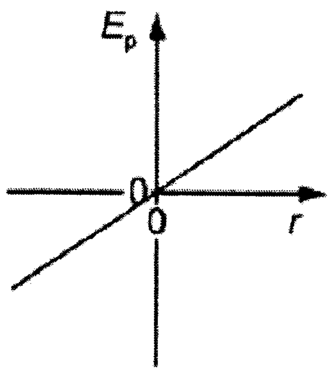
B



C



D

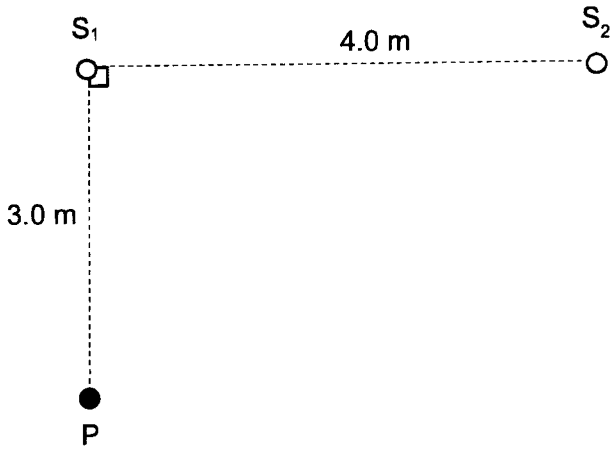


17 A sound wave of frequency 400 Hz is travelling in air at a speed of 320 m s^{-1}. What is the difference in phase between two points on the wave 0.2 m apart in the direction of travel?

A $\frac{\pi}{4}$ rad **B** $\frac{\pi}{2}$ rad **C** $\frac{2\pi}{5}$ rad **D** $\frac{8\pi}{5}$ rad

[Turn over

18 Water waves of wavelength 2.0 m are produced by two generators, S_1 and S_2, placed 4 m apart. Each generator, when operated by itself, produces waves which have an amplitude of A at point P as shown in the diagram.



When the generators are operating in antiphase, the amplitude of the oscillation at P is

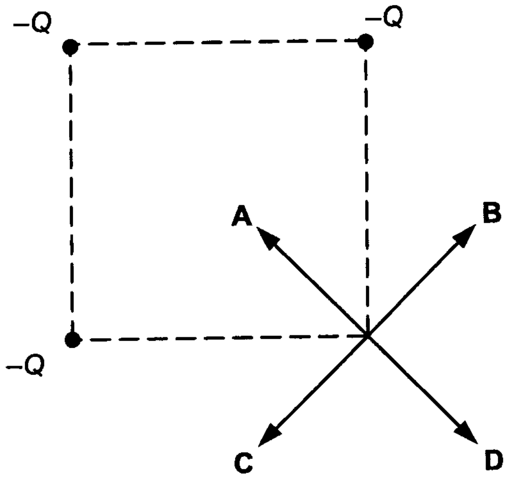
A 0 **B** ½ A **C** A **D** 2 A

19 A student blows gently across the top of a piece of glass tubing, the lower end of which is closed by his finger so that the tube gives its fundamental note of frequency f. While blowing, he removes his finger from the lower end. The note he then hears will have a frequency of approximately

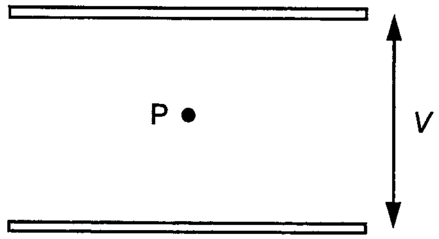
A $\frac{f}{4}$ **B** $\frac{f}{2}$ **C** $2f$ **D** $4f$

20 The diagram shows point charges, each of magnitude Q placed at three corners of a square.

What is the direction of the resultant electric field at the fourth corner?



21 A small positively-charged particle P is balanced halfway between two horizontal plates when a potential difference *V* is applied between the plates.



When *V* is increased, P rises towards the upper plate.

Which statement is correct?

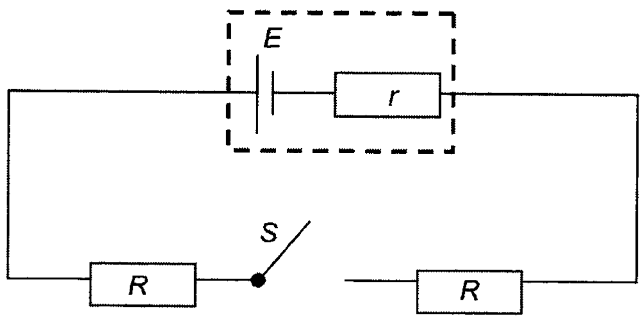
A Decreasing *V* decreases both the gravitational and electric potential energy of the particle.

B Decreasing *V* decreases the gravitational potential energy and increases the electric potential energy of the particle.

C Increasing *V* increases both the gravitational and electric potential energy of the particle.

D The change of electric potential energy of the particle must equal the change of gravitational potential energy of the particle.

22 A battery, with an e.m.f *E* and internal resistance *r*, is connected to a switch *S* and two identical resistors in series. Each resistor has resistance *R*.



Which one of the following statements is correct when the switch *S* is closed?

When an ideal voltmeter is connected

A across one resistor, the voltmeter's reading is 0.5 *E*.

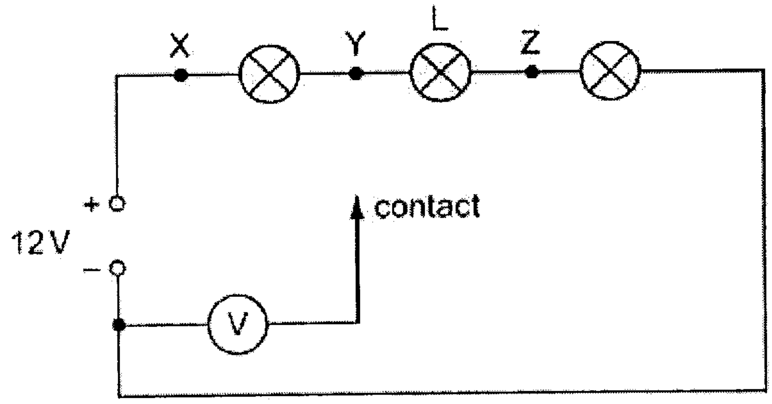
B across two resistors, the voltmeter's reading is *E*.

C across the battery, the voltmeter's reading is *E*.

D across the battery, the voltmeter's reading is less than *E*.

[Turn over

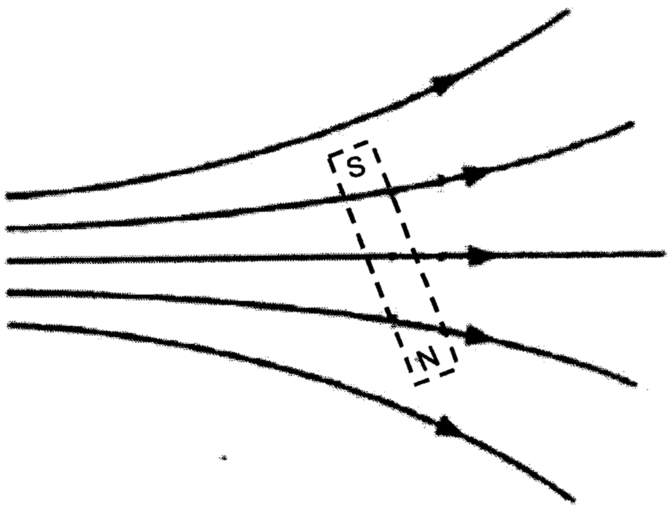
23 The diagram shows three lamps in series with a 12 V supply.



To test the circuit, the contact is connected in turn to points X, Y and Z. The lamps **do not light** because lamp L has a broken filament.
Which of the following is correct?

	reading at X	reading at Y	reading at Z
A	12 V	8 V	4 V
B	8 V	8 V	0 V
C	12 V	12 V	0 V
D	8 V	12 V	4 V

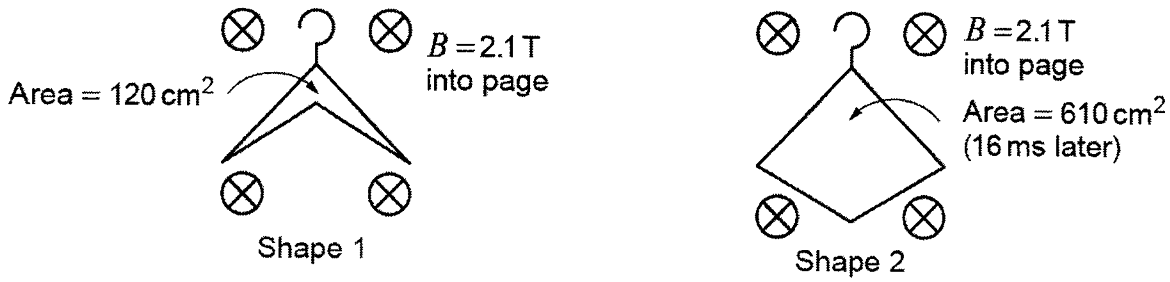
24 A bar magnet is to be placed in a non-uniform magnetic field as shown.



Which line of the table describes the subsequent motion of the magnet?

	rotation	movement
A	anticlockwise	to the left
B	anticlockwise	to the right
C	clockwise	to the left
D	clockwise	to the right

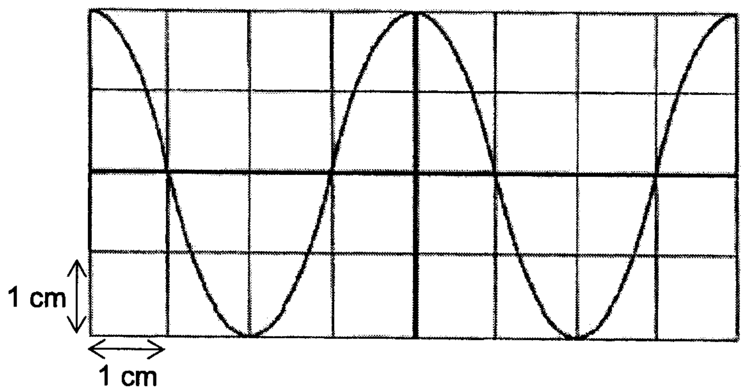
25 An experiment is carried out in a very strong uniform magnet in order to confirm the Faraday's Law under extreme conditions. A coat hanger made of aluminum wire is bent from Shape 1 to Shape 2 in a time of 16 ms as shown below.



What is the magnitude of the average e.m.f. induced in the hanger?

A 0 V **B** 6.4×10^{-3} V **C** 6.4 V **D** 64 V

26 A cathode-ray oscilloscope (c.r.o.) screen with a grid of 1 cm squares displays an alternating voltage waveform. The Y-plates sensitivity of c.r.o is 0.50 V cm^{-1} and the time-base setting is 5.0 ms cm^{-1}.



The voltage V of this waveform is related to time t by the expression

A $V = 1.0 \cos 50\, t$

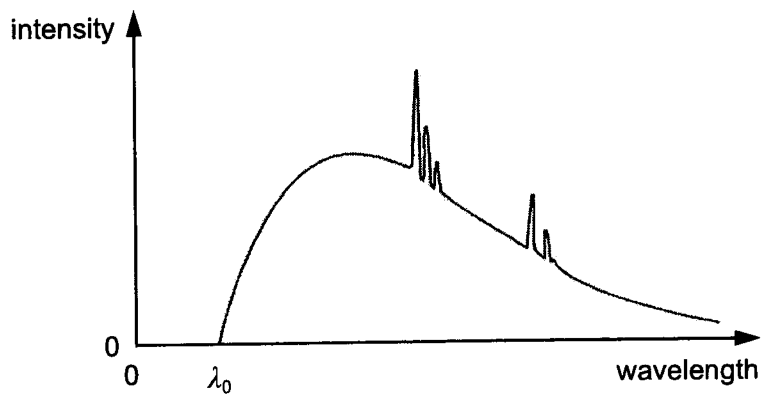
B $V = 2.0 \cos 50\, t$

C $V = 1.0 \cos 310\, t$

D $V = 2.0 \cos 310\, t$

[Turn over

27 An electron is accelerated from rest through a potential difference (p.d.) of 8.0 kV in a vacuum and incident on a tungsten target to produce X-ray spectrum below.



λ_0 is the minimum wavelength of the spectrum.

The potential difference is reduced to 6.0 kV.

What is the ratio $\dfrac{\text{minimum wavelength when p.d. is 6.0 kV}}{\text{minimum wavelength when p.d. is 8.0 kV}}$?

A 0.5 **B** 0.75 **C** 1.3 **D** 1.5

28 An electron of mass 9.11×10^{-31} kg travelling at 3.00×10^{7} m s^{-1} passes through a narrow slit of width 1.00×10^{-10} m.

What is the uncertainty in the momentum of the electron after passing through the slit?

A 6.63×10^{-24} kg m s^{-1}

B 2.73×10^{-23} kg m s^{-1}

C 7.28×10^{6} kg m s^{-1}

D 1.00×10^{9} kg m s^{-1}

29 In the Rutherford scattering experiment most α-particles passed through the foil undeflected. Which one of the following is a correct conclusion from this result?

A The atom is overall electrically neutral.

B The nucleus is positively charged.

C The diameter of the nucleus is much less than the diameter of the atom.

D Mass of electrons is negligible compared to the mass of nucleus.

30 A student placed different types of radioactive sources which can emit alpha, beta and gamma radiation into an aluminium container of 10 mm thick. He uses a Geiger-Muller tube to read the radiation outside the container. The Geiger-Muller counter register counts from

A gamma radiation only.

B alpha particles and beta particles only.

C beta particles and gamma radiation only.

D alpha particles, beta particles and gamma radiation.

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NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2 PRELIMINARY EXAMINATION

Higher 2

CANDIDATE NAME

SUBJECT CLASS | REGISTRATION NUMBER

PHYSICS

Paper 2 Structured Questions

9749/02

23 August 2022
2 hours

Candidate answers on the Question Paper.

No Additional Materials are required.

READ THE INSTRUCTION FIRST

Write your subject class, registration number and name in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a 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.
Answers **all** questions.

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

For Examiner's Use	
1	/ 10
2	/ 10
3	/ 10
4	/ 8
5	/ 8
6	/ 14
7	/ 20
Total (80)	

This document contains **22** printed pages and **2** blank pages.

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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	$V = \frac{Q}{4\pi\varepsilon_0 r}$
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radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

[Turn over

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

1 As a ship is approaching the dock at 45.0 cm s^{-1}, an important piece of landing equipment needs to be thrown to it before it can dock. This equipment is thrown at 15.0 m s^{-1} at 60.0° above the horizontal from the top of a tower at the edge of the water, 8.75 m above the ship's deck as shown in Fig. 1.1.

For this equipment to land at the front of the ship's deck, the distance from the dock to the ship when the equipment is thrown should be D as shown in Fig.1.1

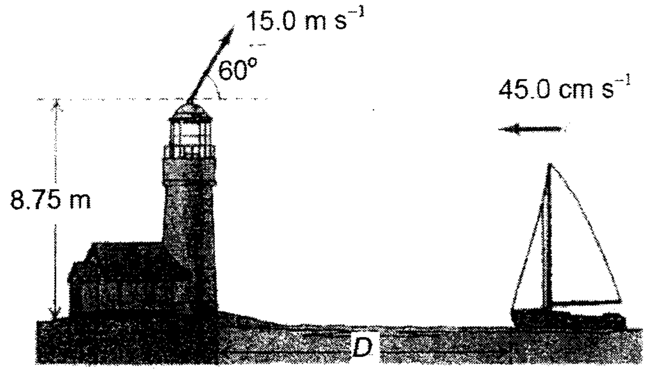

Fig 1.1

(a) Assuming that air resistance is negligible.

(i) Show that the time of flight of the equipment is 3.21 s.

[1]

(ii) Hence, determine the value of D.

D = ... m [3]

(b) If air resistance is not negligible, comment on whether D should be longer or shorter.

....

....

.... [2]

(c) Sketch and label clearly on the same axes in Fig 1.2, a graph to show the variation with time of flight t of the vertical component of velocity V_y of the equipment during its flight if

(i) air resistance is negligible,

(ii) air resistance is not negligible.

For both graphs, take upwards direction as positive.

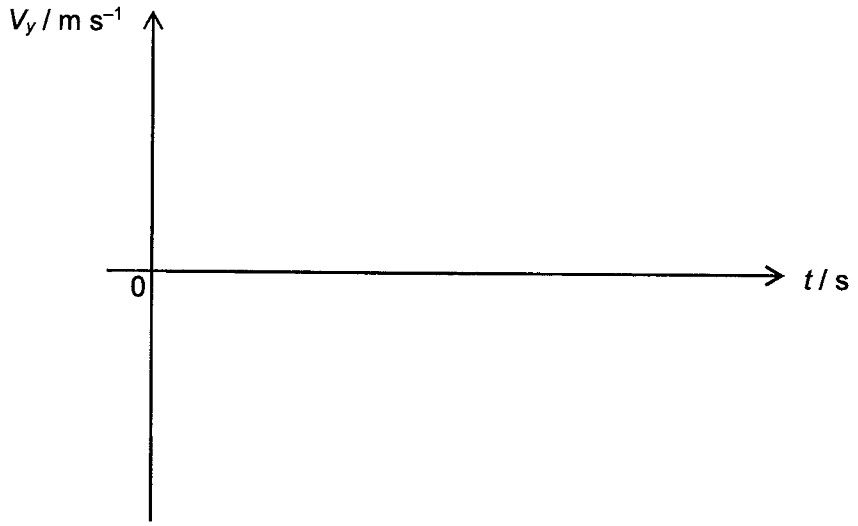

Fig 1.2

[4]

[Total: 10]

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2 Two blocks travel directly towards each other along a horizontal, frictionless surface. The blocks collide, as illustrated in Fig. 2.1.

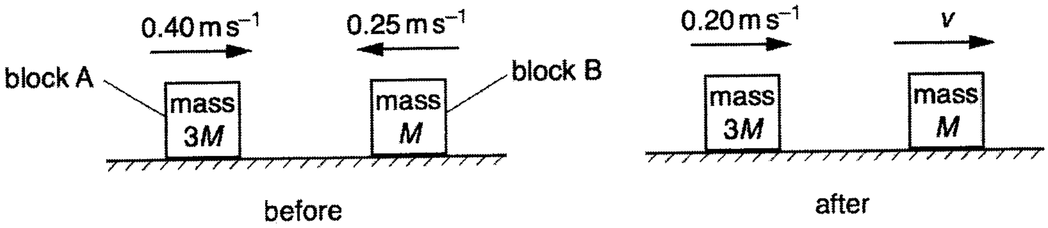


Fig. 2.1

Block A has mass $3M$ and block B has mass M.
Before the collision, block A moves to the right with speed 0.40 m s^{-1} and block B moves to the left with speed 0.25 m s^{-1}.
After the collision, block A moves to the right with speed 0.20 m s^{-1} and block B moves to the right with speed v.

(a) **(i)** Use Newton's laws of motion to explain why the change in momentum of each block is equal in magnitude and opposite in direction.

....

....

....

....

....

....

....

.... [4]

(ii) Hence, explain whether it is possible for both blocks to be at rest simultaneously during the collision.

....

....

....

.... [2]

(b) **(i)** Determine speed *v*.

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

(ii) Deduce whether the collision is elastic or inelastic.

....

....

....

.... [2]

[Total: 10]

[Turn over

3 Fig. 3.1 shows the front view of a container ship.

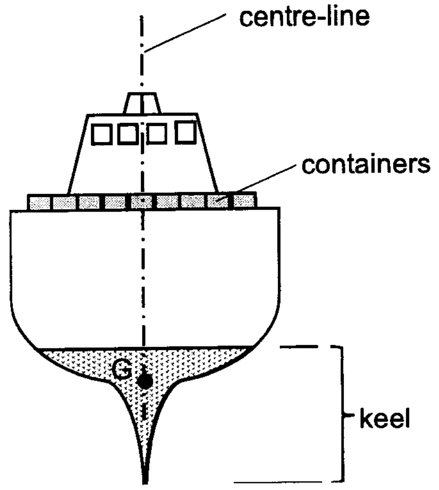


Fig. 3.1

The line of symmetry of the ship is known as the centre-line.

An important part of the ship is the ballast keel, a vertical downward extension of the ship's hull, that is loaded to keep the centre of gravity G of the boat low as shown in Fig. 3.1.

When the ship floats in the sea, the upthrust of the ship is equal in magnitude but opposite in direction to the weight of the ship.

(a) Explain

(i) what is meant by the *centre of gravity* of the ship,

....

....

.... [2]

(ii) the origin of the upthrust acting on the ship.

....

.... [1]

(b) The ship has a mass of 2.20×10^8 kg and the density of seawater is 1030 kg m^{-3}.

Calculate the volume of seawater displaced by the ship.

volume = ... m^3 [2]

(c) A ship will roll on its sides due to the wind and the water waves. Fig 3.2 shows ship on its side at a particular instant.

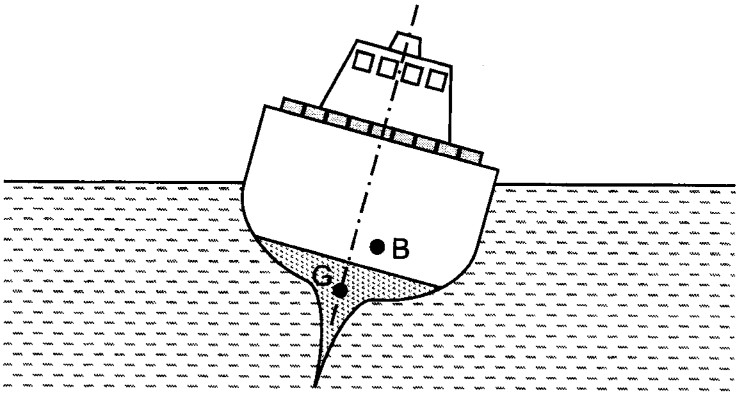


Fig. 3.2

The upthrust acts through the centre of gravity of the displaced fluid, known as the centre of buoyancy B shown in Fig. 3.2.

(i) On Fig. 3.2, mark with arrows labelled *W* for the weight and labelled *U* for the upthrust. [1]

(ii) By reference to the completed diagram of Fig. 3.2, explain why the ship will not overturn.

....

....

.... [2]

(d) When the ship is fully loaded with containers (you may assume the containers are secured and will not shift), the centre of gravity G will be at a higher position along the centre-line.

Draw relevant forces on Fig. 3.3 to explain the danger of a fully loaded ship rolling to its side.

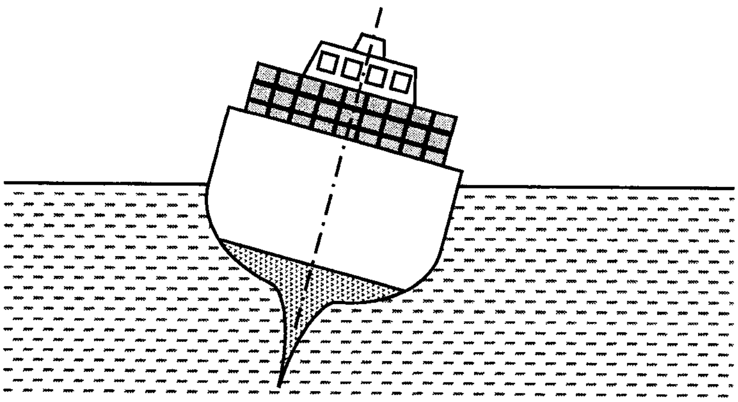


Fig. 3.3

....

.... [2]

[Total: 10]

[Turn over

4 **(a)** A resistor "ladder" with 2 stages "*R*-2*R*" resistors, with values of *R* and 2*R*, are connected to an ideal cell of e.m.f. *V* as shown in Fig. 4.1.

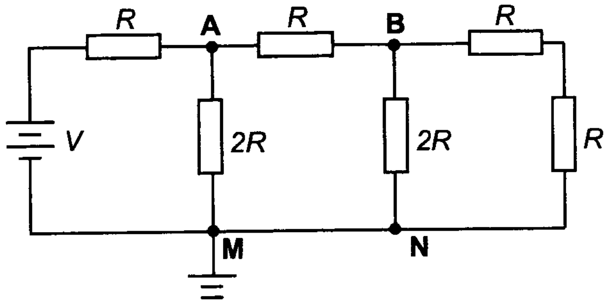


Fig. 4.1

(i) Show that the effective resistance between junction **A** and **M** is *R*.

[1]

(ii) Determine the potential at junction **A** in terms of *V*.

potential at **A** in terms of *V* .... [2]

(iii) Two additional "*R*-2*R*" stages, are added to the resistor "ladder" as shown in Fig 4.2.

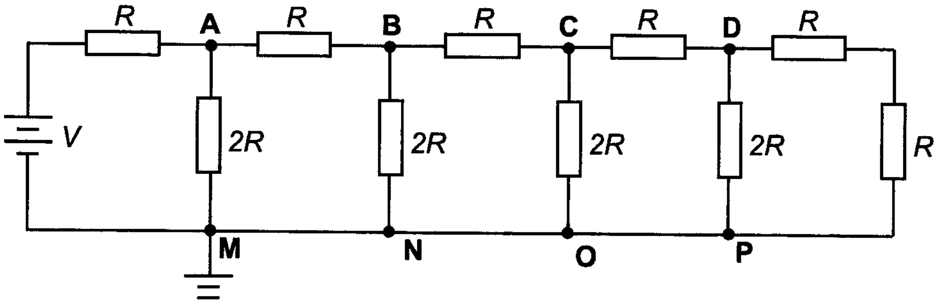


Fig 4.2

Using your answers from **(i)** and **(ii)**, deduce the potential at junction **D**, in Fig. 4.2 in terms of *V*.

potential at **D** in terms of *V* .... [2]

[Turn over

(b) The current-potential difference relationship for two electrical components P and Q is shown in Fig. 4.3.

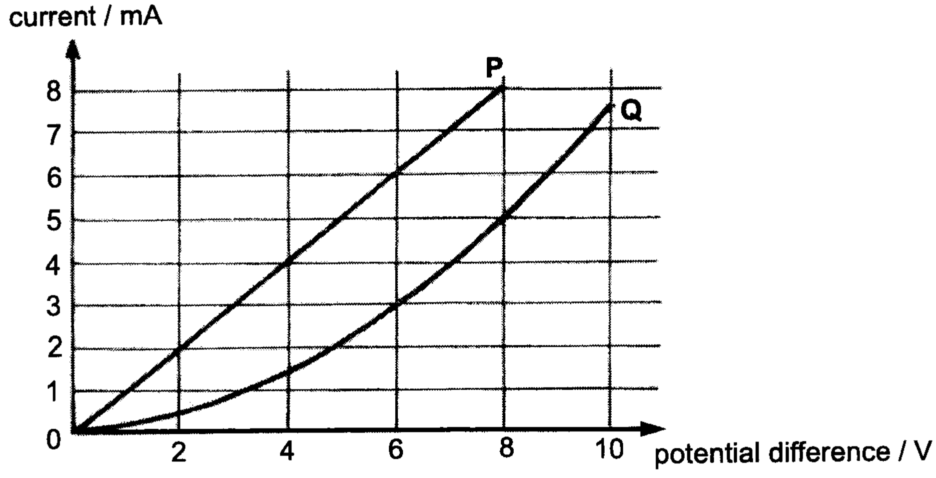
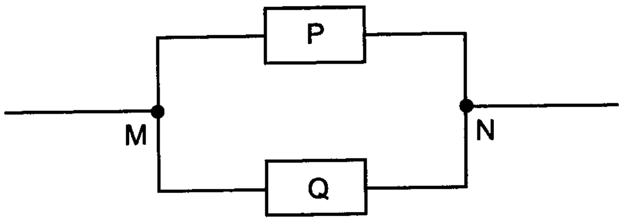


Fig. 4.3

P and Q are connected in parallel. The current flowing through P is 6 mA.



Determine the effective resistance between M and N.

effective resistance = ... Ω [3]

[Total: 8]

5 **(a)** Force-fields may be represented using lines that have direction.

State

(i) what is meant by a *field of force,*

.... [1]

(ii) how, using lines of force, changes in the strength of a force-field are represented.

....

.... [1]

(b) A large horseshoe magnet produces a uniform magnetic field of flux density B between its poles. Outside the region of the poles, the flux density is zero.

The magnet is placed on a top-pan balance and a stiff wire XY is situated between its poles as shown in Fig. 5.1.

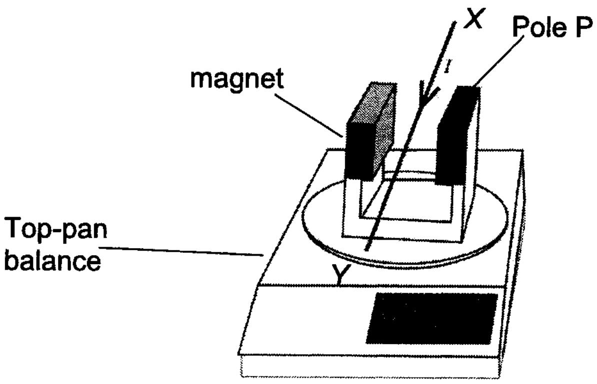


Fig. 5.1

The wire XY is horizontal and normal to the magnetic field.

A direct current is now passed through the wires in the direction from X to Y.
The reading on the top-pan balance increased.

State and explain the polarity of the pole P of the magnet.

....

....

....

....

....

.... [3]

[Turn over

(c) A charged particle of mass m and charge $+q$ travelling with velocity v in a vacuum. It enters a region of uniform magnetic field of flux density B as shown in Fig. 5.2.

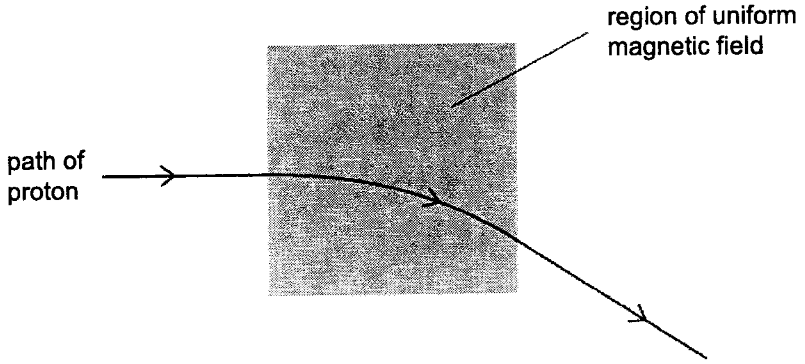


Fig. 5.2

A thin metal foil is placed in the magnetic field in **(c)**.
A second charged particle enters the region of the magnetic field. It loses kinetic energy as it passes through the foil.

The particle follows the path as shown in Fig. 5.3.

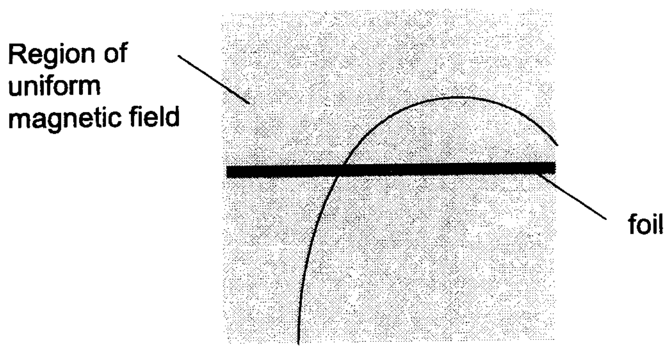


Fig. 5.3

(i) On Fig. 5.3, mark with an arrow the direction of travel of particle. [1]

(ii) The path of the particle has different radii on each side of the foil.
The radii are 7.4 cm and 5.7 cm.

Determine the ratio

$$\frac{\text{final momentum of particle}}{\text{initial momentum of particle}}$$

for the particle as it passes through the foil.

ratio = ... [2]

[Total: 8]

[Turn over

6 (a) Radon-220 ($^{220}_{86}Rn$), at rest, decays spontaneously to form polonium (Po). During this decay, an α-particle of kinetic energy 6.29 MeV and a γ-ray photon of energy 0.55 MeV are emitted.

(i) Write down the nuclear equation to represent the decay of a Radon-220 nucleus.

[2]

(ii) Calculate in joules the energy of 1.0 MeV.

energy = ... J [1]

(iii) Calculate, for this decay,

1. the mass equivalence of the energy released during the decay, and

mass = ... kg [2]

2. the wavelength of the emitted γ-ray photon.

wavelength = ... m [2]

(b) Measurements are made of the activity of a specimen of carbon from pieces of wood found in a fireplace at an archaeological site. The specimen is found to contain one Carbon-14 (C-14) atom per 8.6×10^{10} Carbon-12 (C-12) atoms. In a modern firewood, the concentration of C-14 atoms is one C-14 atom per 3.3×10^{10} C-12 atoms. The difference between these two figures is because C-14 is radioactive and some atoms have decayed over the years.

(i) The half-life of C-14 is 5700 years. C-12 is stable.
Calculate the age of the wood from the ancient fire.

age of the wood = ... years [3]

[Turn over

(ii) The technique of dating described above is difficult to carry out accurately. This difficulty can be minimised by using all the C-14 atoms rather than just those which happen to undergo radioactive decay when the dating is being carried out. Carbon atoms from the wood can be ionised by removing one electron from each atom. They are then formed into a beam which is passed through a magnetic field as shown in Fig. 7.1.

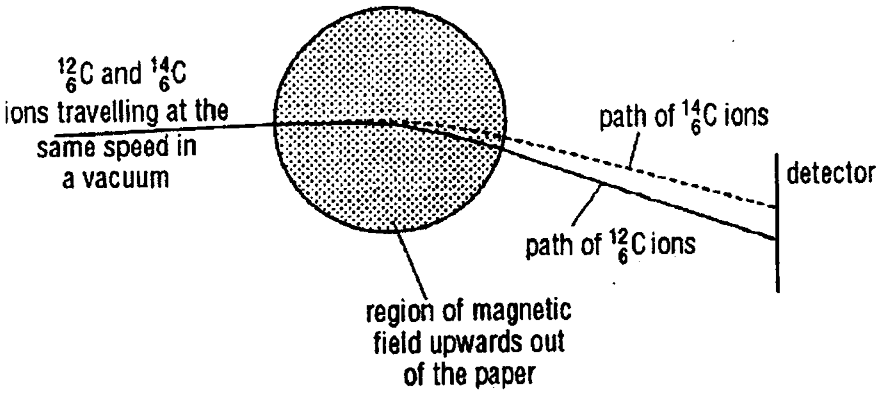


Fig. 7.1

1. Explain why the paths of the two types of ions are different.

....

....

....

.... [2]

2. Suggest why this method of measuring the ratio of C-14 to C-12 atoms is more reliable.

....

....

....

.... [2]

[Total: 14]

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7 In the first half of the last century, numerous experiments were conducted to investigate the absorption and scattering of X-rays by matter.

It was discovered that when a monochromatic beam of X-rays is incident on a light element such as carbon, the scattered X-rays have wavelengths dependent on the angle of scattering.

Compton (1923) assumed that the scattering process could be treated as an elastic collision between an X-ray photon and a 'free' electron, and that energy and momentum would be conserved.

(a) Explain what is meant by a *photon*.

....

....

.... [2]

(b) The elastic collision between a photon and a stationary electron may be represented as in Fig. 7.1.

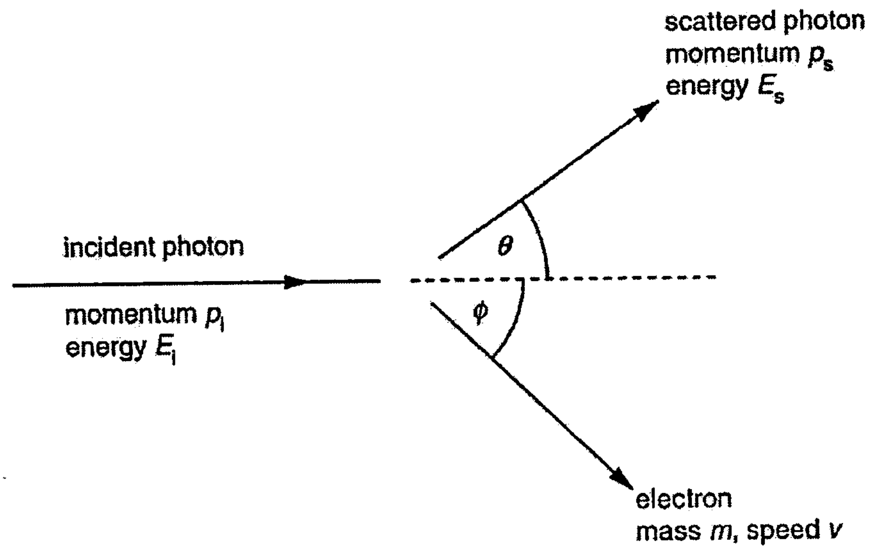

Fig. 7.1

The incident photon has momentum p_i and energy E_i. The photon is scattered through an angle θ and, after scattering has momentum p_s and energy E_s. The electron of mass m, which was originally stationary, moves off with speed v at an angle ϕ to the original direction of the incident photon.

(i) Write down equations, in terms of p_i, p_s, E_i, E_s, m, v, θ and ϕ, that represent, for this interaction,

1. conservation of energy,

.... [1]

2. conservation of momentum along the direction of the incident photon.

.... [1]

(ii) Suggest, with a reason, whether the scattered photon will have a wavelength that is greater or less than that of the incident photon.

....

....

....

.... [3]

(c) In an experiment to provide evidence to justify Compton's theory, measurements were made of the wavelength λ_i of the incident photon, the wavelength λ_s of the scattered photon and the angle θ of scattering. Some data from this experiment are given in Fig. 7.2.

λ_i / 10^{-12} m	λ_s /10^{-12} m	θ / °
191.92	193.27	57
153.30	154.65	57
965.04	966.84	75

Fig. 7.2

Use the data in Fig. 7.2 to show that, when a photon is scattered, the change in wavelength produced is independent of the wavelength of the incident photon.

....

....

.... [2]

[Turn over

(d) In this experiment, the uncertainty in the measurement of θ is $\pm 5°$.
Determine the value of $\cos\theta$, with its uncertainty, for the angle $\theta = 75° \pm 5°$.

$\cos\theta$ = ... ± .... [3]

(e) Compton's theory suggests that the change in wavelength $\Delta\lambda$ is related to the angle θ of the scattering by this expression

$$\Delta\lambda = k(1 - \cos\theta)$$

where k is a constant.

Experimental data for the variation with $\cos\theta$ of $\Delta\lambda$ are shown in Fig. 7.3.

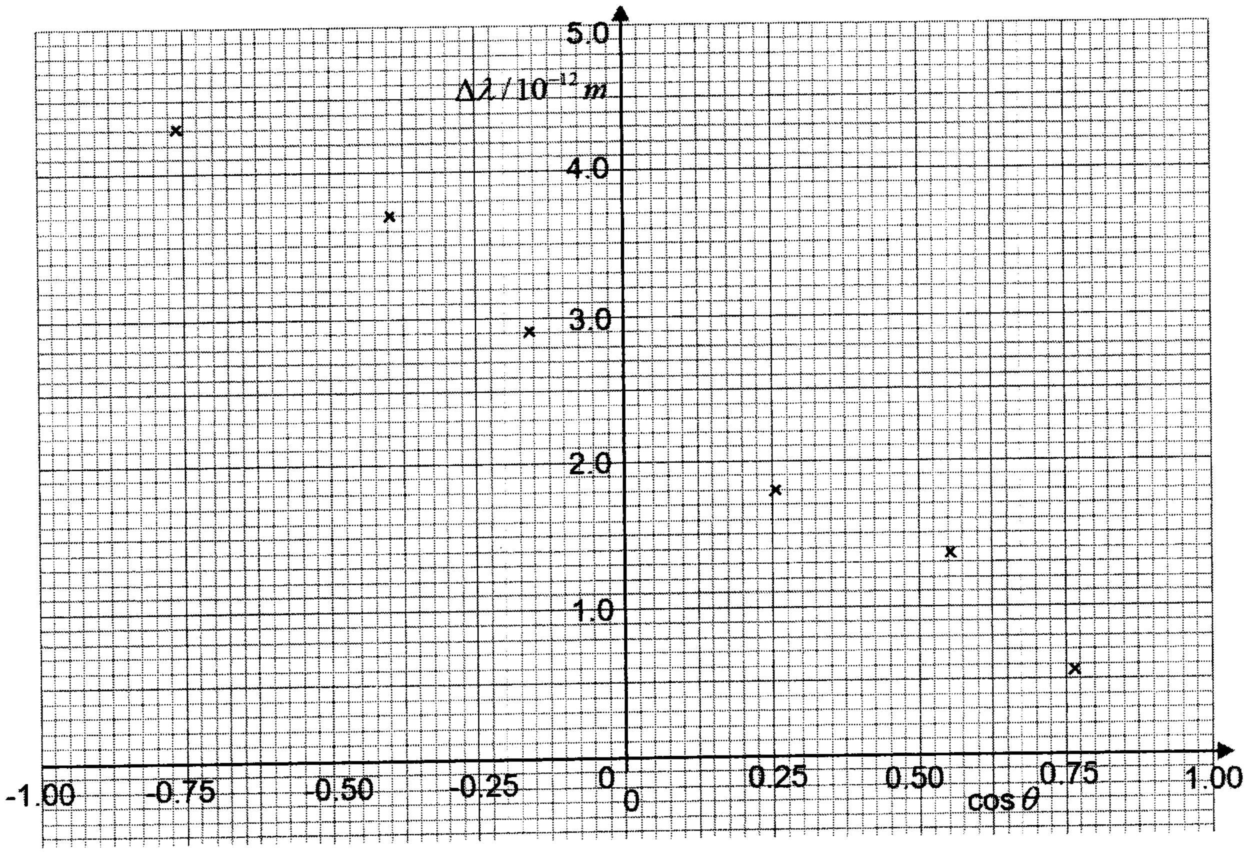

Fig. 7.3

(i) On Fig. 7.3, draw the best-fit line for the points. [1]

(ii) State and explain two different ways by which the constant k may be determined from the graph of Fig. 7.3.

....

....

....

.... [3]

(iii) Determine the constant k, with its unit.

k = ... [2]

(f) For a carbon atom, the binding energy of an electron is of the order of a few electronvolts.

Compton's theory assumes that the electrons are not bound in the atoms but are free.

Suggest whether, for 30 keV photons, this assumption is justified.

....

....

....

.... [2]

[Total: 20]

[Turn over

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NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2 PRELIMINARY EXAMINATION

Higher 2

CANDIDATE NAME	

SUBJECT CLASS		REGISTRATION NUMBER	

PHYSICS **9749/03**

Paper 3 Structured Questions

26 Aug 2022
2 hours

Candidate answers on the Question Paper.

No Additional Materials are required.

READ THE INSTRUCTION FIRST

Write your subject class, registration number and name in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a 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
Answers **all** questions.

Section B
Answer one question only.

You are advised to spend one and a 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 Examiner's Use	
Section A	
1	/ 10
2	/ 12
3	/ 14
4	/ 10
5	/ 6
6	/ 8
Section B	
7	/ 20
8	/ 20
Total (80)	

This document contains **24** printed pages and **4** blank pages.

[Turn over

Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(1/(36\pi)) \times 10^{-9}\,\mathrm{F\,m^{-1}}$
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 constant	$u = 1.66 \times 10^{-27}\,\mathrm{kg}$
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	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -Gm/r$
temperature	$T/\text{K} = T/°\text{C} + 273.15$
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	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

[Turn over

Section A

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

1 If an object is projected vertically upwards from the surface of a planet at a fast enough speed, it can escape the planet's gravitational field. This means that the object can arrive at infinity where it has zero kinetic energy. The speed that is just enough for this to happen is known as the escape speed.

(a) r is the distance from the centre of the planet.
On Fig 1.1, draw the variation with distance r of the kinetic energy E_K, gravitational potential energy E_P and the total energy E_T of this object from the surface of the planet.

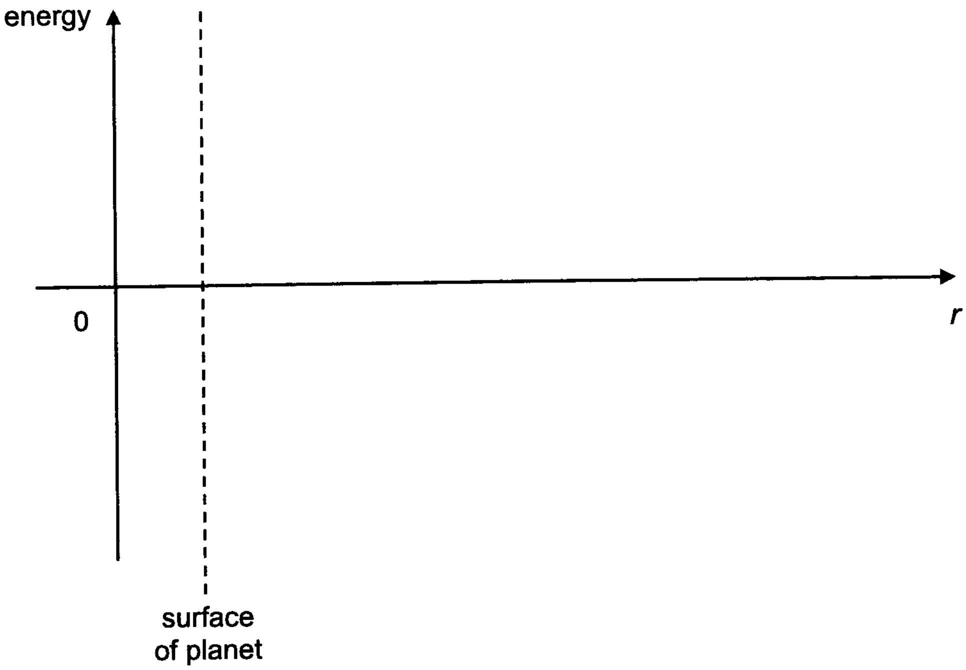

Fig. 1.1

[3]

(b) **(i)** By equating the kinetic energy of the object at the planet's surface to its total gain of potential energy in going to infinity, show that the escape speed v is given by

$$v^2 = \frac{2GM}{R}$$

where R is the radius of the planet and M is its mass.

[1]

(ii) Hence show that

$$v^2 = 2Rg$$

where g is the acceleration of free fall at the planet's surface.

[2]

(c) The mean kinetic energy E_k of an atom of an ideal gas is given by

$$E_k = \frac{3}{2}kT$$

where k is the Boltzmann constant and T is the thermodynamic temperature.

(i) Using the equation in **(b)(ii)**, estimate the temperature at the Earth's surface such that helium atoms of mass 6.6×10^{-27} kg could escape to infinity.

You may assume that helium gas behaves as an ideal gas and that the radius of Earth is 6.4×10^6 m.

temperature = ... K [3]

(ii) The temperature estimated in **(i)** is measured in thermodynamic scale. Explain what is absolute zero in the thermodynamic scale.

....

.... [1]

[Total: 10]

[Turn over

2 A container contains an ideal gas at a thermodynamic temperature T. The kinetic theory of gas assumes that the molecules of the gas behave as hard, identical spheres that are in continuous random motion. The theory shows that

- the pressure exerted on the wall of the container by the gas is due to the elastic collisions of the molecules with the wall of the container
- the pressure is proportional to the mean-square speed of the molecules
- the mean translational kinetic energy of a molecule is $E_K = \frac{3}{2}kT$ where k is the Boltzmann constant.

(a) Explain why the internal energy of the gas is equal to the total kinetic energy of the molecules of the gas.

....

....

....

....

....

.... [3]

(b) A container with 1.2 mol of an ideal gas. The gas has a mass of 0.0384 kg.

During the heating of the gas,

- the volume of the gas increases (the container does not have a fixed volume)
- the pressure of the gas remains constant
- the temperature of the gas changes from 280K to 460K
- the gas does 1.3×10^3 J of work.

(i) Explain, in terms of the force produced by the molecules of the gas, how the pressure remains constant as the volume increases.

....

....

....

....

....

....

....

.... [3]

(ii) Use the first law of thermodynamics to determine the specific heat capacity of the gas.

specific heat capacity = ... J kg^{-1} K^{-1} [4]

(c) The container in **(b)** is now replaced with one that has a fixed volume. Thermal energy is supplied to the gas to increase its temperature from 280K to 460K.

Suggest, with a reason, how the specific heat capacity of the gas would now compare with the value in **(b)(ii)**.

....

....

....

.... [2]

[Total: 12]

[Turn over

3 Hydrogen gas at low pressure can be made to emit photons in a discharge tube using a high voltage supply, as shown Fig. 3.1.

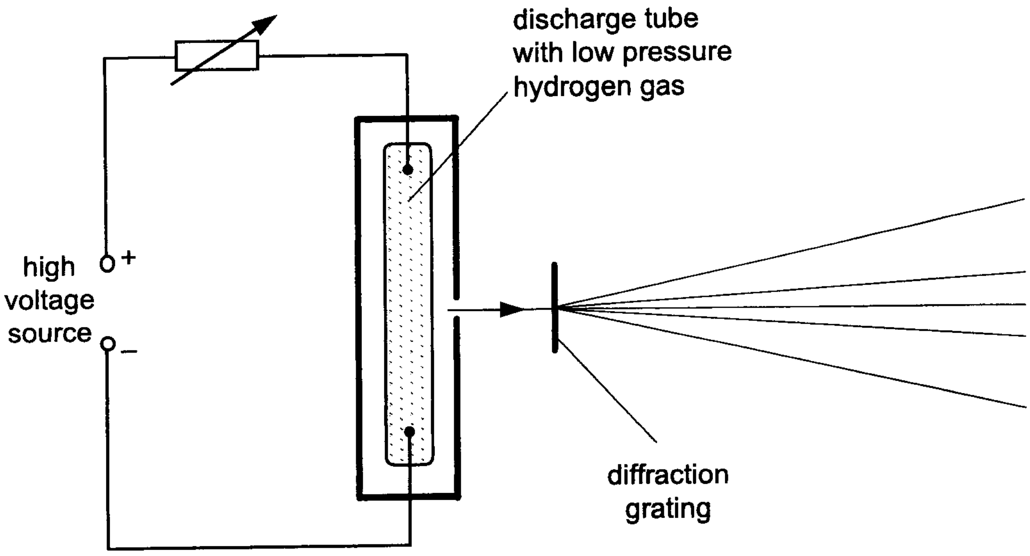

Fig. 3.1

The photons are incident normally on a diffraction grating and projected on a screen.

An emission line spectrum is observed.

(a) Explain what is meant by emission line spectrum.

....

.... [1]

(b) Explain how the line spectrum of the hydrogen provides evidence for the existence of discrete energy levels in atoms.

....

....

....

....

....

.... [3]

(c) Some electron energy levels in atomic hydrogen are illustrated in Fig. 3.2.

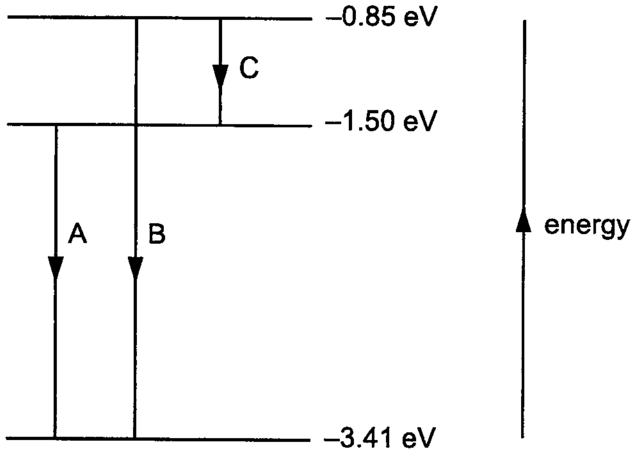

Fig. 3.2 (not to scale)

The electron transitions A and B cause light of visible wavelengths 654 nm and 488 nm to be emitted.

Explain why the third transition C in Fig. 3.2 cannot be observed.

....

....

....

.... [3]

(d) The central maximum and the first order maxima of the two visible wavelengths from the hydrogen gas in **(c)** on the screen is shown in Fig. 3.3.

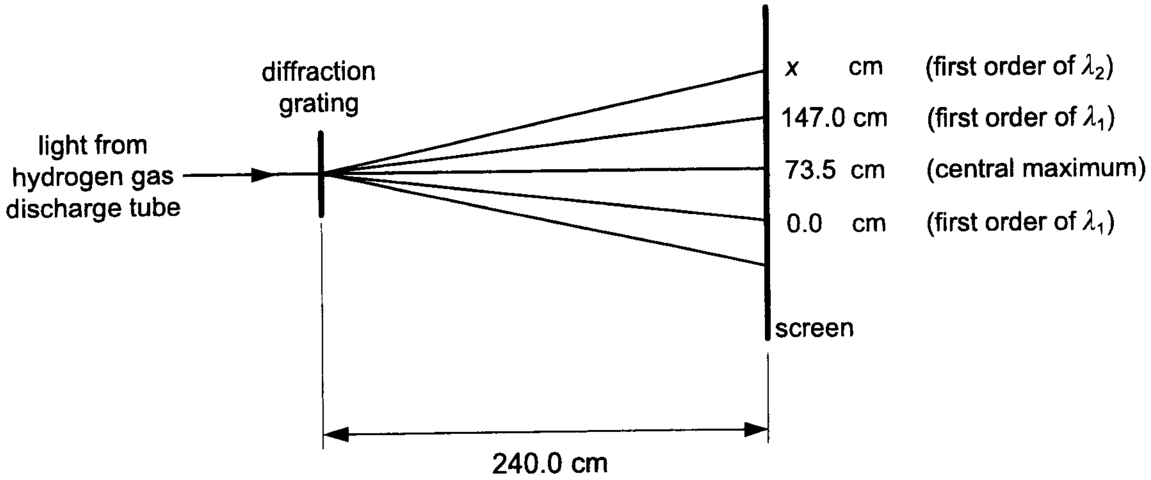

Fig. 3.3 (not to scale)

The screen is placed 240.0 cm from the diffraction grating.
The maxima positions on a scale on the screen is shown.

(i) Explain how the diffraction and the interference of light at the diffraction grating leads to the first order maxima for λ_1.

....

....

....

.... [3]

(ii) Determine the position x on the scale for λ_2.

x = ... cm [4]

[Total: 14]

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[Turn over

4 (a) State what is meant by the *photoelectric effect.*

....

....[1]

(b) Use the theory of the particulate nature of electromagnetic radiation to explain why there is a threshold frequency for the photoelectric effect.

....

....

....

....

....

....[3]

(c) A circuit was used to investigate the photoelectric effect as shown in Fig. 4.1

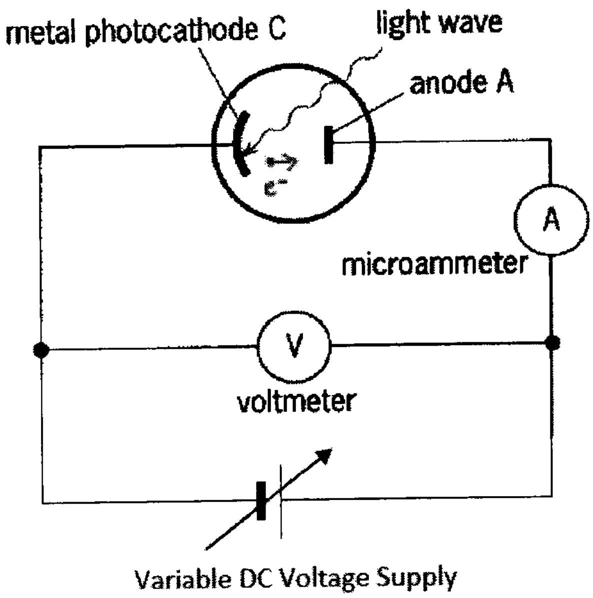

Fig 4.1

The variation with potential difference V of current I is shown in Fig. 4.2

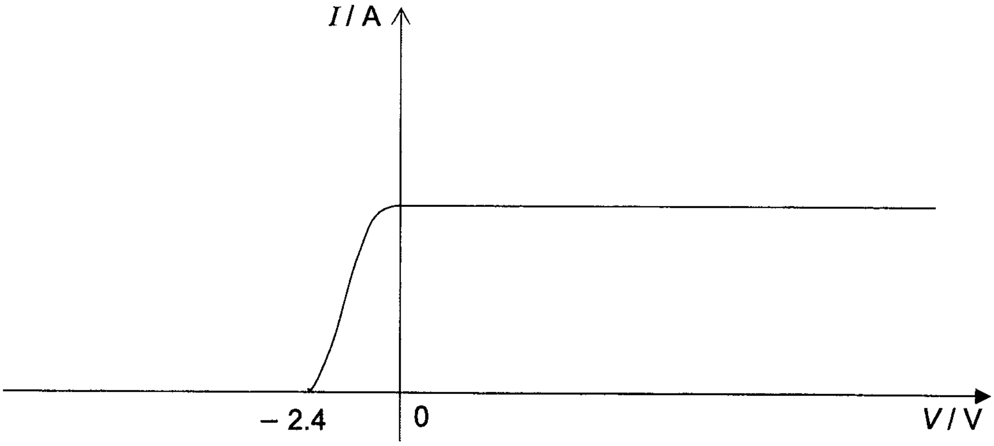

Fig. 4.2

(i) Explain why there is a minimum stopping potential difference V_s to reduce the current to zero.

....

....[1]

(ii) Explain why the current does not continue to increase for positive values of V.

....

....[1]

(iii) The work function of anode A is 1.6 eV. Use Fig. 4.2 to calculate the frequency of the electromagnetic radiation used.

frequency = ... Hz [2]

(iv) The frequency of the electromagnetic radiation is kept constant as its intensity is doubled. On Fig. 4.2 sketch a graph to show the variation with V of I for this increase in intensity. [2]

[Total: 10]

[Turn over

5 A long straight wire carries a steady direct current. A circular loop of conducting wire is placed directly below the straight wire such that the wire is in the plane of the loop.

The loop falls vertically due to gravity from the wire as shown in Fig. 5.1.

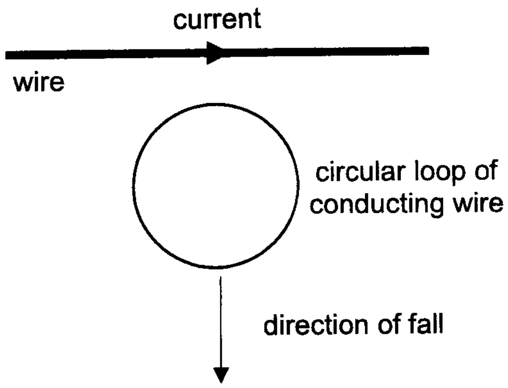

Fig 5.1

(a) **(i)** Explain why an e.m.f. is induced in the loop.

....

....

....

.... [2]

(ii) Determine and explain the direction of induced current in **(i)**.

....

....

....

....

....

.... [3]

(b) The circular loop has a radius of 5.0 cm, The magnetic flux density within the loop decreases from 120 mT to 30 mT in 0.040 s.

Show the magnitude of the average e.m.f. induced in the loop during this time is 18 mV.

[1]

[Total: 6 m]

[Turn over

6 The variation with time t of the sinusoidal current I in a resistor 450 Ω is shown in Fig. 6.1.

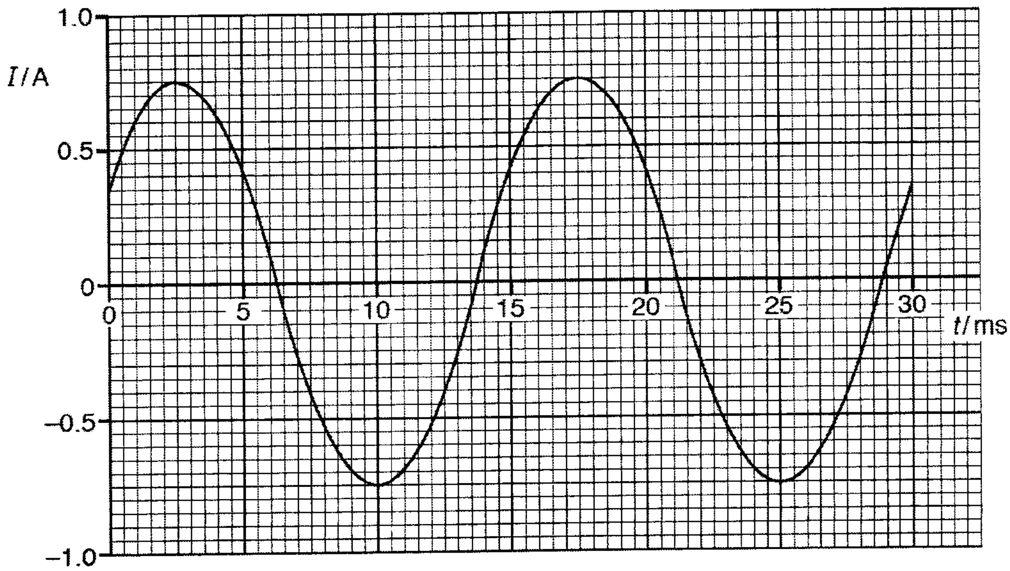

Fig. 6.1

Use data from Fig. 6.1 to determine, for the time t = 0 to t = 30 ms,

(i) the frequency of the current,

frequency = ... Hz [2]

(ii) the root-mean-square (r.m.s) current,

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

(iii) the energy dissipated by the resistor.

energy = ... J [2]

(iv) The average current in the resistor is zero.

Explain why there is a heating effect in the resistor.

....

....

....

....[2]

[Total: 8]

[Turn over

Section B

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

7 (a) Explain what is meant by a *progressive longitudinal wave*

Progressive ....

....

Longitudinal ....

....[2]

(b) Fig. 7.2 shows the variation of displacement *y* with time *t* of a sound wave incident on a person's ear drum.

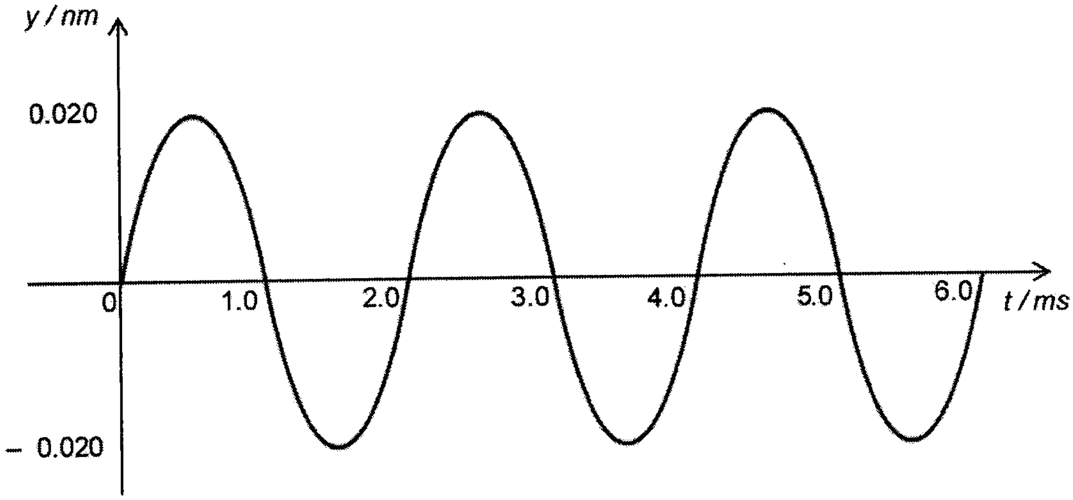

Fig. 7.2

Assume that the eardrum vibrates with simple harmonic motion and with the same frequency and amplitude as the incident sound wave.

(i) Determine the amplitude and frequency of the oscillating eardrum.

amplitude = ... m [1]

frequency = ... Hz [1]

(ii) Show maximum speed of the oscillating eardrum is 6.3×10^{-8} m s^{-1}.

[1]

(iii) Determine the mass of a human eardrum if the maximum kinetic energy of the oscillating eardrum is 2.4×10^{-19} J.

mass = ... kg [2]

(iv) On the axes of Fig. 7.3, sketch a clearly labelled graph to show the variation of the velocity of the ear drum *v* with displacement *y*.

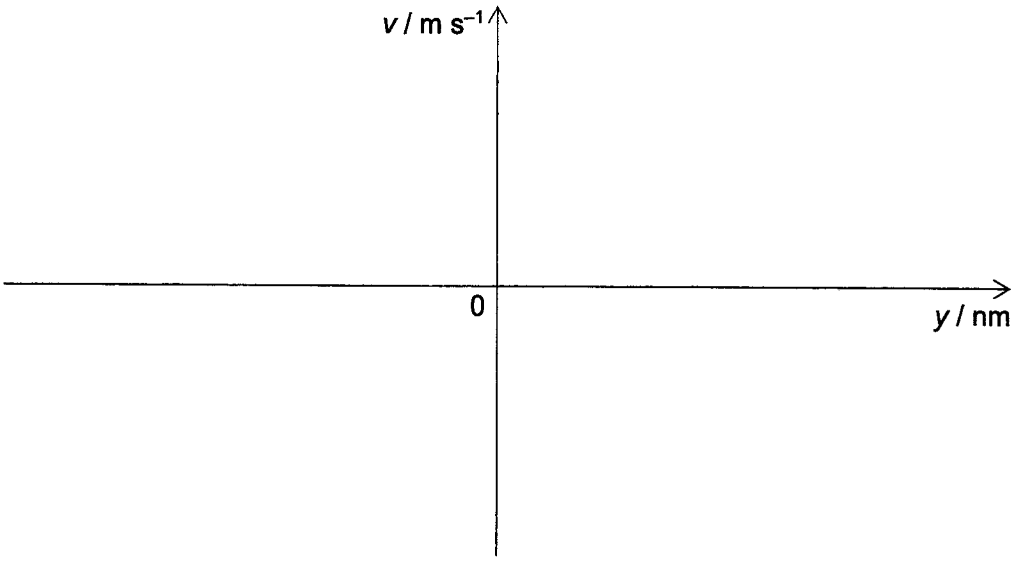

Fig. 7.3

[2]

(c) Hummingbirds can hover around flowers by beating their wings at a frequency between 20 and 80 times per second. It can be assumed that the air molecules around the birds vibrate at the same frequency.

(i) Deduce why a person standing near a hovering hummingbird may hear a buzzing sound.

....

....

....

.... [2]

[Turn over

(ii) A bird watcher is initially 2.0 m from a hummingbird. To pick up a louder buzz, the bird watcher moves nearer to the bird by a distance x. Determine the value of x, in metres, for an increased intensity of 60%.

x = ... m [3]

(iii) It is assumed that for a hummingbird which beats its wings at 75 times per second, the air molecules around it can vibrate in simple harmonic motion at an amplitude of 5.0×10^{-9} m. Calculate the distance covered by an air molecule over the duration in which the hummingbird beats its wings for 1800 times.

distance = ... m [2]

(iv) Another bird watcher dislikes the buzzing sound and uses noise-cancelling technology to generate certain frequencies to cancel out the buzzing sound. Explain how the generation of such frequencies could cancel out the buzzing sound.

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....

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....[4]

[Total:20]

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[Turn over

8 (a) (i) Force-fields may be represented using lines that have direction. Conventionally, arrows on the field lines define the direction of a force acting on a test object.

State the property of the object that experiences a force in this direction for

1. gravitational field,

....[1]

2. an electric field

....[1]

(ii) Suggest why, when defining electric field strength, the object must be stationary.

....

....[1]

(b) Two long wires *X* and *Y* carrying the same current 290 A but in opposite direction is placed parallel to each other as shown in Fig. 8.1. Distance between each wire is 5.0 cm.

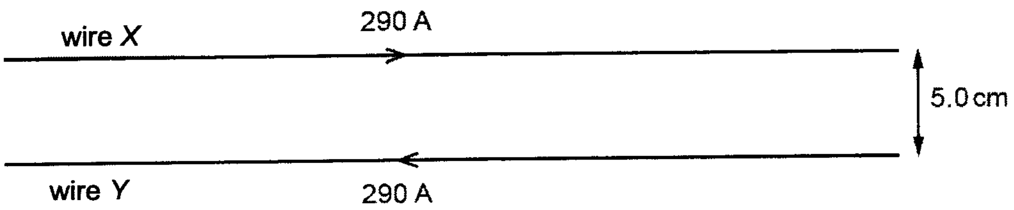

Fig. 8.1

(i) Show that the magnitude of magnetic flux density at wire *X* is 1.2×10^{-3} T.

[1]

(ii) Calculate the force per unit length on wire *X*.

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

(c) An electron is halfway between the wires *X* and *Y* in **(b)**, travelling at a speed of 2.9×10^7 m s^{-1} parallel to the wires as shown in Fig. 8.2.

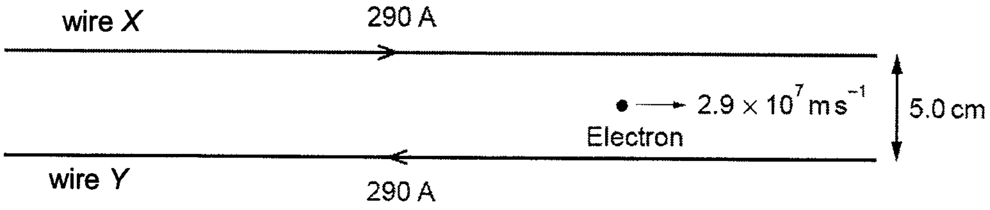

Fig. 8.2

(i) The magnetic flux density halfway between the wires is 4.64 mT. Show that the resultant force acting on the electron is 2.2×10^{-14} N.

Explain your working.

[2]

(ii) A student claims that this electron will perform a circular motion between the wires.

Explain why the student's claim is incorrect.

....

....

....

....[2]

(iii) Sketch the motion of the electron in Fig. 8.3.

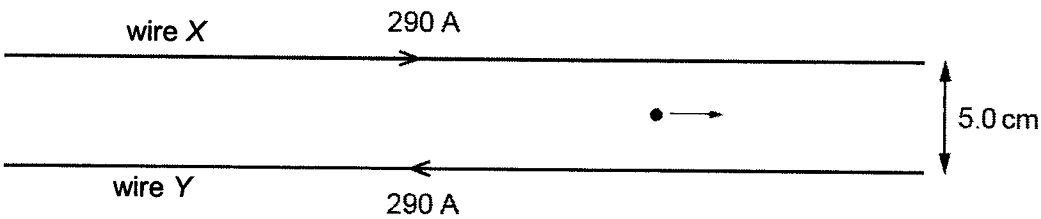

Fig. 8.3

[1]

[Turn over

(d) Suppose that an electron travels in a region with a magnetic field and an electric field due to two parallel metal plates as shown in Fig. 8.4.

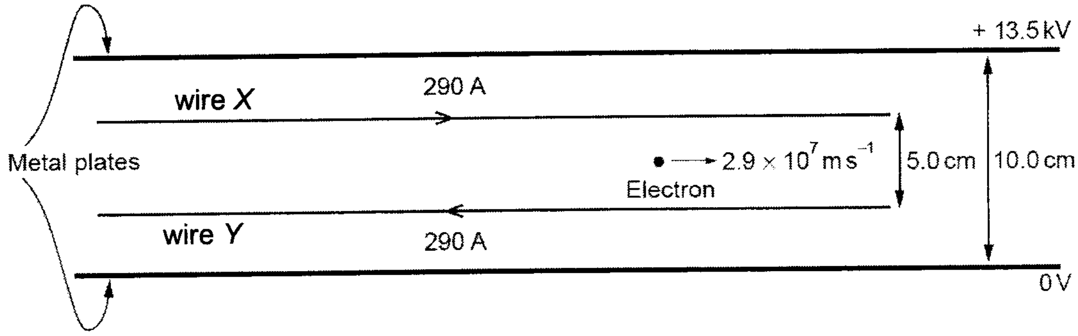

Fig. 8.4

Deduce whether the electron continues with constant velocity.

....[2]

(e) Assume that the Earth is an isolated perfect sphere as shown in Fig. 8.5, draw its gravitational field lines with solid line and equipotential surfaces with dashed line.

Fig. 8.5

[3]

[Turn over

(f) The Earth E and the Moon M can be considered as isolated point masses at their centres. The mass of the Earth is 5.98×10^{24} kg and the mass of the Moon is 7.35×10^{22} kg. The Earth and Moon are separated by a distance of 3.84×10^5 km as shown in Fig. 8.6.

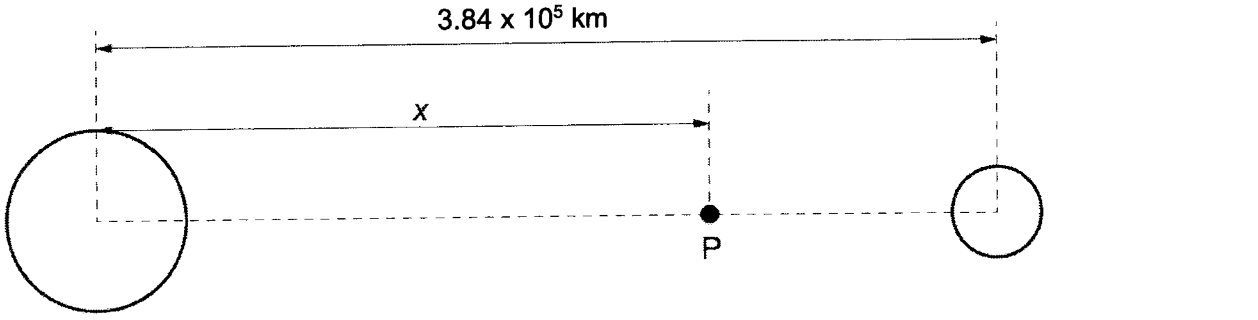

Fig. 8.6 (not to scale)

Point P is a point along the line joining the centres of E and M, where the resultant gravitational field strength is zero. Point P is at a distance x from centre of the Earth.

(i) Show that x is approximately 3.5×10^8 m.

[2]

(ii) The resultant force on a 2.5×10^4 kg spaceship is zero at point P. The force would increase by approximately 0.50 N for every 10 km moved away from point P towards the Earth.

A student claims that the spaceship will perform simple harmonic motion about point **P.** Deduce whether or not the student's claim is correct. (No further calculations are required.)

....

....

....

....[2]

[Total: 20 m]

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NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2 PRELIMINARY EXAMINATION

Higher 2

CANDIDATE NAME	

SUBJECT CLASS		REGISTRATION NUMBER	

PHYSICS **9749/04**

Paper 4 Practical

18 Aug 2022
2 hours 30 minutes

Candidates answer on the Question Paper.

Additional Materials: As listed in the Confidential Instructions

READ THE INSTRUCTION FIRST

Write your subject class, registration number and name in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams, graphs or rough workings.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions.

Write your answers in the spaces provided on the question paper.
The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

Give details of the practical shift and laboratory, where appropriate, in the boxes provided.

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.

Shift
Laboratory

For Examiner's Use	
1	
2	
3	
4	
Total	

This document contains **18** printed pages and **2** blank pages.

[Turn over

1 In this experiment, you will investigate an electrical circuit.

(a) **(i)** Set up the circuit shown in Fig. 1.1.

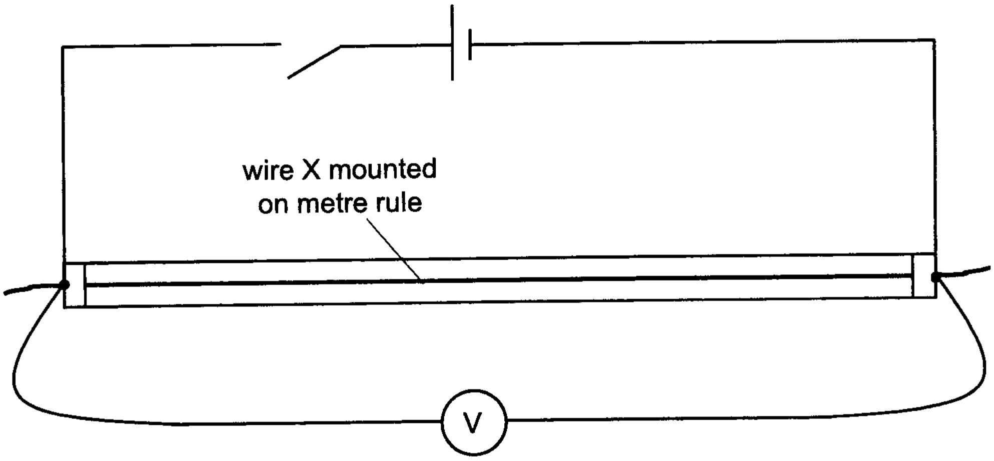

Fig. 1.1

(ii) Close the switch.

Record the voltmeter reading *V*.

V = ... [1]

Open the switch.

(iii) Calculate $\frac{V}{2}$.

$\frac{V}{2}$ = ...

[Turn over

(b) **(i)** Set up the circuit shown in Fig. 1.2.

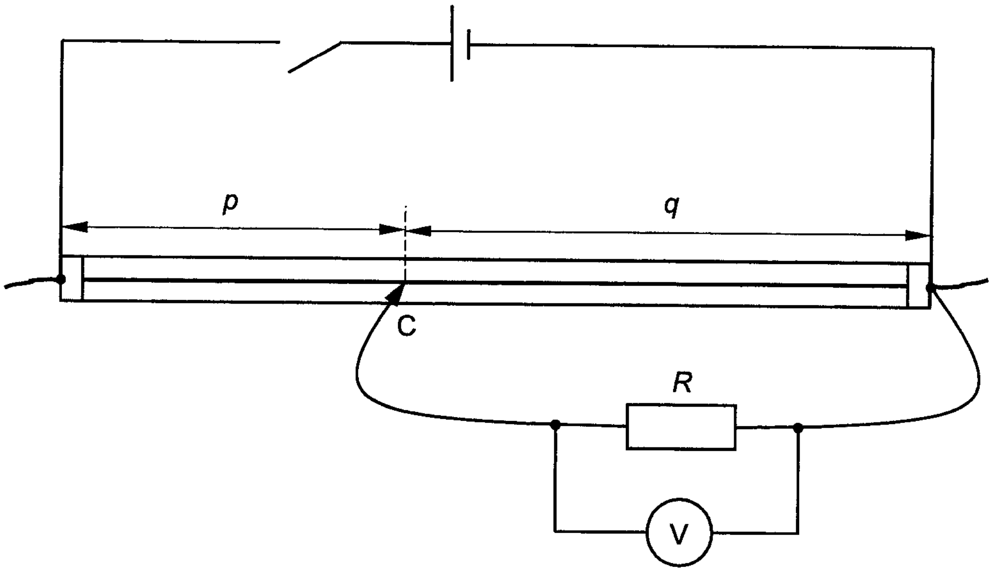

Fig. 1.2

The value of R should be 10 Ω.

(ii) Close the switch.

Move crocodile clip C along the wire until the voltmeter reading is equal to your value for $\frac{V}{2}$ in **(a)(iii)**.

(iii) Measure and record the distances p and q as shown in Fig. 1.2.

p = ...

q = ...

[1]

(iv) Open the switch.

(c) Using one resistor at a time, vary R and repeat **(b)(ii)**, **(b)(iii)** and **(b)(iv)** until you have six sets of readings of p, q and R. You must include your results from **(b)**.

Record your results in a table. Include values of $\frac{q}{p}$ and $\frac{q}{R}$ in your table.

[5]

(d) The quantities p, q and R are related by the equation

$$\frac{q}{p} = \frac{aq}{R} + b$$

where a and b are constants.

(i) Plot a graph of $\frac{q}{p}$ against $\frac{q}{R}$. [3]

(ii) Determine the gradient of this line.

gradient = ... [1]

(e) Theory suggests that the resistivity ρ of the wire X can be determined by

$$\rho = \sigma a$$

where σ is the cross sectional area of the wire.

Take measurements to determine the value of ρ.

ρ = ... Ω m [3]

[Total: 14]

[Turn over

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2 In this experiment, you will investigate the patterns produced by overlaid grids.

(a) You have been provided with a grid (labelled grid A) printed on a A4 paper.

Take measurements to determine the average spacing s_A between the centres of the lines on grid A.

s_A = ... mm [2]

(b) You have been provided with a second grid (labelled grid B) printed on a transparent sheet.

Place grid B on top of grid A.

Turn grid B so that angle G is 10° between the grids. A pattern of fringes will be produced, as shown in the example in Fig. 2.1.

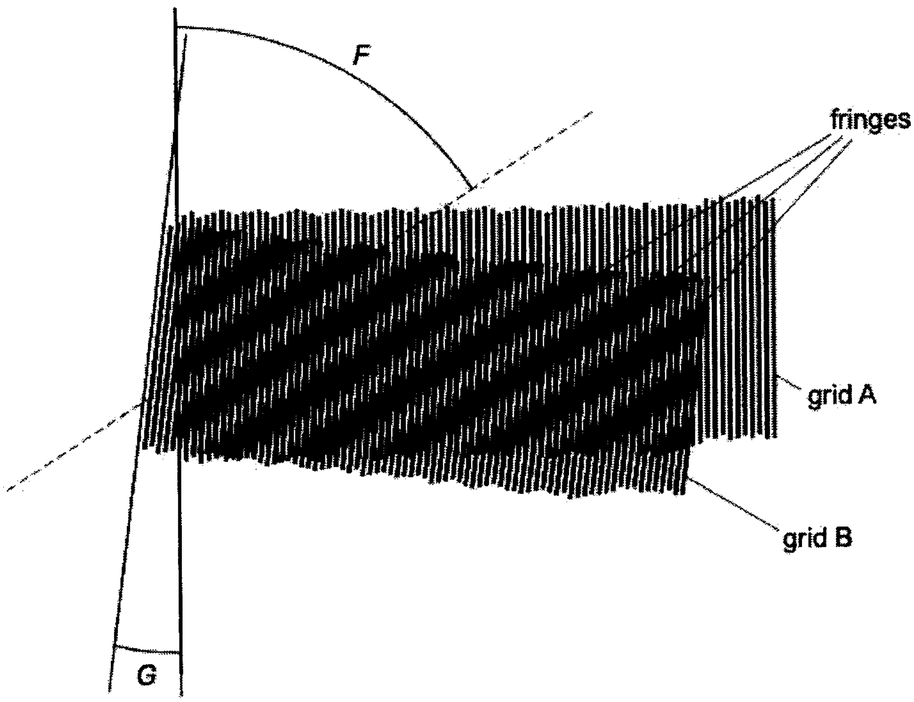


Fig. 2.1

The fringes make an angle F with grid A.

Take measurements with the two grids provided and do not write on them. Do not take measurements from Fig. 2.1.

Measure and record your value of F.

F = ... °
[1]

(c) The quantities F and G are related by the equation

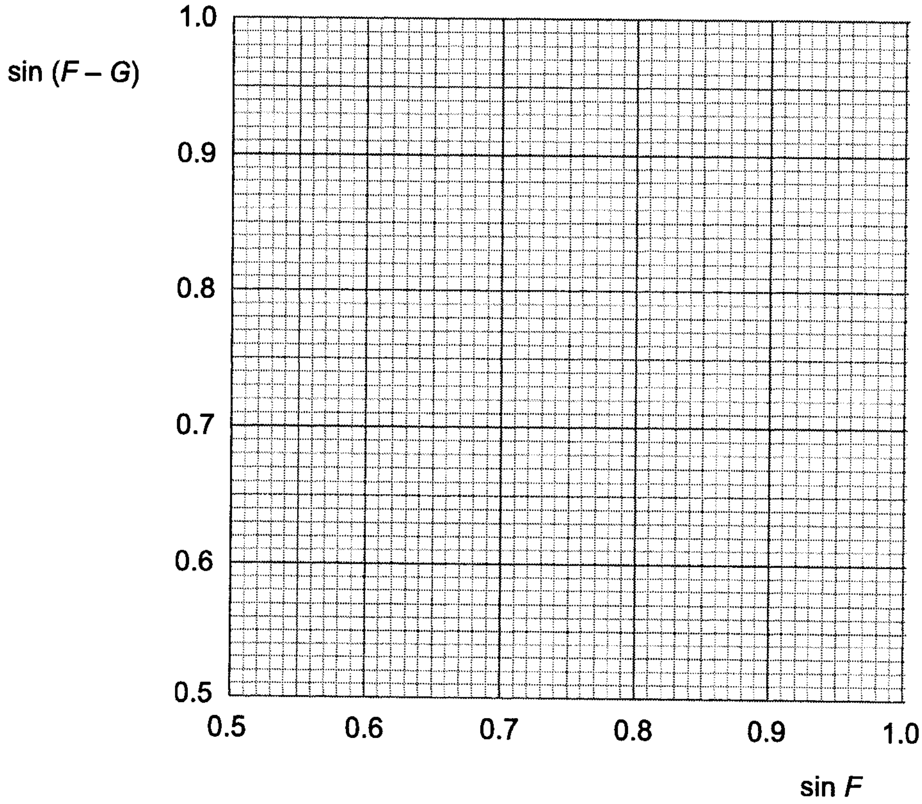
$$\sin(F - G) = p \sin F + q$$

where p and q are constants.

(i) Complete the table below. [1]

G / °	5	8	10	12	15
F / °	38	55		65	72
$\sin F$	0.62	0.82		0.91	0.95
$\sin(F - G)$	0.54	0.73		0.80	0.84

(ii) Plot $\sin(F - G)$ against $\sin F$ on the grid and draw the straight line of best fit. [1]



(iii) Explain why, in theory, your graph should pass through the point (0, 0).

....

....

....

.... [2]

[Total: 7]

[Turn over

3 The swinging spring system is a simple mechanical system that exhibits complex dynamics. The swinging spring consists of a heavy mass suspended from a light spring and it can oscillate in two different ways – vertical motion and swinging motion like a pendulum.

There is an interesting special case when the frequency of the vertical oscillations is twice that of the swinging oscillations. The system is in resonance where energy is transferred back and forth between vertical and swinging oscillations.

In this experiment, you will investigate the oscillations of a swinging spring system.

(a) Set up the apparatus as shown in Fig. 3.1 using the silver spring.

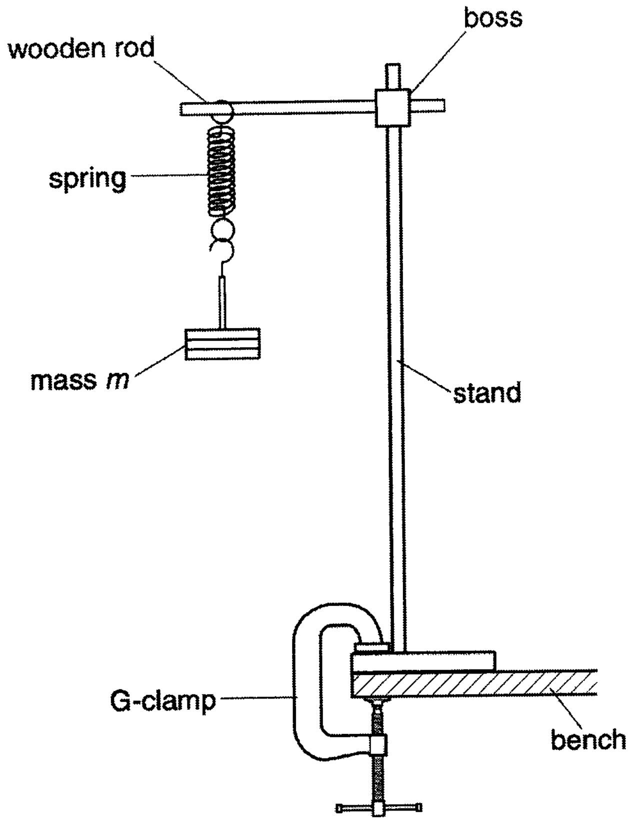


Fig. 3.1

The value of m should be 300 g.

The retort stand **must be secured to the bench with the G-clamp** provided.

(b) **(i)** Record m.

m = ... kg

(ii) Pull the mass hanger down through a short distance.

Release the mass hanger and watch the vertical oscillations.

(iii) Take measurements to determine the period T of the vertical oscillations.

Record T.

T = ... [2]

(c) **(i)** Calculate the value of l using the equation

$$l = \frac{gT^2}{\pi^2}$$

where $g = 9.81\ \text{m s}^{-2}$.

l = ...m [1]

(ii) Justify the number of significant figures that you have given for your value of l.

....

....

.... [1]

[Turn over

(d) **(i)** Set up the apparatus shown in Fig. 3.2 using some of the string.

The length *d* is the distance from the top of the string to the centre of the masses.

Tie knots so that length *d* is approximately equal to your calculated value of *l*.

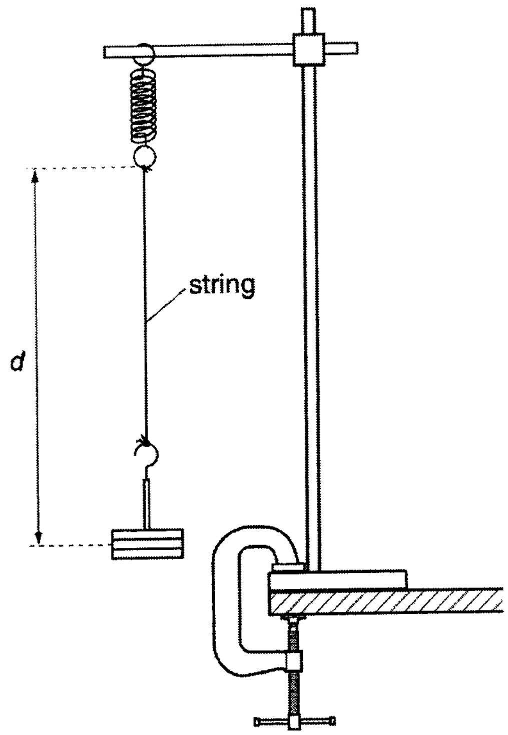


Fig. 3.2

(ii) Measure and record *d*.

d = ...m [1]

(iii) Estimate the percentage uncertainty in your value of *d*.

percentage uncertainty = ... [1]

(e) **(i)** Displace the mass approximately 10 cm to the right.

Release the mass. The mass will move to the left and back again.

Now ignore the movement of the mass and **watch the coils of the spring**.

Observe the coils moving further apart, then closer, further apart then closer.

At certain times the coils appear to stay the same distance apart.

(ii) Determine the time interval *t* between two consecutive times when the coils appear to stay the same distance apart.

Record *t*.

t = ... [1]

(iii) Remove the string from the mass and spring.

(f) Using a mass *m* of 400 g, set up the apparatus as shown in Fig. 3.1.
Repeat **(b)**, **(c)(i)**, **(d)(i)**, **(d)(ii)** and **(e)**.

m = ... kg

T = ...

l = ...

d = ...

t = ...

[2]

[Turn over

(g) It is suggested that the relationship between t and m is

$$t = \alpha\sqrt{m}$$

where α is a constant.

(i) Using your data, calculate two values of α.

first value of α = ...

second value of α = ...
[1]

(ii) State whether or not the results of your experiment support the suggested relationship. Justify your conclusion by referring to your values in **(d)(iii)**.

....

....

....

.... [1]

(h) **(i)** Describe how you could make use of the apparatus provided in this question to determine the force constant *k* of the silver and the black springs.

....

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.... [3]

(ii) Determine the force constant *k* of the two springs.
Present your results and conclusion clearly.

force constant *k* of silver spring = ... $N\ m^{-1}$

force constant *k* of black spring = ... $N\ m^{-1}$

[3]

[Turn over

(iii) The time interval t depends on m and k only. The relationship in **(g)** can therefore be extended.

The equation relating t, m and k is

$$t = \beta \, k^{p} \sqrt{m}$$

where β and p are dimensionless constants.

By considering the homogeneity of the equation, determine the value of p.

p = ... [2]

(iv) By taking relevant measurements, comment whether the **trend** of t due to k is described by the equation in **(h)(iii)**.

*Note: You are not required to show your results satisfy the equation in **(h)(iii)** exactly.*

....

....

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.... [3]

[Total: 22]

[Turn over

4 A student is investigating the motion of magnets falling through a vertical copper pipe as shown in Fig. 4.1.

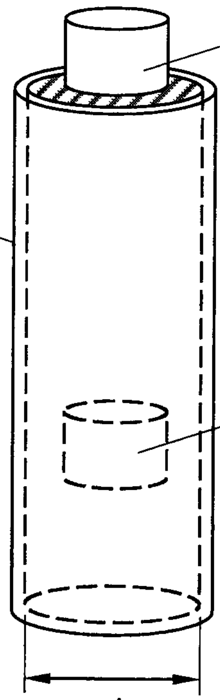

Fig. 4.1

The magnet is released from rest just above the pipe. For a sufficiently long pipe, the magnet will reach terminal speed v inside the pipe before leaving the pipe.

It is suggested that v is related to the magnetic flux density B at the ends of the magnet and the internal diameter d of the pipe by

$$v = kB^m d^n$$

where k, m and n are constants.

Design an experiment to determine the values of m and n.

You are provided with

- cylindrical magnets of the same dimensions and mass but different flux density B at the ends
- copper pipes of the same thickness with different internal diameters (you may assume that the length of the pipes is sufficient for all the magnets to reach terminal velocity).

Draw a diagram to show the arrangement of your apparatus. Pay particular attention to:

(a) the equipment you would use
(b) the procedure to be followed
(c) the control of variables
(d) any precautions that should be taken to improve the accuracy and safety of the experiment.

[Turn over

Diagram

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[Turn over

[12]

[Total: 12]

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