NAME ______________________ CLASS 2T ______

Catholic Junior College
JC2 Preliminary Examinations
Higher 2

PHYSICS
9749/01

Paper 1: Multiple Choice

4 September 2019
1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write your name and tutorial group on this cover page.
Write and/or shade your name, NRIC / FIN number and HT group on the Answer Sheet (OMR sheet), unless this has been done for you.
Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all 30 questions in** this paper.
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 (OMR sheet).

Read the instructions on the Answer Sheet carefully.

Each correct answer will be awarded 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 permitted, where appropriate.

PHYSICS DATA:

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
			$\approx (1/(36\pi)) \times 10^{-9}$ 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} mol^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

PHYSICS 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	=	ρgh
gravitational potential	ϕ	=	$-\dfrac{Gm}{r}$
temperature	T/K	=	$T/^{\circ}C + 273.15$
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	=	$x_0 \sin \omega t$
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	=	$\dfrac{Q}{4\pi\varepsilon_0 r}$
alternating current / voltage	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\dfrac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\dfrac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\dfrac{\ln 2}{t_{\frac{1}{2}}}$

1 The table below shows the estimates of some physical quantities.

Which row is **not** a reasonable estimate?

	quantity	value
A	current used in an electric kettle	8 A
B	mass of an adult male	70 kg
C	speed of an Olympic sprint runner	$10\ \text{m s}^{-1}$
D	water pressure at the bottom of a public swimming pool	10^4 Pa

2 A potential difference (p.d.) is carefully measured with a high-quality instrument and found to be 2.321 V.

Two students, using two different methods to measure the p.d., quote the p.d. as 2.33 V and 2.344 V respectively.

Which statement is correct?

A The reading 2.33 V is more accurate and more precise than the reading 2.344 V.

B The reading 2.33 V is more accurate but less precise than the reading 2.344 V.

C The reading 2.33 V is less accurate but more precise than the reading 2.344 V.

D The reading 2.33 V is less accurate and less precise than the reading 2.344 V.

3 A man is parachuting towards the Earth. According to Newton's third law of motion, the force which makes an action-reaction pair with the gravitational force on the man is

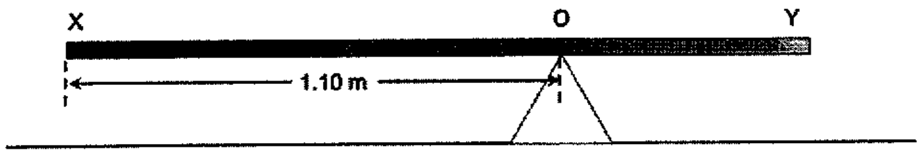
A the gravitational force on the Earth due to the man.

B the viscous force of the man and his parachute on the air.

C the viscous force of the air on the man and his parachute.

D the tension in the harness of the parachute.

4 A non-uniform rod XY is balanced horizontally on top of a triangular wedge. The top of the wedge O is at a distance 1.10 m from the end X of the rod.

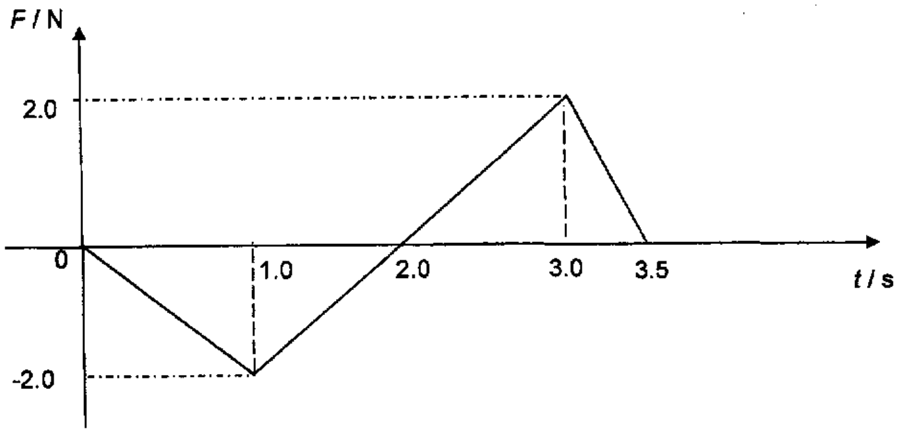


A 1500 g mass is hung at a distance of 0.20 m from X. The rod now needs to be moved 0.25 m to the right to balance horizontally.

What is the mass of the rod?

A 1.2 kg **B** 3.9 kg **C** 6.6 kg **D** 7.8 kg

5 A resultant force F acts on a mass of 150 g. The variation with time t of F is shown on the diagram below.

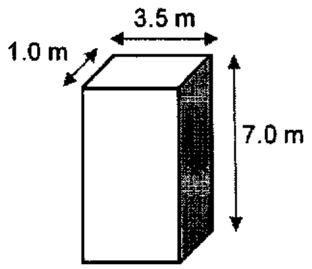


At time t = 0 s, the mass is moving with a velocity of 2.0 m s^{-1}.

What is the speed of the mass at t = 3.0 s?

A 2.7 m s^{-1}
B 4.7 m s^{-1}
C 6.7 m s^{-1}
D 8.7 m s^{-1}

6 The diagram below shows a wooden block in its upright position, with length 1.0 m, width 3.5 m and height 7.0 m. The density of wood is 850 kg m^{-3}.

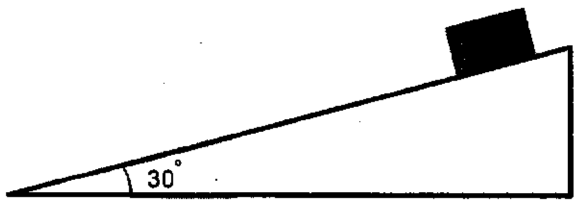


What is the submerged depth of the wooden block when it floats upright in water?

Density of water is 1000 kg m^{-3}.

A 0.85 m **B** 5.6 m **C** 6.0 m **D** 7.0 m

7 A block starts to slide down a 30° slope from rest as shown in the figure below.



Assume that the friction on the block is negligible. What is the final speed of the block after it has travelled 10 m down the slope?

A 4.9 m s^{-1} **B** 8.5 m s^{-1} **C** 9.9 m s^{-1} **D** 13 m s^{-1}

8 A body of mass 90 kg travels along a horizontal road at a speed of 5.0 m s^{-1}. It then accelerates at 1.5 m s^{-2}. At the time it begins to accelerate, the total resistive force acting on the car is 200 N.

What total output power is developed by the car as it begins the acceleration?

A 680 W
B 1700 W
C 4400 W
D 5400 W

9 A car is making a circular turn of radius r with speed v. The centripetal force on the car is F.

What is the centripetal force on the car when it makes the same turn at speed $2v$?

A $\frac{F}{2}$
B F
C $2F$
D $4F$

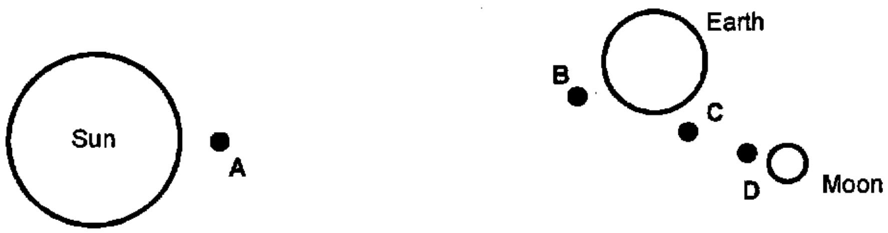
10 A small sphere is moving in a vertical circle at constant speed.

The magnitude of the resultant force on the sphere

A at the bottom of the circle is greater than the resultant force at the top.
B at the top of the circle is greater than the resultant force at the bottom.
C decreases as the sphere moves from the bottom to the top of the circle.
D is the same at the top of the loop as it is at the bottom of the circle.

11 The neutral point in the gravitational field between the Sun, the Earth and the Moon is the point at which the resultant gravitational field due to the three bodies is zero. The mass of the Earth is about 80 times the mass of the Moon.

At what position is it possible for the neutral point to be? (The diagram is not drawn to scale)



12 Which statement about two satellites of different masses in the geostationary orbit around the Earth is ***incorrect***?

A The gravitational forces acting on the two satellites are different.
B The centripetal acceleration of each satellite is different.
C The total energy of each satellite is different.
D The angular velocities of the two satellites are the same.

13 Two monoatomic gases, X and Y, are in thermal equilibrium in a mixture. The molecular mass of gas Y is half the molecular mass of gas X.

The root mean square speed of the molecules of gas Y is v. What is the root mean square speed of the molecules of gas X?

A $\frac{v}{2}$

B $\frac{v}{\sqrt{2}}$

C v

D $2v$

14 The piston is pushed very slowly into a metal cylinder containing an ideal gas.

If the temperature of the gas does not change in the process. Which of the following statements is ***incorrect***?

A The work done on the gas is equal to the heat lost by the gas.
B The pressure of the gas increases.
C The average kinetic energy of the gas molecules increases due to the work done on the gas.
D The internal energy of the gas remains constant.

15 A small mass undergoes simple harmonic motion about a point O with amplitude x_o and period T. Its displacement x from O at time $\frac{1}{6}T$ after passing through O is

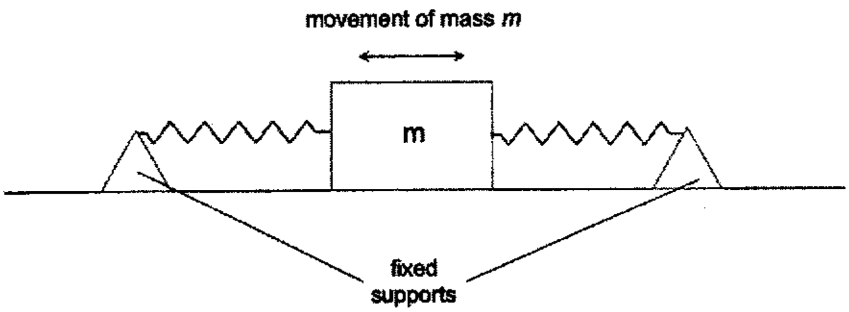
A $\frac{x_o}{6}$

B $\frac{x_o}{2\sqrt{3}}$

C $\frac{x_o}{2}$

D $\frac{\sqrt{3}x_o}{2}$

16 A mass *m* on a smooth horizontal table is attached by two light springs to two fixed supports as shown below. The mass executes simple harmonic motion of amplitude *a* and period *T*.



The total energy of oscillation is

A $2\pi ma^2/T^2$

B $2\pi m^2a^2/T$

C $\pi^2 ma^2/T^2$

D $2\pi^2 ma^2/T^2$

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** $\frac{4\pi}{5}$ rad

18 Fig. 1 shows how the displacement of a wave varies with distance along the wave at one particular time.

Fig. 2 shows how the displacement of one particular point P of the same wave varies with time.

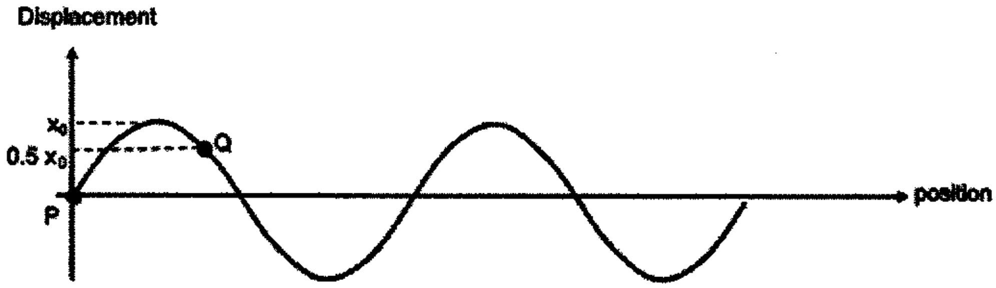


Fig. 1

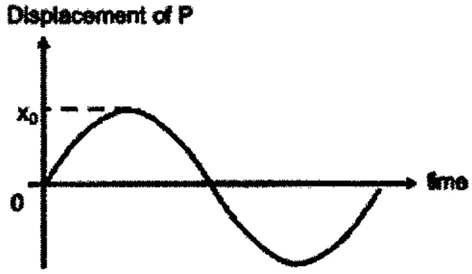
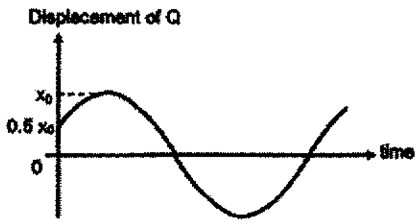


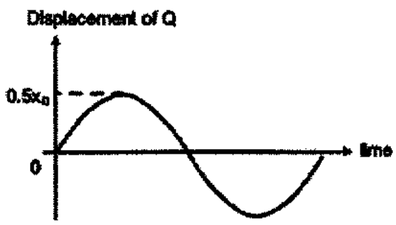
Fig. 2

Which of the following graphs correctly depicts the displacement-time graph for point Q?

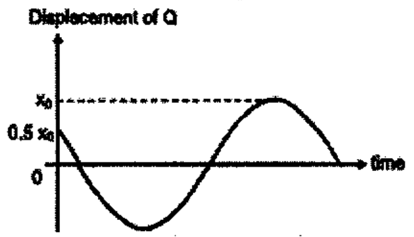
A



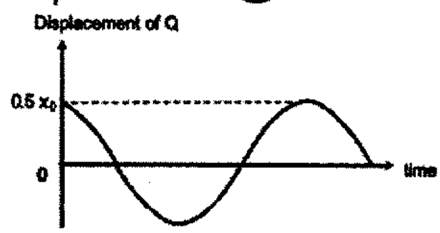
B



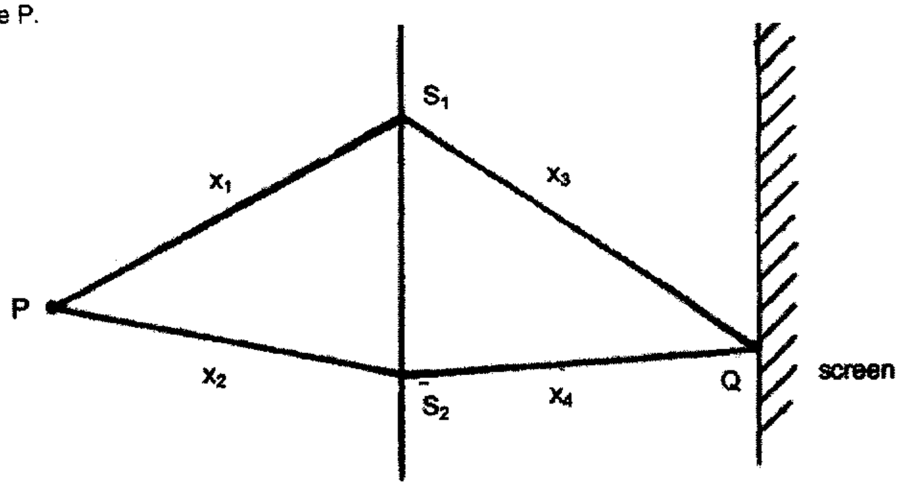
C



D



19 Two identical narrow slits S_1 and S_2 are illuminated with light of wavelength λ from a point source P.



If, as shown in the diagram above, the light is then allowed to fall on a screen, and if m is a positive integer, the condition for constructive interference at Q is

A $x_1 - x_2 = (2m+1)\frac{\lambda}{2}$

B $x_3 - x_4 = (2m+1)\frac{\lambda}{2}$

C $x_3 - x_4 = m\lambda$

D $(x_1 + x_3) - (x_2 + x_4) = m\lambda$

20 A beam of light that consists of all wavelengths between 480 nm and 600 nm is projected onto a diffraction grating that contains 500 lines per millimeter.

What is the maximum number of complete continuous spectra that can be observed emerging from the grating?

A 6 **B** 7 **C** 8 **D** 9

21 The charge of a uranium nucleus is 1.5×10^{-17} C.

What is the potential at the mid-point between a uranium nucleus and an alpha particle if they are separated by a distance of 1.0×10^{-13} m?

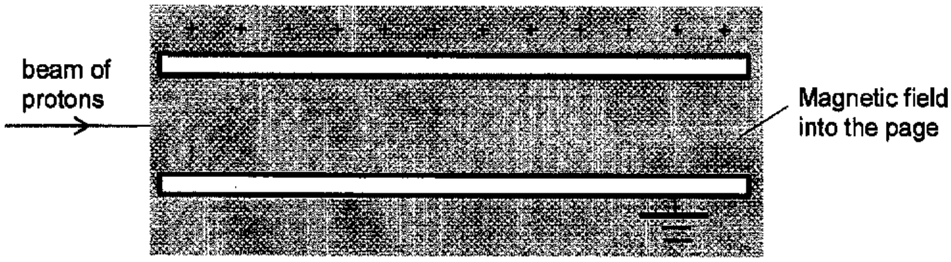
A 2.2×10^{-13} V

B 4.3×10^{-13} V

C 2.8×10^{6} V

D 5.5×10^{6} V

22 A velocity selector for protons has an electric field of strength 3.0×10^5 V m^{-1}, produced by two horizontal plates. The upper plate is connected to a positive potential and the lower plate is earthed. A magnetic field of flux density 1.5×10^{-2} T, directed into the plane of the paper, is at right-angle to the electric field as shown in the diagram.



Which of the following could be the possible speed of a proton and its observation?

	speed	observation
A	1.8×10^7 m s^{-1}	undeflected
B	2.0×10^7 m s^{-1}	deflected downwards
C	2.2×10^7 m s^{-1}	deflected downwards
D	2.4×10^7 m s^{-1}	deflected upwards

23 When four identical resistors are connected as shown in diagram 1, the ammeter reads 1.0 A and the voltmeter reads zero.

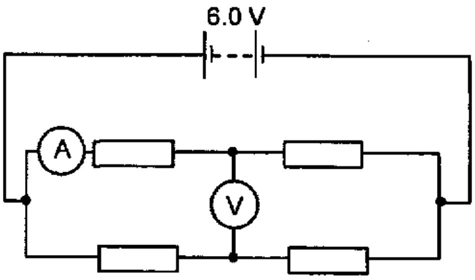


diagram 1

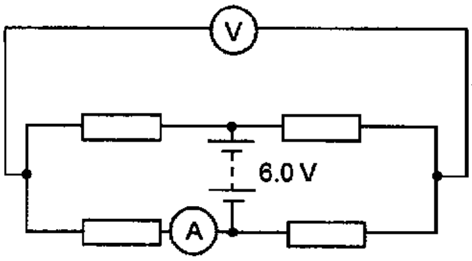


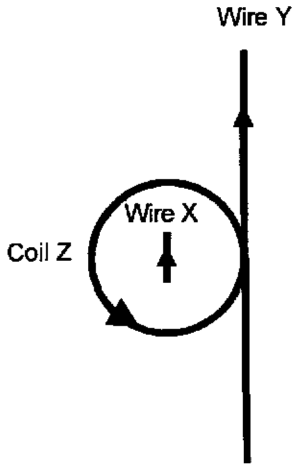
diagram 2

The resistors and meters are reconnected to the supply as shown in diagram 2.

What are the meter readings in diagram 2?

	voltmeter reading / V	ammeter reading / A
A	0	1.0
B	0	0.5
C	3.0	1.0
D	6.0	0.5

24 The diagram below shows a setup of two current-carrying wires X and Y, and a single-turn coil Z.



Wire X has length 0.050 m with a current of 1.0 A flowing through it. Wire Y has length 2.0 m with a current of 0.50 A. Coil Z has a diameter of 0.20 m with a current of 1.5 A.

What is the resultant force on wire X if the centre of coil Z is on wire X?

A 5.0×10^{-8} N
B 4.2×10^{-7} N
C 5.2×10^{-7} N
D 9.4×10^{-6} N

25 Diagram A shows an aluminium rod moving away from point O, at right angle to a uniform magnetic field.

Diagram B shows the variation with time *t* of its displacement *s* from O.

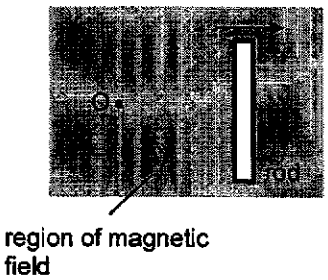


Diagram A

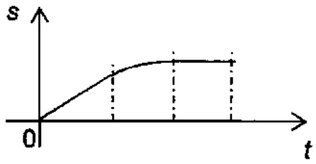
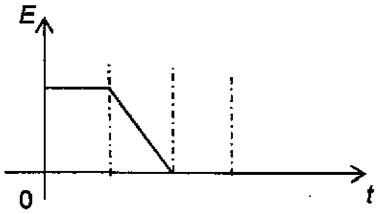


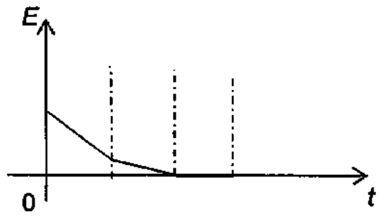
Diagram B

Which graph best shows the variation with *t* of the e.m.f. *E* induced in the rod?

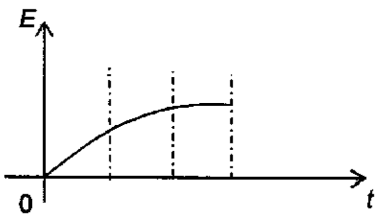
A



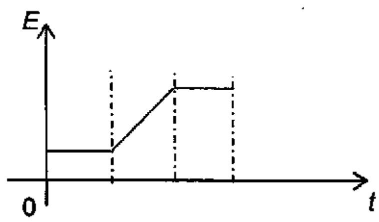
B



C



D



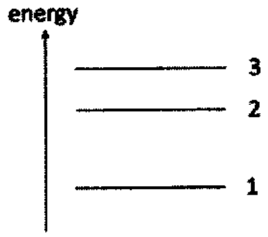
26 A sinusoidal current is represented by the equation

$$I = I_o \sin(\omega t)$$

Which equation represents the sinusoidal current with both its period and amplitude doubled?

A $2I = I_o \sin(2\omega t)$
B $I = 2I_o \sin(2\omega t)$
C $I = \frac{1}{2} I_o \sin(2\omega t)$
D $I = 2I_o \sin(\frac{1}{2}\omega t)$

27 Part of the energy level diagram of a certain atom is shown below. The energy spacing between levels 1 and 2 is three times that between 2 and 3. If an electron makes a transition from level 3 to level 2, the radiation of wavelength λ is emitted.



What possible radiation wavelengths might be produced by other transitions between the three energy levels?

A only $\frac{\lambda}{3}$

B both $\frac{\lambda}{3}$ and $\frac{\lambda}{4}$

C only 3λ

D only 4λ

28 Which one of the following statements, referring to a photoelectric emission, is true?

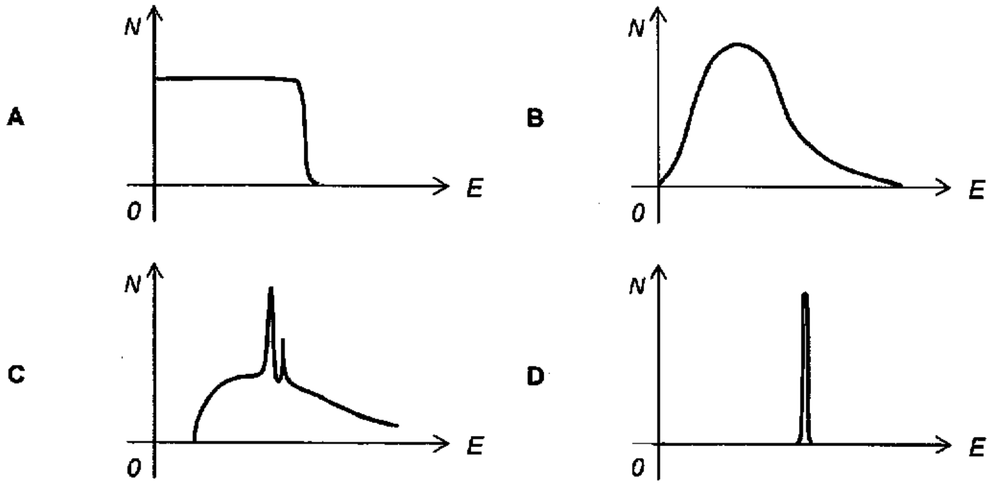
A No emission of electrons occurs for very low intensity illumination, even if the illumination's frequency is above the threshold frequency.

B For a given metal there is a minimum frequency of radiation below which no emission occurs.

C The velocity of the emitted electrons is proportional to the intensity of the incident radiation.

D The number of electrons emitted per second is dependent on the threshold frequency of the given metal if the frequency of the incident photon is higher than the threshold frequency.

29 Which one of the following best represents the number N of alpha-particles emitted from a given radioactive source possessing energy E ?



30 Which nuclide has the greatest initial activity?

	nuclide	amount/mole	half-life/day
A	$^{228}_{88}Ra$	0.7	2100
B	$^{225}_{89}Ac$	0.002	10
C	$^{228}_{90}Th$	0.09	400
D	$^{241}_{94}Pu$	0.09	4800

-- END OF PAPER 1 –

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Catholic Junior College

JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME	
CLASS	2T

PHYSICS

9749/02

Paper 2: Structured Questions

26 August 2019
2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen in the space provided. [PILOT FRIXION ERASABLE PENS ARE NOT ALLOWED]
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions in Paper 2.

FOR EXAMINER'S USE		DIFFICULTY		
		L1	L2	L3
Q1	/ 10			
Q2	/ 11			
Q3	/ 11			
Q4	/ 12			
Q5	/ 8			
Q6	/ 8			
Q7	/ 20			
PAPER 2	/ 80			

This document consists of **22** printed pages and **zero** blank page.

[Turn over

PHYSICS DATA:

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permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
			$\approx (1/(36\pi)) \times 10^{-9}$ 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} mol^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

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	v^2	=	$u^2 + 2as$
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hydrostatic pressure	P	=	ρgh
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	=	$x_0 \sin \omega t$
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	=	$\dfrac{Q}{4\pi\varepsilon_0 r}$
alternating current / voltage	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\dfrac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\dfrac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\dfrac{\ln 2}{t_{\frac{1}{2}}}$

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

1 **(a)** A truck is accelerated from rest by a constant driving force. It experiences a drag force which is proportional to its speed. Eventually, the truck travels at a constant velocity.

Explain why the truck reaches a constant velocity.

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....

.... [2]

(b) On Fig. 1.1 sketch a graph to show how the acceleration of the truck varies with time from the time when it was at rest to the time when it reaches the constant velocity.

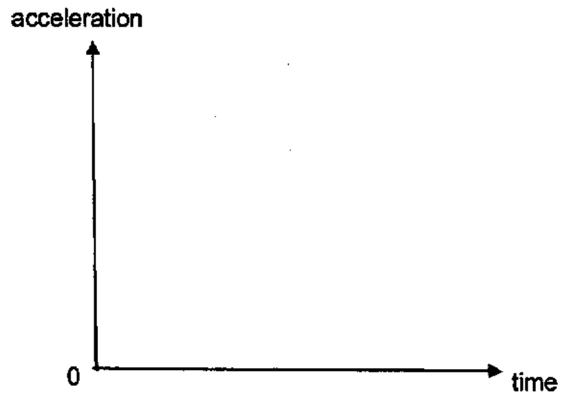
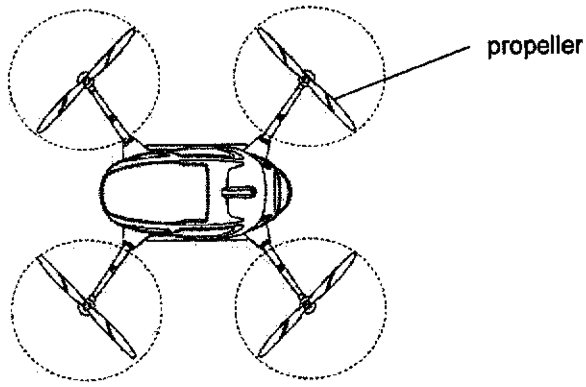


Fig. 1.1 [1]

(c) Fig. 1.2 shows a drone that is able to hover by rotating the four horizontal propellers attached to its body. The propellers push the air downwards and impart the air with a certain speed. The mass of the drone is 0.50 kg and each of the propellers has a radius of 15.0 cm.



Top view of a drone

Fig. 1.2

(i) Calculate the upward force by the air on the drone.

upward force = ... N [1]

(ii) State, with a reason, the magnitude of the downward force exerted by all of the drone's propellers on the air.

....

....

....

....

.... [2]

(iii) The density of air is 1.3 kg m^{-3}.

Determine using Newton's second law of motion the speed imparted to the air by the propellers.

speed = ... m s^{-1} [4]

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

....

....

....

.... [2]

(b) A fixed mass of monatomic ideal gas undergoes a cycle of changes A → B → C → A as shown in Fig. 2.1.

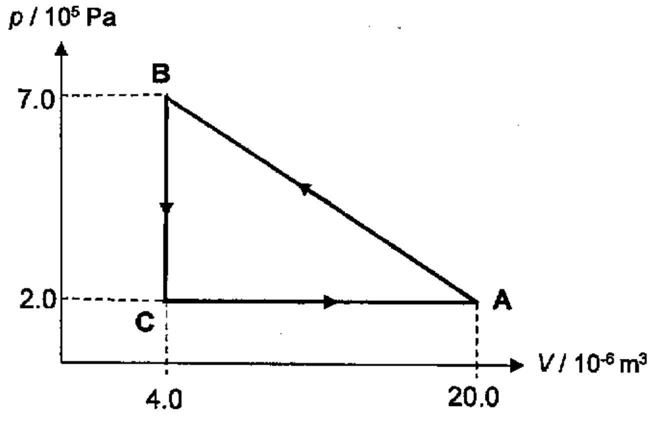


Fig. 2.1

(i) Explain why the change in internal energy of the ideal gas during a complete cycle A → B → C → A is zero.

....

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.... [2]

(ii) Calculate the work done on the gas during the process from A to B.

work done on gas = ... J [2]

(iii) Calculate the change in internal energy of the gas when it undergoes the process from A to B.

Change in internal energy = ... J [2]

(iv) Calculate the heat supplied to the ideal gas during the process from A to B.

heat supplied = ... J [2]

(v) In a car engine, the expanding combustion gases push the piston which causes the car to move.

Suggest, with a reason, whether the cycle of changes A → B → C → A could be the cycle in the piston engine of a car.

....

....

....

.... [1]

3 **(a)** Two light identical springs are joined in series and a 120 g bar magnet is hung from the lower end as shown in Fig. 3.1. The effective spring constant of the combined springs is 11 N m^{-1}.

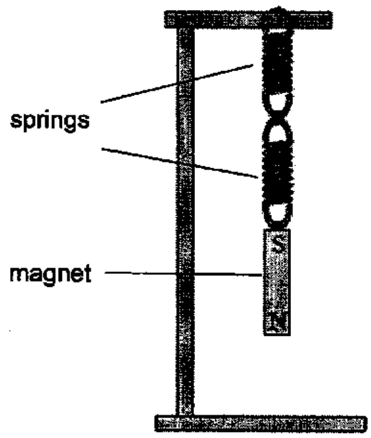

Fig. 3.1

The bar magnet is displaced a small distance vertically downward from its equilibrium position and released. It then oscillates in simple harmonic motion.

(i) By considering the forces on the magnet at its equilibrium position, and also at a small displacement x downward from its equilibrium position, show that the oscillation is a simple harmonic motion where the acceleration a is given by the equation

$$a = -92\,x$$

[4]

(ii) Hence calculate the frequency at which the magnet oscillates.

frequency = ... Hz [2]

(b) Two systems in part **(a)** are now suspended with the North pole of their magnets located inside a coil of wire. The two coils are connected together with conducting leads as shown in Fig. 3.2.

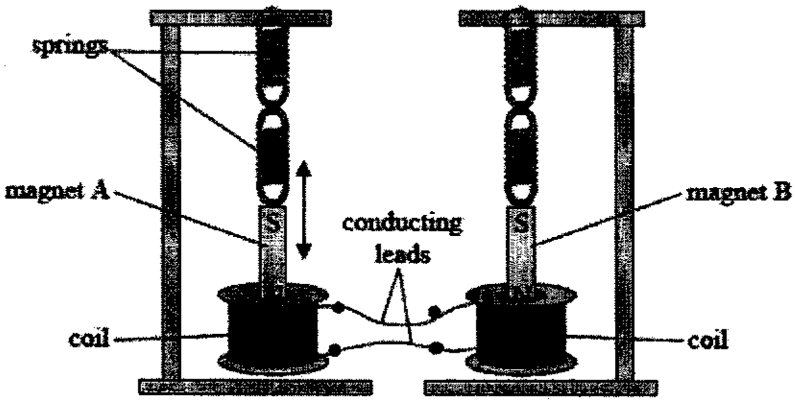

Fig. 3.2

Magnet A is displaced so that it oscillates vertically. The North pole of magnet A moves into and out of the coil of wire with simple harmonic motion. As this motion continues, magnet B starts to oscillate. The amplitude of oscillation of magnet B increases over time.

Explain why magnet B starts to oscillate with an increasing amplitude.

....

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.... [5]

4 **(a)** Define *electromotive force* of a cell, and explain its difference from the *terminal potential difference* across the terminals of the cell.

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.... [2]

(b) The variation with current I of terminal potential difference V across a battery with e.m.f. E and internal resistance r is shown in Fig. 4.1.

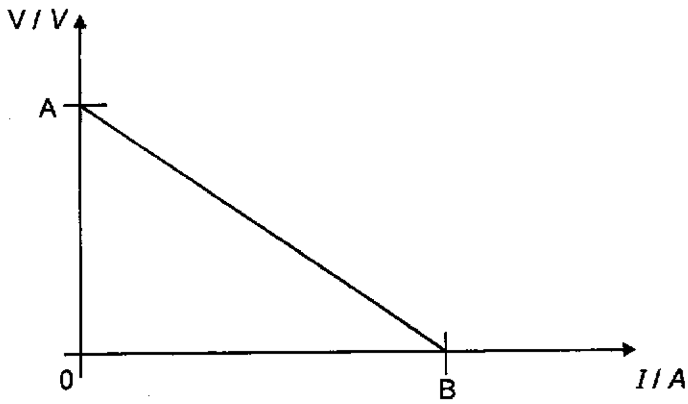

Fig. 4.1

In Fig. 4.1, state and explain the significance of the values of

(i) the vertical intercept, A;

....

....

.... [2]

(ii) the horizontal intercept, B.

....

....

....

....

.... [2]

(c) In an attempt to obtain the graph of Fig. 4.1 for the battery, a student sets up a circuit as shown in Fig. 4.2.

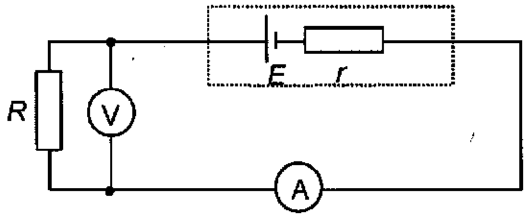

Fig. 4.2

State and explain why the circuit shown in Fig. 4.2 is inappropriate for obtaining data for the full range of values in Fig. 4.1.

....

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....

.... [4]

(d) In the space below draw a circuit diagram, using the appropriate components, from which the full range of values in Fig. 4.1 may be obtained.

[2]

5 Fig. 5.1 shows a point source S emitting continuous waves at a distance *h* from a plane reflector R. As a result, regions of high intensity such as C, C' and C" are produced.

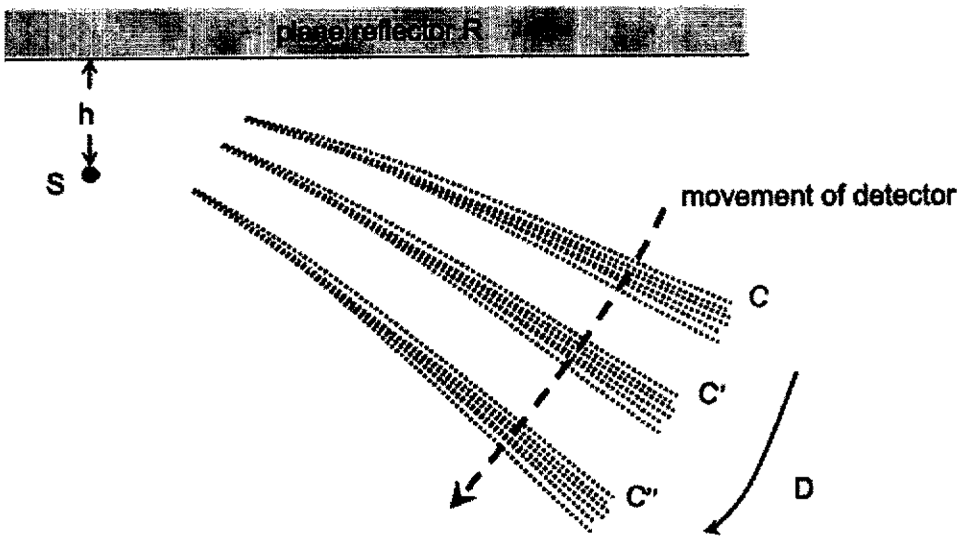

Fig. 5.1

(a) Explain why regions of high intensity such as C, C' and C" are produced.

....

....

....

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....

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....

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.... [3]

(b) A detector is moved in the direction indicated by the dotted arrow in Fig. 5.1. Explain how the detected intensity of the waves would vary.

.... [3]

(c) When the frequency of S is decreased slowly, the regions C, C' and C" move in the direction D as shown in Fig. 5.1. Explain this phenomenon.

.... [2]

6 **(a)** A simple a.c. generator which consists of a rectangular coil with 40 turns is rotating at 50 revolutions per second in a uniform magnetic field of flux density 50 mT. The coil is 50 cm long and 35 cm wide, as shown in Fig. 6.1.

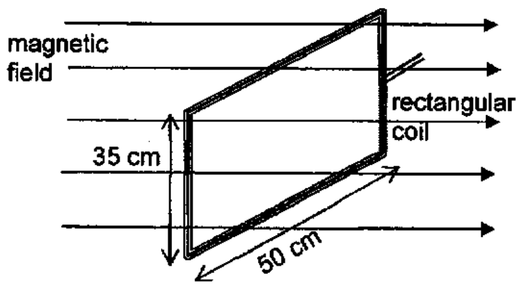


Fig. 6.1

(i) Define *magnetic flux.*

....

....

.... [1]

(ii) Calculate the maximum e.m.f. induced in the coil.

maximum e.m.f. = ... V [2]

(b) The output from the generator in part **(a)** is connected to the input of a transformer. The transformer has 40 turns on its primary coil and 10 turns on its secondary coil. The transformer may be considered to be ideal. The output from the transformer is connected to a resistor of resistance 100 Ω and a diode, as shown in Fig. 6.2.

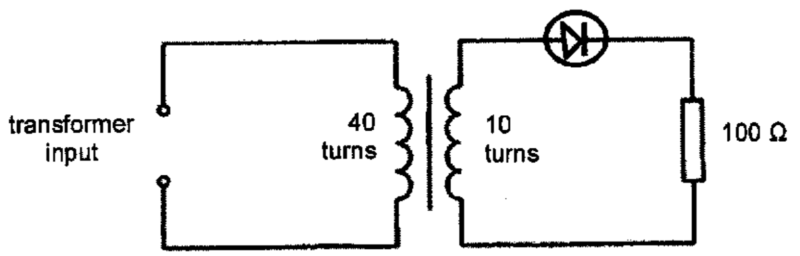


Fig. 6.2

Calculate the root-mean-square voltage across the resistor.

root-mean-square voltage = ... V [3]

(c) In an attempt to draw the circuit diagram that represents the system in part **(b)**, a student drew Fig. 6.3 instead.

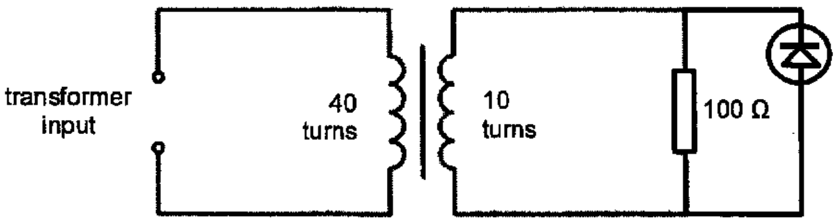


Fig. 6.3

Suggest, with a reason, what will happen if the circuit is set up according to Fig. 6.3.

....

....

....

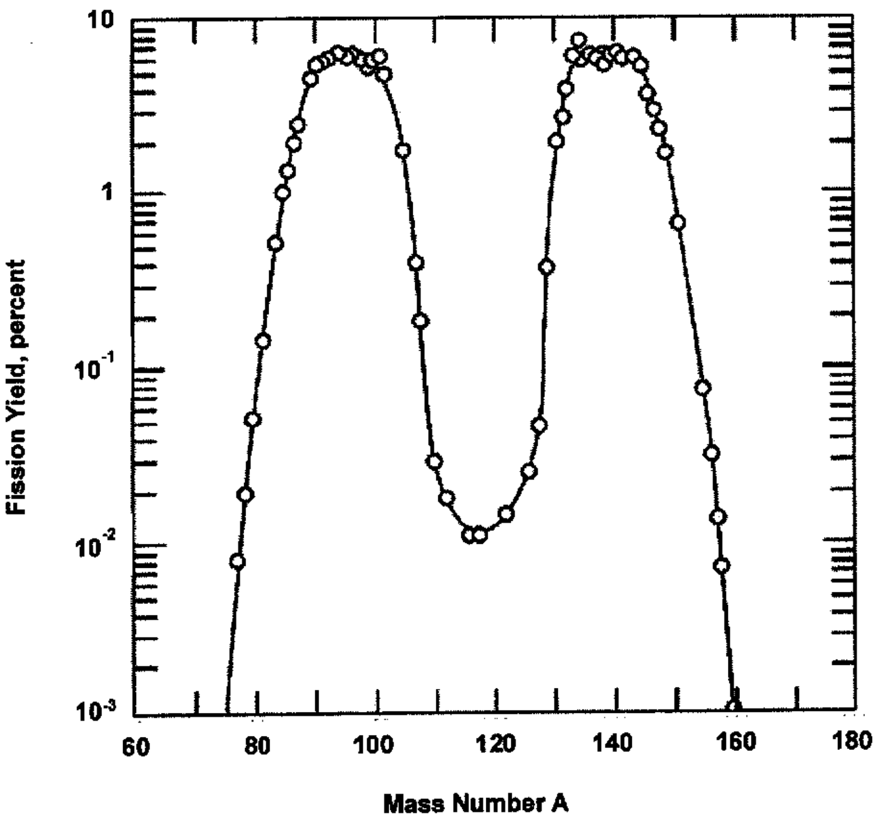
....

....

.... [2]

7 When a very strong earthquake of magnitude 9.0 hit Japan on 11 March 2011, the accompanying tsunami caused the devastation of the Fukushima Dai-ichi Nuclear Power Plant (Fk-1). A large amount of radioactive material leaked out of Fk-1 as a result, mainly through cracks made by the quake on some reactors, explosions, intentional vents to relieve pressure, and leakage of cooling water that was contaminated with the melted fuel rod debris.

Fk-1 was capable of generating up to 4.7 gigawatts of power through neutron-induced fissions of Uranium-235 (^{235}U) nuclei. Fission resulting from neutron absorption is called *induced* fission. Some nuclides can also undergo *spontaneous* fission, but that is quite rare. Nuclear fission is a decay process in which an unstable nucleus splits into two fragments of comparable mass, although nearly equal mass is unlikely. Over 100 different nuclides, representing more than 20 different elements, have been found among the fission products. Fig. 7.1 shows the distribution of mass numbers for fission fragments from the fission of ^{235}U. Fission yield refers to the percentage of a nuclide of a fission fragment produced per fission. Two or three free neutrons usually appear along with the fission fragments.



Source: https://www.quora.com/Why-is-promethium-produced-from-uranium-235

Fig. 7.1

The induced fission of ^{235}U may be represented by a nuclear equation of the form

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{a}_{b}P + ^{c}_{d}Q + (2 \text{ or } 3)^{1}_{0}n + \text{energy}$$

where P represents the lower mass number fission fragment, and Q represents the higher mass number fission fragment.

One day after the earthquake, elevated levels of Iodine-131, Cesium-134 and Cesium-137, which are common fission fragments of Uranium-235, were detected near the nuclear plant site. Fig. 7.2 shows some general information of the three fission fragments.

Isotope	Symbol	Half-life
Iodine-131	$^{131}_{53}I$	8.0197 days
Cesium-134	$^{134}_{55}Cs$	2.065 years
Cesium-137	$^{137}_{55}Cs$	30.17 years

Fig. 7.2

(a) Explain the difference between *induced* and *spontaneous* fission.

....

....

.... [1]

(b) Suggest why the *percentage fission yield* in Fig. 7.1 is shown on a logarithmic scale.

....

....

.... [1]

(c) Deduce the two most common ranges of mass numbers of the fission fragments (P and Q) of ^{235}U.

most common range of mass numbers of P: .... [1]

most common range of mass numbers of Q: .... [1]

(d) **(i)** Uranium-235 undergoes nuclear fission to produce Rubidium-97 and Cesium-137. Write down the nuclear equation to represent this reaction. Use the chemical symbol Rb to represent Rubidium.

[2]

(ii) With reference to Fig. 7.1, state the percentage fission yield of

1. Cesium-137;

2. Rubidium-97.

Indicate clearly on Fig. 7.1, the points that you read off.

percentage yield of Cesium-137= .... %

percentage yield of Rubidium-97 = ... % [1]

(iii) Comment on the similarity of your answers in **(d)(ii)**.

....

....

....

....

.... [1]

(iv) State the mass number of the other fission fragment produced if one of the fragments has a mass number of 81 in the nuclear fission of Uranium-235.

mass number = ... [1]

(e) Deduce which isotope in Fig. 7.2 will be about 47% as radioactive after 33 years.

isotope is .... [2]

(f) The release of Iodine-131, Cesium-134 and Cesium-137 into the air, ground and seawater were monitored closely by the Japanese authority because they readily decay by emitting beta-particles and gamma-rays. For example, Cesium-137 decays into Barium-137 (Ba) through beta-emission.

95% of Cesium-137 decays to a metastable excited nuclear energy state (Barium -137m) and is responsible for all emission of gamma-rays, while the other 5% directly decays to the ground state (Barium-137) of the nucleus. Fig. 7.4 illustrates the decay scheme of Cesium-137.

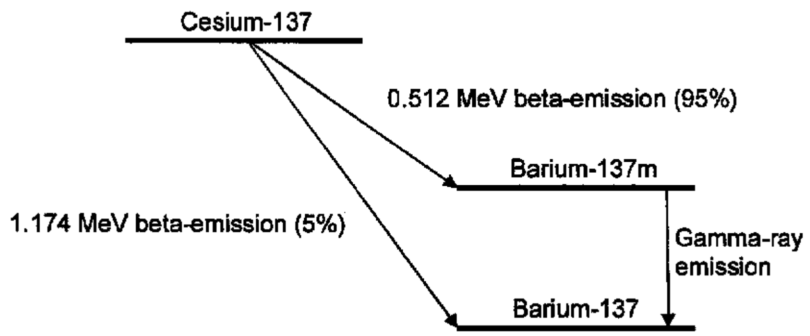
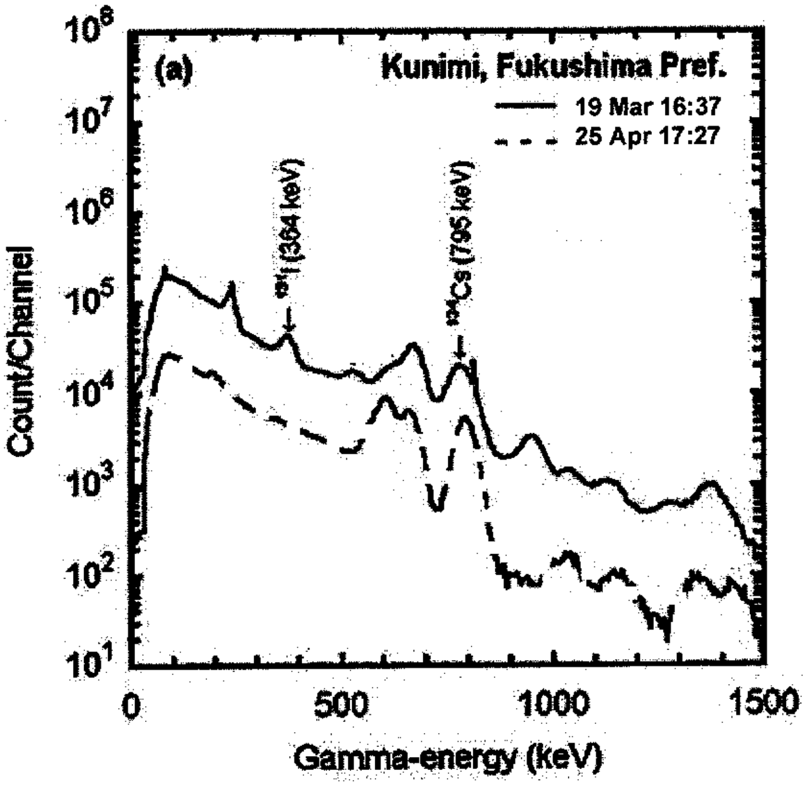


Fig. 7.4

Determine the photon energy of the gamma-rays emitted during Cesium-137 decay.

energy = ... MeV [1]

(g) Gamma spectroscopy is a technique used by scientists to identify specific radioactive products from the many possible products that can be produced from the nuclear fission of Uranium-235. Fig. 7.5 shows the gamma spectra measured at Kunimi, Fukushima Prefecture on both 19 March 2011 and 25 April 2011. Photon peaks generated by Tellurium-132, Iodine-131, -132, and Cesium-134, -136 and -137 were observed in the spectra given in Fig. 7.5. The photon peaks corresponding to Iodine-131 and Cesium-134 are indicated in Fig. 7.5.



Source: https://www.nature.com/articles/srep00087 (modified)

Fig. 7.5

(i) Using your answer from **(f)**, indicate on Fig. 7.5 the position of Cesium-137 in the gamma spectra. [1]

(ii) Suggest why no photon peak of Iodine-131 was observed on 25 April 2011.

....

....

....

.... [1]

(h) The sievert (Sv) is the SI unit of effective radiation dose. It is a measure of the biological effects of radiation. One sievert carries with it a 4% chance of developing a fatal cancer in an adult, and a 0.8% chance of hereditary defects in his or her future offspring. Doses greater than one sievert received over a short time period are likely to cause radiation poisoning, possibly leading to death within weeks.

Fig. 7.6 shows the dose rate of gamma-rays recorded by a monitoring car at Fukushima Daiichi Nuclear Power Station during the incident.

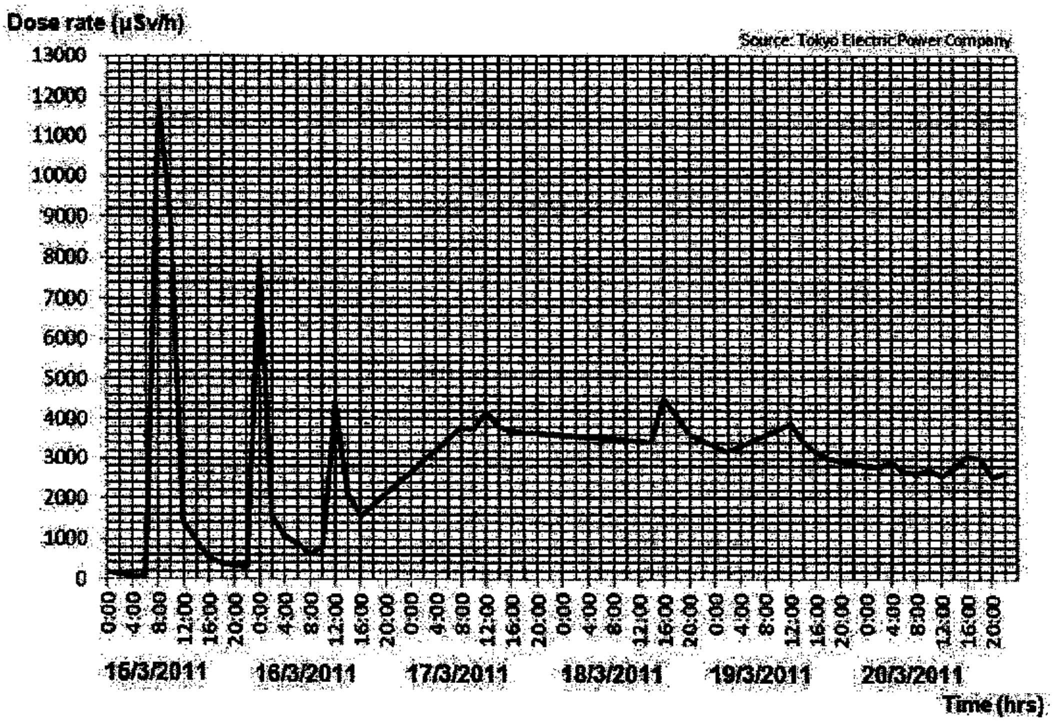


Fig. 7.6

On 15 March 2011, the Japanese Health and Labour Ministry increased the maximum permissible dose for Japanese nuclear workers from 100 mSv per year to 250 mSv per year for emergency situations.

If a worker was at the nuclear site from 16:00 hrs on 16/3/2011, estimate the time that he must be evacuated from the site before his life is in danger. Assume that the worker does not leave the site.

time : ....hrs

date: .... [2]

(i) Compare the three types of radioactive decay: alpha-decay, beta-decay and gamma-decay. Explain which of the three poses the greatest health risk if the source is:

1. outside the body;

....

....

....

....

....[2]

2. ingested and enters the body.

....

....

....

....

....[2]

-- END OF PAPER 2 --

Catholic Junior College
JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME

CLASS 2T

PHYSICS
9749/03

Paper 3: Longer Structured Questions

29 Aug 2019

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen in the space provided. [PILOT FRIXION ERASABLE PENS ARE NOT ALLOWED]
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A: Answer **all** questions.

Section B: Answer **one** question only. **Circle** the question number attempted in Section B.

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

FOR EXAMINER'S USE		DIFFICULTY		
		L1	L2	L3
SECTION A				
Q1	/ 4			
Q2	/ 9			
Q3	/ 9			
Q4	/ 14			
Q5	/ 6			
Q6	/ 11			
Q7	/ 7			
SECTION B				
Q8	/ 20			
Q9	/ 20			
PAPER 3	/ 80			
PAPER 2	/ 80			
PAPER 1	/ 30			
TOTAL FOR THEORY	/ 190			

This document consists of **21** printed pages and **one** blank page.

PHYSICS DATA:

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
			$\approx (1/(36\pi)) \times 10^{-9}$ 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} mol^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

PHYSICS 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	=	ρgh
gravitational potential	ϕ	=	$-\frac{Gm}{r}$
temperature	T/K	=	$T/°C + 273.15$
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	=	$x_0 \sin \omega t$
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	=	$R_1 + R_2 + ...$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + ...$
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	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

Answer **all** the questions in this section in the space provided.

1 **(a)** State *Newton's second law of motion*.

____

____

____

____ [2]

(b) Use Newton's second law of motion to deduce the principle of conservation of linear momentum.

____

____

____

____ [2]

2 A student constructs a potentiometer as shown in Fig. 2.1. The driver battery has negligible internal resistance and an e.m.f. of E_1 = 2.0 V. Wire PQ has a total length of 50.0 cm and resistivity ρ. Wire PQ also has a total resistance of 10.0 Ω. Unfortunately, there is a defect in wire PQ (shaded in Fig. 2.1) where that part of the wire has a cross-sectional area, S, that is half of the rest of the wire. This defective portion has a length that is denoted by x.

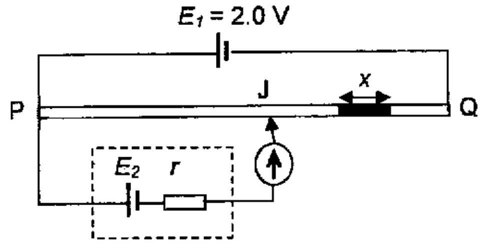


Fig. 2.1

The student carried out an experiment and determined that the e.m.f. E_2 was 1.01 V. The balance length PJ which did not include the defective portion, was 25.5 cm.

(a) When the potentiometer is balanced, determine the current I_{PQ} in the wire PQ.

current, I_{PQ} = ____________ A [1]

(b) **(i)** Using your answer from **(a)**, obtain an expression for

1. V_{PJ}, the potential difference between points P and J, in terms of S and ρ;

[1]

2. V_{PQ}, the potential difference between points P and Q, in terms of ρ, S and x.

[1]

(ii) Hence determine the defective length, x.

defective length, x = ____________ cm [2]

(c) In a further experiment, the student swaps the connections to the wire PQ and repeats the measurement, as shown in Fig. 2.2.

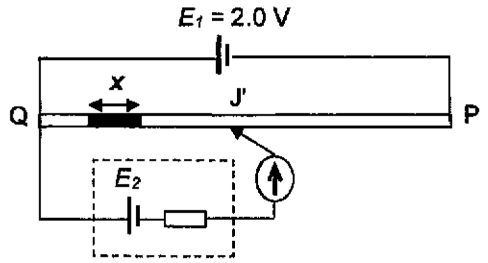


Fig. 2.2

State and explain if the new balance length QJ' would be shorter, longer or unchanged from the set-up in Fig. 2.1.

____

____

____

____

____

____

____ [4]

3 A binary star system shown in Fig. 3.1 consists of two stars orbiting around their common centre of mass, P. One such binary star system is known as Sirius where the mass of Sirius A is twice the mass of Sirius B. The mass of Sirius B is 1.99×10^{30} kg.

Sirius A is at a distance of $\frac{1}{3}D$ from P. Sirius B is at a distance of $\frac{2}{3}D$ from P.

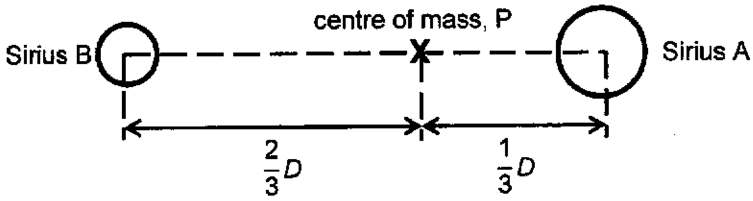


Fig. 3.1

(a) State *Newton's law of gravitation.*

____

____

____

____ [2]

(b) The orbital period of this binary star system is 50 years. Determine the distance D between the binary stars, assuming that the stars move in circular orbits.

distance D = __________ m [4]

(c) Determine the speed of a probe, originally at rest at infinity, when it reaches the centre of mass of the star system.

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

4 **(a)** Fig. 4.1 shows two identical small positive charged spheres A and B, each having a mass of 5.0×10^{-4} kg in equilibrium. Sphere A is fixed in position by an insulated rod while sphere B is free to move and attached to the ceiling by a string with length 0.20 m.

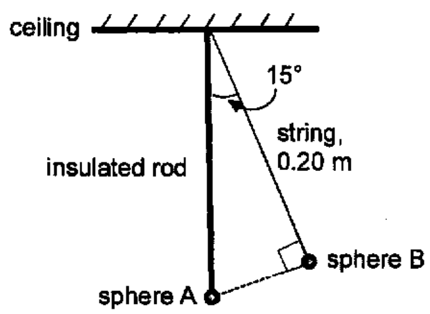


Fig. 4.1

The string suspends at an angle of 15° to the vertical insulating rod and it also makes a right angle with the straight line connecting the two spheres.

Calculate

(i) the repulsive force acting on sphere B due to sphere A;

repulsive force = ____________ N [3]

(ii) the magnitude of the charge on each sphere.

charge = ____________ C [2]

(b) Sphere B connected with the same string as part **(a)** is now projected into the page at a speed of 0.50 m s^{-1} such that it orbits horizontally around the same vertical insulating rod as shown in Fig. 4.2.

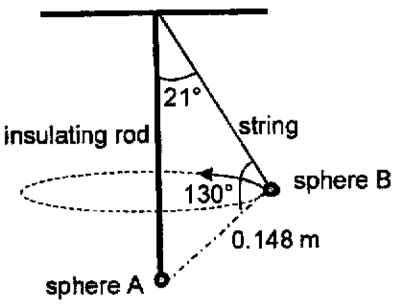


Fig. 4.2

The string makes an angle of 21° with the insulating rod. The distance between sphere A and sphere B is now found to be 0.148 m and the angle between the string and this line connecting sphere A and B is now 130°.

(i) Show that the resultant horizontal force on sphere B is 1.7 x 10^{-3} N.

[2]

(ii) Calculate the tension in the string.

tension = ____________ **N** [3]

(c) A uniform magnetic field perpendicular to the motion of sphere B is now introduced to the system in part **(b)** as shown in Fig. 4.3.

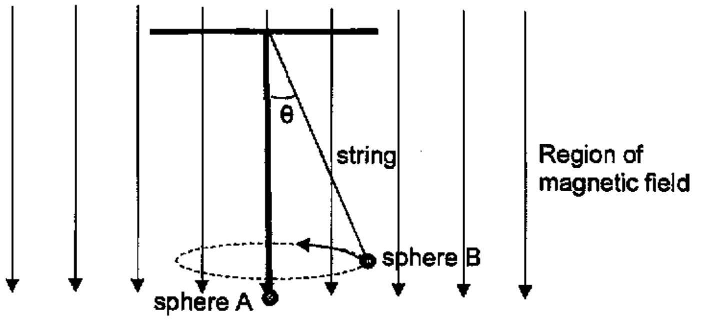


Fig. 4.3

Discuss how this might affect the subsequent motion of sphere B.

____

____

____

____ [3]

(d) In the presence of air, sphere A and B will slowly discharge as they ionize the air particles around them.

Describe the path of sphere B when this happens.

____

____

____ [1]

5 **(a)** State two differences between a progressive wave and a stationary wave.

____

____

____

____ [2]

(b) Two coherent radiowave sources S_1 and S_2 that are in phase face each other, separated by a distance of 1.25 m, as shown in Fig. 5.1. Point P is located along line AB, x metres away from A.

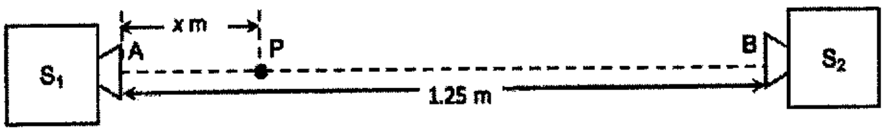


Fig. 5.1

(i) Show that the positions of minimum intensity along the line AB can be described by the following equation:

$$2L = (2n+1)\lambda$$

where
L is the path difference between the waves from S_1 and S_2,
n is any integer and
λ is the wavelength of the radiowaves.

[1]

(ii) Determine the number of points along AB where minima would be expected when radiowave signals of wavelength 0.429 m are produced.

number of points = ____________ [3]

6 (a) A metal plate has work function of 4.5 eV. When ultraviolet radiation of wavelength 120 nm is incident on the plate, a photoelectric current is detected.

(i) Calculate the maximum speed of the photoelectrons as a result of this illumination.

maximum speed = ____________ $m\ s^{-1}$ [2]

(ii) The uncertainty in the speed of the photoelectrons in **(a)(i)** is 0.50%.

Assuming that the photoelectrons are moving in the horizontal direction,

1. determine the uncertainty in the horizontal momentum of the photoelectrons;

uncertainty = ____________ N s [3]

2. determine the minimum uncertainty in the position of the electron.

uncertainty = ____________ m [2]

(b) Fig. 6.1 shows an x-ray spectrum.

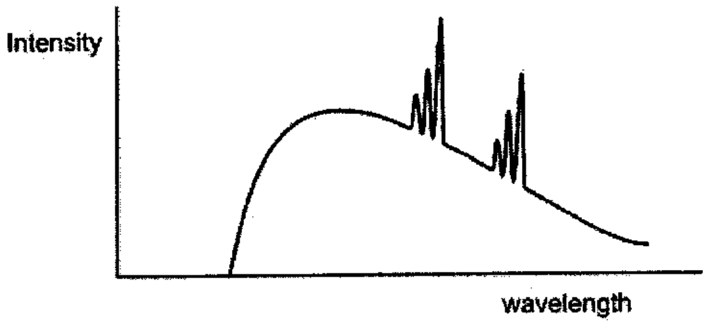


Fig. 6.1

Describe how the continuous spectrum is produced.

____

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____

____

____

____

____ [4]

7 **(a)** State experimental evidence to suggest that the process of radioactive decay is

(i) random;

____

____

____ [1]

(ii) spontaneous.

____

____

____ [1]

(b) A student measured the count rate from a sample of pure iodine-131 at various times. The results are shown in Fig. 7.1. Iodine-131 decays by beta emission to form xenon-131 which is stable.

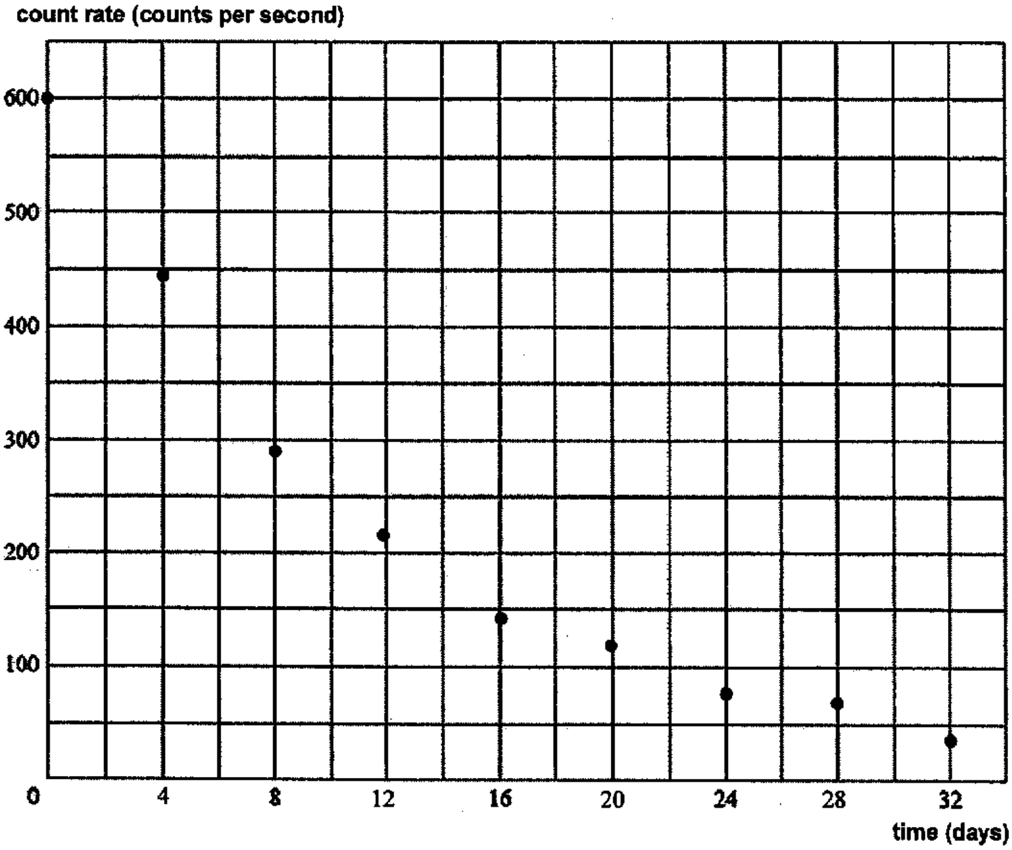

Fig. 7.1

Use Fig. 7.1 to determine a value for the half-life, in days, of iodine-131.

half life = ____________ days [3]

(c) Explain why the determination of the half-life of iodine-131 by the method in **(b)** requires that the product of the decay is stable.

____

____

____ [1]

(d) Suggest why the percentage systematic error will not be significant if the student neglected the background radiation.

____

____

____ [1]

Section B

Answer **one** question in this section in the spaces provided.

8 In a roller coaster ride, a train of mass 1200 kg and carrying a load of 400 kg is pulled up a smooth slope at a constant speed of 1.5 m s^{-1} by an electric motor to a height of 80.0 m as shown in Fig. 8.1. The train with its load is then released from rest at point A and moved to point B along the curved track.

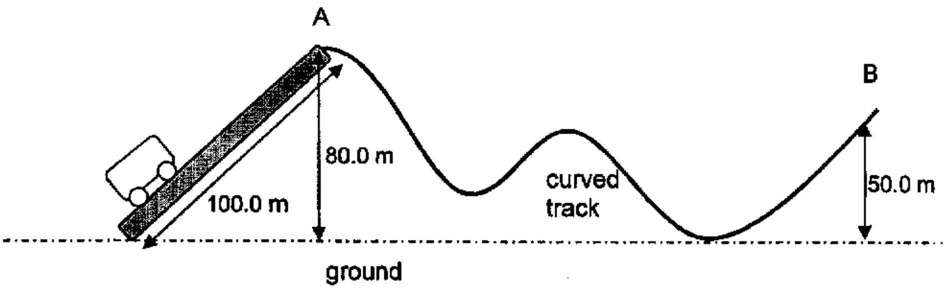

Fig. 8.1

(a) **(i)** Calculate the minimum force required to pull the train with its load up the slope at the given speed.

minimum force = ____________ N [2]

(ii) The efficiency of the motor is 80%. Calculate the electrical power that is supplied to the motor to pull the train with its load up the slope to point A.

electrical power = ____________ kW [3]

(iii) Between A and B, the train experiences an average resistive force of 3.0 kN. If the train arrives at B with a speed of 8.0 m s^{-1}, determine the distance travelled by the train between A and B.

distance travelled = ____________ m [3]

(iv) Suggest why the resistive force on the train is unlikely to remain constant. (Ignore the resistive force due to air resistance.)

____

____

____

____ [1]

(b) In another segment of the ride, the train loop the loop in a circular track as shown in Fig.8.2. The radius of the circular motion is 25 m.

Point D is at the bottom of the circular motion.
Point E is at the right of the circular motion.
Point F is at the top of the circular motion.
Point G is at the left of the circular motion.

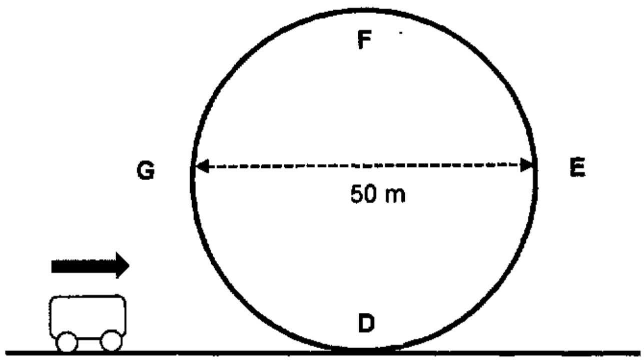

Fig. 8.2

(i) On Fig. 8.3 below, draw the free body diagram of the train at point D and point F.

Fig. 8.3

[2]

(ii) Determine the minimum speed of the train at point D so that it can loop the loop.

minimum speed = ____________ m s^{-1} **[4]**

(c) It is suggested to keep the speed of the train constant.

(i) On Fig. 8.4, sketch the graph to show how the normal contact force experienced by the train varies as it moves from Point D to G and back to D.

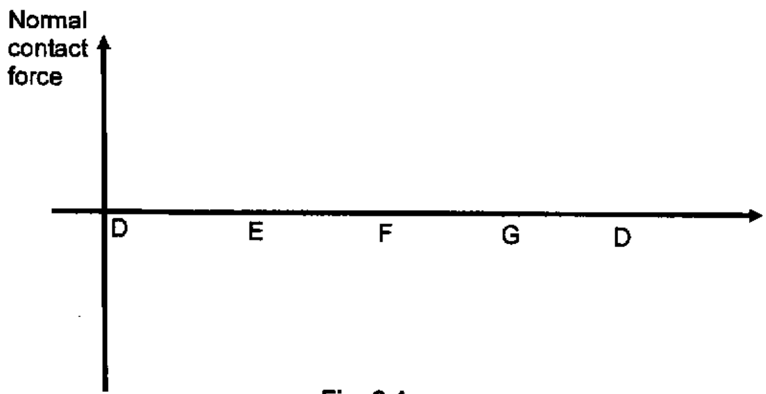

Fig. 8.4

[3]

(ii) Discuss why it is difficult to maintain the train at constant speed during the loop the loop.

____

____

____

____ [2]

9 **(a)** Define *electric potential.*

____

____

____ [2]

(b) Two identical point charges, of +Q each, are located at a distance $2d$ apart as shown in Fig 9.1.

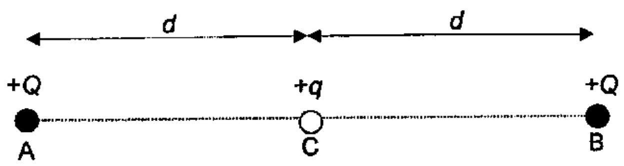

Fig. 9.1

A third charge of mass m, and charge $+q$ is placed at C, midpoint between the two charges.

(i) Obtain an expression for the electric potential at point C due to the two point charges at A and B.

electric potential at point C = ____________ V [2]

(ii) Sketch in Fig. 9.2 to show how the electric potential varies with the position along AB for the following cases:

1. due to the point charge at A
2. due to the point charge at B
3. due to both point charges at A and B.

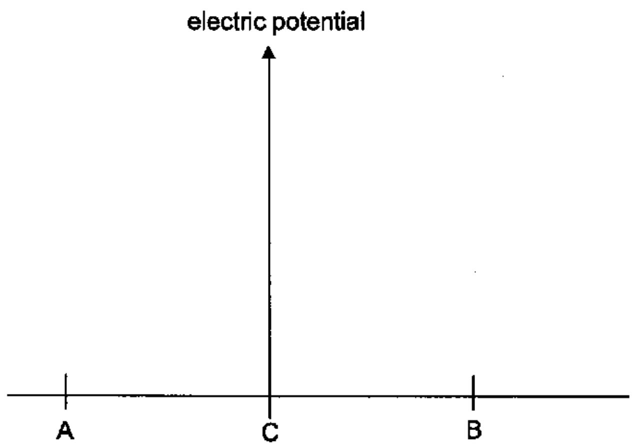

Fig. 9.2 [3]

(iii) The charge $+q$ is then being displaced horizontally and released. It is observed that charge $+q$ exhibits simple harmonic motion with an amplitude of x_o, where x_o is significantly smaller than d.

1. On Fig. 9.3, draw a well-labelled free body diagram to show the electrostatic forces acting on the third charge $+q$ at the instant when it is being displaced at a distance of x to the left of C.

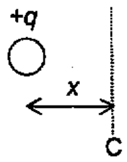

Fig. 9.3 [2]

2. Derive an expression for the magnitude of the resultant electrostatic force experienced by the charge due to the point charges at A and B.

resultant electrostatic force = ____________ N [1]

3. The angular frequency of the oscillations can be expressed as follows.

$$\omega = \sqrt{\frac{qQ}{\pi\varepsilon_o m d^3}}$$

Determine the period of oscillation using the data provided below:

m: 6.8×10^{-25} kg
q: 3.2×10^{-19} C
Q: 1.28×10^{-18} C
d: 8.6 cm

period = ____________ s [1]

4. On Fig. 9.4, sketch three graphs to show how the *total energy*, *potential energy* and *kinetic energy* of the charge +*q* vary as it oscillates between $-x_o$ and x_o. Label each graph.

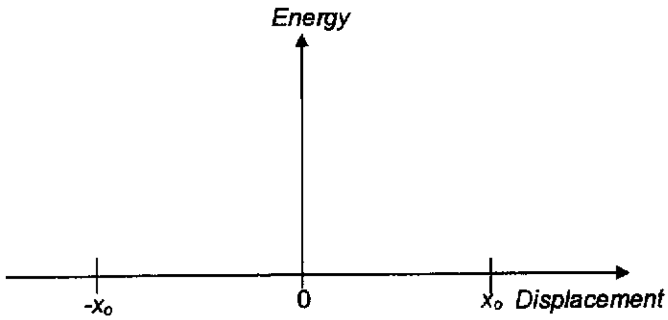

Fig. 9.4

[3]

(c) An electron was accelerated from rest with potential difference of 1.0×10^4 V, before entering at right angle into a uniform electric field region provided by a pair of charged parallel plates, separated at a distance of 3.0 cm as shown in Fig. 9.5.

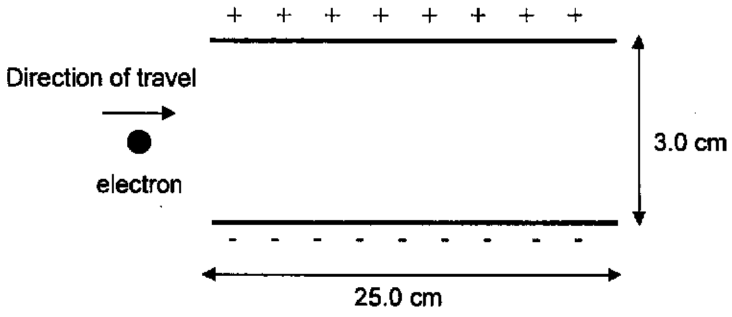

Fig. 9.5

(i) Determine the speed of the electron when it entered the uniform electric field region.

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

(ii) On Fig. 9.5, draw the electric field lines between the pair of charged parallel plates. [1]

(iii) The electron entered the uniform electric field region at the midpoint between the two charged parallel plates.

1. On Fig. 9.5, sketch the trajectory of the electron within and beyond the parallel plates. [1]

2. Show that the electron did not hit any of the parallel plates when it emerged from the uniform electric field region. The electric field strength between the parallel plates is 5.7×10^3 N C^{-1}.

[2]

- END OF PAPER –

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NAME: ______________________________ CLASS: __________

CATHOLIC JUNIOR COLLEGE
JC2 Preliminary Examinations
Higher 2

PHYSICS
Paper 4: Practical

9749/04
20 August 2019
2 hours and 30 minutes

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper. **[PILOT FRIXION ERASABLE PENS ARE NOT ALLOWED]**
You may use an HB or 2B pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, 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 assessment, fasten all your work securely together.
The number of marks is given in brackets [ ] at end of each question or part question.

Shift
Laboratory

For Examiner's Use	
1	/ 14
2	/ 9
3	/ 20
4	/ 12
Total	/ 55

This document consists of **20** printed pages and **zero** blank page.

1. In this experiment, you will investigate the variation of current I with potential difference V of an electrical component Y.

   (a) Set up the circuit as shown in Fig. 1.1, with the rheostat connected as a potential divider and taking care component Y is connected the right way around.

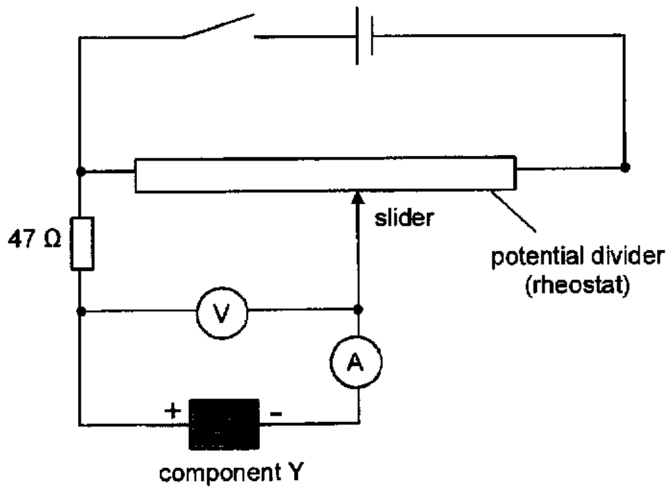

Fig. 1.1

   (b) Place the slider of the rheostat at its mid-point.

   (c) Close the switch. Record the potential difference across component Y and the current flowing through it.

potential difference = ...[1]

current = ...[1]

(d) Adjust the slider to vary the potential difference V, from 0 V to the maximum value, across component Y so as to obtain further readings of the current I through component Y. The current will remain zero for low values of V.

Record sufficient readings of V and I so that a curve could be plotted.

[5]

[Turn Over

(e) On the graph grid on **page 5**, draw a curve to show how I varies with V. [3]

(f) (i) From the curve drawn on **page 5**, describe how the resistance of component Y varies.

....

....

....

....[2]

(ii) Suggest a practical purpose of using component Y in an electrical circuit.

....

....[1]

(g) Suggest a reason for connecting the 47 Ω resistor in series to component Y.

....

....[1]

[Total: 14 marks]

[Turn Over

2. In this experiment, you will investigate the extension of a spring.

(a) You have been provided with a spring.
Measure and record the length x_0 of the unstretched spring, as shown in Fig. 2.1.

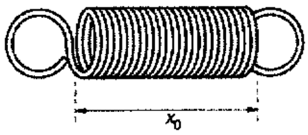

Fig. 2.1

x_0 = ...

(b) Set up the apparatus as shown in Fig. 2.2.

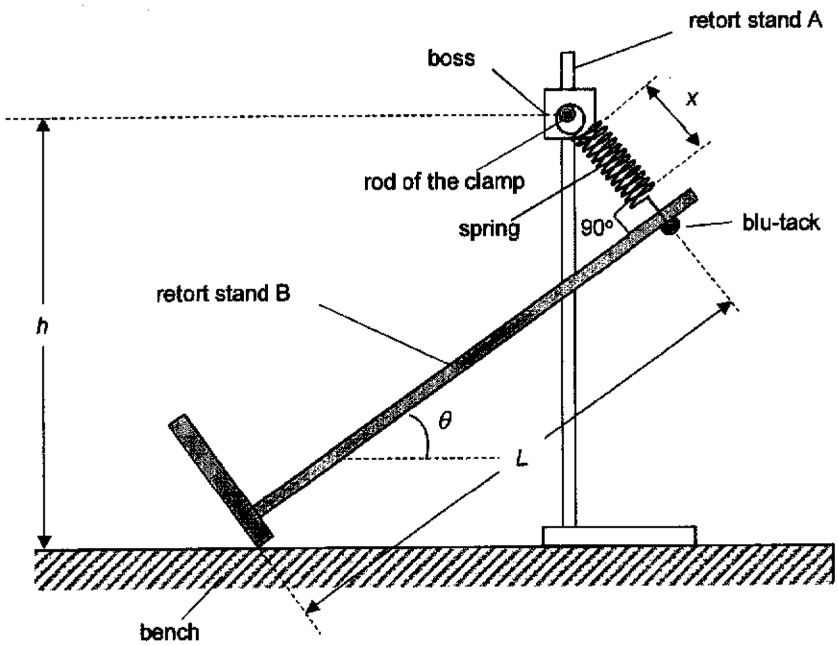

Fig. 2.2

The height *h* of the rod of the clamp above the bench should be approximately 38 cm.

One loop of the spring should be around the rod of the clamp.

The other loop of the spring should be around the rod of retort stand B close to the top of the rod and secured using blu-Tack.

(c) Slide the base of retort stand B until the angle between the rod of retort stand B and the stretched spring is 90°.

The length of the coiled section of the spring is x.
The angle between the rod of retort stand B and the horizontal is θ.
The length between the base of the retort stand B and the spring is L.

Measure and record x, θ and L.

x = ...

θ = ...

L = ...
[2]

(d) Calculate e where

$$e = x - x_0$$

e = ...[1]

(e) Estimate the absolute uncertainty of θ.

absolute uncertainty = ...[1]

[Turn Over

(f) Reduce the height h of the rod of the clamp to approximately 32 cm. Keeping L constant, slide the base of retort stand B until the angle between the rod of retort stand B and the stretched spring is again 90°.

Measure and record x and θ. Calculate e.

x = ...

θ = ...

e = ...

(g) Theory suggests that the quantities e and θ are related by the equation

$$e + \frac{mp}{L}\tan\theta\cos\theta = \frac{mq}{L}\cos\theta$$

where p and q are constants and m is the mass of retort stand B.

(i) Using the values in **(c)**, **(d)**, **(f)** and m = 1800 g, calculate p and q.

$p =$ ....

$q =$ ....
[2]

(ii) It is also found that

$$p = \frac{gy}{k}$$

where $g = 9.81 \text{ m s}^{-2}$, $y = 4.2$ cm and k is the spring constant of the spring.

Calculate k.

$k =$ ....N m^{-1}
[1]

(iii) If you were to repeat this experiment with other values of θ, describe the graph that you would plot to determine k.

....

....

....

....[2]

[Total: 9 marks]

[Turn Over

3. In this experiment, you will investigate the variation of the fundamental frequency f of a stretched string with a fixed tension T.

(a) Fig. 3.1 shows the apparatus which has been set up for this experiment.

The mass M = 1.000 kg.

Do not dismantle the apparatus during the experiment.

L is the length between the bridges and is initially set to approximately 25 cm.

The paper rider should be placed on the string around the mid-point between the two bridges.

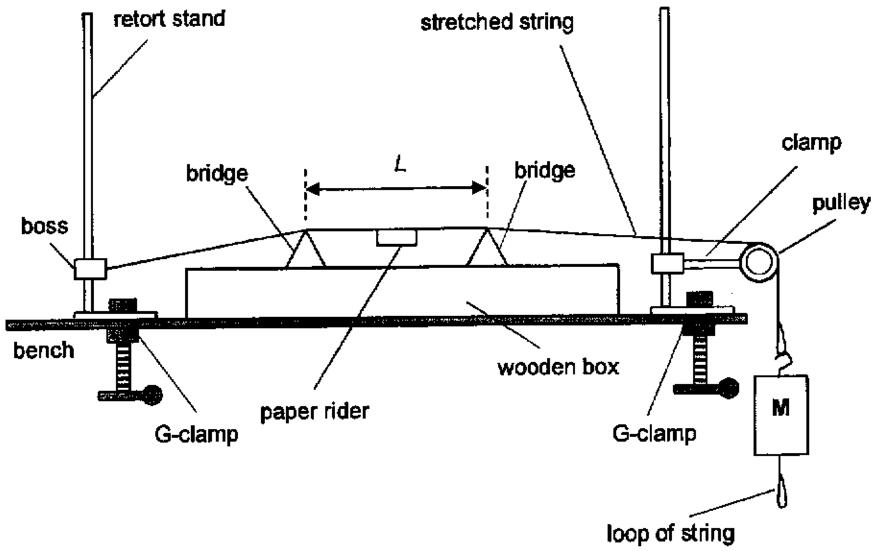

Fig. 3.1

(i) Hit the tuning fork against the rubber bung to set the tuning fork into vibration and, immediately, rest its handle gently on the wooden box as shown in Fig. 3.2.

(ii) While keeping the handle of the vibrating tuning fork resting on the wooden box, move the bridges gradually to increase the length *L* until you observe the **strongest** vibration of the paper rider or the paper rider jumps off the string. You may need to hit the tuning fork more than once.

The length *L* should not exceed 35 cm.

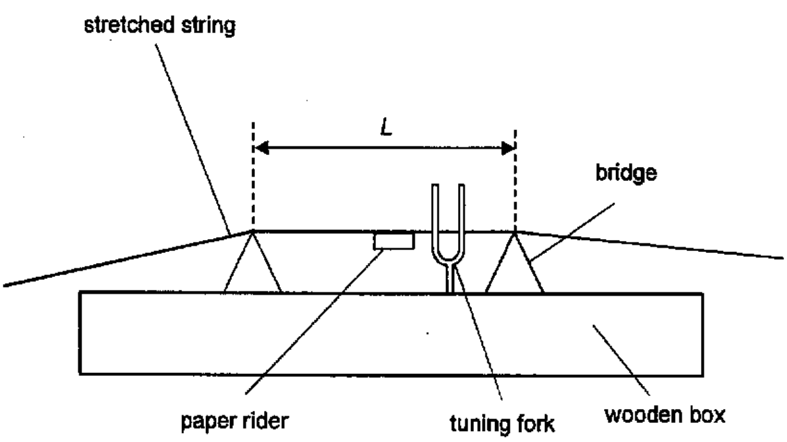

Fig. 3.2

(iii) Measure and record the length *L* and the frequency *f* of the tuning fork, when the paper rider has the strongest vibration or jumps off the string.

frequency *f* = ...

length *L* = ...
[2]

[Turn Over

(b) Estimate the percentage uncertainty in your value of L.

percentage uncertainty in L = ... [1]

(c) Choose another tuning fork of a different frequency and repeat **(a)(i) and (a)(ii)** to obtain another set of readings for L and f.

Measure and record L and f.

frequency f = ...

length L = ...

(d) It is suggested that

$$2Lf = k\sqrt{mg}$$

where k is a constant and m is the total mass hung on the stretched string.

(i) Use your values from **(a)(iii)** and **(c)** to determine two values of k.

Give your values of k to an appropriate number of significant figures.
Assume $g = 9.81$ m s^{-2}.

first value of k = ...

second value of k = ...
[2]

(ii) State whether the results of your experiment support the suggested relationship in **(d)**.

Justify your conclusion by referring to your values in **(b)**.

....

....

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....[1]

[Turn Over

(e) You will now determine two more values of *k* by varying *m* for two different frequencies of tuning fork.

(i) Adjust the bridges such that the length *L* is **fixed** at 35.0 cm. **Do not change the length *L* in this part of the experiment.**

(ii) Hang the 100 g mass hanger onto the loop of string, shown in Fig. 3.3.

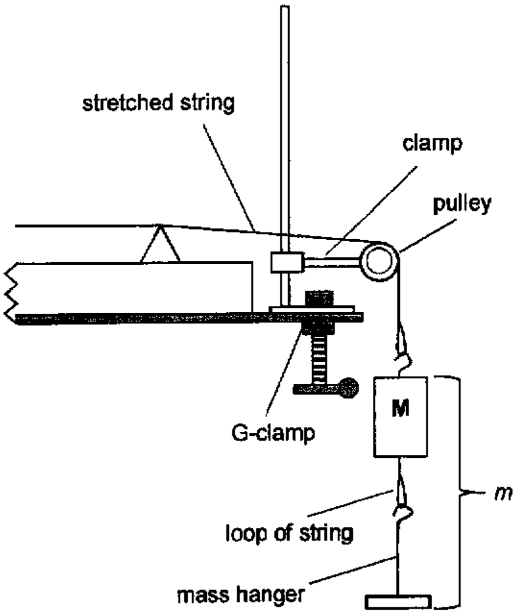

Fig. 3.3

(iii) Hit the tuning fork against the rubber bung to set the tuning fork into vibration and, immediately, rest its handle gently on the wooden box. Observe the vibration of the paper rider.

(iv) If the paper rider does not show the **strongest** vibration or jump off the string, increase *m* in steps of 100 g slotted mass and repeat step **(iii)**.

(v) Stop increasing *m* when you observe the **strongest** vibration of the paper rider or the paper rider jumps off the string.

Measure and record *f* and *m*.

Repeat for a second tuning fork.

Tabulate your results of *m* and *f*, including the values of *k*.

[3]

[Turn Over

(vi) Comment on your values of *k* in **(d)(i)** and **(e)(v)**.

....

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....[3]

(f) **(i)** State two significant sources of error in this experiment.

1 ....

....

....

2 ....

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....[2]

(ii) Suggest an improvement that could be made to the experiment to address one of the sources of error identified in **(f)(i)**. You may suggest the use of other apparatus or a different procedure.

....

....

....[1]

(g) The oscillation of a stretched string depends on the properties of the string.

It is suggested that the fundamental frequency *f* is inversely proportional to the square root of the diameter *d* of the string.

Explain how you would investigate this relationship using the same apparatus. In addition, you have access to a set of 12 tuning forks and 6 strings of different diameters.

Your account should include:

- your experimental procedure
- control of variables
- how you would use your results to show inverse proportionality
- why you might not have enough results to reach a valid conclusion.

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....[5]

[Total: 20 marks]

[Turn Over

4. A student is investigating the force between two charged metal spheres S and T, as shown in Fig. 4.1.

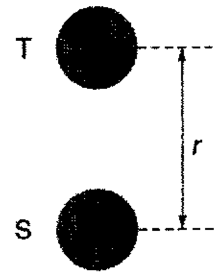

Fig. 4.1

Each sphere may be charged by connecting the positive lead from a power supply to the sphere and then removing the lead. The electromotive force (e.m.f.) of the power supply used to charge sphere T is V.

The force F between the two charged spheres may be determined by attaching sphere S to an electronic balance.

For a constant charge on sphere S, it is suggested that the relationship between F and V is

$$F = kV^m r^n$$

where r is the distance between the centres of the spheres; and k, m and n are constants.

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

You should draw a diagram to show the arrangement of your apparatus and you should pay particular attention to

(a) the equipment you would use

(b) the procedure to be followed

(c) the measurements to be taken

(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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[Turn Over

[12]

[Total: 12 marks]

2019 H2 PHYSICS J2 PRELIM PRACTICAL

APPARATUS LIST - PREPARATION

Q1

1. One 6 V dry cell
2. One rheostat (22 ohm, 3.3 A)
3. One Cyan LED – Fully covered with card and labelled Y, '+' and '-'
   The student does not need to know that Component Y is a LED.
4. One 47 ohm resistor – labelled '47Ω'
5. Two digital multimeter – No presetting of range to be done. The multimeters should be switch off before the exam starts.
6. One switch
7. Six connecting leads

Q2

1. One boss and clamp
2. Two retort stand
3. One spring (dark colored) – Spring constant of approximately 27 N m^{-1}
4. One metre rule
5. One half-metre rule
6. One protractor
7. Some Blu-Tack

Q3

1. Four tuning forks of 271 Hz, 288 Hz, 302 Hz and 320 Hz (Shared Basis)
   Each lab should be 6 sets of tuning fork
2. Four pieces of paper riders on petri dish
   Each paper rider has dimension of approx.. 1 cm x 0.5 cm and folded into half.
3. One mallet / rubber bung to be used as tuning fork striker
4. One 1 kg standard mass or 2 x 500 g standard mass – labelled as 'M'
5. One 100 g mass hanger
6. Four 100 g standard masses

7. One goggle
8. One Half-meter rule
9. The following will be pre-setup for students : (See Note 1)

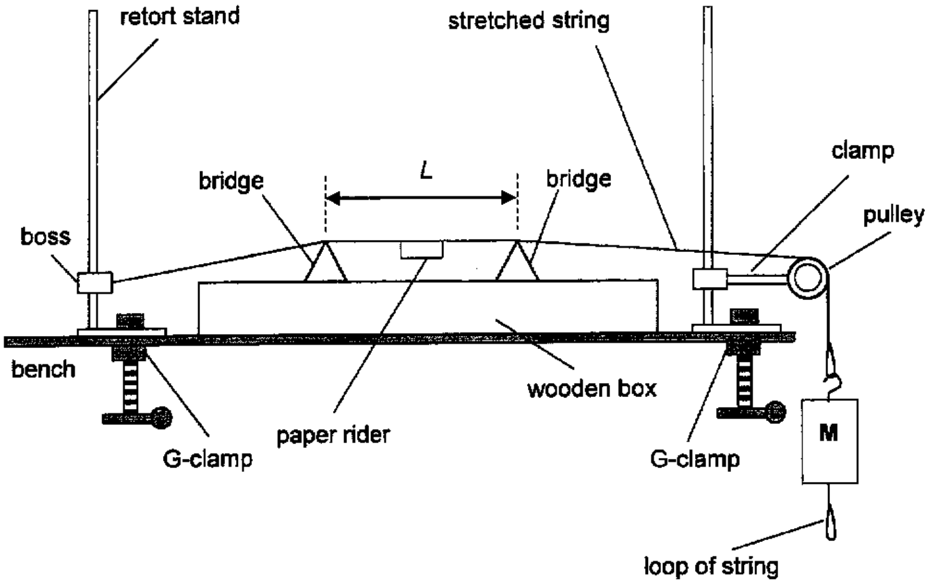


Fig. 3.1

Note: 1

(a) The mass M 1 kg is hung on the top loop of string at the pre-setup.

(b) The string used is braided fishing line string (Darcon Fishing line – 30 lb Test, www.izorline.com)
The string is 2 m long with 2 loops tied at one end as shown in diagram.

(c) One end of the string is connected to the boss while the end has two loops. One loop will be used to hang the 1 kg mass M at pre-setup. The second loop will be used by the student to hang the mass hanger during the experiment.

(d) The two retort clamps must be G-clamped.

(e) The wooden box has the dimension of 60 cm x 10 cm x 10 cm

(f) The bridges are two triangular wooden block of approx..60 cm (length) x 1.5 cm (height).

(g) L is set to 25 cm.

(h) The paper rider is placed at the mid point at the pre-setup.

APPARATUS LIST – WRITTEN ON WHITE BOARD

Q1

1. One 6 V dry cell
2. One rheostat
3. One electrical component labelled Y
4. One 47 ohm resistor
5. Two digital multimeter
6. One switch
7. Six connecting leads

Q2

1. One boss and clamp
2. Two retort stand
3. One spring
4. One metre rule
5. One half-metre rule
6. One protractor
7. Some Blu-Tack

Q3

1. Four tuning forks of 271 Hz, 288 Hz, 302 Hz and 320 Hz (Shared Basis)
2. Four pieces of paper riders on petri dish
3. One rubber bung (tuning fork striker)
4. One 100 g mass hanger
5. Four 100 g standard masses
6. One goggle
7. One Half-meter rule
8. A apparatus has been set up as shown in Fig. 3.1.

NAME ____________________ CLASS 2T

Catholic Junior College
JC2 Preliminary Examinations
Higher 2

PHYSICS — 9749/01

Paper 1: Multiple Choice

4 September 2019
1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write your name and tutorial group on this cover page.
Write and/or shade your name, NRIC / FIN number and HT group on the Answer Sheet (OMR sheet), unless this has been done for you.
Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all 30 questions** in this paper.
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 (OMR sheet).

Read the instructions on the Answer Sheet carefully.

Each correct answer will be awarded 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 permitted, where appropriate.

MARK SCHEME

This document consists of **21** printed pages and **one** blank page.

[Turn over

PHYSICS DATA:

speed of light in free space	c	=	3.00×10^8 m s^{-1}
permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
			$\approx (1/(36\pi)) \times 10^{-9}$ 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} mol^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

PHYSICS 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	=	ρgh
gravitational potential	ϕ	=	$-\frac{Gm}{r}$
temperature	T/K	=	$T/{}^\circ C + 273.15$
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	=	$x_0 \sin \omega t$
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	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

1 The table below shows the estimates of some physical quantities.

Which row is not a reasonable estimate?

	quantity	value
A	current used in an electric kettle	8 A
B	mass of an adult male	70 kg
C	speed of an Olympic sprint runner	10 m s^{-1}
D	water pressure at the bottom of a public swimming pool	10^4 Pa

Answer: D

Option A: With I = 8 A, and V = 240 V, power rating of kettle = 8 x 240 = 1920 W which is a reasonable estimate.

Option B: Typically Singaporean adult weighs between 50 kg and 100 kg. Therefore 70 kg is a reasonable estimate.

Option C: The timing for 100 m race is the Olympic is about 10 s; therefore the average speed of 10 m s^{-1} is a reasonable estimate.

Option D: Atmospheric pressure = 10^5 Pa.
Assume that the swimming pool has depth of 2 m,
Pressure at the bottom pool = Atmospheric pressure + hρg
= 10^5 + (2 x 1000 x 9.81)
= 10^5 + 1.96 x 10^4 = 1.196 x 10^5 Pa

10^4 Pa is less than 1.196 x 10^5 Pa. Therefore 10^4 Pa is not a reasonable estimate. Answer is D.

2 A potential difference (p.d.) is carefully measured with a high-quality instrument and found to be 2.321 V.

Two students, using two different methods to measure the p.d., quote the p.d. as 2.33 V and 2.344 V respectively.

Which statement is correct?

A	The reading 2.33 V is more accurate and more precise than the reading 2.344 V.
B	The reading 2.33 V is more accurate but less precise than the reading 2.344 V.
C	The reading 2.33 V is less accurate but more precise than the reading 2.344 V.
D	The reading 2.33 V is less accurate and less precise than the reading 2.344 V.

Answer: B

Explanation:

The reading 2.33 V has a precision of 0.01 V which is less precise than the reading 2.344 V as the reading 2.344 V has a precision of 0.001 V. Eliminate Option A and C.

True Value = 2.321 V

The reading 2.33 V is 0.009 V from the True Value while the reading 2.344 V is 0.023 V from the True Value. Therefore the reading 2.33 V is more accurate than the reading 2.344 V

Answer is B

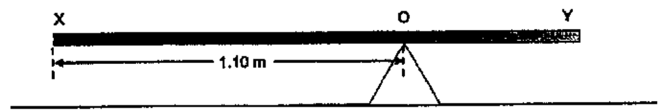
3 A man is parachuting towards the Earth. According to Newton's third law of motion, the force which makes an action-reaction pair with the gravitational force on the man is

A	the gravitational force on the Earth due to the man.
B	the viscous force of the man and his parachute on the air.
C	the viscous force of the air on the man and his parachute.
D	the tension in the harness of the parachute.

Answer: A

Understanding and applying N3L.

4 A non-uniform rod XY is balanced horizontally on top of a triangular wedge. The top of the wedge O is at a distance 1.10 m from the end X of the rod.



A 1500 g mass is hung at a distance of 0.20 m from X. The rod now needs to be moved 0.25 m to the right to balance horizontally.

What is the mass of the rod?

A	1.2 kg	B	3.9 kg	C	6.6 kg	D	7.8 kg

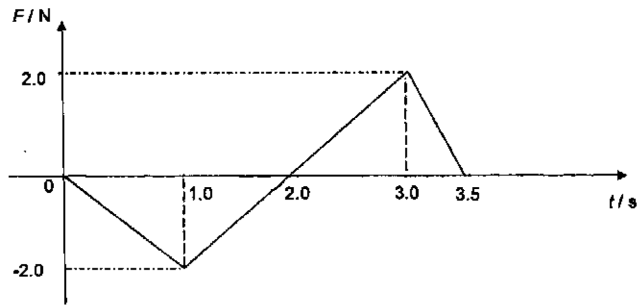
Answer: B

As the rod is balanced at O, it can be deduced that the centre of mass of the rod is at 1.10 m away from X (at O).

After the extra mass is added, and balanced distance achieved,

Taking moments about point O,
Sum of clockwise moments = Sum of anticlockwise moments
0.25 x m x 9.81 = (1.10 - 0.20 - 0.25) x (1500 x 10^{-3}) x 9.81
m = 3.9 kg

5 A resultant force F acts on a mass of 150 g. The variation with time t of F is shown on the diagram below.



At time t = 0 s, the mass is moving with a velocity of 2.0 m s^{-1}.

What is the speed of the mass at t = 3.0 s?

A	2.7 m s^{-1}
B	4.7 m s^{-1}
C	6.7 m s^{-1}
D	8.7 m s^{-1}

Answer: B

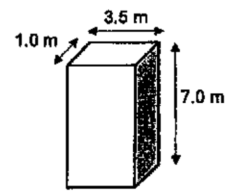
Change in momentum = area under the graph
= - ½ (2) (2) + ½ (2) (1)
= - 1.0 Nm

Therefore, $m\Delta v$ = - 1.0
Δv = -1.0 / (150 x 10^{-3})
= - 6.67 m s^{-1}

Hence, $V_f - v_i$ = - 6.67
V_f = -6.67 + 2.0 = - 4.67 m s^{-1}

Therefore the speed of mass = 4.7 m s^{-1} (2 s.f.)

6 The diagram below shows a wooden block in its upright position, with length 1.0 m, width 3.5 m and height 7.0 m. The density of wood is 850 kg m^{-3}.



What is the submerged depth of the wooden block when it floats upright in water?
Density of water is 1000 kg m^{-3}.

A	0.85 m	B	5.6 m	C	6.0 m	D	7.0 m

Answer: C

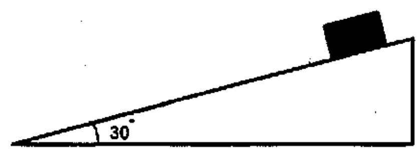
Weight of water displaced = weight of wooden block

$\rho_{water}\, g\, V_{water\ displ.} = \rho_{wood}\, g\, V_{wood}$

1000 x g x $h_{water\ displ.}$ x A = 850 x g x 7.0 x A

$h_{water\ displ.}$ = 5.95 m = 6.0 m (2 s.f.).

7 A block starts to slide down a 30° slope from rest as shown in the figure below.



Assume that the friction on the block is negligible. What is the final speed of the block after it has travelled 10 m down the slope?

A	4.9 m s^{-1}	B	8.5 m s^{-1}	C	9.9 m s^{-1}	D	13 m s^{-1}

Answer: C

Acceleration along the slope = g sin 30° = 4.905 m s^{-1}.

$v^2 = u^2 + 2as$

v^2 = 0 + 2 x 4.905 x 10

v = 9.9 m s^{-1}

8 A body of mass 90 kg travels along a horizontal road at a speed of 5.0 m s^{-1}. It then accelerates at 1.5 m s^{-2}. At the time it begins to accelerate, the total resistive force acting on the car is 200 N.

What total output power is developed by the car as it begins the acceleration?

A	680 W
B	1700 W
C	4400 W
D	5400 W

Answer: B

ma = F – resistive force

F = 90 x 1.6 + 200 = 335 N

Therefore power required to give the 90 kg, 5.0 m s^{-1} body to accelerate at 1.5 m s^{-2} is

F x v

= 335 x 5

= 1675 W

= 1700 W

9 A car is making a circular turn of radius *r* with speed *v*. The centripetal force on the car is *F*.

What is the centripetal force on the car when it makes the same turn at speed 2*v*?

A	$\frac{F}{2}$
B	F
C	$2F$
D	$4F$

Answer : D

$$F = \frac{mv^2}{r}$$

$$\frac{m(2v)^2}{r} = 4\frac{mv^2}{r} = 4F$$

10 A small sphere is moving in a vertical circle at constant speed.

The magnitude of the resultant force on the sphere

A	at the bottom of the circle is greater than the resultant force at the top.
B	at the top of the circle is greater than the resultant force at the bottom.
C	decreases as the sphere moves from the bottom to the top of the circle.
D	is the same at the top of the loop as it is at the bottom of the circle.

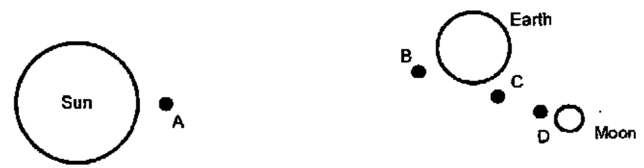
Solution: D

Resultant force = Centripetal force, mv^2 / r

Since the mass, speed and radius remain unchanged throughout, the resultant force is unchanged in magnitude.

11 The neutral point in the gravitational field between the Sun, the Earth and the Moon is the point at which the resultant gravitational field due to the three bodies is zero. The mass of the Earth is about 80 times the mass of the Moon.

At what position is it possible for the neutral point to be? (The diagram is not drawn to scale)



Answer: D

The null point should be closest to the body with the smallest mass. In this case, the moon has smallest mass. The null point will be slightly affected by the mass of the Sun so therefore it is slightly off the line joining the centre of mass of the Earth and Moon.

12 Which statement about two satellites of different masses in the geostationary orbit around the Earth is ***incorrect***?

A	The gravitational forces acting on the two satellites are different.
B	The centripetal acceleration of each satellite is different.
C	The total energy of each satellite is different.
D	The angular velocities of the two satellites are the same.

Answer: B

By equating Gravitational force with centripetal force, show that:
$T^2 \propto R^3$
where T is the period and R is the radius of the orbital motion.

All geostationary satellites have equal period T, hence all are at the same distance R from Earth.

Since $a_c = R\omega^2 = R\left(\frac{2\pi}{T}\right)^2$**, all have equal magnitude of centripetal acceleration.**

[OR, Since orbital motion is free fall motion, $a_c = g_{\text{due to Earth at R}} = G\frac{M}{R^2}$**, all have equal magnitude of centripetal acceleration.]**

Hence Option B is false.

Option A is true because $F_G = F_c = m\,a_c$. a_c same, but with different m, F_G differs.
Option C is true because it can be shown that Total Energy = - ½ GMm/R, which depends on the satellite's mass.
Option D is true because geostationary implies same period, hence same angular velocity.

13 Two monoatomic gases, X and Y, are in thermal equilibrium in a mixture. The molecular mass of gas Y is half the molecular mass of gas X.

The root mean square speed of the molecules of gas Y is *v*. What is the root mean square speed of the molecules of gas X?

A	$\frac{v}{2}$
B	$\frac{v}{\sqrt{2}}$
C	v
D	$2v$

Solution: B

Thermal equilibrium means same temperature.
Same temperature means that the mean translational KE is the same.
But rms speed need to be $\frac{v}{\sqrt{2}}$ for the mass to be doubled and KE to be still the same.

$\langle E_K \rangle = \frac{3}{2}kT$

$\frac{1}{2}m\langle c^2 \rangle = \frac{3}{2}kT$

14 The piston is pushed very slowly into a metal cylinder containing an ideal gas.

If the temperature of the gas does not change in the process. Which of the following statements is ***incorrect***?

A	The work done on the gas is equal to the heat lost by the gas.
B	The pressure of the gas increases.
C	The average kinetic energy of the gas molecules increases due to the work done on the gas.
D	The internal energy of the gas remains constant.

Answer: C

Metal → good conductor of heat. There can be heat transfer in/out of the cylinder.

A: $\Delta U = \frac{3}{2}nR\Delta T = 0$. Hence by First Law of thermodynamics, W = -Q. Correct.

B: Ideal gas equation, pV = nRT = constant since T & n are both constants. So since V decreases, p increases. Correct
C: $\langle E_K \rangle = \frac{3}{2}kT$. Same temperature means that the mean translational KE is the same. Incorrect
D: internal energy of an ideal gas = 3/2 nRT. For a fixed n, internal energy remains constant at constant T.

15 A small mass undergoes simple harmonic motion about a point O with amplitude x_o and period *T*. Its displacement *x* from O at time $\frac{1}{6}T$ after passing through O is

A	$\frac{x_o}{6}$
B	$\frac{x_o}{2\sqrt{3}}$
C	$\frac{x_o}{2}$
D	$\frac{\sqrt{3}x_o}{2}$

Answer: D

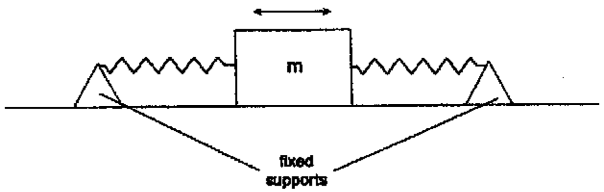
Since time is measured starting from the instant when the object is at O, we use the sine-function.

Using
$x = x_0 \sin(\omega t)$
$x = x_0 \sin\left(\frac{2\pi}{T}t\right)$

When $t = \frac{T}{6}$,

$x = x_0 \sin\left(\frac{2\pi}{T} \times \frac{T}{6}\right)$
$= x_0 \sin\left(\frac{\pi}{3}\right)$
$= \frac{\sqrt{3}x_0}{2}$

16 A mass m on a smooth horizontal table is attached by two light springs to two fixed supports as shown below. The mass executes simple harmonic motion of amplitude a and period T.



The total energy of oscillation is

A	$2\pi ma^2/T^2$
B	$2\pi m^2a^2/T$
C	$\pi^2 ma^2/T^2$
D	$2\pi^2 ma^2/T^2$

Answer: D

The total energy of oscillation is equal to the **maximum** KE of the object in the oscillation.

$KE_{max} = \frac{1}{2}mv_0^2$

$= \frac{1}{2}m(x_0\omega)^2$

$= \frac{1}{2}ma^2\left(\frac{2\pi}{T}\right)^2$

$= \frac{1}{2}ma^2\left(\frac{4\pi^2}{T^2}\right)$

$= \frac{2ma^2\pi^2}{T^2}$

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	$\frac{4\pi}{5}$ rad

Answer: B

$\lambda = \frac{v}{f}$

$= \frac{320}{400}$

$= 0.8$ m

$\frac{\Delta\phi}{2\pi} = \frac{\Delta x}{\lambda}$

$= 2\pi\left(\frac{0.2}{0.8}\right)$

$= \frac{\pi}{2}$ rad

18 Fig. 1 shows how the displacement of a wave varies with distance along the wave at one particular time.

Fig. 2 shows how the displacement of one particular point P of the same wave varies with time.

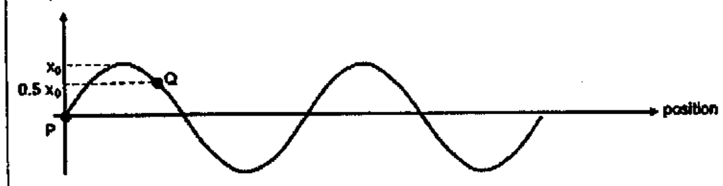


Fig. 1

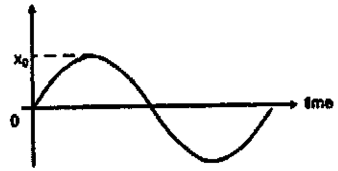
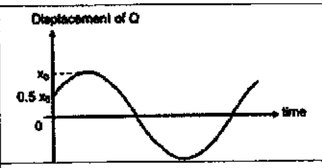
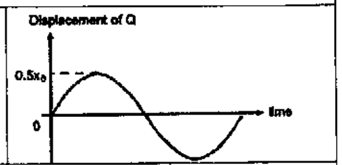
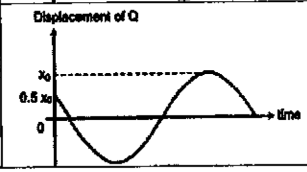


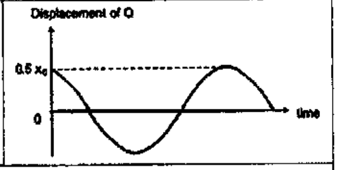
Fig. 2

Which of the following graphs correctly depicts the displacement-time graph for point Q?

A


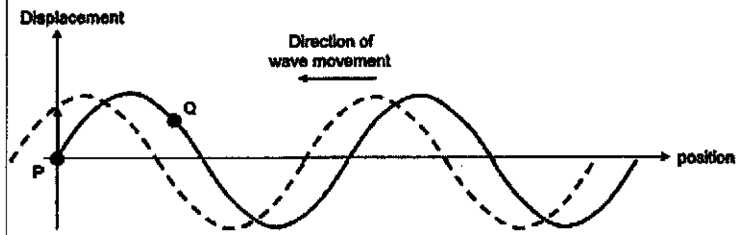
B


C


D


Answer: C

From Fig. 2, we can deduce that the wave is moving in the leftwards direction, as depicted below.

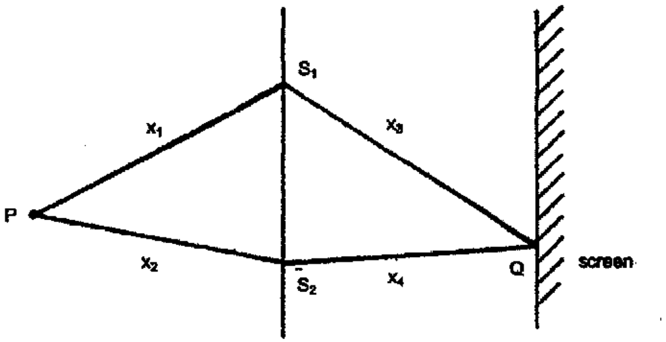


If the wave is travelling to the left, its next position can be represented by the dotted line shown above. A can be seen to be moving from equilibrium to a displacement in the positive direction, and B is moving downwards.

As such, Option A is not correct. In the same light, Option B is also not correct.

Since P and Q are succumbed to the same wave, P and Q will encounter the same amplitude magnitude, which is x_0. Therefore, Option D is wrong.

19 Two identical narrow slits S_1 and S_2 are illuminated with light of wavelength λ from a point source P.



If, as shown in the diagram above, the light is then allowed to fall on a screen, and if m is a positive integer, the condition for constructive interference at Q is

A	$x_1 - x_2 = (2m+1)\frac{\lambda}{2}$
B	$x_3 - x_4 = (2m+1)\frac{\lambda}{2}$
C	$x_3 - x_4 = m\lambda$
D	$(x_1 + x_3) - (x_2 + x_4) = m\lambda$

Answer: D

For constructive interference to take place, the waves meeting at the point must have a path difference (difference in the lengths of paths from the source to the meeting point) to be a full wavelength, or integers of multiples of the wavelengths of the waves.

20 A beam of light that consists of all wavelengths between 480 nm and 600 nm is projected onto a diffraction grating that contains 500 lines per millimeter.

What is the maximum number of complete continuous spectra that can be observed emerging from the grating?

A	6	B	7	C	8	D	9

Answer: A

$d \sin\theta = n\lambda$

For longest wavelength, find the maximum order that can be observed:
$n\lambda / d \le 1 \rightarrow n \le (1.0\times10^{-3} / 500) / 600\times10^{-9} = 3.3$
max n = 3
Thus there will be 6 spectra observed. (Zeroth order maximum is not a spectrum.)

21 The charge of a uranium nucleus is 1.5×10^{-17} C.

What is the potential at the mid-point between a uranium nucleus and an alpha particle if they are separated by a distance of 1.0×10^{-13} m?

A	2.2×10^{-13} V
B	4.3×10^{-13} V
C	2.8×10^{6} V
D	5.5×10^{6} V

Answer: C

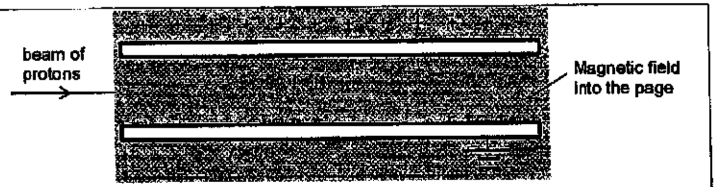
Alpha particle is a ${}^4_2He$ nucleus, hence its charge = +2e = 3.2×10^{-19} C

Using $V = \frac{Q_1}{4\pi\varepsilon_0 r_1} + \frac{Q_2}{4\pi\varepsilon_0 r_2}$

Since the distances from the two charges to mid-point are the same, $r_1 = r_2$.

$V = \frac{1.5\times10^{-17} + 3.2\times10^{-19}}{4\pi(8.85\times10^{-12})(0.5\times10^{-13})} = 2.8 \times 10^{6}$ V (2 s.f.)

22 A velocity selector for protons has an electric field of strength 3.0×10^{5} V m^{-1}, produced by two horizontal plates. The upper plate is connected to a positive potential and the lower plate is earthed. A magnetic field of flux density 1.5×10^{-2} T, directed into the plane of the paper, is at right-angles to the electric field as shown in the diagram.



Which of the following could be the possible speed of a proton and its observation?

	speed	observation
A	1.8×10^7 m s^{-1}	undeflected
B	2.0×10^7 m s^{-1}	deflected downwards
C	2.2×10^7 m s^{-1}	deflected downwards
D	2.4×10^7 m s^{-1}	deflected upwards

Answer: D

Protons entering the velocity have a range of speeds.

If protons are undeflected, Upwards magnetic force = Downwards electric force.

i.e. $Bqv = qE$

$v = E/B = 3.0 \times 10^5 / 1.5 \times 10^{-2}$

$= 2.0 \times 10^7$ m s^{-1}.

Protons with speeds higher than this value will have a greater magnetic force, but the electric force is constant regardless of speed, hence deflected upwards.

Conversely, protons with speeds lower than this value will deflect downwards.

23 When four identical resistors are connected as shown in diagram 1, the ammeter reads 1.0 A and the voltmeter reads zero.

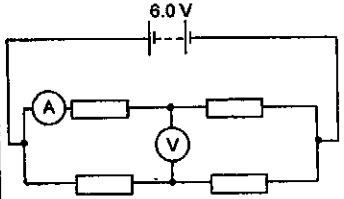


diagram 1

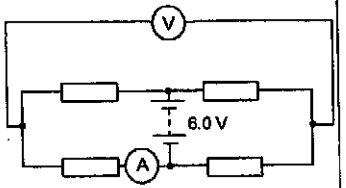


diagram 2

The resistors and meters are reconnected to the supply as shown in diagram 2.

What are the meter readings in diagram 2?

	voltmeter reading / V	ammeter reading / A
A	0	1.0
B	0	0.5
C	3.0	1.0
D	6.0	0.5

Answer: A

Moving the battery source and the meters to the new position does not change the effective layout of the circuit. By circuit analysis the 4 resistors are still connected similar to the first i.e. 2 in series with each other and then these 2 in parallel with the other branch.

Therefore based on the position of the ammeter it is measuring the current in one branch of the circuit hence the current is still 1.0 A and the voltmeter is now measuring across two points in the circuit where the potentials of these two points are the same. So potential difference is 0 V.

OR

Based on diagram 1,

Let the unknown value of the resistors be R.

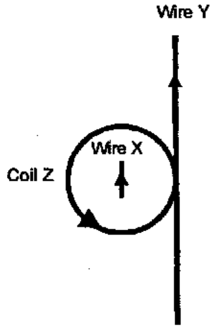
$(1.0)(R+R) = 6.0$ V
$2R = 6.0$ V
$R = 3.0\ \Omega$

Based on diagram 2,

$I(6.0) = 6.0$ V
$I = 1.0$ A

Since the potential difference is measured after the first resistor in both branches the potentials at these two points are the same. Hence potential difference is 0 V.

24 The diagram below shows a setup of two current-carrying wires X and Y, and a single-turn coil Z.



Wire X has length 0.050 m with a current of 1.0 A flowing through it. Wire Y has length 2.0 m with a current of 0.50 A. Coil Z has a diameter of 0.20 m with a current of 1.5 A.

What is the resultant force on wire X if the centre of coil Z is on wire X?

A	5.0×10^{-6} N
B	4.2×10^{-7} N
C	5.2×10^{-7} N
D	9.4×10^{-6} N

Answer: C

By right-hand grip rule, the magnetic flux densities due to wire Y and due to coil Z are both out of the page.

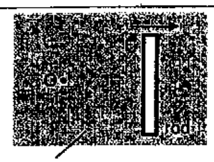
Hence, the resultant magnetic flux density experienced by wire X

$= \frac{\mu_0 NI}{2r} + \frac{\mu_0 I}{2\pi d} = \frac{4\pi\times10^{-7}\times1\times1.5}{2(0.1)} + \frac{4\pi\times10^{-7}\times0.5}{2\pi(0.1)}$

$= 1.042 \times 10^{-5}$ T

Therefore, the resultant force on wire X = BIL = $1.042 \times 10^{-5} \times 1.0 \times 0.05 = 5.2 \times 10^{-7}$ N

25 Diagram A shows an aluminium rod moving away from point O, at right angles to a uniform magnetic field. Diagram B shows the variation with time *t* of its displacement *s* from O.



region of magnetic field

Diagram A

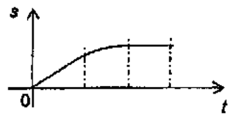
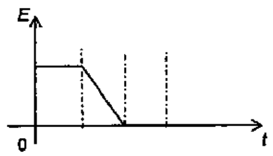
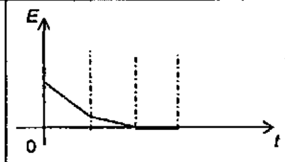
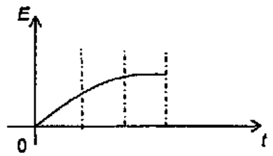
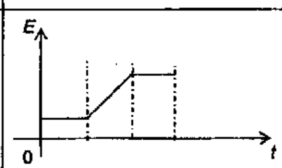


Diagram B

Which graph best shows the variation with *t* of the e.m.f. *E* induced in the rod?

A		B	
C		D	

Answer: A

By Faraday's law, e.m.f. induced is the rate of change of magnetic flux linkage. Since the rate of change of magnetic flux linkage is proportional to the velocity of the rod, the e.m.f.-time graph has the same shape as the velocity-time graph. i.e. refers to the gradient of s-t graph.

26 A sinusoidal current is represented by the equation

$$I = I_o \sin(\omega t)$$

Which equation represents the sinusoidal current with both its period and amplitude doubled?

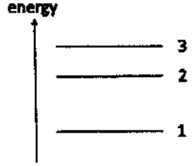
A	$2I = I_o \sin(2\omega t)$
B	$I = 2I_o \sin(2\omega t)$
C	$I = ½ I_o \sin(2\omega t)$
D	$I = 2I_o \sin(½ \omega t)$

Answer: D

I_o is the amplitude and ω is the angular frequency.

With double the period, it means half the angular frequency.

27 Part of the energy level diagram of a certain atom is shown below. The energy spacing between levels 1 and 2 is three times that between 2 and 3. If an electron makes a transition from level 3 to level 2, the radiation of wavelength λ is emitted.



What possible radiation wavelengths might be produced by other transitions between the three energy levels?

A	only $\frac{\lambda}{3}$
B	both $\frac{\lambda}{3}$ and $\frac{\lambda}{4}$
C	only 3λ
D	only 4λ

Answer: B

$E_{3\to2}=\frac{hc}{\lambda}$

Possible transitions:

$E_{2\to1}=3E_{3\to2}$
$=3\frac{hc}{\lambda}$
$=\frac{hc}{(\lambda/3)}$

$E_{3\to1}=4E_{3\to2}$
$=4\frac{hc}{\lambda}$
$=\frac{hc}{(\lambda/4)}$

Therefore, these transitions will produce the wavelengths $\frac{\lambda}{3}$ and $\frac{\lambda}{4}$.

28 Which one of the following statements, referring to a photoelectric emission, is true?

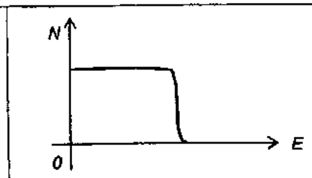
A	No emission of electrons occurs for very low intensity illumination, even if the illumination's frequency is above the threshold frequency.
B	For a given metal there is a minimum frequency of radiation below which no emission occurs.
C	The velocity of the emitted electrons is proportional to the intensity of the incident radiation.

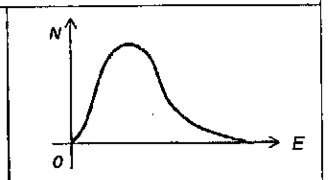
D	The number of electrons emitted per second is dependent on the threshold frequency of the given metal if the frequency of the incident photon is higher than the threshold frequency.

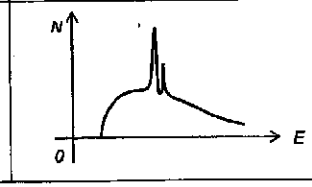
Answer: B

Option A is incorrect: no emissions occurs for frequency lower than the threshold frequency
Option C is incorrect: The velocity of the emitted electrons is dependent on the photon energy and work function of metal surface
Option D is incorrect: The number of electrons emitted per second is independent of the threshold frequency.

29 Which one of the following best represents the number N of alpha-particles emitted from a given radioactive source possessing energy E ?

A


B


C


D


Answer: D

In alpha-decay, there are only 2 products: parent nucleus → daughter nucleus + alpha-particle (only one particular reaction, and no other forms of energy).
Hence to ensure conservation of momentum and conservation of energy, each product's speed and kinetic energy would be of fixed values.

30 Which nuclide has the greatest initial activity?

	nuclide	amount/mole	half-life/day
A	$^{228}_{88}Ra$	0.7	2100
B	$^{225}_{89}Ac$	0.002	10
C	$^{228}_{90}Th$	0.09	400
D	$^{241}_{94}Pu$	0.09	4800

Answer: A

$A = \lambda N = (\ln 2 / t_{1/2})\, N$, where $N = n.N_A$ (i.e. $N \alpha n$)

$A \propto \frac{N}{t_{1/2}} \propto \frac{n}{t_{1/2}}$

Of the four options, option A gives the largest ratio $\frac{n}{t_{1/2}}$ hence greatest activity.

Option A: 3.33×10^{-4}
Option B: 0.0002
Option C: 0.000225
Option D: 0.00001875

– END OF PAPER 1 –

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Catholic Junior College
JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME: MARK SCHEME

CLASS: 2T

PHYSICS — 9749/02
Paper 2: Structured Questions

26 August 2019
2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen in the space provided. [PILOT FRIXION ERASABLE PENS ARE NOT ALLOWED]
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions in Paper 2.

FOR EXAMINER'S USE		DIFFICULTY		
		L1	L2	L3
Q1	/ 10			
Q2	/ 11			
Q3	/ 11			
Q4	/ 12			
Q5	/ 8			
Q6	/ 8			
Q7	/ 20			
PAPER 2	/ 80			

This document consists of **27** printed pages and 1 blank page.

[Turn over

PHYSICS DATA:

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
			$\approx (1/(36\pi)) \times 10^{-9}$ 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} mol^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

PHYSICS 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	=	ρgh
gravitational potential	ϕ	=	$-\frac{Gm}{r}$
temperature	T/K	=	$T/°C + 273.15$
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	=	$x_0 \sin \omega t$
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	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

Answer all the questions in the spaces provided.

1 (a) A truck is accelerated from rest by a constant driving force. It experiences a drag force which is proportional to its speed. Eventually, the truck travels at a constant velocity.

Explain why the truck reaches a constant velocity.

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.... [2]

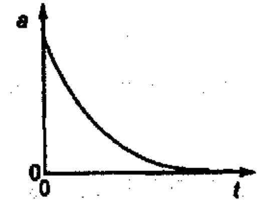
Due to the acceleration by the constant driving force, **truck's speed increases, hence the drag force** which opposes the driving force **increases in magnitude.** B1

Eventually the drag force become equal in magnitude to the constant driving force. Hence net force becomes zero, acceleration equals zero, hence constant velocity. B1

(b) On Fig. 1.1 sketch a graph to show how the acceleration of the truck varies with time from the time when it was at rest to the time when it reaches the constant velocity.

Fig. 1.1 [1]

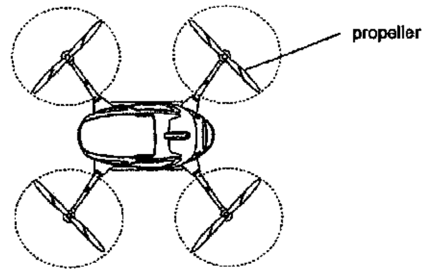
Solution:



B1

– acceleration decreases and reaches zero
– acceleration decreasing at a decreasing rate from start to the end

(c) Fig. 1.2 shows a drone that is able to hover by rotating the four horizontal propellers attached to its body. The propellers push the air downwards and impart the air with a certain speed. The mass of the drone is 0.50 kg and each of the propellers has a radius of 15.0 cm.



Top view of a drone

Fig. 1.2

(i) Calculate the upward force by the air on the drone.

upward force = ... N [1]

For equilibrium,
Upward force = Downward force = mg = 0.50 x 9.81 = 4.905 = 4.9 N **A1**

(ii) State, with a reason, the magnitude of the downward force exerted by all of the drone's propellers on the air.

....

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.... [2]

According Newton's 3rd Law, the downward force of the propellers on the air must be of the same magnitude as the upward force of the air on the propellers. **M1**

Total downward force = 4.9 N **A1**

(iii) The density of air is 1.3 kg m^{-3}.

Determine using Newton's second law of motion the speed imparted to the air by the propellers.

speed = ... m s^{-1} [4]

L2 **Assume propellers push air downward with a speed v.**

Total cross sectional area of the air (for 4 propellers)
= 4 x πr^2 = 4 x π (0.15)^2 = 0.2827 m^2
[Alternatively, divide the total downwards force of 4.905 N by 4]

Mass of air being pushed per unit time **M1**
= A ρ *v*
= 0.2827 x 1.3 x v
= 0.3676 v

Momentum gained by air per unit time **M1**
= 0.3676 v x Δ*v*
= 0.3676 v x (*v* – *0*)
= 0.3676 v^2

Rate of change of momentum of air = 0.3676 v^2

By Newton's 2nd Law,
Total downwards force on air by 4 propellers **M1**
= Rate of change of momentum of air
4.905 = 0.3676 v^2 **A1**
***v* = 3.654 = 3.7 m s^{-1}**

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

....

....

....

.... [2]

The increase in internal energy of a closed system is equal to the sum of heat supplied to the system and the work done on the system. **B2**

B1 – Correct quantities referred to
B1 – Directions clearly and correctly stated. Use of "sum of" or equivalent.

(b) A fixed mass of monatomic ideal gas undergoes a cycle of changes A → B → C → A as shown in Fig. 2.1.

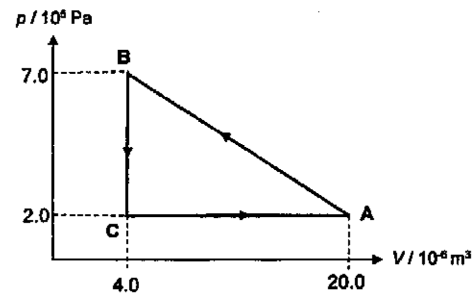

Fig. 2.1

(i) Explain why the change in internal energy of the ideal gas during a complete cycle A → B → C → A is zero.

....

....

....

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....

....

....

.... [2]

....

L2 In a complete cycle, the (p, V) state of the gas returns to the original state. Therefore, using the equation of state of an ideal gas, the temperature of the gas also returns to the original temperature. **B1**

As the internal energy of an ideal gas is proportional to the thermodynamic temperature of the gas, there is no net change in the internal energy in a complete cycle. **B1**

(ii) Calculate the work done on the gas during the process from A to B.

work done on gas = ... J [2]

L1 work done on gas

= area under the graph

$= \frac{1}{2}[(7.0+2.0)\times10^5][(20.0-4.0)\times10^{-6}]$ **C1**

$=7.2$ J **A1**

(iii) Calculate the change in internal energy of the gas when it undergoes the process from A to B.

Change in internal energy = ... J [2]

L2

For a monoatomic ideal gas,
$\Delta U = 3/2\ nR\Delta T = 3/2\ \Delta(pV)$

M1

change in internal energy **A1**

$= \frac{3}{2}[(7.0\times10^5)(4.0\times10^{-6})-(2.0\times10^5)(20.0\times10^{-6})]$

$=-1.8$ J

(iv) Calculate the heat supplied to the ideal gas during the process from A to B.

heat supplied = ... J [2]

L1 Using 1st law of thermodynamics,

$\Delta U = Q + W$

$Q = -1.8 - (7.2)$ **C1**

$= -9.0$ J ***(No Negative, No marks)*** **A1**

(v) In a car engine, the expanding combustion gases push the piston which causes the car to move.

Suggest, with a reason, whether the cycle of changes A → B → C → A could be the cycle in the piston engine of a car.

....

....

....

.... [1]

L3 **Not possible, because for a car to move, there must be a positive net work done by the gas per cycle** in the piston engine. (i.e. net work done on gas is negative.) **B1**

Whereas the net work done by the gas in the cycle A→ B → C → A is negative.

.... [2]

The horizontal intercept is the value of the <u>maximum current</u> that will flow through the battery when <u>there is no (external) resistance applied across it</u>. (i.e. short circuit current) **M1** **A1**

(c) In an attempt to obtain the graph of Fig. 4.1 for the battery, a student sets up a circuit as shown in Fig. 4.2.

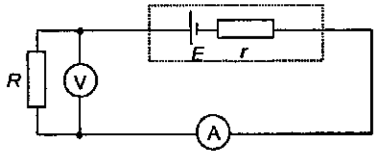


Fig. 4.2

State and explain why the circuit shown in Fig. 4.2 is inappropriate for obtaining data for the full range of values in Fig. 4.1.

....

.... [4]

The <u>resistor R used is a fixed resistor</u>. **B1**

<u>This would not allow the current to vary in Fig. 4.1, but the graph in Fig. 4.1 shows that there is a varying current in the circuit</u>. Thus it is not possible to have the variation of potential difference plotted while current is varying. **B1**

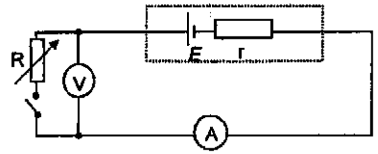
In addition, the **<u>voltmeter will not be able to measure the e.m.f. of the battery as well as the current at lower values / voltage at higher values even when the fixed resistor has been replaced by a rheostat/variable resistor</u>.** **B1**

This is because the rheostat cannot be adjusted to infinite resistance and thus **<u>there would always be some current</u> flowing through the circuit.** **B1**

(d) In the space below draw a circuit diagram, using the appropriate components, from which the full range of values in Fig. 4.1 may be obtained.

[2]

Solution:



- **Replace the fixed resistor with a rheostat.** **B1**
- **Add in a switch in series with the rheostat.** **B1**

5 Fig. 5.1 shows a point source S emitting continuous waves at a distance *h* from a plane reflector R. As a result, regions of high intensity such as C, C' and C" are produced.

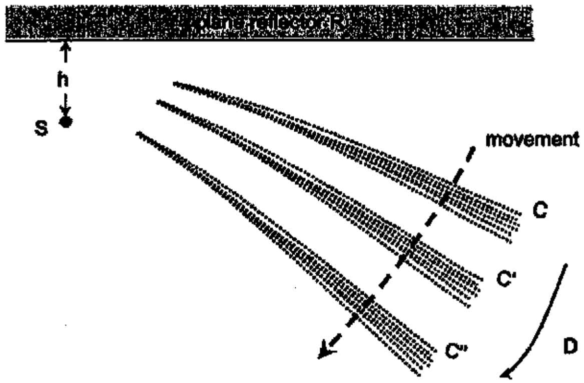


Fig. 5.1

(a) Explain why regions of high intensity such as C, C' and C'' are produced.

.... [3]

When the waves are emitted from S, there are some waves that are **reflected off the reflector screen and directed towards the regions below R.** B1

These reflected waves will then **meet the wave coming directly from S, that are directed towards the same regions.** B1

When the reflected signal and the direct signal **meet in phase, constructive interference occurs**, and the resultant intensities will be increased, giving rise to C, C' and C''. B1

(b) A detector is moved in the direction indicated by the dotted arrow in Fig. 5.1. Explain how the detected intensity of the waves would vary.

.... [3]

As the detector moves along the indicated path, it registers **alternating regions of high intensity and low intensity**. B1

However, as it moves from C to C'', the **regions of high intensity are relatively lower in magnitude compared to the previous high intensity region** (e.g. C has a higher intensity compared to C' and likewise, C' has a higher intensity compared to C''). B1

The low intensity regions will also not remain at the same low intensity – meaning to say, **the contrast between the high and low intensity region would be poorer as we move from C to C'**. B1

(c) When the frequency of S is decreased slowly, the regions C, C' and C'' move in the direction D as shown in Fig. 5.1. Explain this phenomenon.

.... [2]

When the frequency of the signal decreases, the **wavelength of the waves will increase.** B1

This will then **cause an increase in the path difference between the two waves meeting at the constructive interference fringes/intensity maxima.** As such, previously the regions of high intensities will shift to the new positions where the waves will meet constructively again. B1

6 **(a)** A simple a.c. generator which consists of a rectangular coil with 40 turns is rotating at 50 revolutions per second in a uniform magnetic field of flux density 50 mT. The coil is 50 cm long and 35 cm wide, as shown in Fig. 6.1.

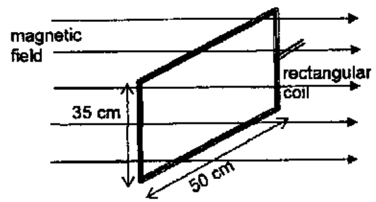


Fig. 6.1

(i) Define *magnetic flux*.

....

....

.... [1]

The magnetic flux through a **plane surface** is defined as the **product of the magnetic flux density normal to the surface and the area of the surface.** **B1**

(ii) Calculate the maximum e.m.f. induced in the coil.

maximum e.m.f. = ... V [2]

E = $NBA\omega$
= (40)(50 x 10^{-3})(50 x 10^{-2})(35 x 10^{-2})(2π)(50) **C1**
= 109.96 = 110 V (2 s.f.) **A1**

(b) The output from the generator in part **(a)** is connected to the input of a transformer. The transformer has 40 turns on its primary coil and 10 turns on its secondary coil. The transformer may be considered to be ideal. The output from the transformer is connected to a resistor of resistance 100 Ω and a diode, as shown in Fig. 6.2.

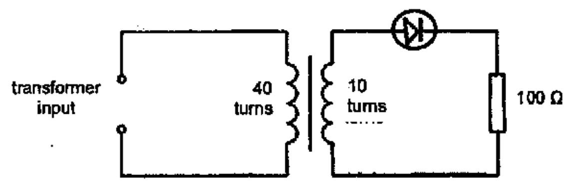


Fig. 6.2

Calculate the root-mean-square voltage across the resistor.

root-mean-square voltage = ... V [3]

Let V_0 be the peak voltage across the resistor.

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$ **M1**

$$\frac{V_0}{110} = \frac{10}{40}$$

V_0 = 27.5 V (2 s.f.)

Since the voltage across the resistor is half-wave rectified,
Mean of v_0^2 for a half-wave rectified voltage
= area under the graph/period
= (v_0^2x T)/(4 x T)
= $v_0^2/4$

Hence the root-mean-square, V_{rms} = $V_0/2$ **M1**
= 14 V (2 s.f.) **A1**

(c) In an attempt to draw the circuit diagram that represents the system in part **(b)**, a student drew Fig. 6.3 instead.

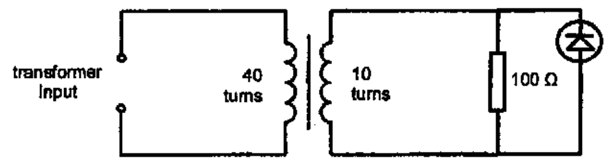


Fig. 6.3

Suggest, with a reason, what will happen if the circuit is set up according to Fig. 6.3.

....

....

....

....

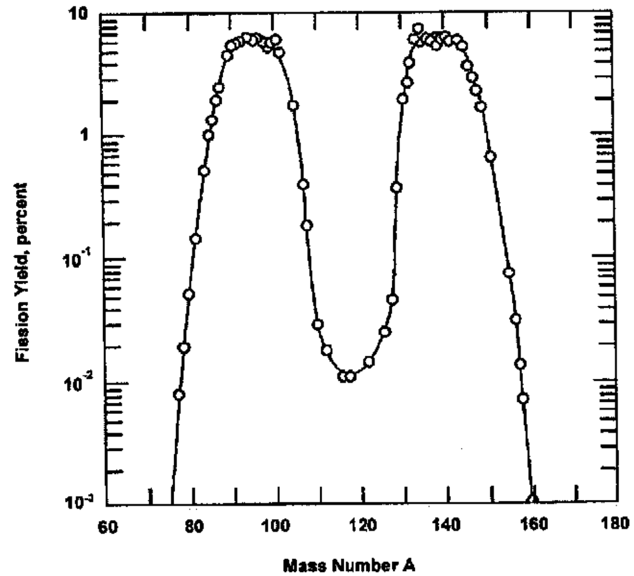
[2]

When the e.m.f. set up in the secondary circuit is such that the diode is in forward bias, all / most current will by-pass the resistor and flow only via the diode back to the secondary coil. B1

This means that the circuit will be short-circuited and the system could be damaged by **overheating**. B1

7 When a very strong earthquake of magnitude 9.0 hit Japan on 11 March 2011, the accompanying tsunami caused the devastation of the Fukushima Dai-ichi Nuclear Power Plant (Fk-1). A large amount of radioactive material leaked out of Fk-1 as a result, mainly through cracks made by the quake on some reactors, explosions, intentional vents to relieve pressure, and leakage of cooling water that was contaminated with the melted fuel rod debris.

Fk-1 was capable of generating up to 4.7 gigawatts of power through neutron-induced fissions of Uranium-235 (^{235}U) nuclei. Fission resulting from neutron absorption is called *induced* fission. Some nuclides can also undergo *spontaneous* fission, but that is quite rare. Nuclear fission is a decay process in which an unstable nucleus splits into two fragments of comparable mass, although nearly equal mass is unlikely. Over 100 different nuclides, representing more than 20 different elements, have been found among the fission products. Fig. 7.1 shows the distribution of mass numbers for fission fragments from the fission of ^{235}U. Fission yield refers to the percentage of a nuclide of a fission fragment produced per fission. Two or three free neutrons usually appear along with the fission fragments.



Source: https://www.quora.com/Why-is-promethium-produced-from-uranium-235

Fig. 7.1

The induced fission of ^{235}U may be represented by a nuclear equation of the form

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{a}_{b}P + ^{c}_{d}Q + (2 \text{ or } 3)^{1}_{0}n + \text{energy}$$

where P represents the lower mass number fission fragment, and Q represents the higher mass number fission fragment.

One day after the earthquake, elevated levels of Iodine-131, Cesium-134 and Cesium-137, which are common fission fragments of Uranium-235, were detected near the nuclear plant site. Fig. 7.2 shows some general information of the three fission fragments.

Isotope	Symbol	Half-life
Iodine-131	$^{131}_{53}I$	8.0197 days
Cesium-134	$^{134}_{55}Cs$	2.065 years
Cesium-137	$^{137}_{55}Cs$	30.17 years

Fig. 7.2

(a) Explain the difference between *induced* and *spontaneous* fission.

....

....

.... [1]

Unlike spontaneous fission, induced fission requires initial <u>neutron absorption</u> to occur. B1

Candidates need to answer this question by reading the passage in context.

(b) Suggest why the *percentage fission yield* in Fig. 7.1 is shown on a logarithmic scale.

....

....

.... [1]

Percentage fission yield varies over a wide range of many orders of magnitude. B1
OR
Logarithmic scale compresses the scale to accommodate the very wide range of percentage fission yield values.
OR
To enable plots on the graph to be well spaced while representing the very wide range of percentage fission yield values.

(c) Deduce the two most common ranges of mass numbers of the fission fragments (P and Q) of ^{235}U.

most common range of mass numbers of P: .... [1]

most common range of mass numbers of Q: .... [1]

From Fig. 7.1,
Most common range of mass numbers of P: **<u>90 to 100 (or 88 to 102)</u>** A1
Most common range of mass numbers of Q: **<u>135 to 145 (or 130 to 150)</u>** A1

Note that Question has already defined P as the fragment with *lower* mass. So answers for P and Q cannot swop.
Marking points:
- Correct reading of the ranges of values.
- Answers for P and Q not swopped.

(d) **(i)** Uranium-235 undergoes nuclear fission to produce Rubidium-97 and Cesium-137. Write down the nuclear equation to represent this reaction. Use the chemical symbol Rb to represent Rubidium.

[2]

$${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{97}_{37}Rb + {}^{137}_{55}Cs + 2\,{}^{1}_{0}n + energy$$

- Correct value of proton number of Rb (= 37). A1
- Deduced that 2 neutrons are emitted. A1
- Deduct 1 mark for other mistakes e.g. used "=" instead of "→"; did not include ${}^{1}_{0}n$ on the LHS of the equation; wrong notations e.g. n^{1}_{0} or ${}^{2}_{0}n$ instead of $2\,{}^{1}_{0}n$

Note: General equation is given in the question, hence no mark purely for writing the equation.

(ii) With reference to Fig. 7.1, state the percentage fission yield of
1. Cesium-137;
2. Rubidium-97.

Indicate clearly on Fig. 7.1, the points that you read off.

percentage yield of Cesium-137= .... %

percentage yield of Rubidium-97 = ... % [1]

6% for both. (Accept also 6.5%.) A1
Mark for correct method (clear indication of points read on Fig. 7.1).
Accept also if answers given a 6.5% for one, and 6% for the other.

(iii) Comment on the similarity of your answers in **(d)(ii)**.

....

....

....

....

.... [1]

Percentage yields of both should be similar since **they are produced from the same (unique) fission process**. So the probabilities of both of them forming are equal/same. B1

(iv) State the mass number of the other fission fragment produced if one of the fragments has a mass number of 81 in the nuclear fission of Uranium-235.

mass number = ... [1]

153 or 152 A1

Method 1:
Using ${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{81}_{a}P + {}^{c}_{d}Q + (2 or 3)\,{}^{1}_{0}n + energy$
By conservation of mass number,
235 + 1 = 81 + c + (2 or 3)
c = 153 or 152

Method 2:

Using Fig. 7.1,

1) Equal percentage fission yield for both. So draw a horizontal line across the "M" shaped curve in Fig. 7.1.
2) By conservation of mass number, and accounting for the neutrons present before and after the fission, it is necessary that either the two inner parts of the "M" shaped curve in Fig. 7.1 is read off, or the two outer parts.

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{81}_{k}P + ^{c}_{d}Q + (2 or 3)^{1}_{0}n + energy$$

236 – 81 = 155
155 – 2 = 153 (if 2 neutrons)
155 – 3 = 152 (if 3 neutrons)

(e) Deduce which isotope in Fig. 7.2 will be about 47% as radioactive after 33 years.

isotope is .... [2]

L2 **Method 1:**
47% ≈ 50%, hence — M1
33 years is close to the half-life of the isotope.
From Fig. 7.2, the isotope with a half-life close to 33 years is **Cesium-137**. — A1

Method 2:
$A = A_o e^{-\lambda t}$ where $\lambda = \ln 2 / t_{1/2}$

"47% as radioactive" → $A / A_o = 0.47$

$0.47 = e^{-\lambda(33 years)}$
$\lambda = 0.022879$ years^{-1}
$\ln 2 / t_{1/2} = 0.022879$ years^{-1}
$t_{1/2}$ = ~30 years
Answer: Cesium-137

(f) The release of Iodine-131, Cesium-134 and Cesium-137 into the air, ground and seawater were monitored closely by the Japanese authority because they readily decay by emitting beta-particles and gamma-rays. For example, Cesium-137 decays into Barium-137 (Ba) through beta-emission.

95% of Cesium-137 decays to a metastable excited nuclear energy state (Barium -137m) and is responsible for all emission of gamma-rays, while the other 5% directly decays to the ground state (Barium-137) of the nucleus. Fig. 7.4 illustrates the decay scheme of Cesium-137.

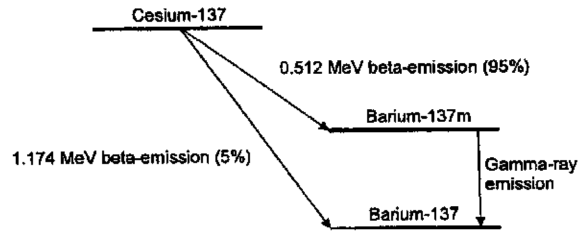
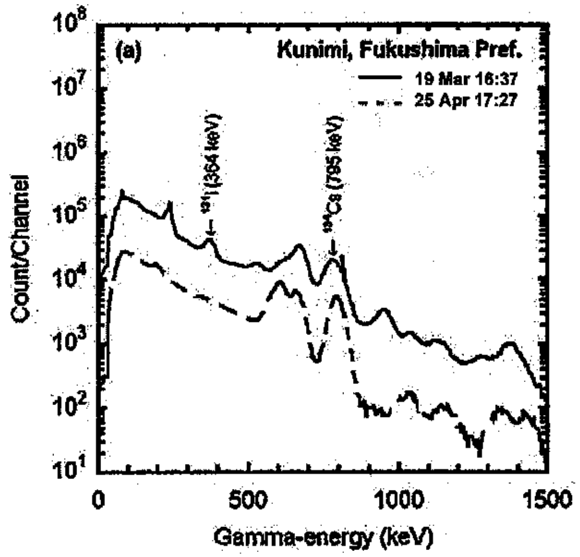


Fig. 7.4

Determine the photon energy of the gamma-rays emitted during Cesium-137 decay.
Energy of gamma-ray photon = 1.174 – 0.512 = **0.662 MeV** — A1

energy = ... MeV [1]

(g) Gamma spectroscopy is a technique used by scientists to identify specific radioactive products from the many possible products that can be produced from the nuclear fission of Uranium-235. Fig. 7.5 shows the gamma spectra measured at Kunimi, Fukushima Prefecture on both 19 March 2011 and 25 April 2011. Photon peaks generated by Tellurium-132, Iodine-131, -132, and Cesium-134, -136 and -137 were observed in the spectra given in Fig. 7.5. The photon peaks corresponding to Iodine-131 and Cesium-134 are indicated in Fig. 7.5.

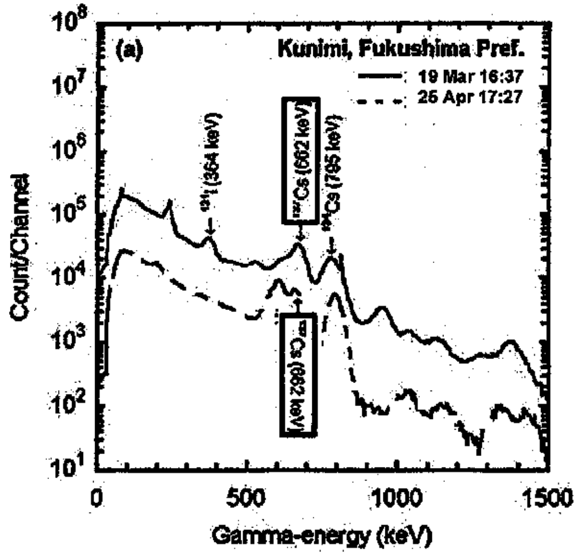


Source: https://www.nature.com/articles/srep00087 (modified)

Fig. 7.5

(i) Using your answer from (f), indicate on Fig. 7.5 the position of Cesium-137 in the gamma spectra. [1]
Solution: A1
0.662 MeV = 662 keV

Accept indication on either one of the solid or dotted line graphs.



(ii) Suggest why no photon peak of Iodine-131 was observed on 25 April 2011.

....

....

.... [1]

As seen from Fig. 7.2 , Iodine-131 has a short half-life of about 8 days, hence **a month after 19 March, on 25 April, <u>about four half-lives had passed, hence most of the Iodine would have already decayed</u>**. B1

OR
Half life of Iodine-131 is only about 8 days, so by 25 April, yield of Iodine-131 is only 4.42% of that on 19 March which is significantly low.
[About 36 days passed → $\frac{t}{t_{\frac{1}{2}}} = \frac{36}{8} = 4.5\ half\ lives\ passed$ →

$\frac{A}{A_o} = \left(\frac{1}{2}\right)^{4.5} = 0.0442$ → A = 4.42%]

(h) The sievert (Sv) is the SI unit of effective radiation dose. It is a measure of the biological effects of radiation. One sievert carries with it a 4% chance of developing a fatal cancer in an adult, and a 0.8% chance of hereditary defects in his or her future offspring. Doses greater than one sievert received over a short time period are likely to cause radiation poisoning, possibly leading to death within weeks.

Fig. 7.6 shows the dose rate of gamma-rays recorded by a monitoring car at Fukushima Daiichi Nuclear Power Station during the incident.

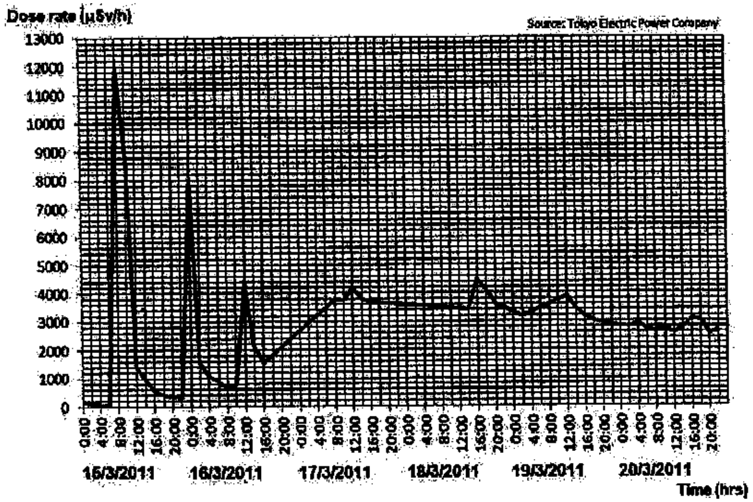


Fig. 7.6

On 15 March 2011, the Japanese Health and Labour Ministry increased the maximum permissible dose for Japanese nuclear workers from 100 mSv per year to 250 mSv per year for emergency situations.

If a worker was at the nuclear site from 16:00 hrs on 16/3/2011, estimate the time that he must be evacuated from the site before his life is in danger. Assume that the worker does not leave the site.

*Show evidence that **area under graph equals to the total dose**. **Find area equal to 250 mSv.*** **M1**
*Time should correspond to **19/3/2011 16:00 hrs.*** **A1**
Allow a range from 19/3/2011 14:00 hrs to 19/3/2011 20:00 hrs.

Accept also if students gave the total duration elapsed.
e.g. 3 days = 72 hrs

time : .... hrs
date: .... [2]

(i) Compare the three types of radioactive decay: alpha-decay, beta-decay and gamma-decay. Explain which of the three poses the greatest health risk if the source is:

1. outside the body;

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

Gamma-decay. Because gamma-ray is the <u>most penetrating</u> **B1**
hence <u>penetrate most deeply</u> into the body and reach living tissues. **B1**
Alpha-particle cannot penetrate the skin. Beta-particle can penetrate the skin but cannot penetrate as deeply.

2. ingested and enters the body.

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

Alpha-decay. Because alpha-particle is the <u>most</u> ionizing **B1**
hence produces the <u>most</u> number of free radicals per unit distance traveled inside the body / causes more extensive mutation of cells or DNA / highest cancer risk. **B1**

-- END OF PAPER 2 --

Catholic Junior College

JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME: MARK SCHEME

CLASS: 2T

PHYSICS — 9749/03

Paper 3: Longer Structured Questions

29 Aug 2019
2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen in the space provided. [PILOT FRIXION ERASABLE PENS ARE NOT ALLOWED]
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A: Answer **all** questions.

Section B: Answer **one** question only. **Circle** the question number attempted in Section B.

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

FOR EXAMINER'S USE		DIFFICULTY		
		L1	L2	L3
SECTION A				
Q1	/ 4			
Q2	/ 9			
Q3	/ 9			
Q4	/ 14			
Q5	/ 6			
Q6	/ 11			
Q7	/ 7			
SECTION B				
Q8	/ 20			
Q9	/ 20			
PAPER 3	/ 80			
PAPER 2	/ 80			
PAPER 1	/ 30			
TOTAL FOR THEORY	/ 190			

This document consists of **28** printed pages and zero blank page.

[Turn over

PHYSICS DATA:

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
			$\approx (1/(36\pi)) \times 10^{-9}$ 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} mol^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

PHYSICS 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	$\phi = -\frac{Gm}{r}$
Temperature	$T/K = T/^{\circ}C + 273.15$
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.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current / voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

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

1 (a) State *Newton's second law of motion.*

.... [2]

The **rate of change of momentum** of a body is **(directly) proportional** to the **net force** acting on it, and,

the **direction of momentum change** is in the direction of the **net force**.

(b) Use Newton's second law of motion to deduce the principle of conservation of linear momentum.

....

....

....

....

.... [2]

From Newton's 2nd law of motion, if a system experiences **no net (external) force**, (the rate of change of momentum of the system must also be zero).

Thus there is no change in **total** momentum of the system / the **total** momentum of a system remains constant / is conserved.

2 A student constructs a potentiometer as shown in Fig. 2.1. The driver battery has negligible internal resistance and an e.m.f. of E_1 = 2.0 V. Wire PQ has a total length of 50.0 cm and resistivity ρ. Wire PQ also has a total resistance of 10.0 Ω. Unfortunately, there is a defect in wire PQ (shaded in Fig. 2.1) where that part of the wire has a cross-sectional area, S, that is half of the rest of the wire. This defective portion has a length that is denoted by x.

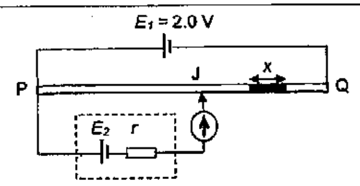


Fig. 2.1

The student carried out an experiment and determined that the e.m.f. E_2 was 1.01 V. The balance length PJ which did not include the defective portion, was 25.5 cm.

(a) When the potentiometer is balanced, determine the current I_{PQ} in the wire PQ.

current, I_{PQ} = ... A [1]

$I = \frac{V}{R} = \frac{2.0}{10.0} = 0.20$ **A**

(b) (i) Using your answer from **(a)**, obtain an expression for

1. V_{PJ}, the potential difference between points P and J, in terms of S and ρ; [1]

$V_{PJ} = I_{PQ} R_{PJ}$

$= (0.20)\,\frac{\rho(0.255)}{2S}$

$= 0.0255\,\frac{\rho}{S}$

Accept if candidate did not convert 25.5 cm to 0.255 m.

2. V_{PQ}, the potential difference between points P and Q, in terms of ρ, S and x. [1]

$V_{PQ} = I_{PQ} R_{PQ}$

$= (0.20)\left[\frac{\rho(0.500 - x)}{2S} + \frac{\rho x}{S}\right]$

Accept if candidate did not convert 50.0 cm to 0.500 m.

3. Hence determine the defective length, x.

$x =$ .... cm [2]

From part 1: $V_{PJ} = 0.0255\frac{\rho}{S}$ ———— (1)

From part 2: $V_{PQ} = (0.20)\left[\frac{\rho(0.50 - x)}{2S} + \frac{\rho x}{S}\right]$ ———— (2)

$\frac{(1)}{(2)}$: $\frac{V_{PJ}}{V_{PQ}} = \frac{0.0255\frac{\rho}{S}}{(0.20)\left[\frac{\rho(0.50 - x)}{2S} + \frac{\rho x}{S}\right]}$

$\frac{1.01}{2.0} = 0.5\left[\frac{1}{(0.50 - x) + 2x}\right]$

$0.50495 = 0.50 + x$

$x = 4.95 \times 10^{-3}$ m $= 0.495$ cm

(c) In a further experiment, the student swaps the connections to the wire PQ and repeats the measurement, as shown in Fig. 2.2.

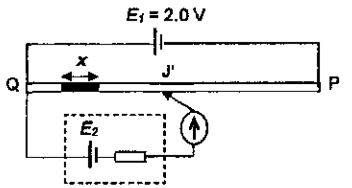


Fig. 2.2

State and explain if the new balance length QJ' would be shorter, longer or unchanged from the set-up in Fig. 2.1.

....

....

....

....

....

.... [4]

For balance length, **the potential difference across QJ' must still be equal to E_2.**

Since the same current flow through PQ, the resistance of length QJ' of the potentiometer wire must be the same/equal as before.

Since the defective portion has a smaller cross-sectional area, it would have a higher resistance compared to the non-defective portion of similar length.

the balance length QJ' is shorter.

3 A binary star system shown in Fig.3.1 consists of two stars orbiting around their common centre of mass, P. One such binary star system is known as Sirius where the mass of Sirius A is twice the mass of Sirius B. The mass of Sirius B is 1.99×10^{30} kg.

Sirius A is at a distance of $\frac{1}{3}D$ from P. Sirius B is at a distance of $\frac{2}{3}D$ from P.

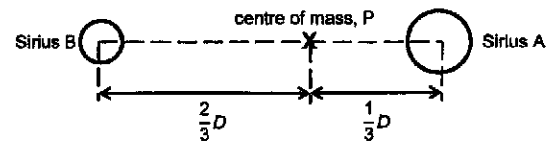


Fig. 3.1

(a) State *Newton's law of gravitation*.

....

....

....

.... [2]

The mutual gravitational force of attraction between two point masses is (directly) proportional to the product of their masses and inversely proportional to the square of their distance apart.

(b) The orbital period of this binary star system is 50 years. Determine the distance D between the binary stars, assuming that the stars move in circular orbits.

distance D = ... m [4]

The centripetal force is provided by the gravitational force.

Consider Sirius B:

$F_g = F_c$

$\frac{GM(2M)}{D^2} = M\omega^2\left(\frac{2D}{3}\right)$

$\frac{GM(2M)}{D^2} = M\left(\frac{2\pi}{T}\right)^2\left(\frac{2D}{3}\right)$

$D^3 = 3GMT^2/4\pi^2$

$= 3 \times 6.67\times10^{-11} \times 1.99 \times 10^{30} \times (365\times50\times24\times60\times60)^2 / 4\pi^2$

$D = 2.93 \times 10^{12}$ m

Solution may also be obtained considering Sirius A.

(c) Determine the speed of a probe, originally at rest at infinity, when it reaches the centre of mass of the star system.

speed = ... m s⁻¹ [3]

L2 By principle of conservation of energy,

Gain in kinetic energy = Loss in gravitational potential energy

$KE_f - KE_i = GPE_i - GPE_f$

$$\frac{1}{2}mv^2 - 0 = 0 - \left[G(\frac{M_A m}{R_A}) + G(\frac{M_B m}{R_B})\right]$$

$$v = \sqrt{\frac{4\times6.67\times10^{-11}\times1.99\times10^{30}}{\frac{1}{3}(2.93\times10^{12})} + \frac{6.67\times10^{-11}\times1.99\times10^{30}}{\frac{2}{3}(2.93\times10^{12})}}$$

$$= \sqrt{\frac{3(6.67\times10^{-11}\times1.99\times10^{30})}{(2.93\times10^{12})}\times(4+\frac{1}{2})}$$

$= 26100$ m s⁻¹

4 (a) Fig. 4.1 shows two identical small positive charged spheres A and B, each having a mass of 5.0×10^{-4} kg in equilibrium. Sphere A is fixed in position by an insulated rod while sphere B is free to move and attached to the ceiling by a string with length 0.20 m.

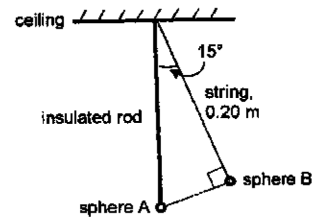


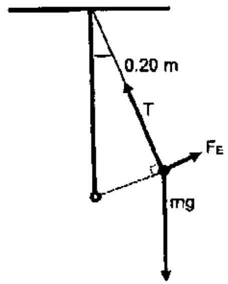
Fig. 4.1

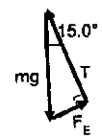
The string suspends at an angle of 15° to the vertical insulating rod and it also makes a right angle with the straight line connecting the two spheres.

Calculate

(i) the repulsive force acting on sphere B due to sphere A;

Draw FBD of sphere B:





Rearranging the vectors, we form a vector triangle

$$\sin 15° = \frac{F_E}{mg}$$

$F_E = 5 \times 10^{-4} \times 9.81 \times \sin 15°$
$= 1.27 \times 10^{-3}$ N
$= 1.3 \times 10^{-3}$ N (2 s.f.)

repulsive force = ... N [3]

(ii) the magnitude of the charge on each sphere.

By Coulomb's law: $F_E = q_1q_2/4\pi\varepsilon_0 r^2 = q^2/\{4\pi\varepsilon_0[(0.20 \tan(15°)]^2\}$

$q = (0.20 \tan(15°))\sqrt{(4\pi(8.85 \times 10^{-12})(1.27 \times 10^{-3})}$
$= 2.01 \times 10^{-8}$ C
$= 2.0 \times 10^{-8}$ C (2 s.f.)

charge = ... C [2]

(b) Sphere B connected with the same string as part **(a)** is now projected into the page at a speed of 0.50 m s^{-1} such that it orbits horizontally around the same vertical insulating rod as shown in Fig. 4.2.

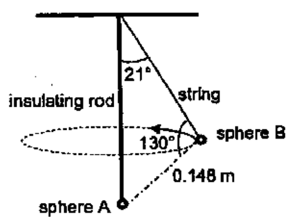


Fig. 4.2

The string makes an angle of 21° with the insulating rod. The distance between sphere A and sphere B is now found to be 0.148 m and the angle between the string and this line connecting sphere A and B is now 130°.

(i) Show that the resultant horizontal force on sphere B is 1.7×10^{-3} N.

The resultant horizontal force is the centripetal force,

$F_c = mv^2/r$
$= 5.0 \times 10^{-4} \times (0.50)^2 / (0.20 \sin 21°)$
$= 1.74 \times 10^{-3}$ N
$= 1.7 \times 10^{-3}$ N

[2]

(ii) Calculate the tension in the string.

The resultant horizontal force by the horizontal component of tension and the horizontal component of the electrostatic force provides the centripetal force.

The new electrostatic force

$= \frac{1}{4\pi\varepsilon_0}\frac{qq}{r^2}$
$= \frac{1}{4\pi(8.85\times10^{-12})}\frac{(2.01\times10^{-8})^2}{0.148^2}$
$= 1.642 \times 10^{-4}$ N

Hence,
$T \sin 21° - F_E \cos 61° = F_c$
$T \sin 21° - 1.642 \times 10^{-4} \cos 61° = 1.74 \times 10^{-3}$
$T = 5.1 \times 10^{-3}$ N (2 s.f.)

tension = ... N [3]

(c) A uniform magnetic field perpendicular to the motion of sphere B is now introduced to the system in part **(b)** as shown in Fig. 4.3.

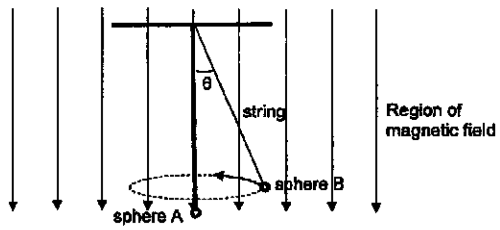


Fig. 4.3

Discuss how this might affect the subsequent motion of sphere B.

With the introduction of the magnetic field, there will be magnetic force directed horizontally towards the vertical insulating rod on sphere B.

The magnitude of the centripetal force will therefore increase.

Hence the speed of motion increase, and/or, the radius of circular motion will decrease.

[3]

(d) In the presence of air, sphere B and A will slowly discharge as they ionize the air particles around them.

Describe the path of sphere B when this happens.

It will spiral inwards / towards sphere A (and eventually come to a stop).

[1]

5 (a) State two differences between a progressive wave and a stationary wave.

difference 1 ....

....

difference 2 ....

....

....

[2]

Any two of the following (1 mark each):

- The amplitude in a stationary wave varies from zero to a maximum (2A) at the antinode, whereas the amplitude is the same for all points in a progressive wave.
- Between any 2 adjacent displacement nodes, all points in a stationary wave are always at the same phase of oscillation; points in adjacent nodal loops are always oscillating in antiphase. However, for a progressive wave, all points within one wavelength are in different phases of oscillation.
- Waveform of a stationary wave does not advance, whereas the waveform of a progressive wave advances (with the velocity of the wave).
- No energy is transferred along a stationary wave, whereas energy is transferred from point to point in the direction of travel of the progressive wave.

(b) Two coherent radiowave sources S_1 and S_2 that are in phase face each other, separated by a distance of 1.25 m, as shown in Fig. 5.1. Point P is located along line AB, x metres away from A.

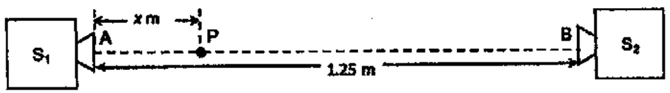


Fig. 5.1

(i) Show that the positions of minimum intensity along the line AB can be described by the following equation:

$$2L = (2n+1)\lambda$$

where
L is the path difference between the waves from S_1 and S_2,
n is any integer and
λ is the wavelength of the radiowaves.

[1]

Since the 2 sources are in phase, for locations where minimum intensity is located, the path difference between the 2 waves must be an odd number integer of half wavelength.

$L = (2n+1)\frac{\lambda}{2}$

$2L = (2n+1)\lambda$

(ii) Determine the number of points along AB where minima would be expected when radiowave signals of wavelength 0.429 m are produced.

number of points = ... [3]

Method 1
1.25 / 0.429 = 2.9 wavelengths
= 5.8 half-wavelengths
→ 6 nodal points

Method 2
$2L = (2n+1)\lambda$
$\mathbf{2(1.25 - 2x) = (2n+1)\lambda}$
$2.5 - 4x = (2n+1)\lambda$
$2.5 - 4x = (2n+1)(0.429)$
$\mathbf{x = \frac{(2n+1)(0.429) - 2.5}{-4}}$

Since $0 \le x \le 1.25$

$0 \le \frac{(2n+1)(0.429) - 2.5}{-4} \le 1.25$
$-5 \le (2n+1)(0.429) - 2.5 \le 0$
$-2.5 \le (2n+1)(0.429) \le 2.5$
$-3.41 \le n \le 2.41$

Therefore, n = -3, -2, -1, 0, 1 and 2.
There are 6 positions.

Method 3
$2L = (2n+1)\lambda$
$\mathbf{2(1.25 - 2x) = (2n+1)\lambda}$
$2.5 - 4x = (2n+1)\lambda$
$2.5 - 4x = (2n+1)(0.429)$
$\mathbf{x = \frac{(2n+1)(0.429) - 2.5}{-4}}$

Substitute n = 0, 1, 2, -1, -2, -3.... until x cannot be more then 1.25 m, or less than 0 m. **There will only be 6 possibilities.**

Mark scheme for Methods 2 & 3:
1 mark: correct derivation of expression for x
1 mark: correct calculations of x for the substitutions
1 mark: final answer (n has 6 possibilities)

6 (a) A metal plate has work function of 4.5 eV. When ultraviolet radiation of wavelength 120 nm is incident on the plate, a photoelectric current is detected.

(i) Calculate the maximum speed of the photoelectrons as a result of this illumination.

maximum speed = ... $m\,s^{-1}$ [2]

Using the Einstein photoelectric equation,

$hf = \phi + KE_{max}$

$hf = \phi + \frac{1}{2} m_e v_{max}^2$

$v_{max} = \sqrt{\frac{2\left(h\frac{c}{\lambda} - \phi\right)}{m_e}}$

$= \sqrt{\frac{2\left(6.63\times10^{-34}\times\frac{3.0\times10^{8}}{120\times10^{-9}} - 4.5\times1.6\times10^{-19}\right)}{9.11\times10^{-31}}}$

$= 1.43\times10^{6}\ m\,s^{-1}$

(ii) The uncertainty in the speed of the photoelectrons in (a)(i) is 0.50%. Assuming that the photoelectrons are moving in the horizontal direction,

1. determine the uncertainty in the horizontal momentum of the photoelectrons;

uncertainty = ... N s [3]

Momentum of the electron:

$p_x = m_e v_x$

$= 9.11\times10^{-31}\times1.43\times10^{6}$

$= 1.30\times10^{-24}\ kg\,m\,s^{-1}$

$\frac{\Delta p_x}{p_x} = \frac{\Delta v_x}{v_x} = \frac{0.50}{100}$ since mass of electron is constant

$\frac{\Delta p_x}{p_x} = \frac{0.50}{100}$

$\Delta p_x = \frac{0.50}{100}\times1.30\times10^{-24}$

$= 0.70\times10^{-26}\ kg\,m\,s^{-1}$ *(must be 2 s.f. Do NOT accept 1 s.f.)*

2. determine the minimum uncertainty in the position of the electron.

uncertainty = ... m [2]

Applying Heisenberg's uncertainty principle,

$\Delta p_x \Delta x \geq h$

$\Delta x \gtrsim \frac{h}{\Delta p_x}$

$\Delta x \gtrsim \frac{6.63\times10^{-34}}{0.70\times10^{-26}}$

$= 9.5\times10^{-8}$ m

Also accept if candidate uses the exact form of Heisenberg's uncertainty principle $\Delta p_x \Delta x \geq \frac{h}{4\pi}$

(b) Fig. 6.1 shows an x-ray spectrum.

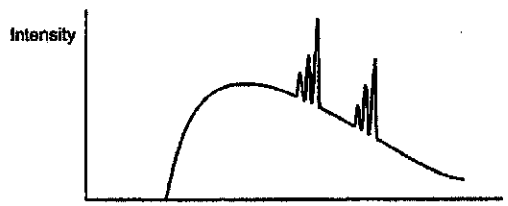


Fig. 6.1

Describe how the continuous spectrum is produced.

....

....

....

....

....

.... [4]

A high speed electron interacts with the nucleus of a target metal. It experiences a net force due to the electric force exerted by the target nucleus, and thus **accelerates/decelerates**. This **produces an x-ray photon of energy equal to the kinetic energy lost by the incident electron** via Bremsstrahlung process.

If an electron has excess kinetic energy after the deceleration, it will continue to interact with another nucleus in the metal, and undergo another Bremsstrahlung process / further deceleration, emitting another photon of a different wavelength.

This process continues until the incident electrons completely loses its kinetic energy. **This series of Bremsstrahlung processes / series of decelerations produce photons of a (continuous) range of wavelengths.**

7 (a) State experimental evidence to suggest that the process of radioactive decay is

(i) random;

....

.... [1]

The points on a count rate against time graph scatter about the (exponential) line of best fit.
OR
Measured count rate fluctuates from instant to instant in time.

(ii) spontaneous.

....

.... [1]

The rate of decrease of the measured count rate is unaffected by external stimuli and changes in physical conditions.
OR
Repeated experiments under different physical conditions result in no change in the rate of decrease of the measured count rate.

Answers must refer to an observable measurement e.g. "measured count rate".

(b) A student measured the count rate from a sample of pure iodine-131 at various times. The results are shown in Fig. 7.1. Iodine-131 decays by beta emission to form xenon-131 which is stable.

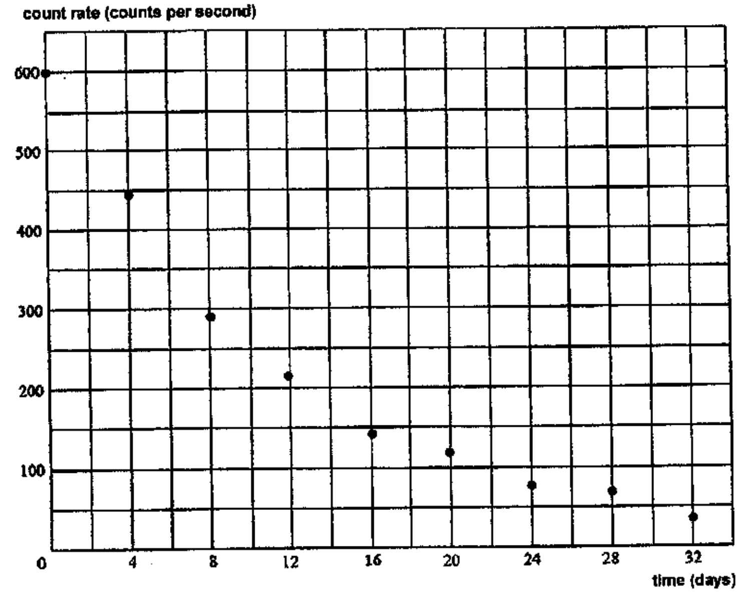
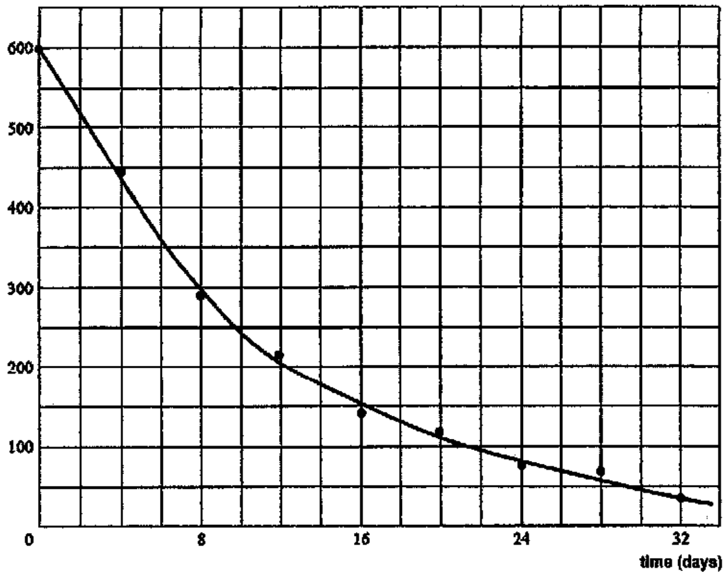


Fig. 7.1

Use Fig. 7.1 to determine a value for the half-life, in days, of iodine-131.

Solution:



- Draw a curve of best-fit on Fig. 7.1.

- Use coordinates from best-fit curve to determine the average time taken for count rate to decrease to half the original value.

e.g.
Read of time taken for count rate to decrease from 600 s^{-1} to 300 s^{-1} → $t_{1/2,1}$
Read of time taken for count rate to decrease from 300 s^{-1} to 150 s^{-1} → $t_{1/2,2}$
Calculate the average of $t_{1/2,1}$ and $t_{1/2,2}$.
[Working for determining the half-life from the average of at least 2 half-lives must be shown.]

- Answer: Accept (8 days ± 1 day). [Actual half-life is about 8.06 days.]

Alternative working:
Accept use of $C = C_0 e^{-\lambda t}$ and $C = C_0 (\frac{1}{2})^{t/t_{1/2}}$ provided coordinates are read off the best-fit curve and not the raw data points.
Also, two values of half-life should be computed from at least two different coordinates that are far apart on the best-fit curve, and average calculated.

half-life = ... days [3]

(c) Explain why the determination of the half-life of Iodine-131 by the method in **(b)** requires that the product of the decay is stable.

....

.... [1]

If the product is unstable, it will decay into another product and emit radiation in the process, and so the **measured count rate would be higher than the actual count rate due to Iodine-131 only.**
OR
the measured count rate would not be due to the decay of Iodine-131 only.

(d) Suggest why the percentage systematic error will not be significant if the student neglected the background radiation.

....

.... [1]

From the graph, the count rate is almost zero eventually; indicating that the background radiation is insignificant (or much smaller) compared to the count rates in this experiment (in the order of hundreds per second).
OR
Background radiation is typically less than 1 count per second (or around 0.5 counts per second or 30 counts per minute), which is much smaller compared to the count rates in this experiment (in the order of hundreds per second).

Section B

Answer one question from this Section in the spaces provided.

8 In a roller coaster ride, a train of mass 1200 kg and carrying a load of 400 kg is pulled up a smooth slope at a constant speed of 1.5 m s^{-1} by an electric motor to a height of 80.0 m as shown in Fig. 8.1. The train with its load is then released from rest at point A and moved to point B along the curved track.

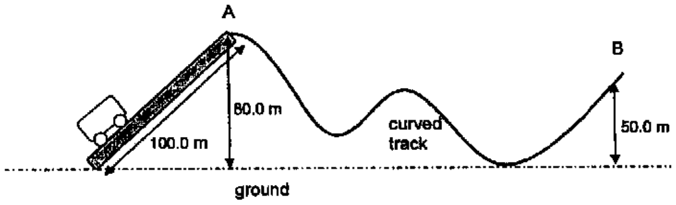


Fig. 8.1

(a) (i) Calculate the minimum force required to pull the train with its load up the slope at the given speed.

minimum force = ... N [2]

Assuming no friction,
The upslope pull needs to balance the downslope component of weight.

Minimum Force required = m g sin θ
= (1200 + 400) x 9.81 x 80.0 / 100.0
= 12556.8 N = 12600 N (3 s.f.)

(ii) The efficiency of the motor is 80%. Calculate the electrical power that is supplied to the motor to pull the train with its load up the slope to point A.

electrical power = ... kW [3]

Output Power = F v
= 12556.8 x 1.5
= 18835 W

Actual power required by motor
= Output Power / efficiency
= 18835 / 0.80
= 23544 W = 24 kW (2 s.f.)

(iii) Between A and B, the train experiences an average resistive force of 3.0 kN. If the train arrives at B with a speed of 8.0 m s^{-1}, determine the distance travelled by the train between A and B.

distance travelled = ... m [3]

By conservation of energy, from A to B,
Loss in GPE = Gain in KE + Work done against resistive force
$mg(h_A - h_B) = (\frac{1}{2} m v_B^2 - 0) + 3000 \times d$
$(1200 + 400)(9.81)(80.0 - 50.0) = \frac{1}{2}(1200 + 400)(8.0^2) + 3000d$
d = 139.89 = 140 m (2 s.f.)

(iv) Suggest why the resistive force on the train is unlikely to remain constant. (Ignore the resistive force due to air resistance.)

....

....

....

.... [1]

A component of resistive force is the frictional force between the wheels and the platform.

<u>Normal contact force</u> exerted by the track on the wheels <u>differs in magnitude at different points of the ride, which causes the frictional force</u> exerted by the track on the wheels <u>to vary</u> as well.

(b) In another segment of the ride, the train loop the loop in a circular track as shown in Fig.8.2. The radius of the circular motion is 25 m.

Point D is at the bottom of the circular motion.
Point E is at the right of the circular motion.
Point F is at the top of the circular motion.
Point G is at the left of the circular motion.

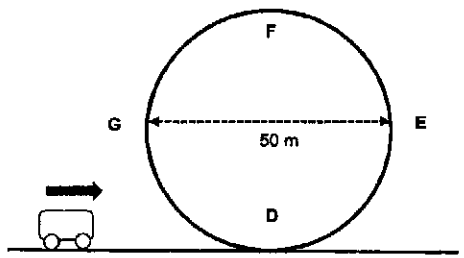


Fig. 8.2

(i) On Fig. 8.3 below, draw the free body diagram of the train at point D and point F.

Fig. 8.3

[2]

Weight directed downwards for both top and bottom.
Normal contact Force (at bottom, D) directed upwards.
Normal contact Force (at Top, F) directed pointing downwards.

1 mark – Labelled and named all forces in the correct directions.
1 mark – Normal contact force at D **greater than** Weight, and Weight constant in magnitude at D and at F.

(ii) Determine the minimum speed of the train at point D so that it can loop the loop.

At the top of the circular motion,
Normal contact force and train's weight provide for the centripetal force required:
$N + mg = F_c$
$N = F_c - mg$
Normal contact force at top needs to be > 0 for the train to stay on track.
$F_c - mg > 0$

$\frac{mv_F^2}{r} - mg > 0$

$\frac{v_F^2}{r} - g > 0$

$v_F^2 > rg$

$v_F > \sqrt{25 \times 9.81}$

$v_F > 15.660 \text{ m s}^{-1}$

Total KE at bottom = min KE at top + GPE gained

$\frac{mv_D^2}{2} = \frac{mv_F^2}{2} + mgh$

$\frac{v_D^2}{2} = \frac{v_F^2}{2} + gh$

$v_D^2 = v_F^2 + 2gh$

$v_D^2 = (15.660)^2 + 2(9.81)(50)$

$v_D = 35.018 = 35 \text{ m s}^{-1}$

Minimum speed = ... m s^{-1} [4]

(c) It is suggested to keep the speed of the train constant.

(i) On Fig. 8.4, sketch the graph to show how the normal contact force experienced by the train varies as it moves from Point D to G and back to D.

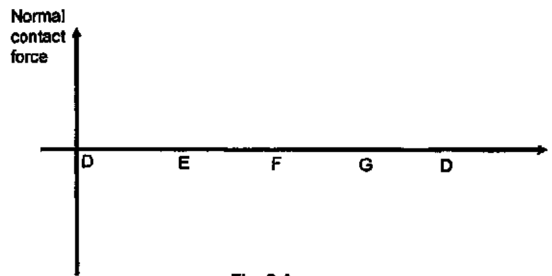
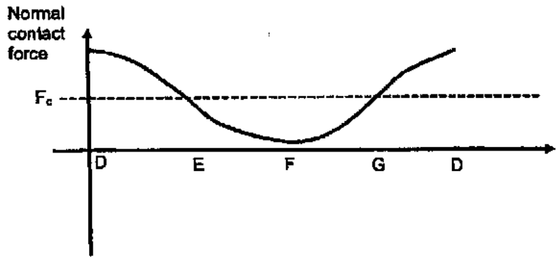
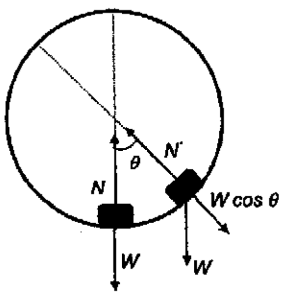


Fig. 8.4

[3]

Solution





General Formula:
$N = Fc + mg\cos\theta$

Point D : $\theta = 0°$
$N = Fc + mg$
Point E : $\theta = 90°$
$N = Fc$
Point F : $\theta = 180°$
$N = Fc - mg$
Point G : $\theta = 270°$
$N = Fc$
Where F_C is constant throughout since m, v, r remain constant.

All positive values. [Deduct 1 mark if there are negative values]
Point D and F correct [B1] : accept N ≥ 0 at F.
Point E and G correct (shows indication that N is equal at these 2 points) [B1]
Sinusoidal shape. [B1]

(ii) Discuss why it is difficult to maintain the train at constant speed during the loop the loop.

....

....

.... [2]

L3 On the upward part of the journey, the train requires an engine to do positive work / supply energy to it at varying rates because kinetic energy (KE) remains unchanged while gravitational potential energy (GPE) needs to increase at varying rates.

On the downwards part of the journey, the train requires a braking system to do negative work / dissipate energy from it at varying rates to prevent increase in KE, since GPE converts to KE at varying rates.

9 (a) Define *electric potential*.

....

.... [2]

The electric potential at a point in an electric field is defined as the work done **per unit positive charge by an external agent in moving a point charge from infinity to that point, (without any change in kinetic energy).**

(b) Two identical point charges, of +*Q* each, are located at a distance 2*d* apart as shown in Fig 9.1.

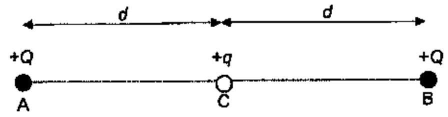


Fig. 9.1

A third charge of mass *m*, and charge +*q* is placed at C, midpoint between the two charges.

(i) Obtain an expression for the electric potential at point C due to the two point charges at A and B.

electric potential at point C = ...V [2]

$V = V_A + V_B$
$V = Q / (4\pi\varepsilon_0 d) + Q / (4\pi\varepsilon_0 d)$
$= 2Q / (4\pi\varepsilon_0 d)$
$= Q / (2\pi\varepsilon_0 d)$

(ii) Sketch in Fig. 9.2 to show how the electric potential varies with the position along AB for the following cases:

1. due to the point charge at A
2. due to the point charge at B
3. due to both point charges at A and B.

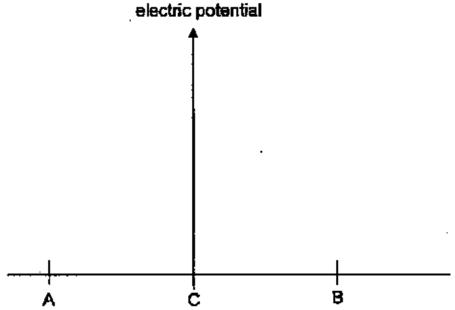
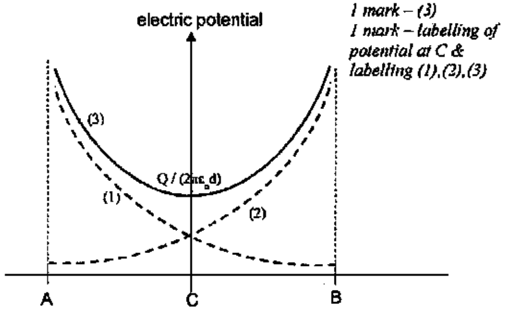


Fig. 9.2

[3]

Solution:



1 mark – (1) and (2)
1 mark – (3)
1 mark – labelling of potential at C & labelling (1),(2),(3)

(iii) The charge $+q$ is then being displaced horizontally and released. It is observed that charge $+q$ exhibits simple harmonic motion with an amplitude of x_o, where x_o is significantly smaller than d.

1. On Fig. 9.3, draw a well-labelled free body diagram to show the electrostatic forces acting on the third charge $+q$ at the instant when it is being displaced at a distance of x to the left of C.

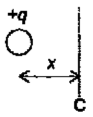
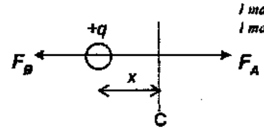


Fig. 9.3

[2]

Solution:



1 mark for label and directions
1 mark for length of arrows

2. Derive an expression for the magnitude of the resultant electrostatic force experienced by the charge due to the point charges at A and B.

resultant electrostatic force = ……………….N [1]

Using $F = Q_1Q_2/(4\pi\varepsilon_0 r^2)$

$F_R = F_A - F_B$

$= Qq/(4\pi\varepsilon_0(d-x)^2) - Qq/(4\pi\varepsilon_0(d+x)^2)$

$= qQ/(4\pi\varepsilon_0)\,[1/(d-x)^2 - 1/(d+x)^2]$

3. The angular frequency of the oscillations can be expressed as follows.

$$\omega = \sqrt{\frac{qQ}{\pi\varepsilon_o m d^3}}$$

Determine the period of oscillation using the data provided below.

m: 6.8 x 10^{-25} kg
q: 3.2 x 10^{-19} C
Q: 1.28 x 10^{-18} C
d: 8.8 cm

period = ………………………. s [1]

Using $T = \frac{2\pi}{\omega}$

$= 2\pi \times \sqrt{\frac{\pi\varepsilon_0 m d^3}{qQ}}$

$= 2\pi \times \sqrt{\frac{\pi \times 8.85\times10^{-12}\times 6.8\times10^{-25}\times 0.086^3}{3.2\times10^{-19}\times 1.28\times10^{-18}}}$

$= 1.08$ s

4. On Fig. 9.4, sketch three graphs to show how the *total energy*, *potential energy* and *kinetic energy* of the charge $+q$ vary as it oscillates between $-x_o$ and x_o. Label each graph.

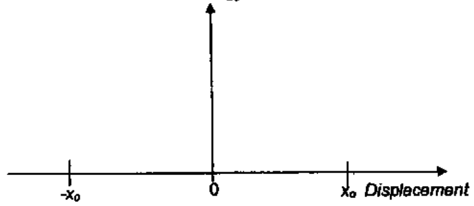
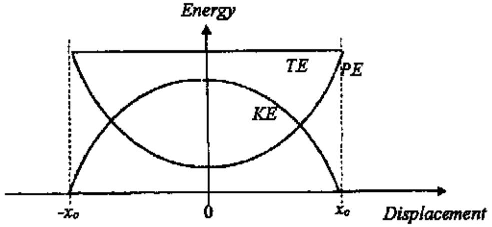


Fig. 9.4

[3]

Solution:



1 mark for each graph

(c) An electron was accelerated from rest with potential difference of 1.0×10^4 V, before entering at right angle into a uniform electric field region provided by a pair of charged parallel plates, separated at a distance of 3.0 cm as shown in Fig. 9.5.

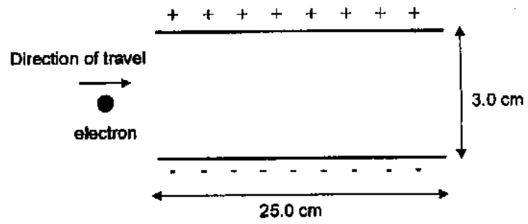


Fig. 9.5

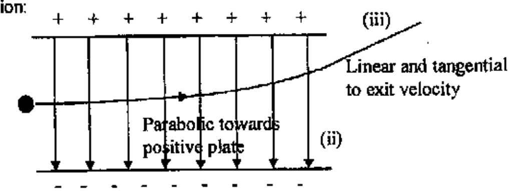
(i) Determine the speed of the electron when it entered the uniform electric field region.

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

During acceleration of the electron,
Gain in KE = Loss in EPE
$\frac{1}{2}mv^2 - 0 = q\Delta V$
$\frac{1}{2} \times 9.11 \times 10^{-31} \times v^2 = 1.60 \times 10^{-19} \times 1.0 \times 10^4$
$v = 5.9 \times 10^7$ m s^{-1}

(ii) On Fig. 9.5, draw the electric field lines between the pair of charged parallel plates. [1]

Solution:



(iii) The electron entered the uniform electric field region at the midpoint between the two charged parallel plates.

1. On Fig. 9.5, sketch the trajectory of the electron within and beyond the parallel plates. [1]

2. Show that the electron did not hit any of the parallel plates when it emerged from the uniform electric field region. The electric field strength between the parallel plates is 5.7×10^3 N C^{-1}.

[2]

				Horizontally: $s_x = u_x t$ $0.26 = 5.9 \times 10^7 \times t$ $t = 4.2 \times 10^{-9}$ s **Vertically:** $s_y = u_y t + ½ a_y t^2$ $= ½ \times (qE/m) \times t^2$ $= ½ \times (1.6 \times 10^{-19} \times 5.7 \times 10^3 / (9.11 \times 10^{-31})) \times (4.2 \times 10^{-9})^2$ $= 0.0088$ m $<$ ($½ \times 0.030$) m	

-- END OF PAPER 3 --

NAME: ______________________ CLASS: __________

CATHOLIC JUNIOR COLLEGE
JC2 Preliminary Examinations
Higher 2

PHYSICS **9749/04**

Paper 4: Practical **MARK SCHEME** **20 August 2019**

2 hours and 30 minutes

READ THESE INSTRUCTIONS FIRST
Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper. **[PILOT FRIXION ERASABLE PENS ARE NOT ALLOWED]**
You may use an HB or 2B pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer <u>ALL</u> 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 assessment, fasten all your work securely together.
The number of marks is given in brackets [ ] at end of each question or part question.

Shift
Laboratory

For Examiner's Use	
1	/ 14
2	/ 9
3	/ 20
4	/ 12
Total	/ 55

[redacted]

1. In this experiment, you will investigate the variation of current I with potential difference V of an electrical component Y.

(a) Set up the circuit as shown in Fig. 1.1, with the rheostat connected as a potential divider and taking care component Y is connected the right way around.

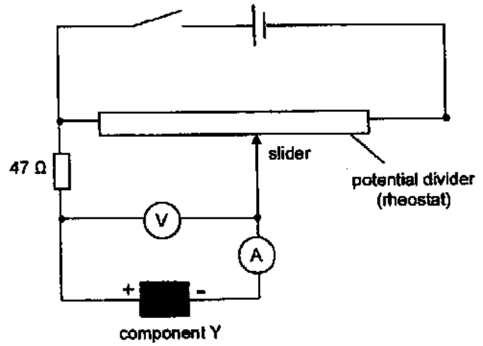


Fig. 1.1

(b) Place the slider of the rheostat at its mid-point.

(c) Close the switch. Record the potential difference across component Y and the current flowing through it.

Accept only 2 d.p. for V (Set to 20 V range)
Accept only 1 d.p. for mA or 4 d.p for A (set to 200 mA range)
Units required
Repeated readings not required.

potential difference = ...2.78 V......................[1]

current = ...5.2 mA.........................[1]

(d) Adjust the slider to vary the potential difference V, from 0 V to the maximum value, across component Y so as to obtain further readings of the current I through component Y. The current will remain zero for low values of V.

Record sufficient readings of V and I so that a curve could be plotted.

8 or more readings – 1 mark

Include (0,0), and also at least 2 readings showing $I = 0$ for small values of V. – 1 mark

Readings should spread out approximately evenly to the maximum range of the rheostat – 1 mark

Correct headings with units – 1 mark
Consistent and correct d.p for raw data – 1 mark (ecf for d.p)

Repeated readings of I not required.

V/V	I /mA
0.00	0.0
1.00	0.0
2.00	0.0
2.50	0.4
2.60	1.2
2.80	5.2
2.90	8.9
3.00	13.2
3.20	24.8
3.40	39.2
3.50	46.4

[5]

(e) On the graph grid on **page 5**, draw a curve to show how I varies with V. [3]

Label axes & scale – 1 mark
All points plotted correctly – 1 mark
Curve line of best fit - 1 mark

(f) (i) From the curve drawn on **page 5**, describe how the resistance of component Y varies. [2]

For V less than 2.4 V, the resistance of Y is infinite (or very large). - 1 mark

For $V >$ 2.4 V, the resistance decreases (significantly). - 1 mark
Cannot accept 'decreases a little or constantly'

(ii) Suggest a practical purpose of using component Y in an electrical circuit. [1]

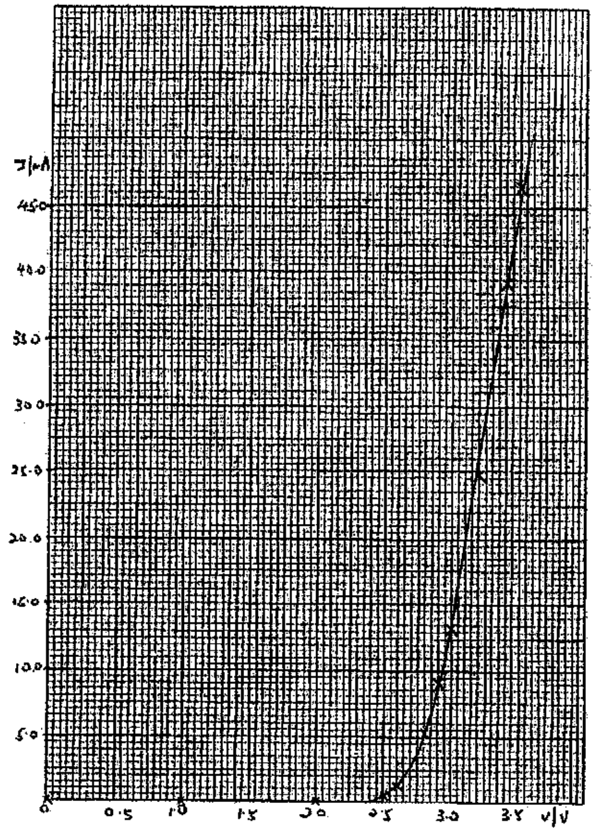
Component Y can be used to allow a current to pass through a circuit only when the potential difference/voltage exceeds a minimum potential difference/voltage.

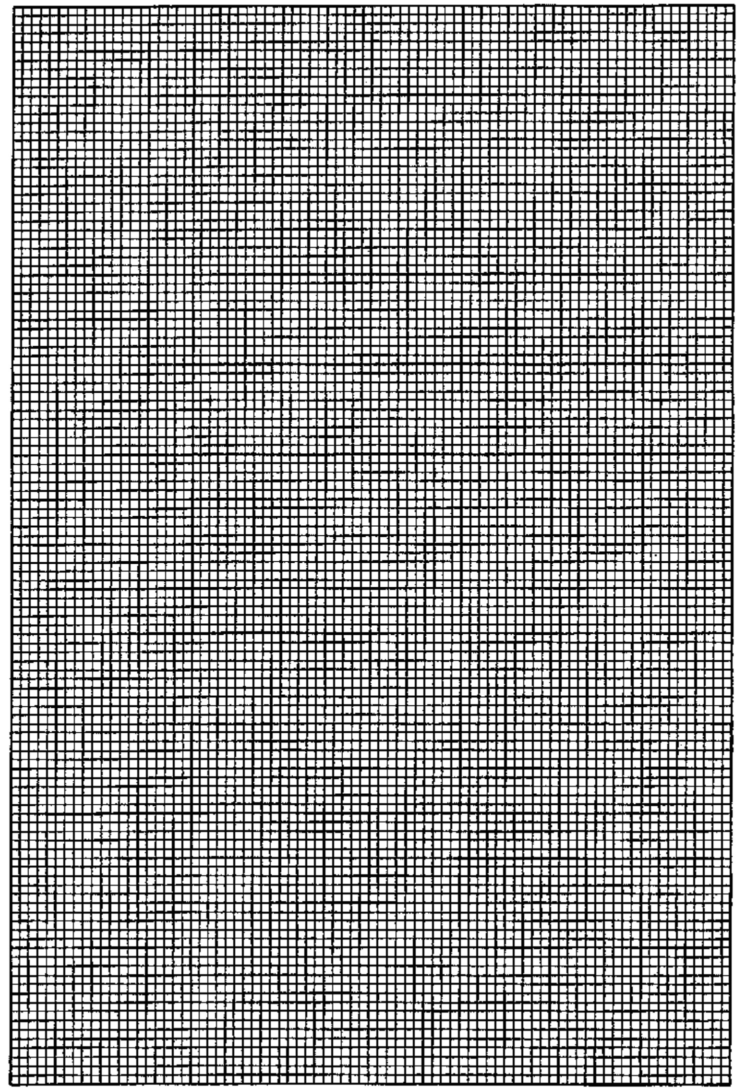
(g) Suggest a reason for connecting the 47 Ω resistor in series to component Y. [1]

The purpose of the 47 Ω is to prevent damage to the Component Y by limiting current flowing through it.
OR
The purpose of the 47 Ω is to adjust V to a limiting range to prevent damage of component Y.

[Total: 14 marks]

[Turn Over


I/mA
450
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
V/V



2. In this experiment, you will investigate the extension of a spring.

(a) You have been provided with a spring.
Measure and record the length x_0 of the unstretched spring, as shown in Fig. 2.1.

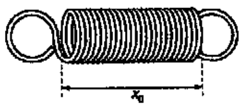


Fig. 2.1

$x_{01} = 2.1$ cm, $x_{02} = 2.1$ cm
$x_{0ave} = 2.1$ cm

x_0 = ...2.1 cm...................

(b) Set up the apparatus as shown in Fig. 2.2.

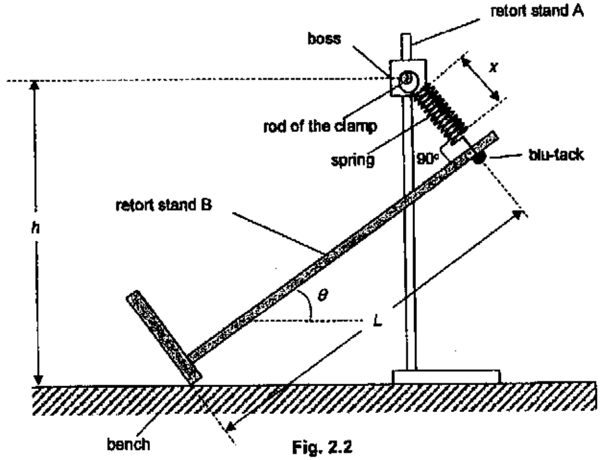


Fig. 2.2

The height h of the rod of the clamp above the bench should be approximately 38 cm.

One loop of the spring should be around the rod of the clamp.

The other loop of the spring should be around the rod of retort stand B close to the top of the rod and secured using blu-Tack.

(c) Slide the base of retort stand B until the angle between the rod of retort stand B and the stretched spring is 90°.

The length of the coiled section of the spring is x.
The angle between the rod of retort stand B and the horizontal is θ.
The length between the base of the retort stand B and the spring is L.

Measure and record x, θ and L.

Repeated readings of x, θ and L.
Correct d.p and units of x, θ and L.

Deduct 1 mark if there is no repeated readings any one of x, θ or L
Deduct 1 mark if there is wrong d.p. in any one of x, θ or L.
Deduct 1 mark if there is wrong units or no units quoted in any one of x, θ or L.

$x_1 = 9.2$ cm $\quad \theta_1 = 22°$ $\quad L_1 = 62.5$ cm
$x_2 = 9.3$ cm $\quad \theta_2 = 21°$ $\quad L_2 = 62.5$ cm

$x_{ave} = \frac{9.3+9.2}{2} = 9.3\,\text{cm}$ $\quad \theta_{ave} = \frac{22+21}{2} = 22°$ $\quad L_{ave} = \frac{62.5+62.5}{2} = 62.5\,\text{cm}$

x = ...9.3 cm....................

θ = ...22°....................

L = ...62.5 cm.................... [2]

(d) Calculate e where

$$e = x - x_0$$

$e = 9.3 - 2.1 = 7.2$ cm

Correct calculation, units and d.p.

e = ...7.2 cm...............[1]

(e) Estimate the absolute uncertainty of θ.

Accept value between 2° and 4° because of the thickness of the rod of retort stand B.
Students need NOT state the reason for their estimated value.

absolute uncertainty = ...Accept 2° to 4° ....[1]

[Turn Over

(f) **Reduce the height *h* of the rod of the clamp to approximately 32 cm. Keeping *L* constant, slide the base of retort stand B until the angle between the rod of retort stand B and the stretched spring is again 90°.**

Measure and record *x* and *θ*. Calculate *e*.

Repeated readings of *x* and *θ*
Correct d.p and units of *x* and *θ*

$x_1 = 10.7$ cm $\theta_1 = 13°$
$x_2 = 10.7$ cm $\theta_2 = 14°$
$x_{ave} = \frac{10.7+10.7}{2} = 10.7\text{ cm}$ $\theta_{ave} = \frac{13+14}{2} = 14^0$

e = 10.7 – 2.1 = 8.6 cm

x = ...10.7 cm......................

θ = ...14°......................

e = ...8.6 cm.........................

(g) **Theory suggests that the quantities *e* and *θ* are related by the equation**

$$e + \frac{mp}{L}\tan\theta\cos\theta = \frac{mq}{L}\cos\theta$$

where *p* and *q* are constants and *m* is the mass of retort stand B.

(i) **Using the values in (c), (d), (f) and *m* = 1800 g, calculate *p* and *q*.**

When θ = 22°, e = 7.2 cm, L = 62.5 cm,

$$7.2 + \frac{1800p}{62.5}\tan 22^0\cos 22^0 = \frac{1800q}{62.5}\cos 22^0$$

$$\frac{7.2}{\cos 22^0} + \frac{1800p}{62.5}\tan 22^0 = \frac{1800q}{62.5} \quad ------(1)$$

When θ = 14°, e = 8.6 cm, L = 62.5 cm,

$$8.6 + \frac{1800p}{62.5}\tan 14^0\cos 14^0 = \frac{1800q}{62.5}\cos 14^0$$

$$\frac{8.6}{\cos 14^0} + \frac{1800p}{62.5}\tan 14^0 = \frac{1800q}{62.5} \quad ------(2)$$

Equating (1) = (2)

$$\frac{7.2}{\cos 22^0} + \frac{1800p}{62.5}\tan 22^0 = \frac{8.6}{\cos 14^0} + \frac{1800p}{62.5}\tan 14^0$$

$$\frac{1800p}{62.5}(\tan 22^0 - \tan 14^0) = \frac{8.6}{\cos 14^0} - \frac{7.2}{\cos 22^0}$$

$$\frac{1800p}{62.5}(0.1547) = 1.0978$$

$$p = \frac{1.0978\times 62.5}{1800\times 0.1547} = 0.2464\text{ cm}^2\text{ g}^{-1} = 0.246\text{ cm}^2\text{ g}^{-1}\text{ or }0.0246\text{ m}^2\text{ kg}^{-1}$$

From Eqn (1),

$$(\frac{62.5}{1800})\frac{7.2}{\cos 22^0} + p\tan 22^0 = q$$

$$(\frac{62.5}{1800})\frac{7.2}{\cos 22^0} + (0.2464)\tan 22^0 = q$$

$$q = 0.36919\text{ cm}^2\text{ g}^{-1} = 0.369\text{ cm}^2\text{ g}^{-1}\text{ or }0.0369\text{ m}^2\text{ kg}^{-1}$$

Units of *p* and *q*:

$$[\frac{mp}{L}\tan\theta\cos\theta] = [\frac{mq}{L}\cos\theta] = [e]$$

$$[\frac{mp}{L}] = [e] \quad \& \quad [\frac{mq}{L}] = [e] \Rightarrow [p] = [q] = \frac{[e][L]}{[m]} = \frac{\text{cm.cm}}{\text{g}} = \text{cm}^2\text{ g}^{-1}$$

Correct substitution to form 2 equations (1) & (2) – 1 mark
Correct calculation of *p* and *q* with correct units – 1 mark
If length, L, was not the same as found in the substituted value in both equations then the first mark cannot be awarded.
Overall if steps taken to determine constants and units of *p* and *q* were correct with all variables correctly substituted then 1 mark awarded for method marks.
If the final answers had units that were not written correctly then the 2nd mark is not awarded.

p = ...0.246 cm² g⁻¹........................

q = ...0.369 cm² g⁻¹..........................

[2]

[Turn Over

(ii) It is also found that

$$p = \frac{gy}{k}$$

where $g = 9.81$ m s^{-2}, $y = 4.2$ cm and k is the spring constant of the spring.

Calculate k.

$$p = \frac{gy}{k} \Rightarrow k = \frac{gy}{p} = \frac{(9.81)(4.2\times10^{-2})}{(0.2464\times10^{-1})} = 16.722 = 16.7 \text{ Nm}^{-1}$$

Correct calculation of k and conversion into N m^{-1}. – 1 mark

k = ……………16.7………………N m^{-1} [1]

(iii) If you were to repeat this experiment with other values of θ, describe the graph that you would plot to determine k.

1 mark -
Linearised the equation into :

$$\frac{e}{\cos\theta} = -\frac{mp}{L}\tan\theta + \frac{mq}{L}$$

Plot $\frac{e}{\cos\theta}$ against $\tan\theta$ to obtain a straight line graph.

1 mark -
Calculate the gradient of the straight line graph to determine p. From the value of p, determine k.

[2]

[Total: 9 marks]

3. In this experiment, you will investigate the variation of the [redacted] frequency f of a stretched string with a fixed tension T.

(a) Fig. 3.1 shows the apparatus which has been set up for this experiment.

The mass M = 1.000 kg.

Do not dismantle the apparatus during the experiment.

L is the length between the bridges and is initially set to approximately 25 cm.

The paper rider should be placed on the string around the mid-point between the two bridges.

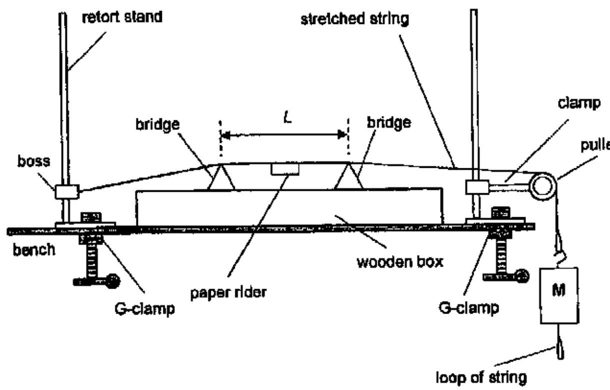


Fig. 3.1

(i) Hit the tuning fork against the rubber bung to set the tuning fork into vibration and, immediately, rest its handle gently on the wooden box as shown in Fig. 3.2.

(ii) While keeping the handle of the vibrating tuning fork resting on the wooden box, move the bridges gradually to increase the length L until you observe the **strongest** vibration of the paper rider or the paper rider jumps off the string. You may need to hit the tuning fork more than once.

The length L should not exceed 35 cm.

[Turn Over

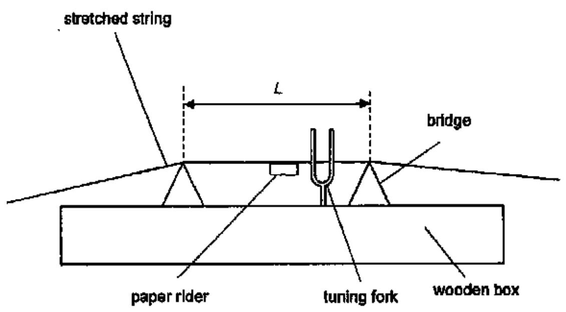


Fig. 3.2

(iii) Measure and record the length L and the frequency f of the tuning fork, when the paper rider has the strongest vibration or jumps off the string.

1 mark - Evidence of Repeated readings of L.
1 mark - zero d.p. for f, and, 1 d.p or zero d.p. for L (d.p. of L must be quoted to the same d.p. of ΔL in part (b)). Units required.

$L_1 = 30.6$ cm $L_2 = 30.8$ cm

$$L_{ave} = \frac{30.6 + 30.8}{2} = 30.7 \text{ cm}$$

frequency f = ……………288 Hz…………………

length L = ……31 cm (rounded off to same precision as ΔL in part (b)…… [2]

Accepted ranges of values of L for corresponding values of f:

f / Hz	271	288	302	320
L / cm	32.8 – 33.4	30.6 – 31.4	29.8 – 30.2	28.3 – 28.5
Theory L / cm	*32.9*	*30.9*	*29.5*	*27.8*

(b) Estimate the percentage uncertainty in your value of L.

ΔL = 2 cm (Accept 0.5 cm to 2 cm) (quoted in 1 s.f. with units)

$$\frac{\Delta L}{L} \times 100\% = \frac{2}{31} \times 100 = 6.45\% = 6\% (1 \text{ s.f})$$

percentage uncertainty in L = ……………6 % (1 s.f.)………………[1]

(c) Choose another tuning fork of a different frequency and repeat **(a)(i)** and **(a)(ii)** to obtain another set of readings for L and f.

Measure and record L and f.

$L_1 = 28.5$ cm $L_2 = 28.5$ cm

$$L_{ave} = \frac{28.5 + 28.5}{2} = 28.5 \text{ cm}$$

frequency f = ……………320 Hz…………………

length L = ……29 cm (rounded off to same precision as ΔL……

(d) It is suggested that

$$2Lf = k\sqrt{mg}$$

where k is a constant and m is the total mass hung on the stretched string.

(i) Use your values from **(a)(iii)** and **(c)** to determine two values of k.

Give your values of k to an appropriate number of significant figures. Assume $g = 9.81$ m s^{-2}.

1 mark - Correct units of k – accept m s^{-1} $N^{-½}$ or m Hz $N^{-½}$ or $m^{½}kg^{-½}$
1 mark - Correct computation and 3 s.f. (since L, f and mg are all 3 s.f.)

$$[k] = \frac{[L][f]}{\sqrt{[mg]}} = \frac{(m)(s^{-1})}{(kg\, m s^{-2})^{½}} = m^{½}kg^{-½}$$

$$k = \frac{2Lf}{\sqrt{Mg}}$$

$$k_1 = \frac{2(30.7 \times 10^{-2})(288)}{\sqrt{1.000 \times 9.81}} = 56.481 = 56.4 \ m^{½}\,kg^{-½}$$

$$k_2 = \frac{2(28.5 \times 10^{-2})(320)}{\sqrt{1.000 \times 9.81}} = 58.236 = 58.2 \ m^{½}\,kg^{-½}$$

first value of k = …………56.4 $m^{½}$ $kg^{-½}$……………………

second value of k = ……………58.2 $m^{½}$ $kg^{-½}$………………… [2]

[Turn Over

(ii) **State whether the results of your experiment support the suggested relationship in (d).**

Justify your conclusion by referring to your values in (b).

Correct calculation of percentage difference of two values of k.
Appropriate comparison with values in (b).

$$\text{Percentage difference} = \frac{k_2 - k_1}{k_1} \times 100\% = \frac{(58.2 - 56.4)}{56.4} \times 100\% = 3.191\% = 3.2\%$$

Since the percentage difference of 3.2 % is less than the uncertainty of L (6 %), the results support suggested relationship

[1]

(e) You will now determine two more values of *k* by varying *m* for two different frequencies of tuning fork.

(i) Adjust the bridges such that the length *L* is fixed at 35.0 cm. **Do not change the length *L* in this part of the experiment.**

(ii) Hang the 100 g mass hanger onto the loop of string, shown in Fig. 3.3.

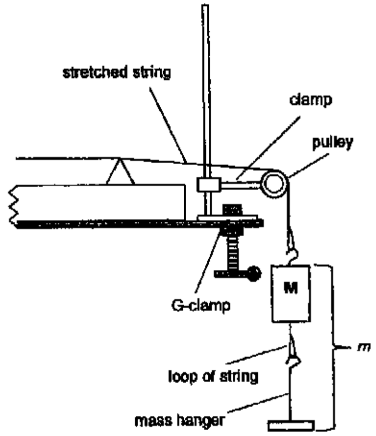


Fig. 3.3

(iii) Hit the tuning fork against the rubber bung to set the tuning fork into vibration and, immediately, rest its handle gently on the wooden box. Observe the vibration of the paper rider.

(iv) If the paper rider does not show the **strongest** vibration or jump off the string, increase *m* in steps of 100 g slotted mass and **repeat step (iii).**

(v) Stop increasing *m* when you observe the **strongest** vibration of the paper rider or the paper rider jumps off the string.

Measure and record *f* and *m*.

Repeat for a second tuning fork.

Tabulate your results of *m* and *f*, including the values of *k*.

f / Hz	m / kg	k / $m^{½}$ $kg^{-½}$
271	1.100	57.7
320	1.400	60.5
d.p. as stated in tuning fork (calibrated precision)	3 d.p. in kg OR 0 d.p. in g m is TOTAL mass, hence should be greater than 1.000 kg	Follow least s.f. of raw values; 3 s.f. in this case.

1 mark – Correct units and d.p. for m & f. m should be 0 d.p. in g or 3 d.p. in kg; f is zero d.p. in Hz.
1 mark – 2 sets of readings (f, m) shown. Correct values of m. (Note: m should be more than 1.000 kg since M is already 1.000 kg).
1 mark – Correct computation of k. (ecf for units or similar computation errors from previous part)

Deduct 1 mark if instructions are not followed. E.g.
- results are not tabulated
- 1 set of readings only, or more than 2 sets of readings
- Values of k not part of the table
- Improper tabulation methods e.g. spit tables, showing a column of Yes/No for maximum vibration for various values of m (question specifically requires m & f to be recorded only for the scenario when maximum vibrations is seen).

[3]

(vi) **Comment on your values of *k* in (d)(i) and (e)(v).**

$$\% \text{ difference} = \frac{k_4 - k_3}{k_3} \times 100\% = \frac{(60.5 - 57.7)}{57.7} \times 100\% = 4.85\% = 4.9\%$$

As L is kept constant in (e)(v), the uncertainty of the experiment is contributed most significantly by m, due to increments of m in quantum of 100g slotted masses.
Uncertainty due to m = $\frac{1}{2}\frac{\Delta m}{m} x100\% = \frac{1}{2}\left(\frac{100}{1100}\right) x100\% = 5\%\ (1\ s.f.)$

Since the percentage difference of 4.9 % is within 5%, the results support that *k* is constant (when L is constant and m & f varied).

[Turn Over

Average of k_3 & $k_4 = \frac{57.7 + 60.5}{2} = 59.1\ m^{½}\ kg^{-½}$

Average of k_1 & $k_2 = \frac{58.2 + 56.4}{2} = 57.3\ m^{½}\ kg^{-½}$

% difference $= \frac{(59.1 - 57.3)}{57.3} \times 100\% = 3.14\%$

Since the percentage difference in the magnitudes of *k* between (d)(i) and (e)(v) is less than the combined uncertainty of m and L (6% + 5% = 11%), the results support that *k* is constant regardless of which variable is changed (L, m or f).

1 mark – correctly calculate the percentage difference of k values in (e)(v) & conclusion about k (constant / not constant) when L is kept constant by comparison with uncertainty in the experiment *.
1 mark – calculate percentage difference in magnitudes of k between (d)(i) and (e)(v).
1 mark – conclusion about k (constant / not constant) overall regardless of which variable is changed (L, m or f) by comparison with uncertainty in the experiment *.
*Note: Accept comparisons with any of the following uncertainties:

- Percentage uncertainty of L in (b)
- Percentage uncertainty due to m [$= \frac{1}{2}\frac{\Delta m}{m} x100\%$]. Factor ½ is necessary due to the formula.
- Combined percentage uncertainty due to L and m [$= \left(\frac{\Delta L}{L} + \frac{1}{2}\frac{\Delta m}{m}\right) x100\%$]

[3]

(f) (i) State two significant sources of error in this experiment.

1 ....

....

....

2 ....

....

....[2]

- If the tuning fork is struck too hard against the rubber bung, there is an initial 'clang' tone that has a frequency different from the one printed on the tuning fork.
- The tension in the string is not equal to mg due to the friction between the bridge and the string. The measured *L* may not be for the length when the tension is equal to mg.
- As L is adjusted, the paper rider may not always be at the mid-point to ascertain that the vibration is the strongest.
- It is not easy to judge when vibration is the strongest, affecting accuracy of L.

- As the increments of m are only in 100g standard mass, the strongest vibration may occur in smaller increments of less than 100g. Thus, the recorded m may not be the value where the strongest vibration is observed.

(ii) Suggest an improvement that could be made to the experiment to address one of the sources of error identified in (f)(i). You may suggest the use of other apparatus or a different procedure.

....

....

....[1]

- Allow the initial 'clang' tone to fade away before placing the tuning fork on the wooden board / bridge.
- Make a mark on the centre of the paper rider and use the rules to ensure the rider is at the mid-point between the bridges.
- Video-record the experiment, with a measuring tape/ruler to measure L also in the recording. Play back the video in magnified view to enhance observation of when the vibration is strongest.
- Use standard mass of 10 g, 20g and 50 g as increments for m so as to obtain a more accurate value of m where the strongest vibration can be observed.

(g) The oscillation of a stretched string depends on the properties of the string.

It is suggested that the fundamental frequency *f* is inversely proportional to the square root of the diameter *d* of the string.

Explain how you would investigate this relationship using the same apparatus. In addition, you have access to a set of 12 tuning forks and 8 strings of different diameters.

Your account should include:

- your experimental procedure
- control of variables
- how you would use your results to show inverse proportionality
- why you might not have enough results to reach a valid conclusion.

Independent variable: d Dependent variable: f Use a micrometer screw gauge to measure d of each string. Select one string to begin the experiment. Starting with the tuning fork of <u>lowest</u> frequency, determine which frequency of tuning fork <u>first</u> causes the paper rider to jump off the string. (This is important to obtain the <u>fundamental</u> frequency.) Record the frequency as f. Repeat for the various diameters of strings.	1 1

[Turn Over

Control of variables: The tension of the string, length of string between the bridges and the density/material of the string used should be kept constant throughout.	1
Plot a <u>graph of f against</u> $\frac{1}{\sqrt{d}}$	1
If the suggested relationship holds, a graph of <u>straight line</u> (i.e. constant gradient) passing through the <u>origin</u> should be obtained.	1
Limitations of results: Use of tuning forks does not allow for a continuous variation of frequency (i.e. small enough increments in frequency), hence it may not be possible to determine f for all the string diameters prepared. This may result in fewer than 6 sets of results.	

[5]

[Total: 20 marks]

4. A student is investigating the force between two charged metal spheres S and T, as shown in Fig. 4.1.

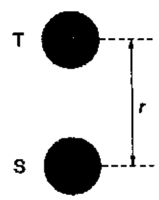


Fig. 4.1

Each sphere may be charged by connecting the positive lead from a power supply to the sphere and then removing the lead. The electromotive force (e.m.f.) of the power supply used to charge sphere T is V.

The force F between the two charged spheres may be determined by attaching sphere S to an electronic balance.

For a constant charge on sphere S, it is suggested that the relationship between F and V is

$$F = kV^m r^n$$

where r is the distance between the centres of the spheres; and k, m and n are constants.

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

You should draw a diagram to show the arrangement of your apparatus and you should pay particular attention to

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

Diagram

[12]

[Total: 12 marks]

[Turn Over

Question 4	Marking Instructions	Mark	Code
Diagram	Fully labelled Diagram with mass at the top end of the rod and clamp at the bottom end of the rod Award 1 mark if the following is the diagram – • retort stand to suspend sphere T • sphere S, on electronic balance, is vertically below T • the spheres have insulated holder	1	A1
Procedure	Procedure 1. Set up the apperatus as shown in the diagram.		
	2. Measuring *r*: Using fiducial markers to reference the top of each sphere, measure the distance between the two markers with a metre rule. This is equal to the distance *r*. [OR, any other methods to measure r accurately e.g. Use of callipers/micrometer to measure diameter of spheres to determine *r*.]	1	B1
	3. Measuring *V*: Measure and record *V* across the power supply with a voltmeter [OR, Read and record *V* from high voltage power supply/EHT power supply.]	1	B2
	4. Measuring *F*: a. Before charging the sphere S and T, measure, using the electronic balance, the total mass of the sphere S with its holder. Record as m_1. b. Charge both spheres S and T by connecting the positive lead from the EHT power supply to each sphere and then removing the lead. c. After charging the sphere S and T, measure the total mass of the Sphere S with its holder. Record as m_2. d. Calculate $F = (m_2 - m_1)$ x *(acceleration due to gravity)*	1	B3
	Varying I.V. Part 1: Vary *r* and keep *V* constant 5. Set the power supply to fixed voltage $V = V_0$, and ensure that the same voltage is used throughout Part 1 of the experiment. Record V_0 as in step 3. 6. Vary *r* by adjusting the clamp holding sphere *T*. 7. For each value of *r*, repeat steps 2 and 4 to obtain further readings of *r* and *F*.	1 (steps 5&6)	B4
	8. $F = kV^m r^n$ Take log on both sides: $\lg F = n\lg r + (\lg k + m\lg V)$ 9. Plot a straight line graph of lg *F* against lg *r*. Calculate the gradient and the value is equal to *n*, where the vertical-intercept is $(\lg k + m\lg V)$.	1	B5
	Part 2: Vary *V* and keep *r* constant 10. Adjust the clamp so that sphere T is at a fixed distance $r = r_0$. from sphere S. Ensure that this distance does not change throughout Part 2 of the experiment. Record r_0 as in step 2. 11. Vary *V* by adjusting the power supply. 12. For each value of *V*, repeat steps 3 and 4 to obtain further readings of *V* and *F*. 13. With the equation in step 8, $\lg F = m\lg V + (\lg k + n\lg r)$	1 (steps 10&11)	B6

	14. Plot a straight line graph of lg *F* against lg *V*. Calculate the gradient and the value is equal to *m*, where the vertical-intercept is $(\lg k + n\lg r)$.	1	B7
	15. To determine *k*, determine the vertical-intercept of the graph of Part 2 and equate to $(\lg k + n\lg r)$, using the value of *n* obtained in Part 1 (step 9), and using the constant value of $r = r_0$ in Part 2 (step 10).	1	B8
Additional Details	Additional details: (Any 2 of the followings)	2	
	1. Insulated holder (e.g. Wood, rubber, Styrofoam) for top and bottom spheres – to prevent spheres from discharging when if they were in contact with the metal clamps or top-pan of the electronic balance, and a 'holder' design prevents roll off. (Reliability)		C1
	2. Put all the above in place first before charging the spheres to prevent discharging. (Reliability)		C2
	3. Ensure the spheres are charged to the same V as that set on the EHT power supply before every reading is taken. This can be ensured by connecting an ammeter along the lead connecting the positive terminal of the EHT power supply and the end touching the sphere, check the current is reduced to zero before removing the lead from the sphere. (Reliability)		C3
	4. Use an EHT power supply so that the spheres can be charged high enough to produce a larger and measureable force using the electronic balance. (Reliability)		C4
	5. Conduct experiment in a room with air-conditioning or de-humidifier to reduce the rate of discharge. (Reliability)		C5
	6. Conduct in the same room conditions throughout e.g. humidity. (Controlled variable)		C6
	7. Ensure the 2 spheres are vertically aligned. E.g. position 2 plumblines behind the setup as fiducial markers, used to ensure the 2 leftmost and rightmost points on the 2 spheres are vertically aligned. (Controlled variable)		C7
Safety	Safety (Any one of the following)	1	
	1. Use insulating gloves to hold charge spheres or leads of power supply to avoid electrocution.		D1
	2. Ensure that there are no bare connections and avoid touching metal parts to avoid electrocution.		D2
	Total Marks		**12**

[Turn Over