Anglo-Chinese Junior College

Physics Preliminary Examination
Higher 2

A Methodist Institution
(Founded 1886)

PHYSICS **9749/01**

Paper 1 Multiple Choice

14 September 2022
1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name and index number on the Answer Sheet provided.

There are **thirty** questions in this section. 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 Question Paper.
The use of an approved scientific calculator is expected, where appropriate.

DATA AND FORMULAE

Data

speed of light in free space,	c	$= 3.00 \times 10^{8}$ m s^{-1}
permeability of free space,	μ_o	$= 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	$= 8.85 \times 10^{-12}$ 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,	$p = \rho g h$
gravitational potential,	$\phi = -\frac{Gm}{r}$
temperature	$T/\text{K} = T/^\circ\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule,	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.,	$x = x_o \sin \omega t$
velocity of particle in s.h.m.,	$v = v_o \cos \omega t$
	$= \pm\omega\sqrt{x_o^2 - x^2}$
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,	$V = \frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage,	$x = x_o \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_o n I$
radioactive decay,	$x = x_o \exp(-\lambda t)$
decay constant,	$\lambda = \frac{\ln 2}{t_{1/2}}$

1 Which estimate is **not** realistic?

A The power of a computer laptop is 50 W.

B The kinetic energy of a car is 100 MJ.

C The mass of a sheet of A4 paper is 5 g.

D The heating element of an iron has a temperature of 500 K.

2 A cannon ball is launched at an angle θ above the horizontal with an initial kinetic energy E. Assume air resistance is negligible.

What is the kinetic energy of the cannon ball at the top of its trajectory?

A $E\cos\theta$ **B** $E\sin^2\theta$ **C** $E\cos^2\theta$ **D** E

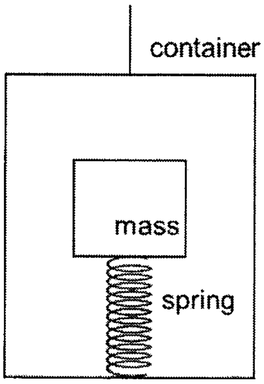
3 In the presence of air resistance, a cyclist and his bicycle of total mass 80.0 kg is able to coast down a smooth slope at a constant speed of 1.4 m s^{-1} as shown below.

The air resistance is directly proportional to the cyclist's speed.

What is the additional force that the cyclist must apply in order to descend the same slope at a steady speed of 5.5 m s^{-1}?

A 200 N **B** 340 N **C** 2200 N **D** 3800 N

4 A light spring of natural length 10.0 cm is attached to the floor of a container. A mass is placed on top of the spring.

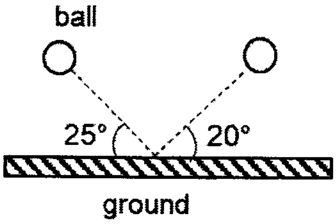


When the container is lifted upwards at a constant speed, the length of the spring is 7.5 cm. The container then moves upwards with a constant deceleration of 2.0 m s^{-2}.

What is the new length of the spring?

A 7.0 cm **B** 8.0 cm **C** 12.0 cm **D** 13.0 cm

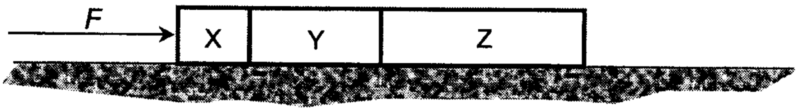
5 A ball of mass 140 g is moving towards the ground at an angle of 25°. It hits the ground at 20 m s^{-1} and bounces off with a speed of 15 m s^{-1} at an angle of 20°.



What is the magnitude of the impulse exerted on the ball?

A 1.9 N s **B** 2.0 N s **C** 4.9 N s **D** 32 N s

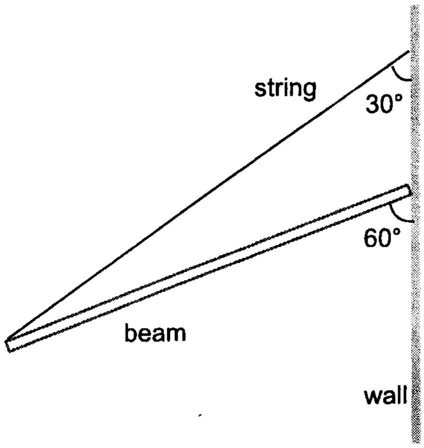
6 Three blocks X, Y and Z of masses m, $2m$ and $3m$ respectively, are accelerated along a smooth horizontal surface by a force F applied to block X as shown in the diagram below.



What is the force exerted on Y by X?

A $\frac{1}{6}F$ **B** $\frac{1}{2}F$ **C** $\frac{5}{6}F$ **D** F

7 A uniform beam of 10 kg is resting against a rough wall at an angle of 60° to it as shown in the figure below. It is attached to an inextensible string which is fixed to the wall at an angle of 30° to the vertical.

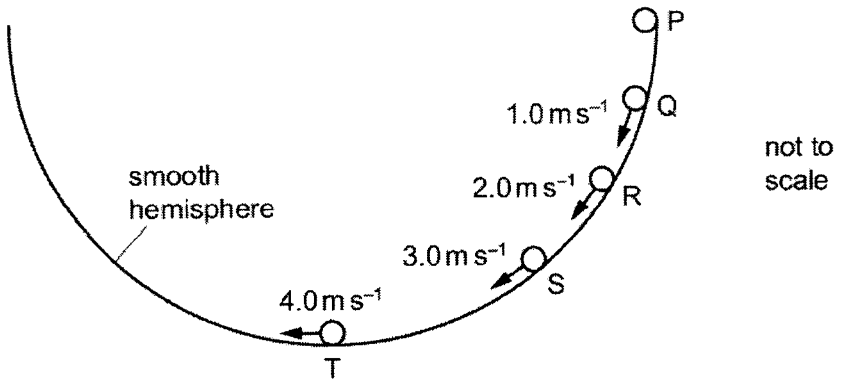


What is the tension *T* in the string?

A 85 N **B** 110 N **C** 130 N **D** 170 N

8 A small mass is placed at point P on the inner surface of a smooth hemisphere as shown in the diagram below. It has an initial gravitational potential energy *E* and is released from rest at point P. The mass has a speed of 4.0 m s^{-1} when it reaches the lowest point at T. Take the gravitational potential energy at T to be 0.

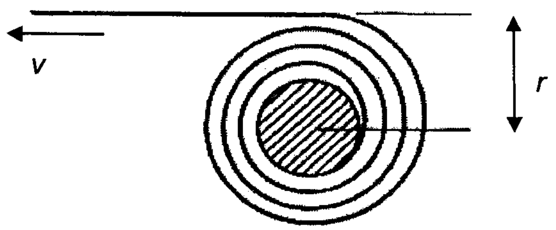
The diagram shows the speeds of the mass at points Q, R and S as it slides down.



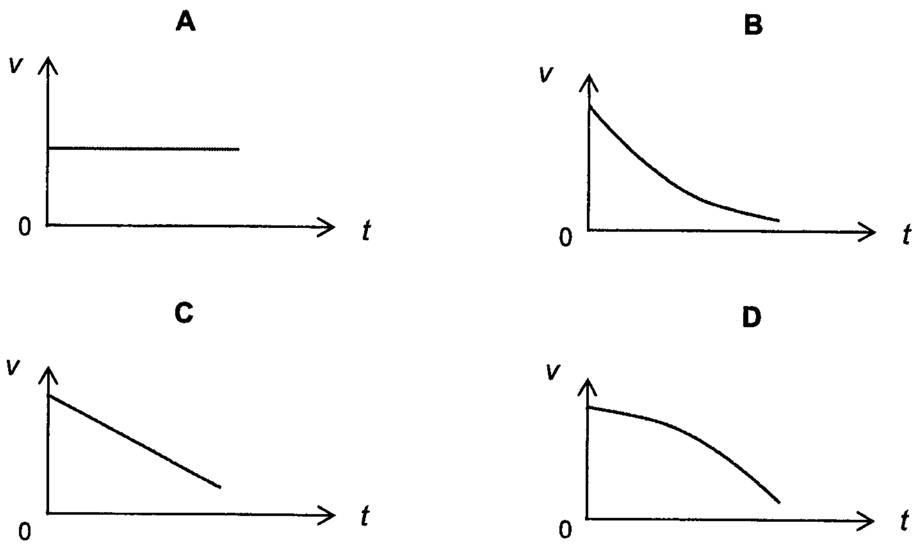
Assuming air resistance is negligible, at which point does the mass possess 75% of its initial gravitational potential energy?

A Q **B** R **C** S **D** None of the points

9 A tape unwinds with speed v from a roll rotating about a fixed axis with constant angular velocity. The radius of the roll r is decreasing at a steady rate.



Which of the following graphs best represents the variation with time t of the speed v of the tape?



10 A satellite of mass 150 kg is launched into a geostationary orbit around the Earth. The Earth has a radius of 6.4×10^3 km and a mass of 6.0×10^{24} kg.

Which statement is correct?

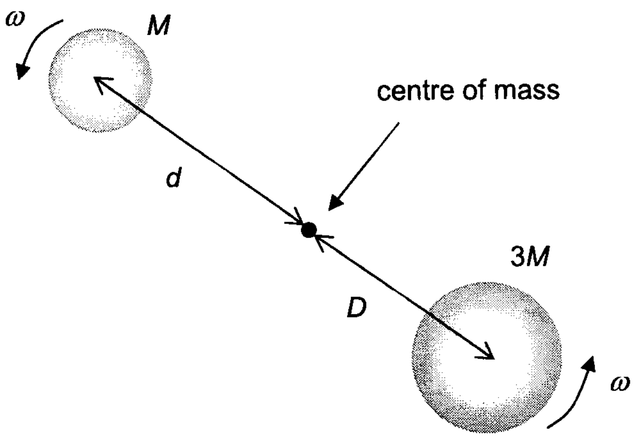
A The satellite need not be above the equator.

B The satellite is launched in the westerly direction.

C The height of the orbit from the surface of the Earth is 4.23×10^7 m.

D All geostationary satellites must have the same orbital radius and linear speed.

11 A binary star is a system of two stars that orbit around each other with angular velocity ω about their centre of mass. The stars have masses M and $3M$ respectively and the distances of stars from their centre of mass are d and D respectively.



Not to scale

Which expression gives the total kinetic energy of the two stars?

A $\frac{3GM^2}{8D}$ **B** $\frac{GM^2}{2D}$ **C** $\frac{3GM^2}{2D}$ **D** $\frac{2GM^2}{D}$

12 A 50 g piece of wood placed next to a 100 g steel bar is at the same temperature as the steel bar. The steel bar is in thermal equilibrium with a 5.0 g piece of paper placed some distance away from it. A student who touched the three objects remarked that the steel bar feels colder to touch than the other two objects.

Which statement is always correct?

A The piece of wood and steel bar have the same amount of internal energy.

B There is no exchange of thermal energy between the piece of wood and the paper.

C The steel bar is at a lower temperature than the other two objects.

D There is no net exchange of thermal energy between the paper and the steel bar.

13 A large tank contains water at a uniform temperature to a depth of 20 m. The tank is open to the atmosphere and atmospheric pressure is equivalent to that of 10 m of water. An air bubble is released from the bottom of the tank and rises to the surface. The air bubbles behave like an ideal gas.

Assuming surface tension effects to be negligible, what happens to the volume of the air bubble?

A Doubles when it reaches the surface

B Triples when it reaches the surface

C Halves when it reaches the surface

D Remains constant

14 Five gas molecules have the following velocities:

velocity / m s^{-1}	250	300	400	100	500

What is the root mean square speed?

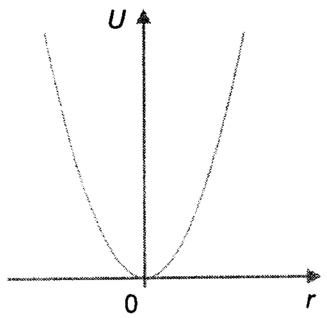
A 150 m s^{-1} **B** 270 m s^{-1} **C** 340 m s^{-1} **D** 750 m s^{-1}

15 An object placed on a horizontal platform is vibrating vertically in simple harmonic motion with a frequency of 2.0 Hz.

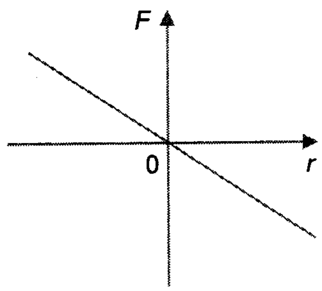
What is the maximum amplitude of oscillation which will allow the object to remain in contact with the platform throughout the motion?

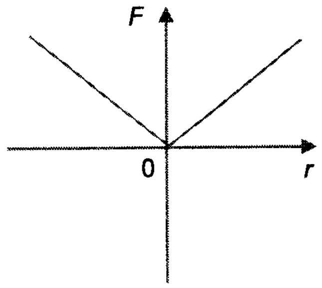
A 2.5 cm **B** 5.1 cm **C** 6.2 cm **D** 7.2 cm

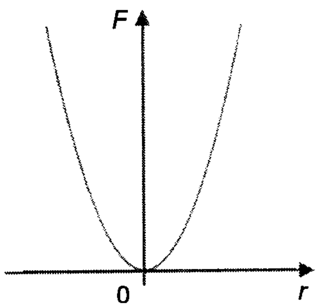
16 The potential energy U of a particle in simple harmonic motion is directly proportional to the square of its displacement r from the origin.

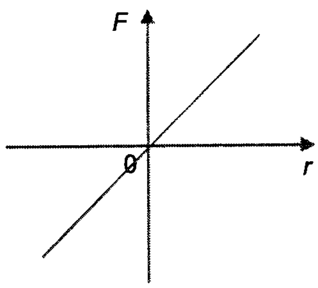


Which of the following graphs best represents the variation with displacement r of the net force F acting on the particle?

A


B


C


D


17 A transmitting aerial emits vertically polarised radio waves. A receiving aerial is positioned at an angle θ from the horizontal and is in the plane perpendicular to the direction of plane-polarised waves. The amplitude of the wave received is A.

Which of the following is the total power of the transmitting aerial directly proportional to?

A $A^2 \cos^2 \theta$ **B** $\dfrac{A^2}{\cos^2 \theta}$ **C** $A^2 \sin^2 \theta$ **D** $\dfrac{A^2}{\sin^2 \theta}$

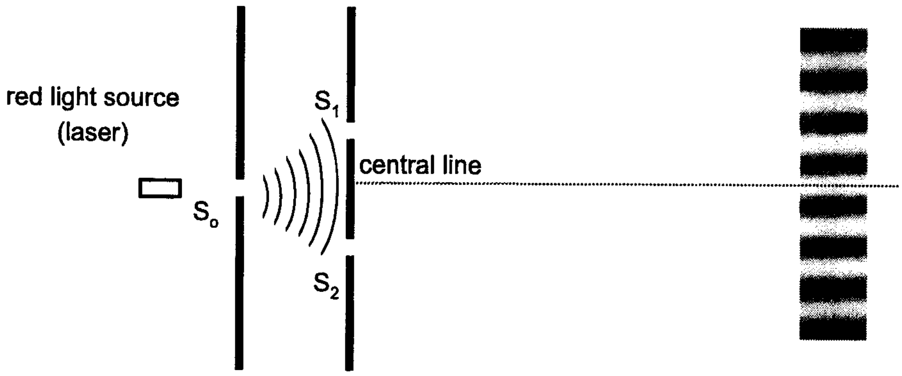
18 A vertical tube is completely filled with water. A small sound source of constant frequency is held slightly above the open upper end. Water runs out from the lower end and a number of resonance positions are detected. The first of these occurs when the water surface is 15 cm below the top of the tube and the next occurs at 49 cm. The speed of sound in air as 330 m s^{-1}.

What is the frequency of the source?

A 390 Hz **B** 490 Hz **C** 500 Hz **D** 550 Hz

19 In a Young's double slit experiment, a red light from a laser is incident on the source slit S_o and passes through the double slits S_1 and S_2, producing red bright fringes as shown the figure below.

Subsequently, a transparent thin glass block is placed in front of S_1.



Which observation is correct?

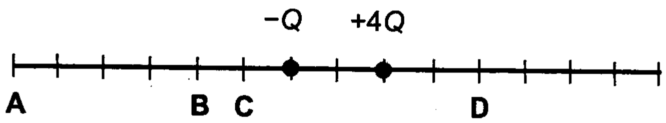
A The fringe separation will decrease.

B The fringe separation will be non-uniform.

C The contrast between bright and dark fringes will increase.

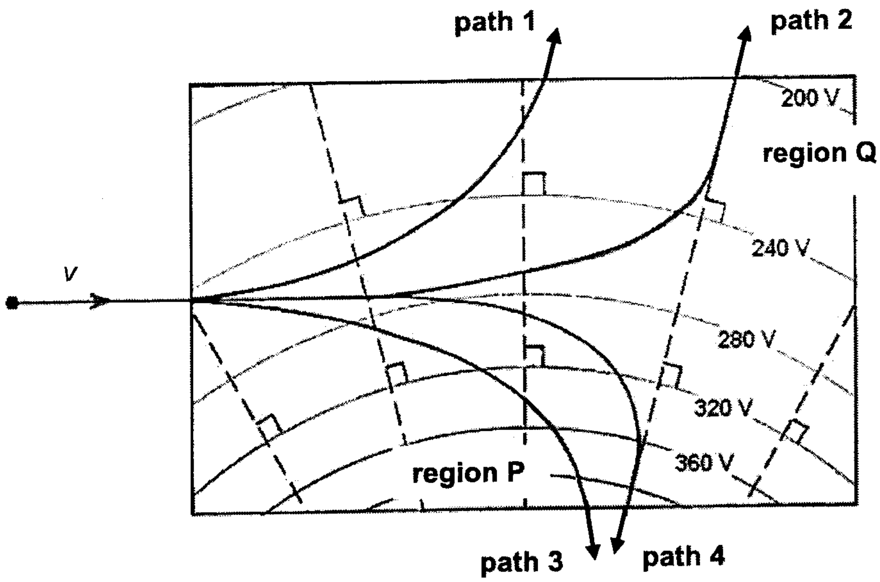
D The central maximum will be shifted upwards.

20 Two point charges −Q and +4Q are situated as shown below. The gridlines are evenly spaced.



At which point could the resultant electric field due to these charges be zero?

21 A charged particle enters a region of non-uniform electric field with speed v as shown in the figure below.



Which row is correct?

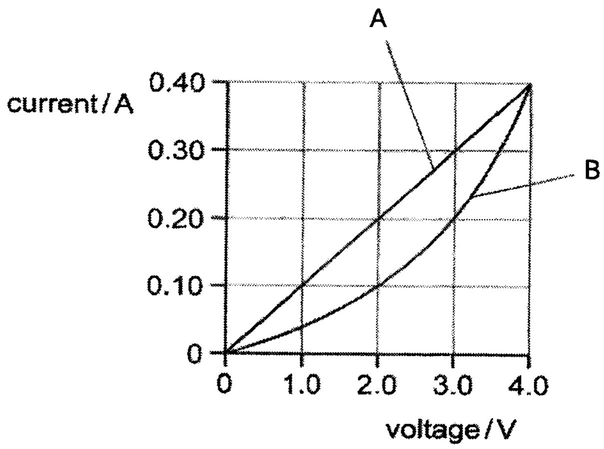
	possible path of charged particle	region with maximum electric field strength
A	1 or 3	P
B	2 or 4	Q
C	1 or 3	Q
D	2 or 4	P

22 Aluminium and copper rods are each designed to have the same length and the same resistance. The resistivity of copper is half that of aluminium, but its density is three times that of aluminium.

What is the ratio of the mass of the aluminium rod to the mass of the copper rod?

A 0.17 **B** 0.33 **C** 0.67 **D** 1.5

23 The current-voltage characteristics of two electrical components A and B are shown below.



Which statement is correct?

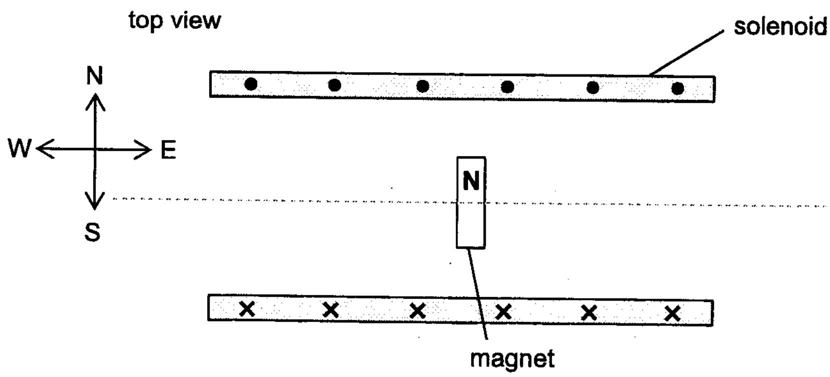
A For a current of 0.20 A, the resistance of B is 50% more than the resistance of A.

B For a current of 0.20 A, the power dissipated in B is double that of the power dissipated in A.

C When A and B are connected in parallel with an e.m.f. of 3.0 V placed across it, the total current is 0.3 A.

D When A and B are connected in series with an e.m.f. of 5.0 V placed across it, the potential difference across B is 2.0 V.

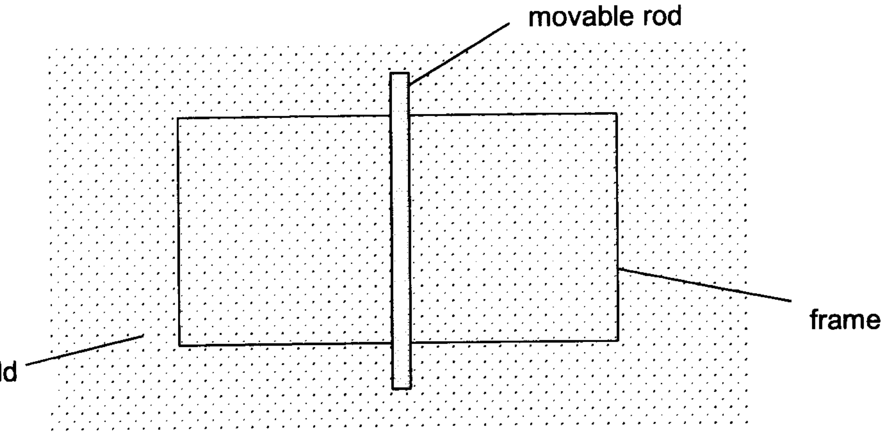
24 A light magnet is suspended inside a solenoid as shown in the figure below. The Earth's magnetic flux density is 2.0×10^{-5} T and the solenoid has 20 turns and a length of 15 cm. When a current is passed through the solenoid, it is found that the magnet rotates through an angle of 68° from its original direction.



What is the value of the current flowing through the solenoid?

A 0.048 A **B** 0.11 A **C** 0.30 A **D** 2.0 A

25 A movable metal rod is placed in the middle of a rectangular metal frame as shown. A uniform magnetic field directed out of the plane of the paper acts perpendicular to the frame.



Which of the following actions could lead to a clockwise current flowing through the frame?

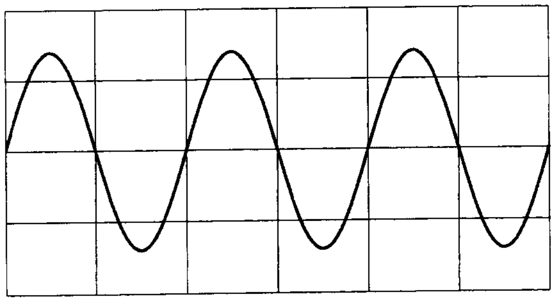
A Decreasing the magnitude of the magnetic flux density of the field.

B Increasing the magnitude of the magnetic flux density of the field.

C Sliding the rod to the left while maintaining contact with the frame.

D Sliding the rod to the right while maintaining contact with the frame.

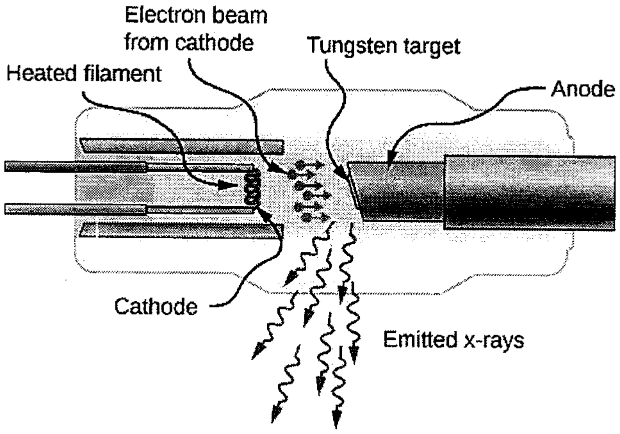
26 An alternating p.d. is applied across the Y-plates of a cathode-ray-oscilloscope (CRO) and produces the trace shown below. The peak voltage of the alternating p.d. is 2.8 V and its frequency is 50 Hz.



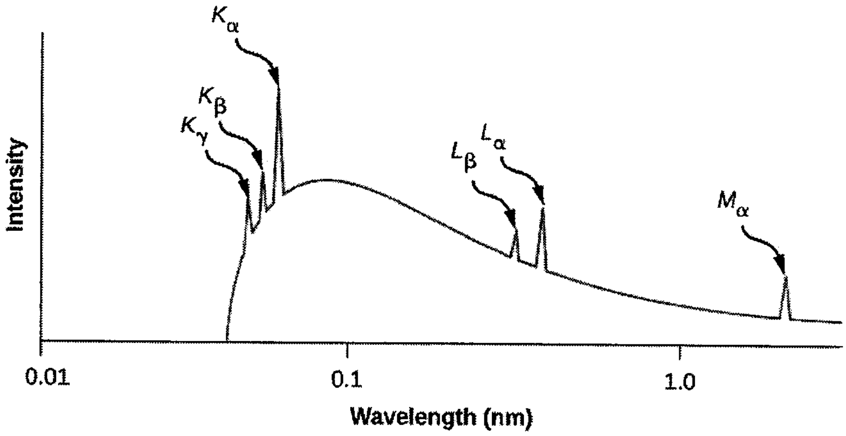
What are the time-base and Y-gain settings of the CRO?

	time-base / ms div^{-1}	Y-gain / V div^{-1}
A	10	1.0
B	20	1.0
C	10	2.0
D	20	2.0

27 X-rays are produced when high speed electrons collide with a tungsten target as shown in the diagram below.



The graph below illustrates variation of wavelength with intensity of X-rays.



Which statement is **not** correct?

A The cut-off wavelength corresponds to the least energetic photon released.

B A continuous spectrum with a minimum wavelength is caused by the braking radiation.

C X-ray photons are produced when the electrons in the outer shells transit to the inner shells.

D The sharp characteristic peaks at well-defined wavelengths are caused by transitions of electrons between energy levels in the tungsten.

28 Which statement about the Heisenberg position-momentum uncertainty principle on a particle is **not** correct?

A The exact values of momentum p and position x cannot be achieved simultaneously.

B The uncertainty of momentum Δp is in the same direction as the uncertainty of position Δx.

C The product of uncertainties of momentum Δp and position Δx will always be greater than the Planck constant.

D The uncertainties of momentum Δp and position Δx can be minimised concurrently with the same experimental equipment.

[Turn over

29 The nuclear fission reaction of Uranium-235 may be represented by the following equation

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + 3^{1}_{0}n + \text{energy}$$

The rest masses of the nuclei are

nuclide	rest mass
$^{235}_{92}U$	235.04393 *u*
$^{141}_{56}Ba$	140.91440 *u*
$^{92}_{36}Kr$	91.92617 *u*
$^{1}_{0}n$	1.00866 *u*

What is the energy released when one nuclide of $^{235}_{92}U$ undergoes fission?

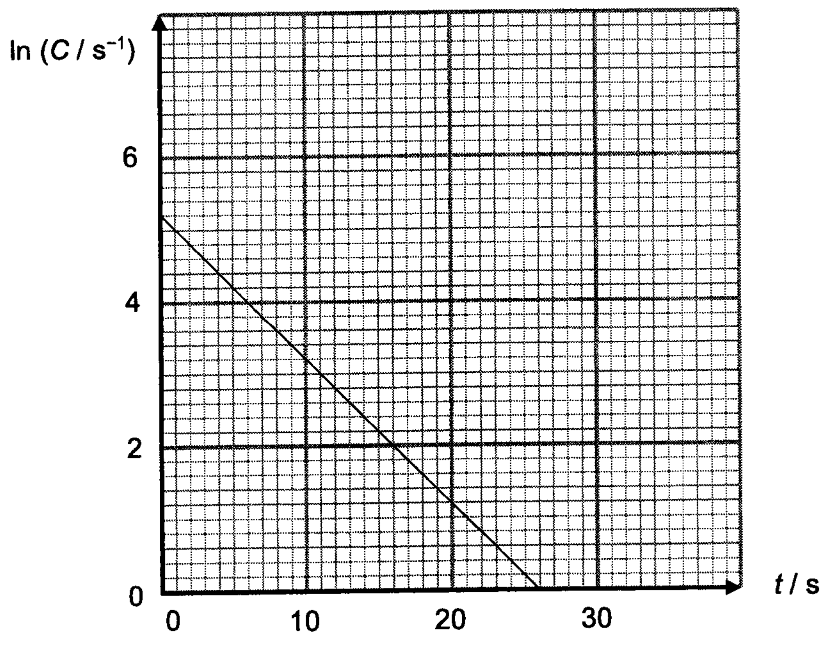
A 3.09×10^{-28} J

B 9.26×10^{-20} J

C 2.78×10^{-11} J

D 3.29×10^{-10} J

30 The graph below shows the variation with time *t* of the natural logarithm of the count rate ln *C* of a radioactive source measured by a Geiger–Müller counter.



What is the half-life of the radioactive source?

A 0.2 s

B 3.5 s

C 13 s

D 26 s

End of Paper

Anglo-Chinese Junior College

Physics Preliminary Examination
Higher 2

A Methodist Institution
(Founded 1886)

CANDIDATE NAME		CLASS	
CENTRE NUMBER	S 3 0 0 4	INDEX NUMBER	

PHYSICS **9749/02**

Paper 2 Structured Questions

25 August 2022
2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number 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 working.
Do not use staples, paper clips, glue or correction fluid.

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

Answer **all** questions.

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.

For Examiners' use only	
1	/ 6
2	/ 12
3	/ 8
4	/ 9
5	/ 11
6	/ 14
7	/ 20
Total	/ 80

This paper consists of 25 printed pages

DATA AND FORMULAE

Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	=	8.85×10^{-12} F m^{-1}
			$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-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	=	$\rho g h$
gravitational potential,	ϕ	=	$-\frac{Gm}{r}$
temperature	T/K	=	$T/^\circ\text{C} + 273.15$
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
mean translational kinetic energy of an ideal gas molecule,	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.,	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_o \cos \omega t$
		=	$\pm\,\omega\sqrt{x_o^2 - x^2}$
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	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage,	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o n I$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant,	λ	=	$\frac{\ln 2}{t_{1/2}}$

[Turn over

For Examiner's Use

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

1 **(a)** In an experiment to determine the thickness of a typical $1 coin, a student used a half meter rule to determine the thickness of one $1 coin and the thickness T of N such coins, as shown in Fig. 1.1.

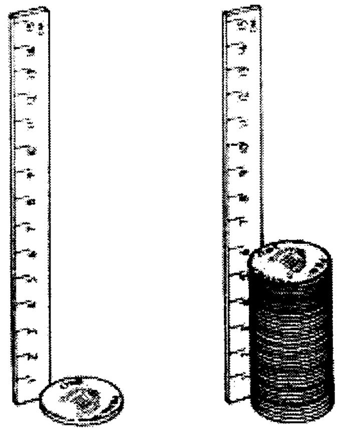


Fig. 1.1

The thickness of a typical $1 coin is then taken to be $\frac{T}{N}$.

(i) In finding the thickness of a $1 coin, explain how dividing T by N reduces random error as compared to measuring the thickness of only 1 coin.

....

....

....

....

.... [2]

(ii) Suggest a method to further improve the accuracy in determining the thickness of the coin. Explain your answer.

....

....

.... [1]

For Examiner's Use

(b) The ideal gas law states that $pV = nRT$

where p is the pressure of the gas,
V is the volume of the gas,
n is the number of moles and
T is the thermodynamic temperature.

In an experiment, the student was attempting to calculate the value of p for a sample of 2.00 millimoles of gas trapped in a sphere.

Assuming ideal gas conditions, if the diameter of the sphere is (50.0 ± 0.1) mm and the temperature of the gas is (36.7 ± 0.1) °C, determine the value of p with its associated uncertainty.

p = (...................... ± ....) Pa [3]

[Total: 6]

[Turn over

For Examiner's Use

2 (a) A man wants to knock down a coconut from the tree by throwing a stone at it as shown in Fig. 2.1. The coconut is 18.0 m above the ground. The man's hand is 2.2 m above the ground when he releases the stone with an initial velocity of 20.0 m s^{-1}. Assume that air resistance is negligible.

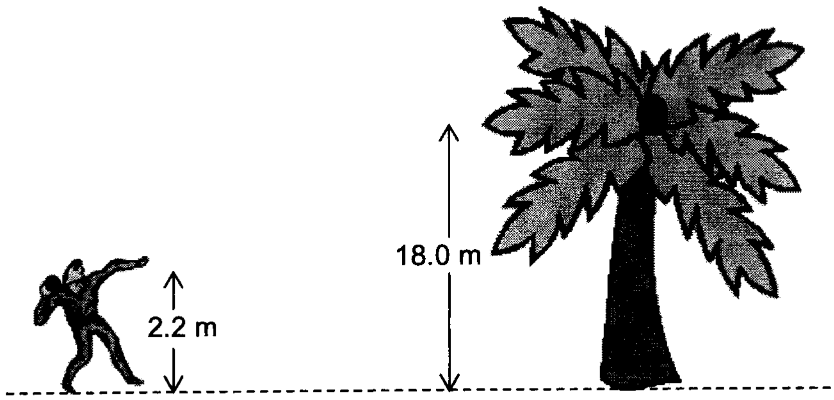


Fig. 2.1 (not to scale)

(i) Explain qualitatively, in terms of acceleration and velocity, why the path taken by the stone is *parabolic*.

....

....

.... [1]

(ii) Show that the angle at which the stone should be released from the horizontal so that it would hit the coconut horizontally is 62°.

[2]

For Examiner's Use

(iii) Hence, calculate the time taken for the stone to reach its maximum height when it is projected at the angle in **(a)(ii)**.

time taken = ... s [2]

(b) A spaceship engine uses solar power to ionise and eject xenon atoms from the spaceship. The speed of the ejected xenon ions is 3.0×10^4 m s^{-1} relative to the spaceship as shown in Fig. 2.2.

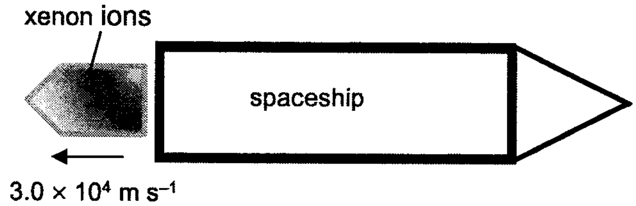


Fig. 2.2

Fig. 2.3 shows the variation with time *t* of the acceleration *a* of the spaceship due to the ejection of xenon ions.

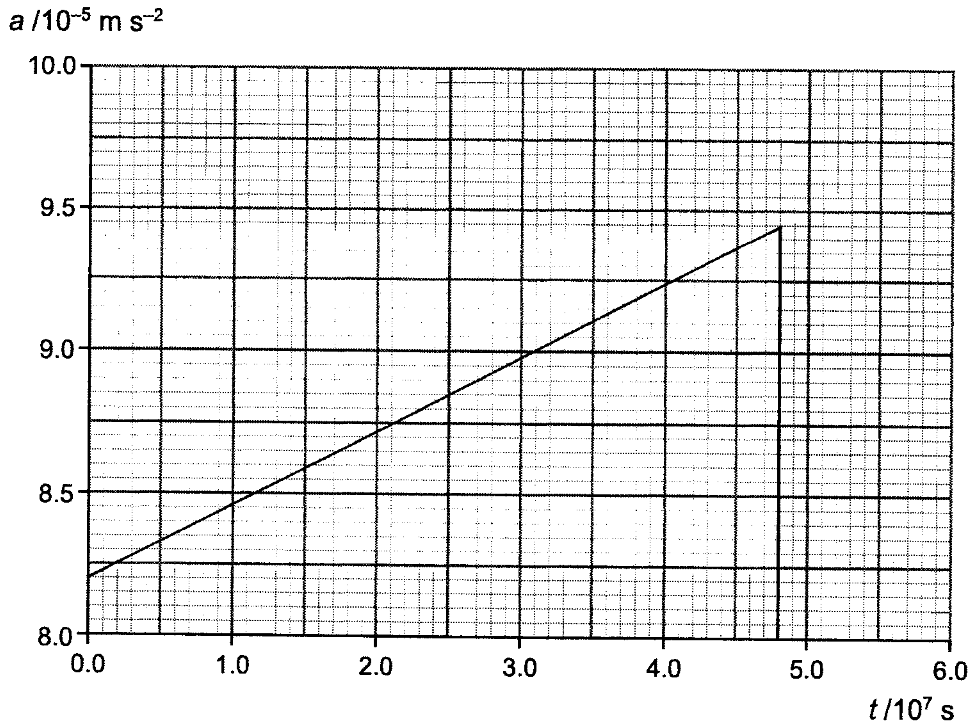


Fig. 2.3

[Turn over

For Examiner's Use

(i) Explain why the acceleration of the spaceship is increasing.

....

....

.... [1]

(ii) Given that the ions are ejected at a constant rate of 1.7×10^{-6} kg s^{-1}, calculate the magnitude of the force exerted on the spaceship by the ions.

magnitude of force = ... N [2]

(iii) The spaceship is initially stationary and its engine is switched on at time $t = 0$ s.

Using Fig. 2.3, calculate the final velocity of the spaceship when the xenon ions run out completely.

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

For Examiner's Use

(iv) On Fig. 2.4, draw the corresponding variation with time t of the velocity v of the spaceship from $t = 0$ to $t = 6.0 \times 10^7$ s.

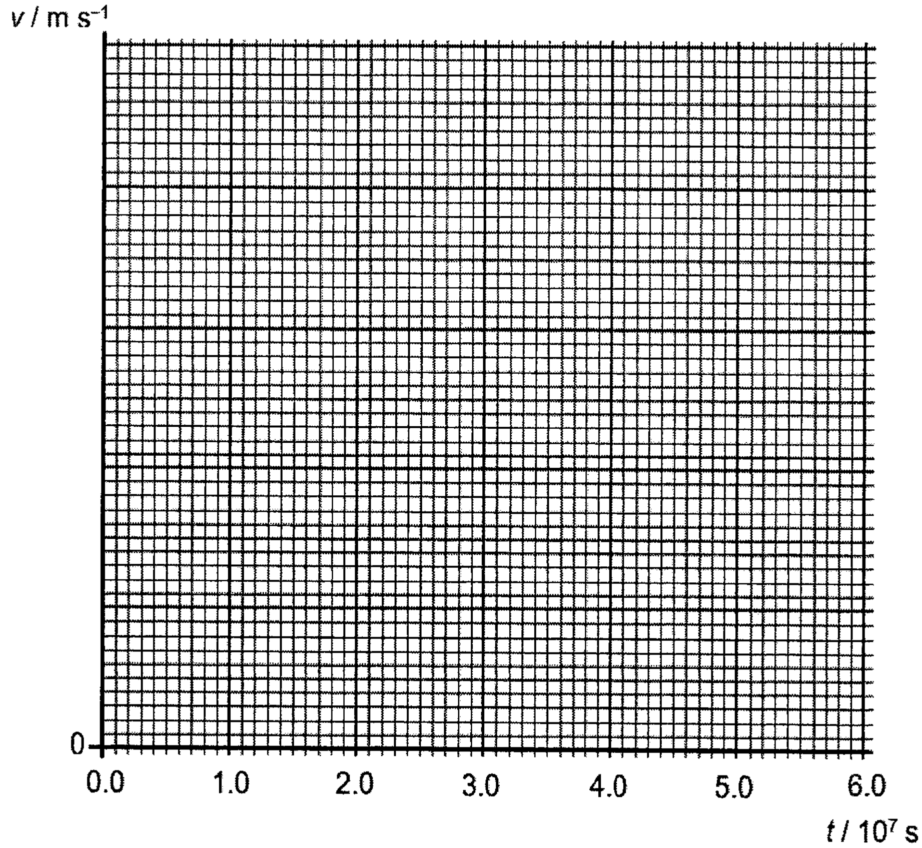


Fig. 2.4

[2]

[Total: 12]

For Examiner's Use

3 **(a)** A metal ball is released in a liquid. With the aid of a free body diagram, explain how the metal ball falling through the liquid can reach terminal velocity.

....

....

....

....

....

.... [3]

(b) Fig. 3.1 shows a ladder resting against a smooth vertical wall at point A and on a rough ground at point B. Three forces, *P*, *Q* and *W* are acting on the uniform ladder which is 6.0 m long and has a weight of 150 N.

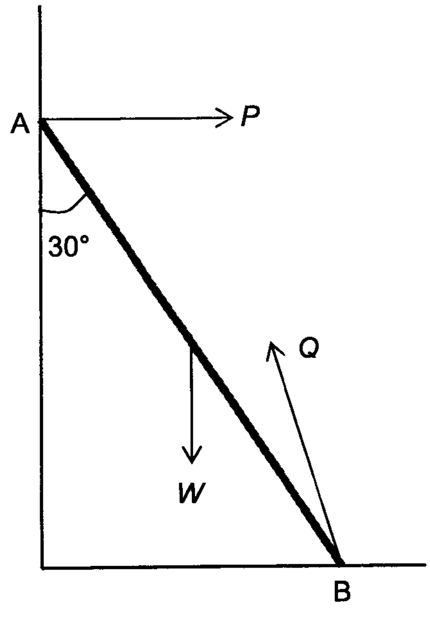


Fig. 3.1 (not to scale)

For Examiner's Use

(i) Show that the magnitude of force *P* is 43 N.

[1]

(ii) Explain why the ground must exert a force on the ladder at B to keep the ladder in equilibrium.

....

....

....

....

.... [2]

(iii) Calculate the magnitude of force *Q*.

force Q = ... N [1]

[Turn over

For Examiner's Use

(iv) Assuming that there is now friction between the ladder and the vertical wall, draw possible directions of the forces acting on points X and Y in Fig. 3.2.

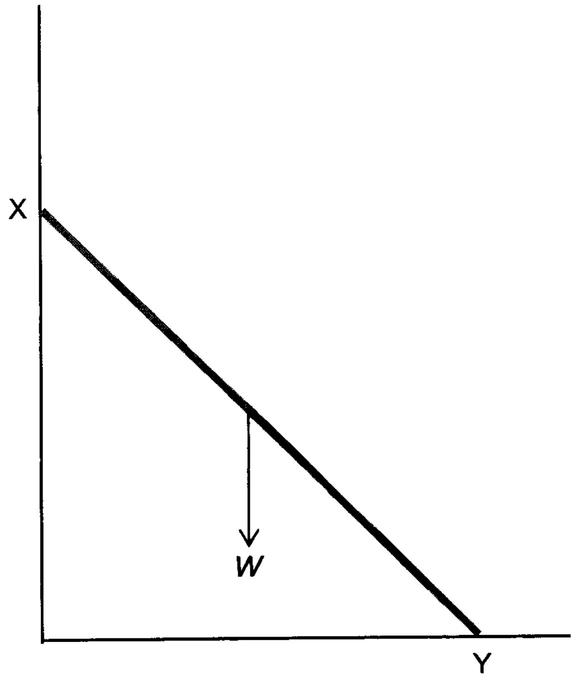


Fig. 3.2

[1]

[Total: 8]

For Examiner's Use

4 The Earth has mass M and radius R, and a uniform density ρ.

(a) Using the definition of gravitational field strength g, show that the magnitude of gravitational field strength g and distance from the centre of the Earth r in terms of G, ρ and R is given by

$$g = \frac{4\pi \rho G R^3}{3 r^2}$$

[2]

(b) The magnitude of the gravitational field strength g at a distance r inside the Earth is given by

$$g = \frac{4\pi \rho G r}{3}$$

On Fig. 4.1, sketch a graph showing the variation with distance r from the centre of the Earth of the gravitational field strength g. Values of g are not required.

Take the positive direction of g to be in the positive horizontal axis.

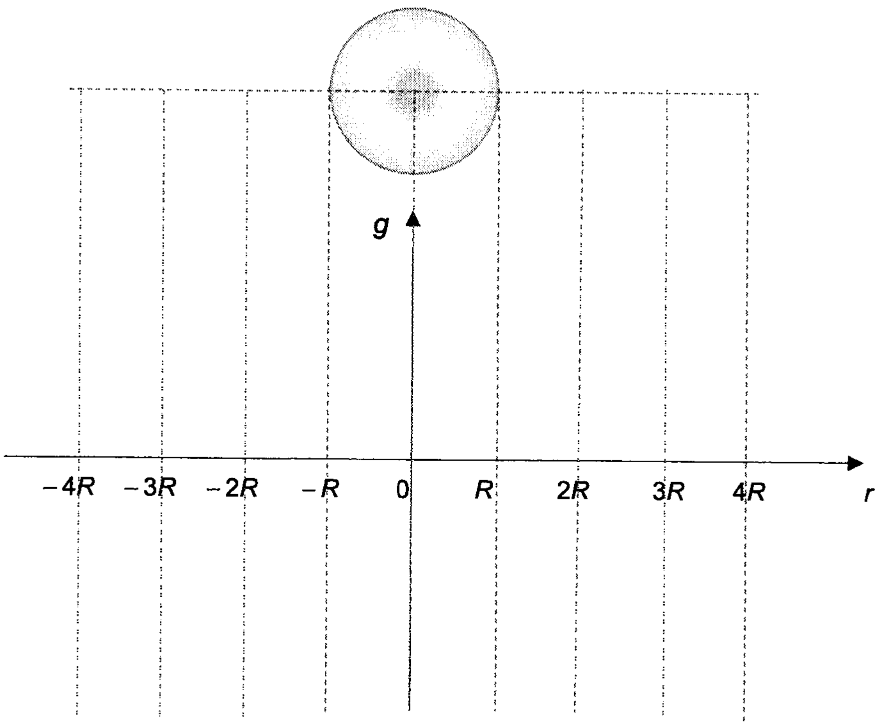


Fig. 4.1

[3]

[Turn over

For Examiner's Use

(c) Quito, Ecuador is the antipodal city of Singapore as it is situated at the other end of the straight line passing through the centre of the Earth. The two countries have built a very narrow frictionless tunnel through the centre of the Earth between Singapore and Quito as shown in Fig. 4.2.

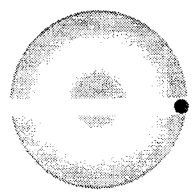


Fig. 4.2

(i) A parcel of medical supplies is released at the Singapore end of the tunnel. The Earth's gravitational field causes the parcel to oscillate with simple harmonic motion about the centre of the Earth with a period of T.

Derive an expression for T, in terms of G and ρ.

[2]

(ii) The density of the Earth ρ is 5.51 g cm^{-3}.

Hence, determine the time taken for a medical supply parcel from Singapore to arrive in Quito.

time taken = ... s [2]

[Total: 9]

For Examiner's Use

5 **(a)** Two circuits are set up using the light dependent resistor LDR in Fig. 5.1(a) and Fig. 5.1(b).

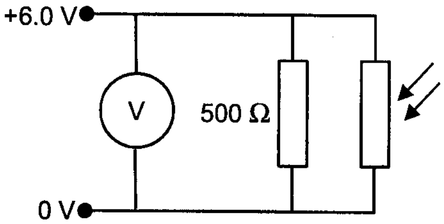


Fig. 5.1(a)

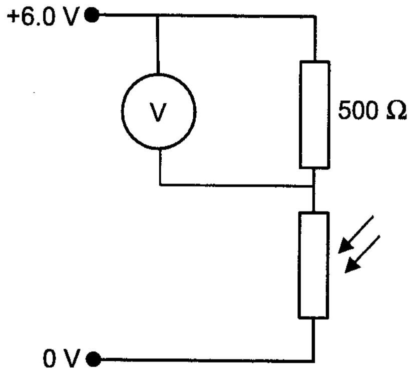


Fig. 5.1(b)

(i) For the circuit to function as a light meter, the voltmeter reading V must increase as the light intensity increases.

Explain why only the circuit in Fig. 5.1(b) can fulfil this function.

....

....

....

....

....

....

.... [3]

(ii) Calculate the resistance of the LDR when V = 3.75 V for the circuit in Fig. 5.1(b).

resistance of LDR = ... Ω [2]

[Turn over

For Examiner's Use

(b) The light-emitting diode, LED, is a semiconductor light source that emits light when current flows through it.

Fig. 5.2 shows a circuit designed by a student.

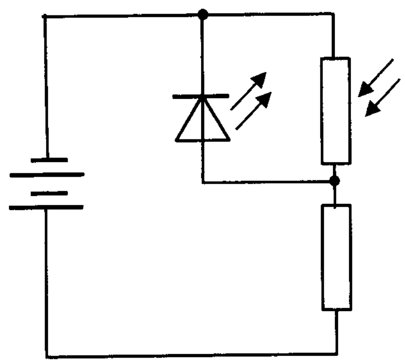


Fig. 5.2

The LED is very close to and facing the LDR. The circuit is taken into a dark room.

(i) The student thought that the LED would switch on.

Instead the LED was found to repeatedly switch on and off.

Explain this behaviour of the LED in the circuit.

....

....

....

....

.... [2]

(ii) Suggest a possible refinement so that the LED switches on permanently when taken into the dark room.

....

....

.... [1]

For Examiner's Use

(c) A variable resistor is connected directly across the terminals of a cell with an e.m.f. of 6.0 V. A voltmeter is connected across the variable resistor and Fig. 5.3 is obtained as the resistance of the variable resistor R changes.

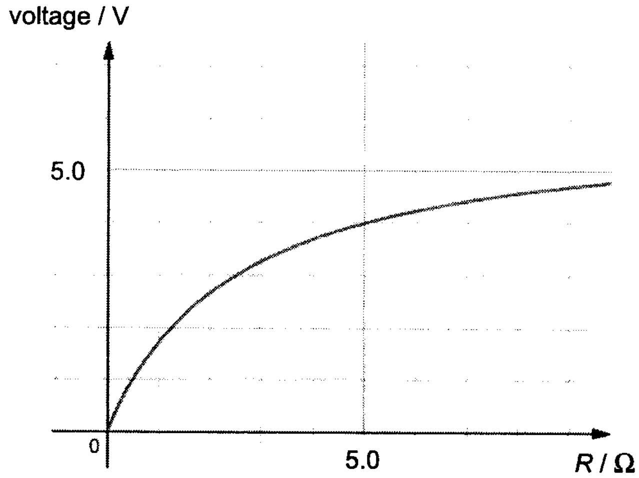


Fig. 5.3

(i) On Fig. 5.3, draw the graph representing the variation in the voltmeter reading if the cell was ideal with no internal resistance. Label the graph **N**. [1]

(ii) Using Fig. 5.3, estimate the internal resistance of the cell.

internal resistance = ... Ω [2]

[Total: 11]

[Turn over

For Examiner's Use

6 (a) Define *half-life*.

....

....

.... [1]

(b) Explain what is meant by the terms *spontaneous* and *random* when describing radioactive decay.

spontaneous: ....

....

random: ....

.... [2]

(c) Carbon-14 ($^{14}_{6}C$) undergoes β^- decay to form Nitrogen (N).

(i) Complete the nuclear equation below for the decay of carbon-14 to form nitrogen.

$$^{14}_{6}C \rightarrow \,^{\cdots\cdots}_{\cdots\cdots}N + \,^{\cdots\cdots}_{\cdots\cdots}\cdots\cdots + \text{ energy}$$

[1]

(ii) The half-life of Carbon-14 is 5730 years.

Calculate the decay constant λ of Carbon-14.

λ = ... s^{-1} [2]

For Examiner's Use

(iii) A fossil of a Neanderthal (an extinct species of archaic humans) was found. Carbon-14 dating was used to determine the age of this fossil.

A 10 kg sample of this fossil was found to have an activity rate of 5.4 Bq. On the other hand, a fresh 1.0 g sample taken from a living organism is expected to have an activity rate of 0.23 Bq.

Determine the age of the fossil.

age = ………………….. years [3]

(d) A sample of polonium-210 (Po) undergoes α-decay forming lead-206 (Pb) with no other products.

The Po nucleus was stationary before the decay and the α-particle was emitted with a velocity of v_α.

(i) Using momentum considerations, show that $\dfrac{\text{kinetic energy of Pb nucleus}}{\text{kinetic energy of } \alpha\text{-particle}}$ is 0.0194.

[3]

[Turn over

For Examiner's Use

(ii) Fig. 6.1 shows the initial positions of of the α-particle and Pb nucleus right after the decay.

The radioactive decay took placed in a magnetic field directed into the plane of the page.

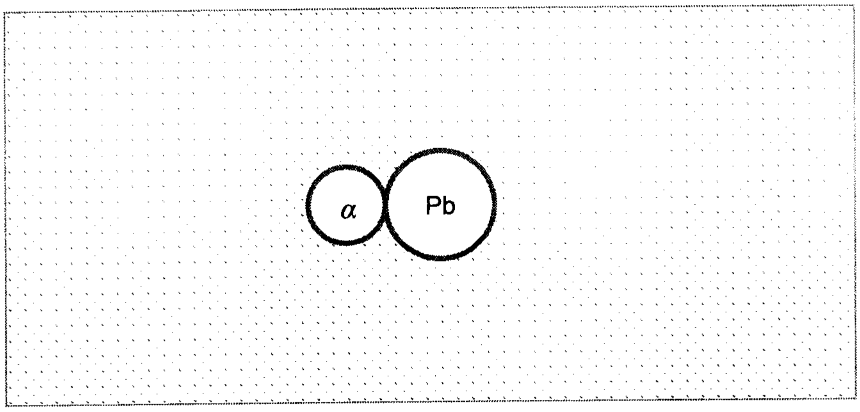


Fig. 6.1

On Fig. 6.1, sketch the paths of the emitted Pb nucleus and α-particle. [2]

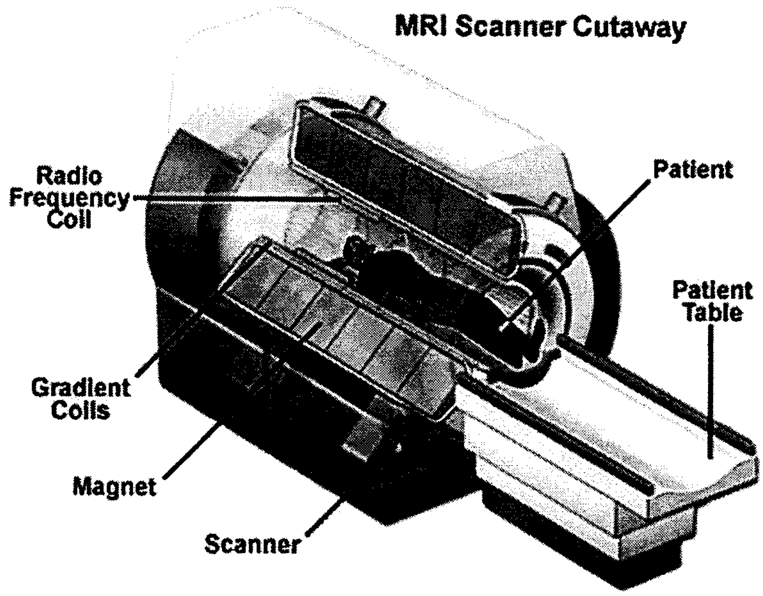
[Total: 14]

For Examiner's Use

7 Read the passage below and answer the questions that follow.

Magnetic resonance imaging (MRI) is a medical imaging technique used in radiology to form pictures of the anatomy and the physiological processes of the body. MRI is widely used in hospitals and clinics for medical diagnosis, staging and follow-up of disease and provides excellent contrast in images of soft tissues, e.g., in the brain or abdomen. However, it may be perceived as less comfortable by patients, due to the usually longer and louder measurements with the subject in a long, confining tube. Additionally, implants and other non-removable metal in the body can pose a risk and may exclude some patients from undergoing an MRI examination safely.

Fig. 7.1 illustrates the basic design of an MRI scanner. The scanner consists of a main magnet of magnetic flux density 0.50 to 2.0 T, a Radio Frequency (RF) coil, gradient coils, patient table, and a computer system.



Source: https://snc2dmri.weebly.com/components--functions.html

Fig. 7.1

MRI is based on the magnetisation properties of atomic nuclei. A powerful, uniform, external magnetic field is used to align the protons that are normally randomly oriented within the water nuclei of the tissue being examined. This alignment (or magnetisation) is next disrupted by introduction of an external RF energy. The nuclei absorb the RF energy and return to their resting alignment through various relaxation processes and emit RF energy while doing so. After a certain period following the initial RF, the emitted signals are measured. The computer system then converts the signals to create different types of images.

[Turn over

Spin is a fundamental property of nature like electrical charge or mass. It comes in multiples of $\frac{1}{2}$. Protons and neutrons possess spin. Individual unpaired protons and neutrons each possesses a spin of $\frac{1}{2}$ while paired protons and neutrons have no spin. For example, in the deuterium nuclei $^{2}_{1}H$, with one unpaired proton and one unpaired neutron, the net spin is 1.

When placed in a magnetic field of magnetic flux density B, a particle with a net nuclear spin can absorb a photon of a particular resonance frequency ν. This is related to B by the equation

$$\nu = \gamma B$$

where γ is a constant called the gyromagnetic ratio, which is specific to the particle.

This process of absorption of photons by particles is called nuclear magnetic resonance. Fig. 7.2 shows the γ values of some nuclei with a net nuclear spin that are of interest in MRI.

nuclei	γ / MHz T^{-1}
$^{1}_{1}H$	42.58
$^{2}_{1}H$	6.54
$^{31}_{15}P$	17.25
$^{23}_{11}Na$	11.27

Fig. 7.2

Two factors that influence the strength of the MRI signal are the natural abundance of the isotope and biological abundance. The natural abundance of an isotope is the fraction of the element's nuclei having a given mass number while the biological abundance is the fraction of one element in the human body. Fig. 7.3 lists the natural and biological abundances of some nuclei studied in MRI.

element	nuclei	natural abundance	biological abundance
Hydrogen	$^{1}_{1}H$	0.99985	0.63
	$^{2}_{1}H$	0.00015	
Phosphorus	$^{31}_{15}P$	1.00	0.0024
Sodium	$^{23}_{11}Na$	1.00	0.00041

Fig. 7.3

Since its development in the 1970s and 1980s, in addition to detailed spatial images, MRI can also be used to form images of non-living objects, such as mummies and capture neuronal tracts and blood flow in the human nervous system.

For Examiner's Use

(a) To generate the magnetic field, the MRI scanner uses a solenoid-shaped coil made of alloys cooled in liquid helium to a temperature of 10 K to create a superconducting magnet. Fig. 7.4 shows the side view of this coil.

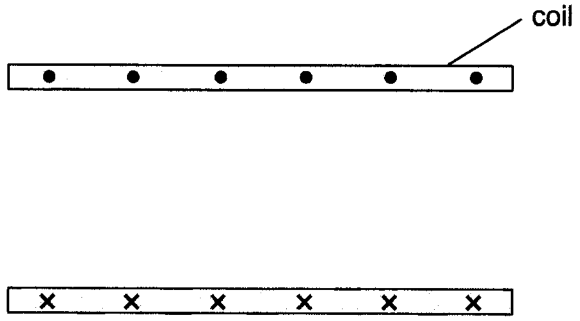


Fig. 7.4

(i) On Fig. 7.4, sketch the magnetic field generated by the coil when current flows in the coil as shown. [2]

(ii) Suggest why the coil is cooled to a temperature of 10 K.

....

....

.... [1]

(b) Suggest why patients with implants and other non-removable metal in the body may not be allowed to undergo an MRI examination.

....

....

.... [1]

(c) **(i)** State and explain the net spin for a Hydrogen $^{1}_{1}H$ nuclei.

....

....

....

.... [2]

For Examiner's Use

(ii) Suggest why a Carbon $^{12}_{6}C$ nuclei cannot undergo nuclear magnetic resonance.

....

....

....

....

.... [2]

(d) Determine the energy of the photon that will be absorbed by a Hydrogen $^{1}_{1}H$ nuclei in a magnetic field of magnetic flux density 1.5 T.

energy = ... eV [3]

(e) MRI is considered a safe imaging technique as it uses radiation that is non-ionising. The ionisation energy for a typical organic molecule is 6.0×10^{-19} J.

(i) State one effect of ionising radiation on living tissues and cells.

....

....

.... [1]

(ii) Using appropriate calculations, show that X-rays are ionising.

[2]

For Examiner's Use

(f) (i) Explain the significance of the Phosphorous $^{31}_{15}P$ nuclei having a natural abundance value of 1.00.

....

....

.... [1]

(ii) Using the information in Fig. 7.3, explain why the hydrogen $^{1}_{1}H$ nuclei gives the strongest MRI signal among the nuclei listed.

....

....

....

....

.... [2]

(iii) Hence, describe how MRI can produce excellent contrast in the images of soft tissues.

....

....

....

....

....

....

....

.... [3]

[Total: 20]

End of Paper

Anglo-Chinese Junior College

Physics Preliminary Examination
Higher 2

A Methodist Institution
(Founded 1886)

CANDIDATE NAME		CLASS	
CENTRE NUMBER	S 3 0 0 4	INDEX NUMBER	

PHYSICS **9749/03**

Paper 3 Longer Structured Questions

30 August 2022

2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number 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 working.
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 a half hours on Section A and half an hour on Section B.

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.

For Examiners' use only	
Section A	
1	/ 12
2	/ 10
3	/ 12
4	/ 12
5	/ 14
Total	/ 60
Section B	
6	/ 20
7	/ 20
Grand Total	/ 80

This paper consists of 28 printed pages

DATA AND FORMULAE

Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	=	8.85×10^{-12} F m^{-1}
			$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-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	=	$\rho g h$
gravitational potential,	ϕ	=	$-\dfrac{Gm}{r}$
temperature	T/K	=	T/°C + 273.15
pressure of an ideal gas	p	=	$\dfrac{1}{3}\dfrac{Nm}{V}\langle c^2\rangle$
mean translational kinetic energy of an ideal gas molecule,	E	=	$\dfrac{3}{2}kT$
displacement of particle in s.h.m.,	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_o \cos \omega t$
		=	$\pm\,\omega\sqrt{x_o^2 - x^2}$
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	=	$\dfrac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage,	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\dfrac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\dfrac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o n I$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant,	λ	=	$\dfrac{\ln 2}{t_{½}}$

For Examiner's Use

Section A

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

1 A student is exploring Physics principles with wooden blocks and some Physics activities.

(a) Fig. 1.1 shows the first experiment with block A attached to a frictionless pulley using an inelastic massless string. Block A accelerates up a frictionless inclined plane of angle 50°. Block B of mass 8.3 kg is attached to the string on the opposite end of the pulley.

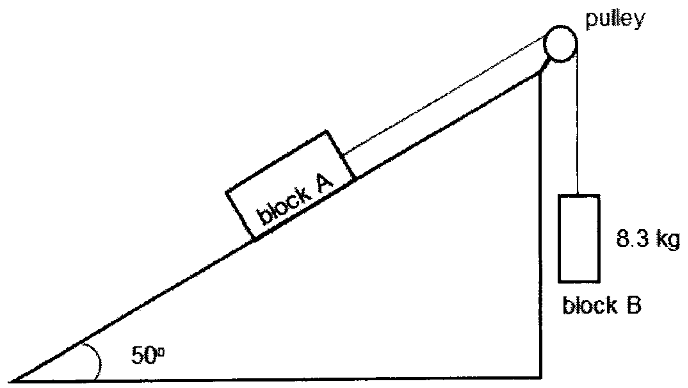


Fig. 1.1

(i) On Fig. 1.2, label the forces acting on block A.

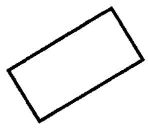


Fig. 1.2

[1]

For Examiner's Use

(ii) The tension of the string is 54 N.

Show that the mass of block A is 5.0 kg.

[3]

(b) Fig. 1.3 shows another experiment with block A from **(a)**. Block A moves along a frictionless horizontal plane towards a stationary block C of mass 10 kg at a constant speed. Block A collides with block C at t = 0 s.

Fig. 1.3

The variation with time t of the momentum p of block A is shown in Fig. 1.4.

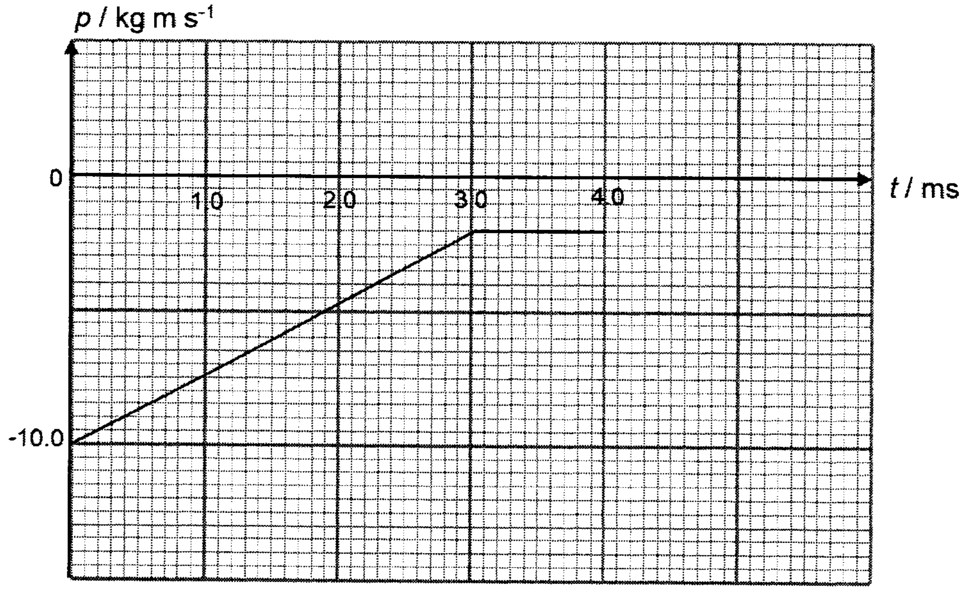


Fig. 1.4

For Examiner's Use

(i) Determine the force acting on block C during the collision.

force = ... N [2]

(ii) Calculate the velocity of block A after the collision.

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

(iii) Deduce whether the collision between the two blocks is elastic or inelastic.

Show your working.

....

.... [4]

[Total: 12]

For Examiner's Use

2 **(a)** Define *electric potential* at a point.

....

....

....

.... [2]

(b) A thin hollow conducting sphere A of radius 0.050 m has an electric potential V of 400 V and an electric field strength E of 8000 N C^{-1} at its surface as shown in Fig. 2.1.

distance from centre of A / m	V / V	E / N C^{-1}
0.050	400	8000
0.200		

Fig. 2.1

Complete Fig. 2.1 for the electric potential V and electric field strength E at 0.200 m from the centre of sphere A.

[2]

(c) Sphere A is placed inside a second thin hollow conducting sphere B of radius 0.200 m carrying a charge of the same magnitude but opposite sign as the charge on A. The spheres have a common centre as shown in Fig. 2.2(a) and Fig. 2.3(a).

Without further calculations, use values in **(b)** to sketch graphs of the variation with distance r from the common centre for **(c)(i)** and **(c)(ii)** below.

Take the positive direction of electric field strength E to be in the positive horizontal axis.

(i) When only sphere A is present.

1. electric potential on Fig. 2.2(b). Label $\boldsymbol{V_A}$. [2]

2. electric field strength on Fig. 2.2(c). Label $\boldsymbol{E_A}$. [2]

(ii) When both spheres A and B are present.

1. electric potential on Fig. 2.3(b). Label $\boldsymbol{V_R}$. [1]

2. electric field strength on Fig. 2.3(c). Label $\boldsymbol{E_R}$. [1]

[Total: 10]

For Examiner's Use

Fig. 2.2(a)

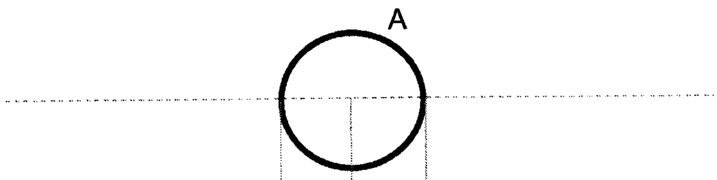


Fig. 2.2(b)

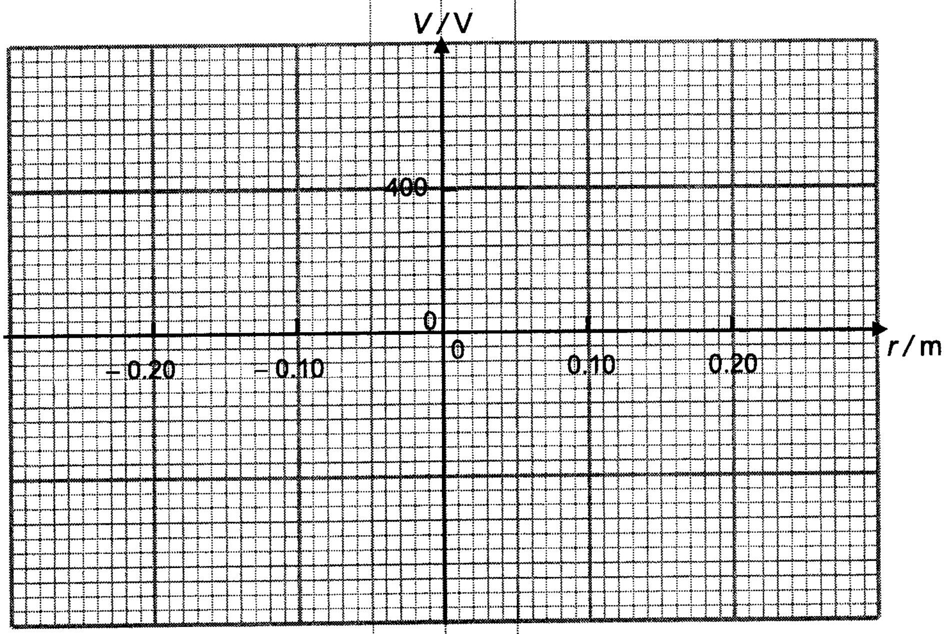


Fig. 2.2(c)

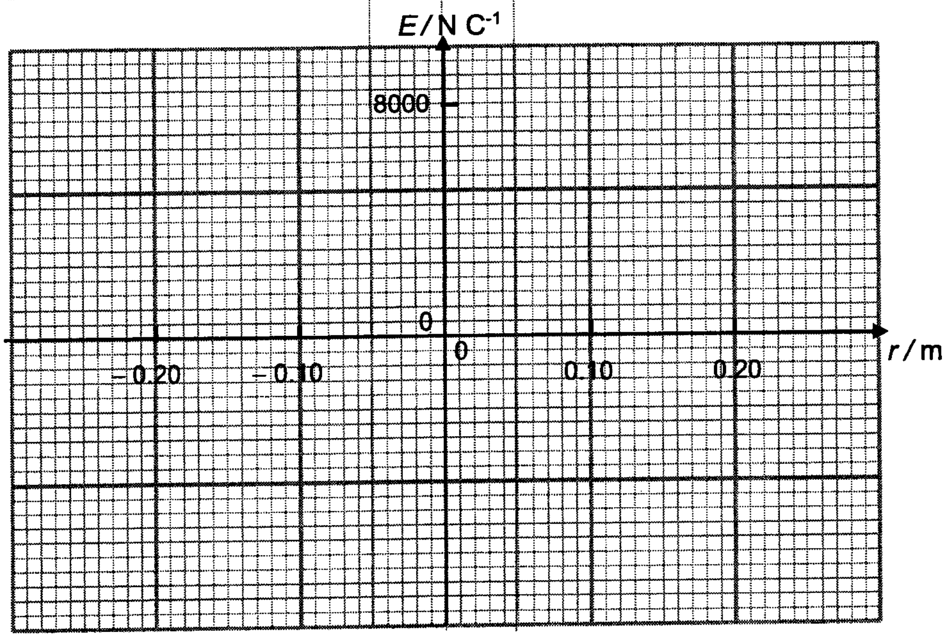


Fig. 2.3(a)

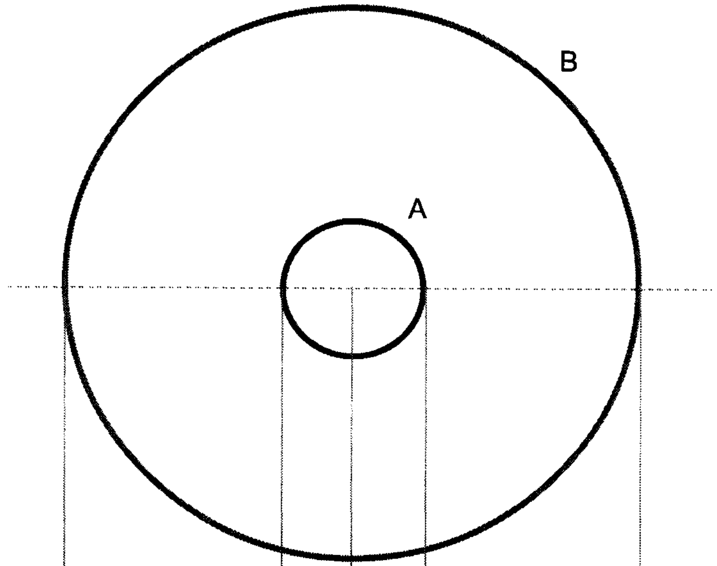


Fig. 2.3(b)

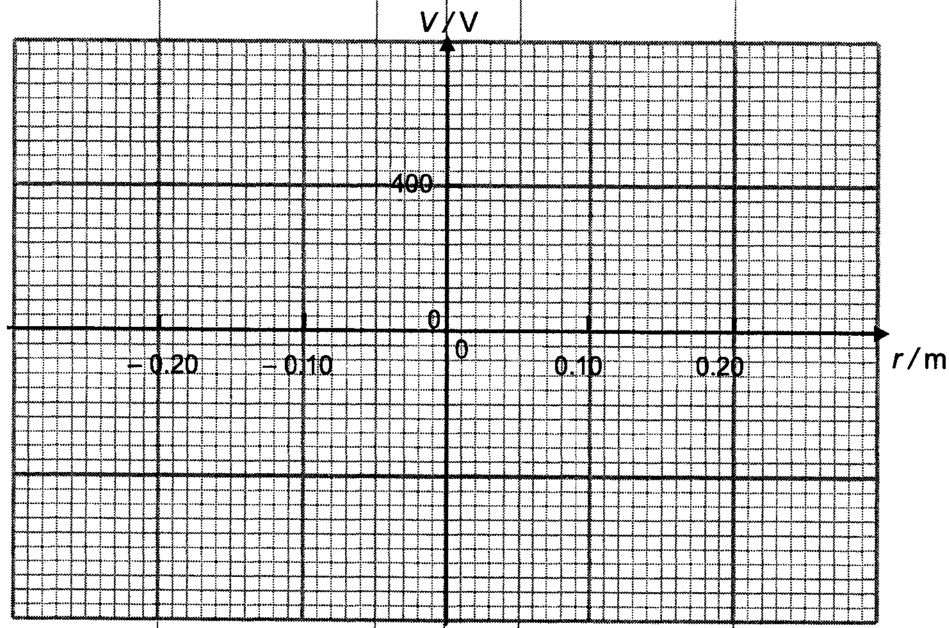
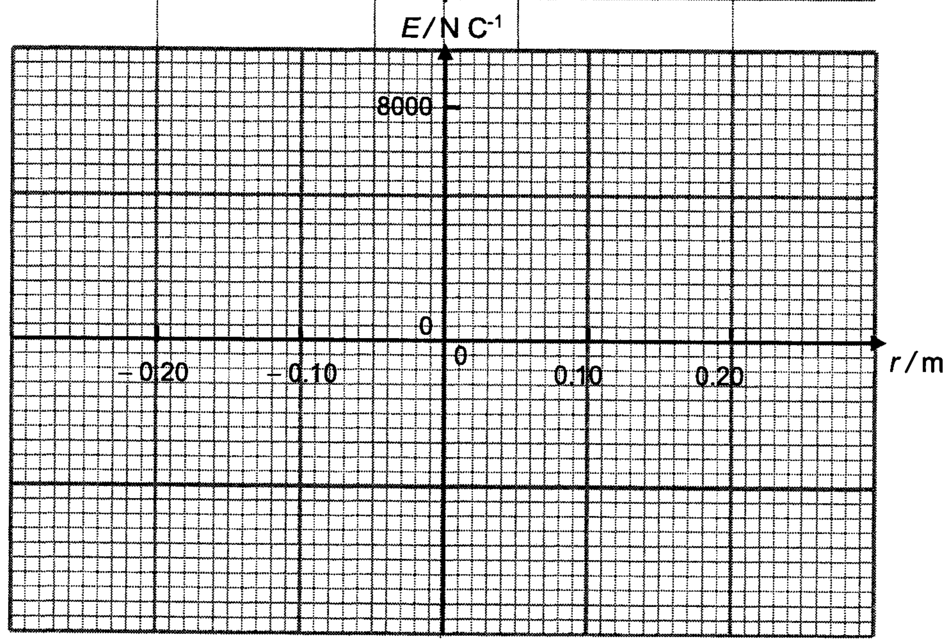


Fig. 2.3(c)



For Examiner's Use

3 **(a)** State the *first law of thermodynamics*.

....

....

....

.... [2]

(b) Use the first law of thermodynamics to calculate the gain in internal energy when 5.0 kg of water at 100 °C is transformed into 5.0 kg of steam at 100 °C at a constant pressure of 1.01×10^5 Pa.

density of steam = 0.598 kg m^{-3}
density of water = 1000 kg m^{-3}
specific latent heat of vaporisation of water = 2.26×10^6 J kg^{-1}

gain in internal energy = ... J [4]

For Examiner's Use

(c) A fixed mass of ideal gas undergoes a cycle of changes as shown in Fig. 3.1. No thermal energy was transferred during the processes from A to B and C to D.

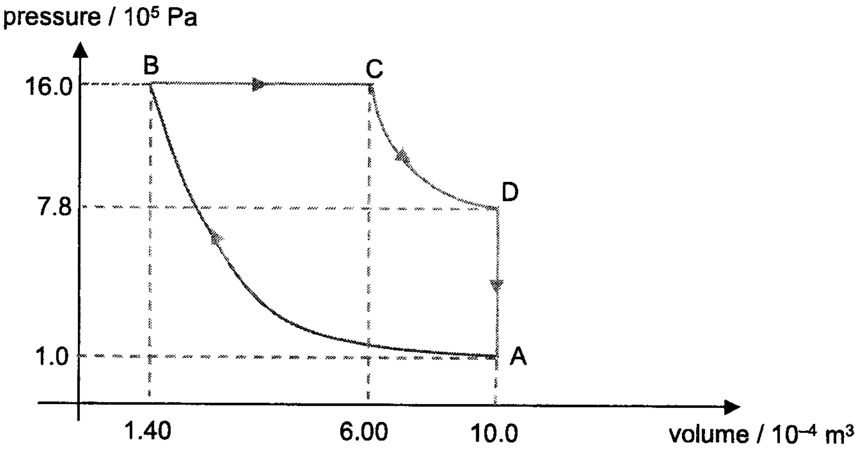


Fig 3.1

(i) State and explain whether the gas is at a higher temperature at C or D.

....

....

....

.... [2]

(ii) Fig. 3.2 shows the energy changes during one complete cycle. Complete the table.

Section of cycle	heat supplied to gas / J	work done on gas / J	increase in internal energy of gas / J
A to B			300
B to C		–740	1840
C to D			
D to A	–1700		

Fig. 3.2

[4]

[Total: 12]

For Examiner's Use

4 A ball of mass m is hung on a spring of spring constant k as shown in Fig. 4.1 below. The ball is in equilibrium and the spring is extended by a length of d.

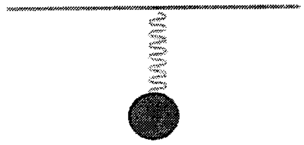


Fig. 4.1

The ball is displaced vertically downwards from its equilibrium position and then released. The acceleration of the ball is a and the vertical displacement of the ball from its equilibrium position is x.

(a) **(i)** By considering the resultant force acting on the ball, show that $a = -\frac{k}{m}x$.

[2]

(ii) Explain why the expression in **(a)(i)** leads to the conclusion that the ball is performing simple harmonic motion.

....

....

....

.... [2]

For Examiner's Use

(iii) The spring and ball system is now attached to an oscillator. The mass of the ball is 50 g and the spring constant is 1.2 N m^{-1}.

With reference to the expression in **(a)(i)**, determine the natural frequency of the system.

frequency = ... Hz [2]

(iv) On Fig. 4.2, sketch a graph showing the variation with frequency *f* of the oscillator of the amplitude *A* of the ball. Air resistance is not negligible.

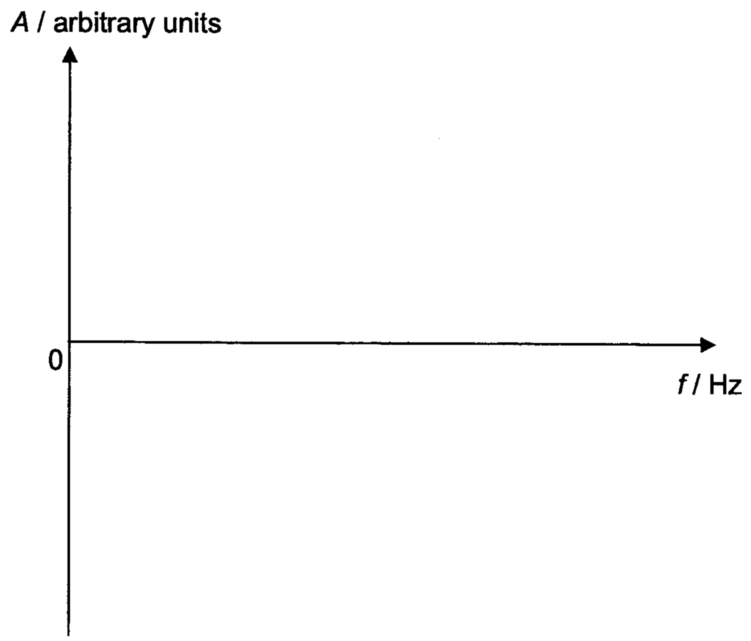


Fig. 4.2

[2]

For Examiner's Use

(b) The spring is now cut into two equal segments.

(i) Determine the natural frequency of the system if only one segment of the spring is used to support the ball.

frequency = ... Hz [2]

(ii) A piece of cardboard with negligible mass is then attached to the ball and the ball is made to oscillate with an initial displacement x_0.

On Fig. 4.3, sketch a graph showing the variation with time t of the displacement x of the ball.

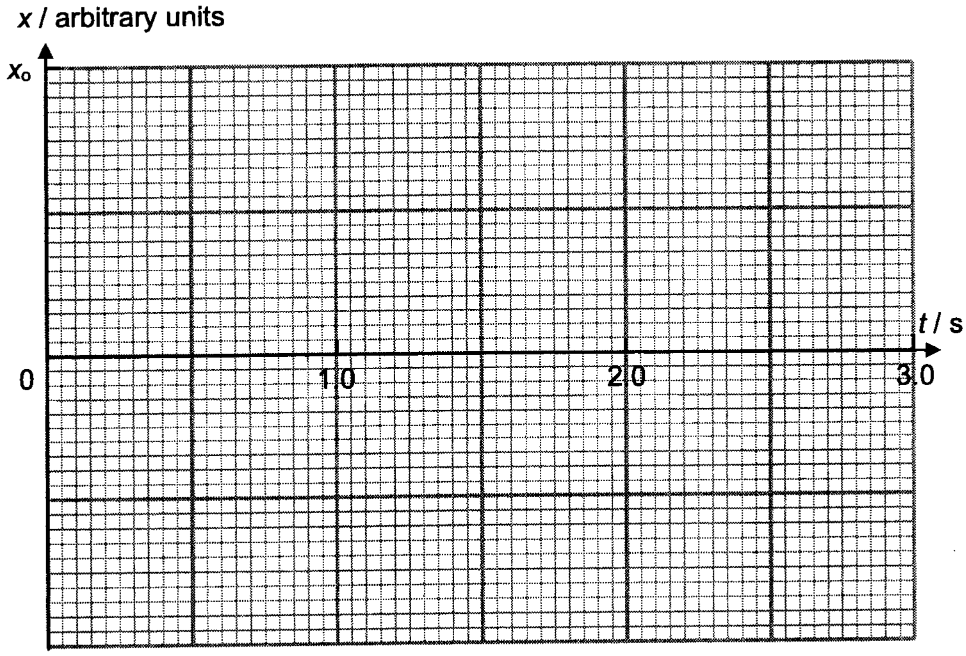


Fig. 4.3

[2]

[Total: 12]

For Examiner's Use

5 **(a)** Fig. 5.1 shows the schematic diagram of an experimental setup to study the photoelectric effect. Photons of wavelength 390 nm are incident on the emitter.

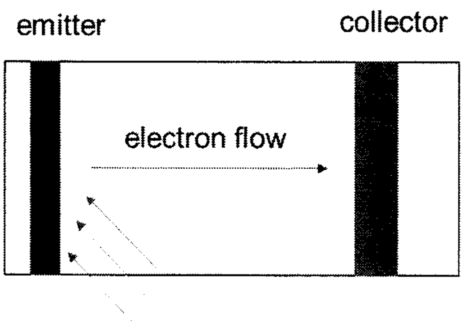


Fig. 5.1

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

....

....

....

.... [2]

(ii) Show that the energy of the photon is 3.19 eV.

[2]

(iii) Sodium and iron are used to investigate the photoelectric effect. The emitter and collector are made of the same metals for two set of experiments. For each metal tested, the photons incident on the emitter results in photocurrent detected. Fig. 5.2 shows the work functions of the metals.

metal	work function/ eV
sodium	2.46
iron	4.50

Fig. 5.2

For Examiner's Use

1. On Fig. 5.3, sketch the variation with frequency f of the maximum kinetic energy E_k of electrons emitted from both metals.

Label **Na** for the graph of sodium and **Fe** for the graph of iron.

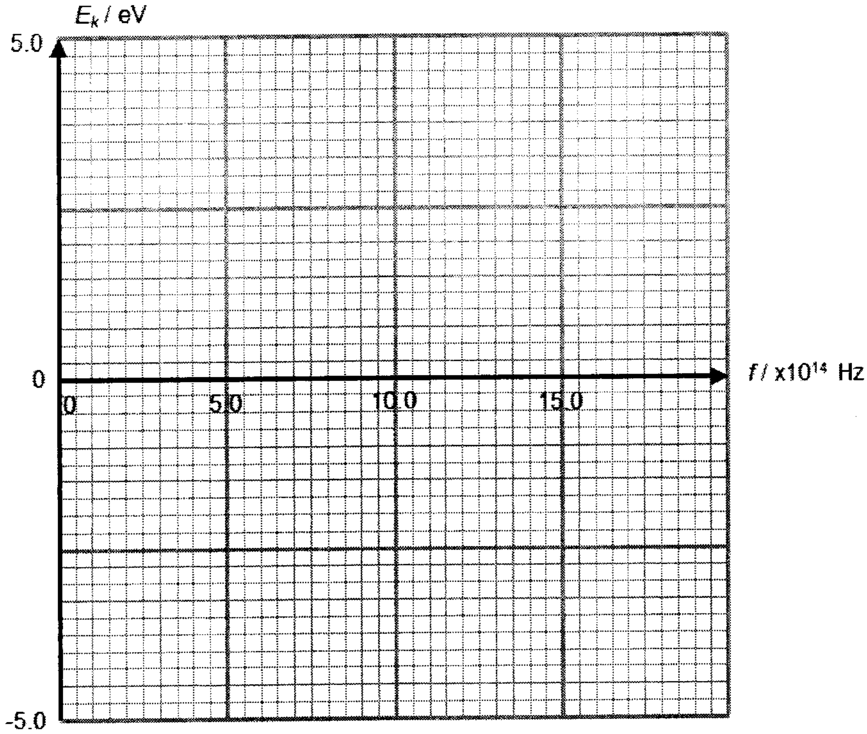


Fig. 5.3

[3]

2. The intensity of light incident on both metals is doubled while the wavelength remains constant.

State and explain the changes, if any, to the gradient and vertical intercept in Fig. 5.3.

gradient: ....

....

vertical intercept: ....

....

[2]

For Examiner's Use

(b) Fig. 5.4 shows some values of the energy levels of the hydrogen atom.

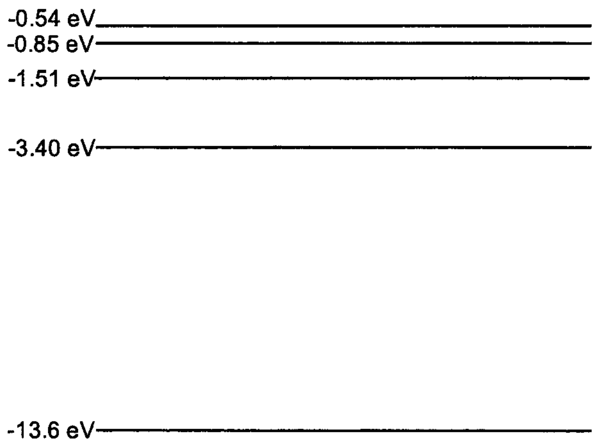


Fig. 5.4

(i) Using Fig. 5.4, state the ionisation energy of hydrogen atom.

ionisation energy = ... eV [1]

(ii) Explain why the energy level values in Fig. 5.4 are negative.

....

.... [1]

(iii) A beam of white light passes through a cloud of hydrogen gas and is observed on a screen. The spectrum of the transmitted light contains a few dark lines.

Explain why the dark lines occur.

....

....

....

....

....

....

.... [3]

[Total: 14]

For Examiner's Use

Section B

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

6 **(a)** Fig. 6.1 shows a six-string electric guitar. The sounds are amplified by electronic pickups (microphones), and an amplifier to convert the vibration of its strings into electrical signals and ultimately reproduced by loudspeakers as sound.

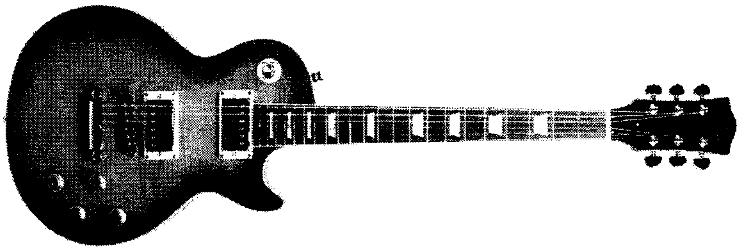


Fig. 6.1

(i) State the conditions required for the formation of stationary waves.

....

....

....

....

.... [2]

(ii) A guitar string produces a note of fundamental frequency 622 Hz. The velocity of wave travelling along the guitar string is 405 m s^{-1}.

1. Determine the effective length of the string.

length = ... m [2]

For Examiner's Use

2. The amplitude of the vibrating guitar string is 3.3 mm.

Determine the maximum velocity of the vibrating string when the whole string is momentarily at the equilibrium position.

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

(iii) The output of the electric guitar is fed into a loudspeaker. The loudspeaker emits hemispherical sound waves of mean power 200 W. A small microphone is placed at a distance 10.0 m from the loudspeaker.

1. Determine the mean intensity I of the sound wave detected by the microphone.

I = ... W m^{-2} [2]

2. Two identical loudspeakers are connected to an electric guitar playing a note of a single frequency. The loudspeakers are then placed a distance apart and facing each other.

State two reasons why a stationary wave may not be formed between the two loudspeakers.

1. ....

....

....

2. ....

....

.... [2]

For Examiner's Use

(b) Fig. 6.2 shows a human eye. To see an object, light from the object enters the eye through a small aperture known as the pupil and forms an image at the retina. The average diameter of the pupil is 3.00 mm and the distance between the pupil and the position of image at the retina is 17.0 mm.

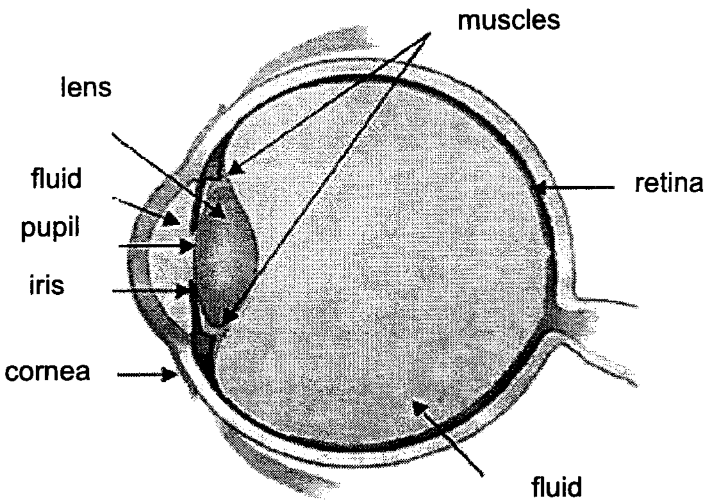


Fig. 6.2

(i) A beam of blue light passes through the pupil. The distance between the positions of zero intensity on both sides of the central bright fringe of the image is 4.80 μm on the retina.

Determine the wavelength of the blue light.

wavelength = ... nm [3]

For Examiner's Use

(ii) The Dutch artist Vincent van Gogh painted the *Irises* in 1889.

Fig. 6.3(a) shows an image of the actual painting.

Fig. 6.3(b) shows a pixelated poster of the *Irises*. The pixels have varying colours, shades or light intensities.

The wavelength of blue light ranges from 380 nm to 500 nm.

Fig. 6.3(a)

Fig. 6.3(b)

1. Explain the *Rayleigh criterion* for the optical resolution of two images.

....

....

....

....

.... [2]

For Examiner's Use

2. Determine the minimum angular resolution for the human eye to distinguish two adjacent pixels of blue light according to the *Rayleigh criterion*.

minimum angular resolution = ... rad [1]

3. In the pixelated poster of *Iris*es, there are 710 pixels within 72 cm vertically, and 820 pixels within 93 cm horizontally. The pixels of the flowers and majority of the leaves are in blue.

In practice, the angular resolution of a human eye is about 2.91×10^{-4} rad.

Determine if an observer can distinguish two adjacent blue pixels of the same wavelength in all directions if the distance between his eye and the poster is 1.5 m.

....

.... [3]

4. In dimmer lighting, the pupil diameter will increase to allow more light to enter the eye. For the observer in **(b)(ii)3.**, state and explain the change, if any, to the minimum distance between his eye and the poster to distinguish two adjacent blue pixels.

....

....

.... [1]

[Total: 20]

For Examiner's Use

7 **(a)** Flat coils are commonly used as metal detectors to detect mines buried underground and concealed metal objects at access points in airports, prisons and military bases.

Fig. 7.1 shows a flat circular coil P carrying a current of 2.0 A. The coil has 300 turns and a mean diameter of 0.10 m.

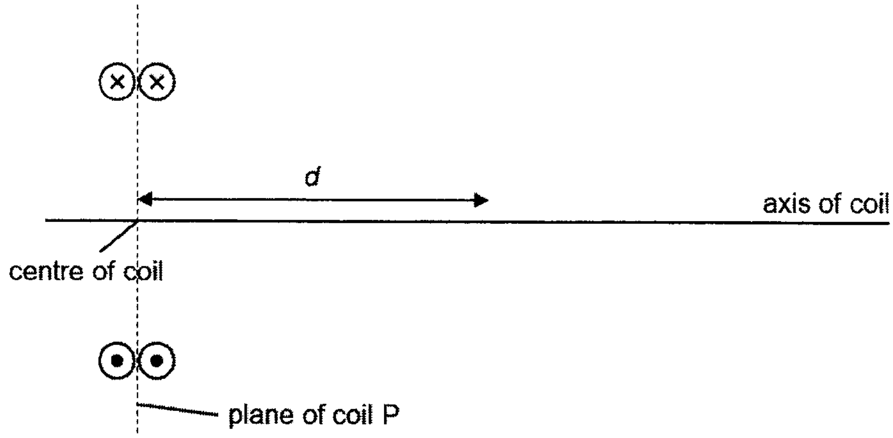


Fig. 7.1

The variation with distance *d* from the centre of the coil along its axis of the magnitude of the magnetic flux density *B* produced by the coil is shown in Fig. 7.2.

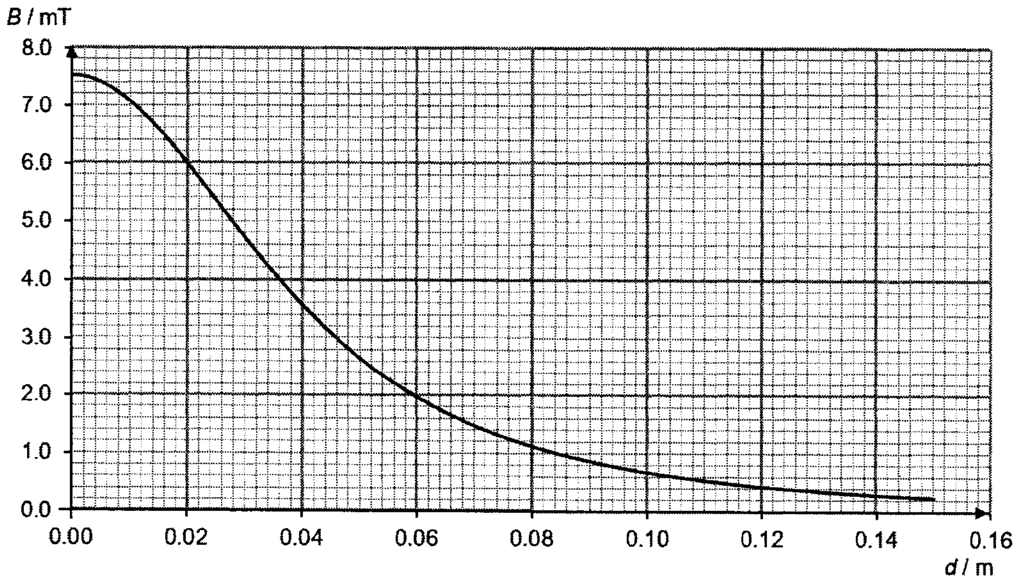


Fig. 7.2

(i) State the magnetic flux density at the centre of the coil B_C.

B_C = ... T [1]

For Examiner's Use

(ii) Hence determine a value for the permeability of free space μ_o.

μ_o = ... H m^{-1} [2]

(b) A smaller coil Q is placed with its axis aligned to coil P as shown in Fig. 7.3. Coil Q is moved away from coil P along the axis of the coils at a steady speed. The magnetic flux is always perpendicular to coil Q.

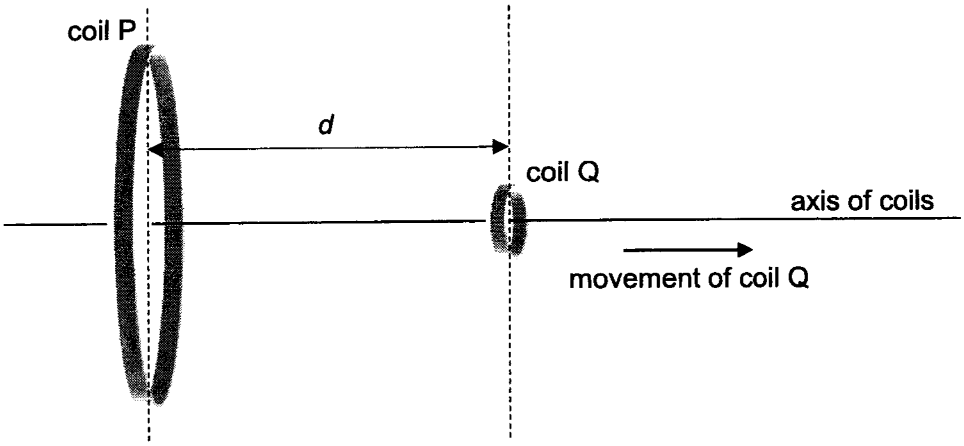


Fig. 7.3

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

....

....

.... [1]

For Examiner's Use

(ii) Estimate the value of *d* where the induced e.m.f. in coil Q is a maximum.

d = ... m [1]

(iii) With reference to Fig. 7.2, explain why the value of *d* in **(b)(ii)** results in maximum induced e.m.f in coil Q.

....

....

....

....

.... [2]

(iv) State and explain the direction of induced current in coil Q as it is moved along the axis of the coils.

....

....

....

....

.... [2]

(v) Coil Q is moved from the centre of coil P to a position 0.040 m along the axis of the coils in 0.25 s.

1. Determine the change in magnetic flux density ΔB during this time interval.

ΔB = ... T [1]

For Examiner's Use

2. Coil Q has 5000 turns, each of effective area 1.5×10^{-4} m^2.

Hence determine the magnitude of the average induced e.m.f. ε_{ave} in coil Q during this time interval.

ε_{ave} = ... V [3]

For Examiner's Use

(c) **(i)** Explain what is meant by the *root-mean-square* value of an alternating current.

....

....

.... [1]

(ii) The input voltage to an ideal transformer is as shown in Fig. 7.4. The turns ratio of the primary coil to the secondary coil is 50:1 and the mean input power is 20 W.

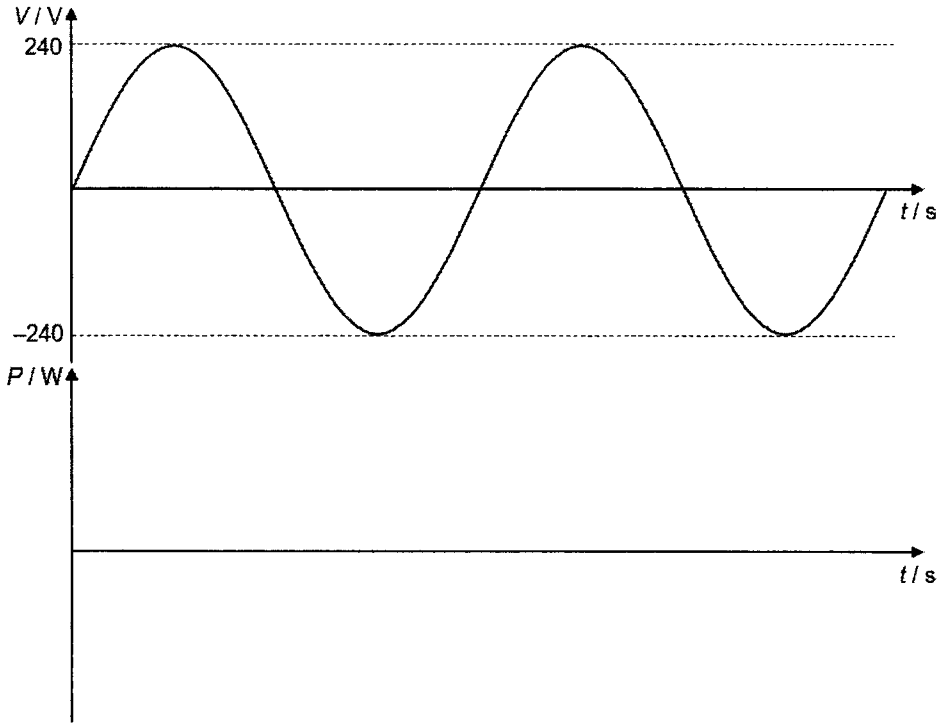


Fig. 7.4

1. On Fig. 7.4, sketch the variation with time t of the input power P to the transformer for two complete cycles. [2]

2. Determine the r.m.s. value of the output voltage.

r.m.s. output voltage = ... V [2]

[Turn over

For Examiner's Use

(iii) Draw a labeled circuit diagram to show how a sinusoidal voltage V_{in} can be converted into half-wave rectified voltage V_{out}.

[1]

(iv) If the output voltage of **(c)(ii)** was half-wave rectified by the circuit in **(c)(iii)**, determine the value of the r.m.s. output voltage.

r.m.s. output voltage = ... V [1]

[Total: 20]

End of Paper

Anglo-Chinese Junior College
Physics Preliminary Examination
Higher 2

A Methodist Institution
(Founded 1886)

CANDIDATE NAME		CLASS	

CENTRE NUMBER	S	3	0	0	4	INDEX NUMBER				

PHYSICS **9749/04**
Paper 4 Practical
1 August 2022
2 hours 30 mins

Candidates answer on the Question Paper.
Additional Materials: As listed In the Confidential Instructions

READ THESE INSTRUCTIONS FIRST

Write your name and index number 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 working.
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 the appropriate units.

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

Shift
Laboratory

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.

For Examiners' use only	
1	/ 10
2	/ 12
3	/ 21
4	/ 12
Total	/ 55

This paper consists of **20** printed pages

1 In this experiment you will investigate an electrical circuit.

(a) (i) Assemble the circuit shown in Fig. 1.1.

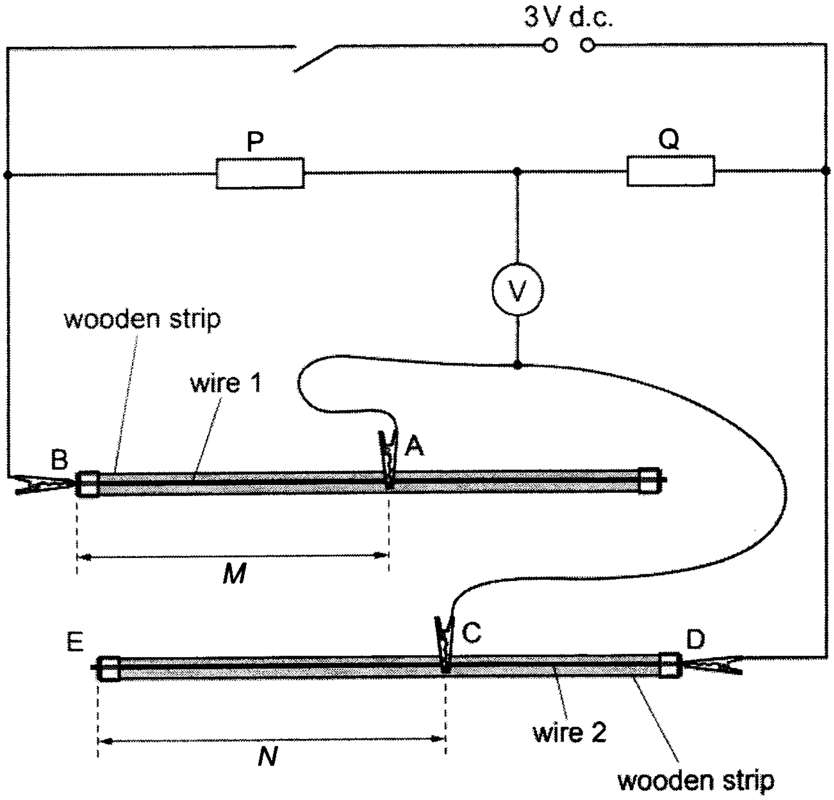


Fig. 1.1

A, B, C and D are crocodile clips.

Connect A approximately half-way along wire 1.

Measure and record the distance *M* between A and B as shown in Fig. 1.1.

M = ...

Close the switch.

Test your circuit by placing C at end E of wire 2. The voltmeter reading should be non-zero. Record the voltmeter reading.

voltmeter reading = ...

[1]

Open the switch.

(ii) Explain why the voltmeter reading in **(a)(i)** is not zero.

....

....

.... [1]

(iii) Close the switch.

Adjust the position of C on wire 2 until the voltmeter reading is as close as possible to zero.

The distance between C and E is *N* as shown in Fig. 1.1.

Measure and record *N*.

N = ...

[1]

Open the switch.

(iv) Move A to a new position on wire 1 such that *M* is approximately $\frac{3}{4}$ the length of wire 1.

Measure and record the distance *M*.

M = ...

Repeat **(a)(iii)**.

N = ...

[1]

For Examiner's Use

(b) It is suggested that the quantities M and N are related by the equation

$$\frac{1}{N} = a\left(\frac{M}{N}\right) + b$$

where a and b are constants.

(i) Use your answers in **(a)** to determine the values of a and b.

a = ...

b = ...

[2]

(ii) Use your answers in **(b)(i)** to determine the value of M when $M = N$.

M = ...

[1]

For Examiner's Use

(c) **(i)** On the cardboard, a sample of wire 1 and wire 2 are provided

Measure and record the diameter of wire 1, d_1.

d_1 = ...

Measure and record the diameter of wire 2, d_2.

d_2 = ...

[2]

(ii) Theory suggests that

$$a = \frac{\rho_1 Q d_2^{\,2}}{\rho_2 P L d_1^{\,2}}$$

where

ρ_1 is the resistivity of wire 1

ρ_2 is the resistivity of wire 2

P is the resistance of resistor P which is 220 Ω

Q is the resistance of resistor Q which is 100 Ω

L is the length of wire 2

Calculate $\frac{\rho_1}{\rho_2}$.

$\frac{\rho_1}{\rho_2}$ = ...

[1]

[Total: 10]

[Turn over

2 In this experiment, you will investigate the equilibrium position of a cardboard triangle.

(a) Assemble the apparatus as shown in Fig. 2.1, with the nail passing through the hole marked A and the wire hook passing through one of the remaining holes.

Ensure that the nail is held securely in the clamp and that the cardboard triangle can swing freely on the nail.

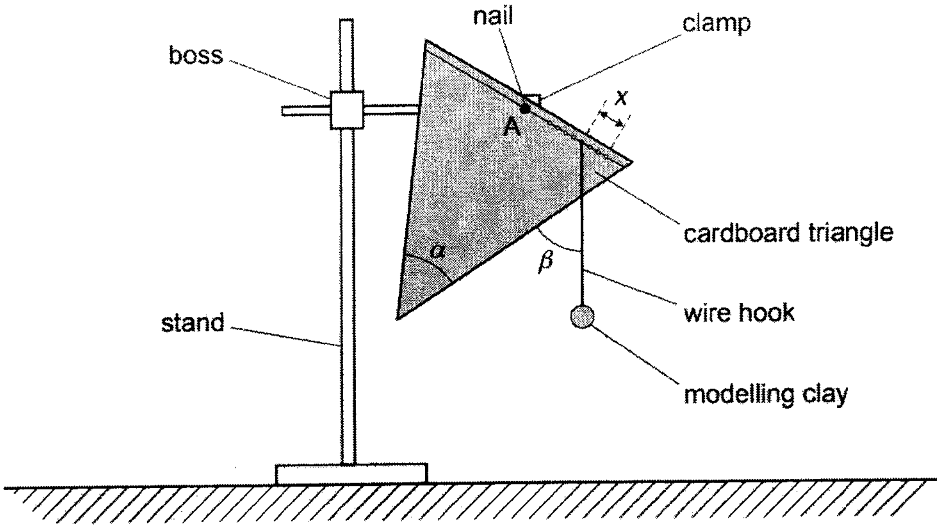


Fig. 2.1

The angle of the lower corner of the card is α, as shown in Fig. 2.1.

Measure and record α.

α = ...

Calculate the value of $\frac{\alpha}{2}$.

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

[1]

(b) The angle between the wire hook and the edge of the card is β, as shown in Fig. 2.1.

Measure and record β.

β = ...

The distance between the hole with the wire hook in it and the hole furthest from A is x, as shown in Fig. 2.1.

Measure and record x.

x = ...

[1]

(c) Vary distance x by moving the wire hook to another hole and repeat **(b)**.

Present your results clearly.

[5]

(d) It is suggested that the relationship between α, β and x is

$$\tan\left(\beta - \frac{\alpha}{2}\right) = Px + Q$$

where P and Q are constants.

Plot a suitable graph to determine the values for P and Q.

P = ...

Q = ...

[5]

[Total: 12]

3 In this experiment, you will explore oscillations of a catenary.

A catenary is the curve that an idealized hanging chain or cable assumes under its own weight when supported only at its ends in a uniform gravitational field. This can be seen in suspension bridges, free-hanging overhead power cables and even in the silk of the spider's web.

(a) **(i)** Assemble the hanging chain of 30 paper clips using the apparatus as shown in Fig. 3.1 with each nail held securely in a boss and at the same height above the bench.

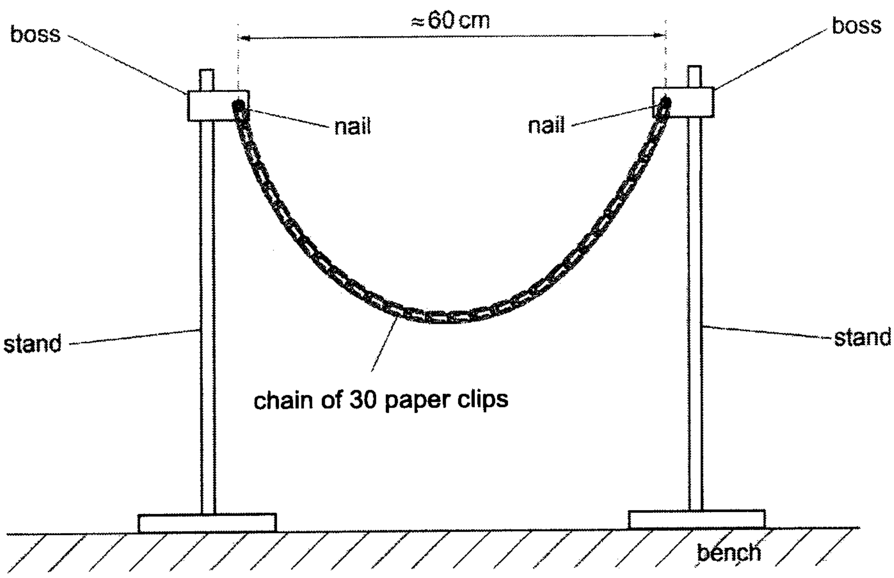


Fig. 3.1

Rest one of the metre rules on the nails, as shown in Fig. 3.2.

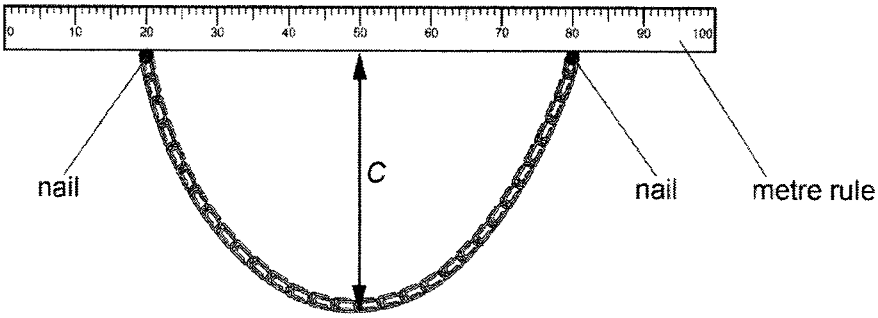


Fig. 3.2

The vertical distance between the horizontal metre rule and the lowest part of the chain is *C*.

Using the other metre rule, measure and record *C*.

C = ... [1]

(ii) Estimate the percentage uncertainty in your value of *C*. Show your working.

percentage uncertainty = ... [1]

(iii) Push the bottom of the chain a short distance away from you. Release it so that it swings towards and away from you.

Take measurements to determine the period *T* of these oscillations.

T = ... [1]

For Examiner's Use

(iv) Estimate the percentage uncertainty in your value of *T*. Show your working.

percentage uncertainty = ... [1]

(b) Shift the position of the stands so that the distance between the nails is approximately 40 cm.

Repeat **(a)(i)**. Measure and record *C*.

C = ...

Repeat **(a)(iii)**. Measure and determine *T*.

T = ...

[2]

(c) **(i)** Suggest one significant source of uncertainty in this experiment.

....

....

.... [1]

(ii) Suggest an improvement that could be made to the experiment to reduce the uncertainty identified in **(c)(i)**.

You may suggest the use of other apparatus or a different procedure.

....

....

.... [1]

For Examiner's Use

(d) It is suggested that the relationship between C and T is

$$\frac{1}{T^2} = \frac{k}{C}$$

where k is a constant.

(i) Using your data from **(a)** and **(b)**, calculate two values of k.

first value of k = ...

second value of k = ...

[1]

(ii) Justify the number of significant figures you have given for your values of k.

....

....

.... [1]

(iii) Using **(a)(ii)** and **(a)(iv)**, explain whether your results in **(d)(i)** support the suggested relationship.

....

....

.... [1]

[Turn over

(e) A student suggests that the period of the oscillation in **(a)(iii)** is independent of the mass of the paper clips.

Plan an investigation to verify if the student's suggestion is true. You will be provided with paper clips of varying mass.

You may suggest the use of any additional apparatus commonly found in a school physics laboratory.

....

....

....

....

....

....

....

....

....

....

....

.... [4]

(f) You will now investigate the small-amplitude oscillations of a vertical chain, suspended from one end, in a vertical plane.

Using the chain of paper clips provided, suspend one end of the chain from the nail so that the chain hangs freely in a vertical plane as shown in Fig. 3.5.

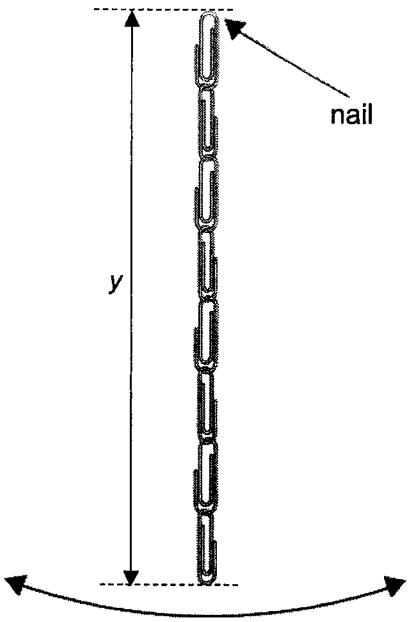


Fig. 3.3

(i) Vary *y*, the vertical length of paper clips chain, and obtain the values of *T*.

Using 10 to 20 paper clips, obtain at least 3 sets of results. Tabulate your results.

[3]

For Examiner's Use

(ii) Comparing your results in **(a)**, **(b)** and **(f)(i)**, suggest if it is possible for a hanging chain and a vertical chain to have the same period if $C = y$.

....

....

.... [1]

(iii) It is suggested that T can be calculated in the same manner as the period of a simple pendulum of length, y, equal to that of the chain.

Given that the period of a simple pendulum is

$$T = 2\pi\sqrt{\frac{y}{g}}$$

where g is the acceleration due to gravity.

Use your results in **(f)(i)** to show if this is true.

....

....

.... [2]

[Total: 21]

4 As a bar magnet is dropped vertically through a coil of *n* turns per unit length, an e.m.f. is induced in the coil. The maximum e.m.f. *E* is induced as the magnet leaves the coil with speed *v*.

It is suggested that the relationship between *E*, *n* and *v* is

$$E = k\,n^a\,v^b$$

where *k*, *a* and *b* are constants.

Design an experiment to determine the values of *k*, *a* and *b*.

Draw a diagram to show the arrangement of your apparatus. You should pay particular attention to

(a) the equipment you would use
(b) the procedure to be followed
(c) how the number of turns per unit length and speed are measured
(d) the control of variables
(e) any precautions that should be taken to improve the accuracy and safety of the experiment.

Diagram

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For Examiner's Use

For Examiner's Use

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