NATIONAL JUNIOR COLLEGE
SENIOR HIGH 2 Preliminary Examination
Higher 2

CANDIDATE NAME

SUBJECT CLASS

REGISTRATION NUMBER

PHYSICS

9749/01

Paper 1 Multiple Choice

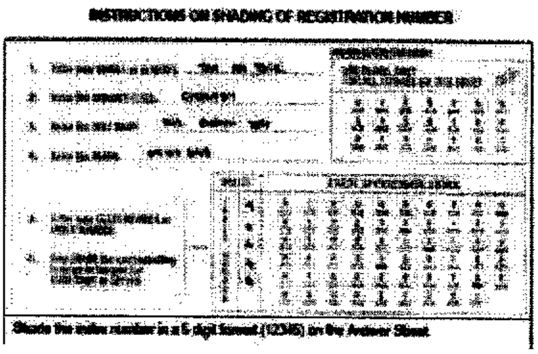
19 September 2019

Additional Materials: Multiple Choice Answer Sheet

1 hour

READ THE INSTRUCTION FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, subject class and registration number on the Answer Sheet in the spaces provided unless this has been done for you.
There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice **in soft pencil** on the separate Optical Mark Sheet.
Read the instructions very carefully.
Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.



OAS index number is in 5-digit format.

5 digit format: **2nd digit** and the **last four digits** of the Reg Number.

This document consists of **18**printed pages and **2** blank pages.

[Turn over

Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(1/(36\pi)) \times 10^{-9}\,\mathrm{F\,m^{-1}}$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
unified atomic mass constant	$u = 1.66 \times 10^{-27}\,\mathrm{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -Gm/r$
temperature	$T/\text{K} = T/{}^\circ\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $= \pm \omega \sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

[Turn over

1 A person is standing still on the ground.

Which value is an estimate of the pressure exerted bythe person's feet on the ground?

A 120 Pa

B 1 200 Pa

C 12 000 Pa

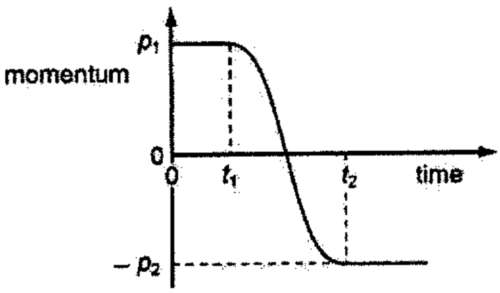
D 120 000 Pa

2 Ball A is projected horizontally at 2.0 ms^{-1} from the top of a vertical cliff while Ball B is released from rest 1.0 s later from the same point. It took Ball B 3.5 s to reach the base of the cliff.

How far from the base of the cliff will Ball A hit the ground?

A7.0 m **B**9.0 m **C**53 m **D**67 m

3 The graph shows the variation with time of the momentum of a ball as it is kicked in a straight line.



At time t_1, the momentum is p_1. At time t_2, the momentum is p_2.

What is the magnitude of the average force acting on the ball between times t_1 and t_2?

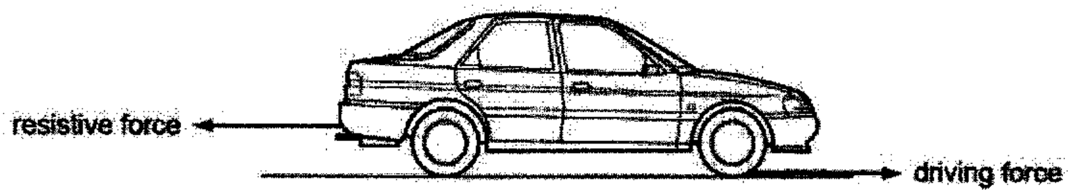
A $\dfrac{p_1 \square p_2}{t_2}$

B $\dfrac{p_1 \square p_2}{t_2 \square t_1}$

C $\dfrac{p_1 + p_2}{t_2}$

D $\dfrac{p_1 + p_2}{t_2 \square t_1}$

4 A car of mass 750 kg has a horizontal driving force of 2.0 kN acting on it. It has a forwardhorizontal acceleration of 2.0 m s^{-2}.



What is the resistive force acting horizontally?

A 0.5 kN

B 1.5 kN

C 2.0 kN

D 3.5 kN

5 An object, made from two equal spherical masses joined by a light rod, falls with uniform velocitythrough air.

The rod remains horizontal.

Which statement about the equilibrium of the system is correct?

A It is not in equilibrium because it is in motion.

B It is not in equilibrium because there is a resultant force.

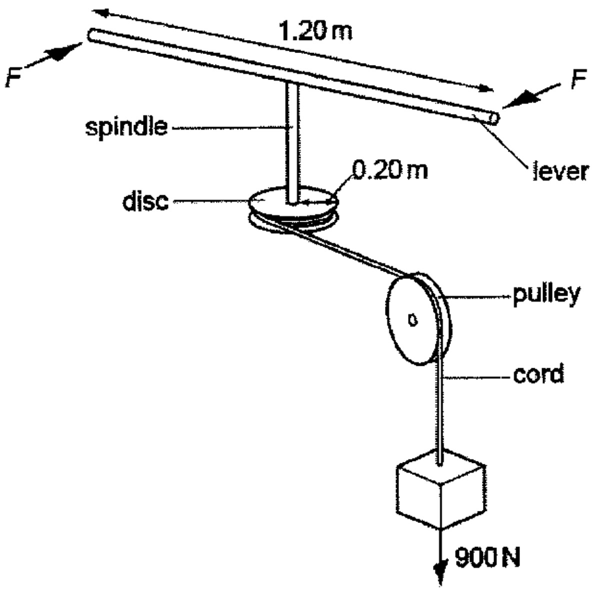
C It is in equilibrium because there is noresultant torque.

D It is in equilibrium because there is no resultant force and no resultant torque.

[Turn over

6 One end of a spindle is attached to the centre of a lever of length 1.20 m and its other end is attached to the centre of a disc of radius 0.20 m as shown in the figure below.

A cord is wrapped around the disc, passes over a pulley and is attached to a 900 N weight at one end.



The mass of the lever, spindle, disc, cord and pulley is assumed to be negligible. Equal and opposite forces of magnitude F is applied to each end of the lever.

Ignoring frictional forces, what is the minimum value of F needed to balance the 900 N weight?

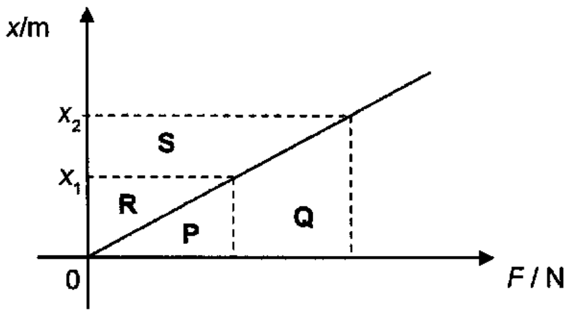
A 75 N

B 150 N

C 300 N

D 950 N

7 The variation with force *F* of the extension *x* of a spring is shown in the figure below.



The work done in stretching the spring from x_1 to x_2 is given by the area

A P + Q

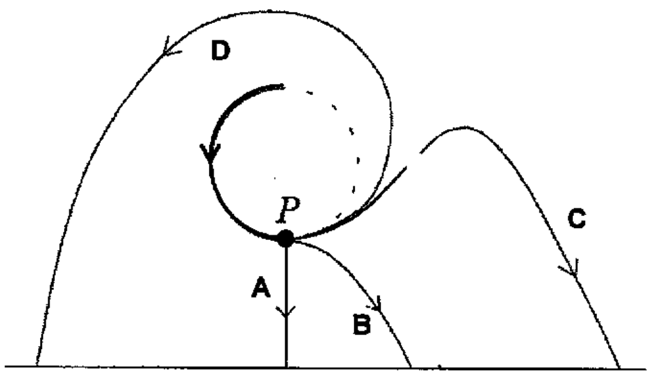
B S

C R + S

D Q

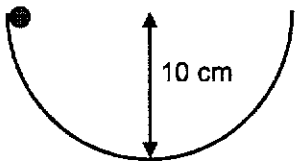
8 A stone, tied to a piece of string, is whirled in a vertical circle as shown in the figure below. The string suddenly breaks at *P*.

Which of the paths (A to D) represents a possible path for the stone from just before the string breaks until the stone hits the ground?



[Turn over

9 A small object of mass 0.050 kg is releasedfrom rest at the rim of a heavy, smoothsemi-spherical bowl of radius 10 cm as shown in the figure below.



When the object passes the bottom of the bowl, what is the normal force exerted on it by the bowl?

A0.49 N **B**0.98 N **C**1.5 N **D**2.0 N

10 Taking the Earth to be a perfect sphere of uniform density rotating about its polar axis, which of the following statements concerning the observed acceleration due to free fall$a$ at the surface of the Earth is true?

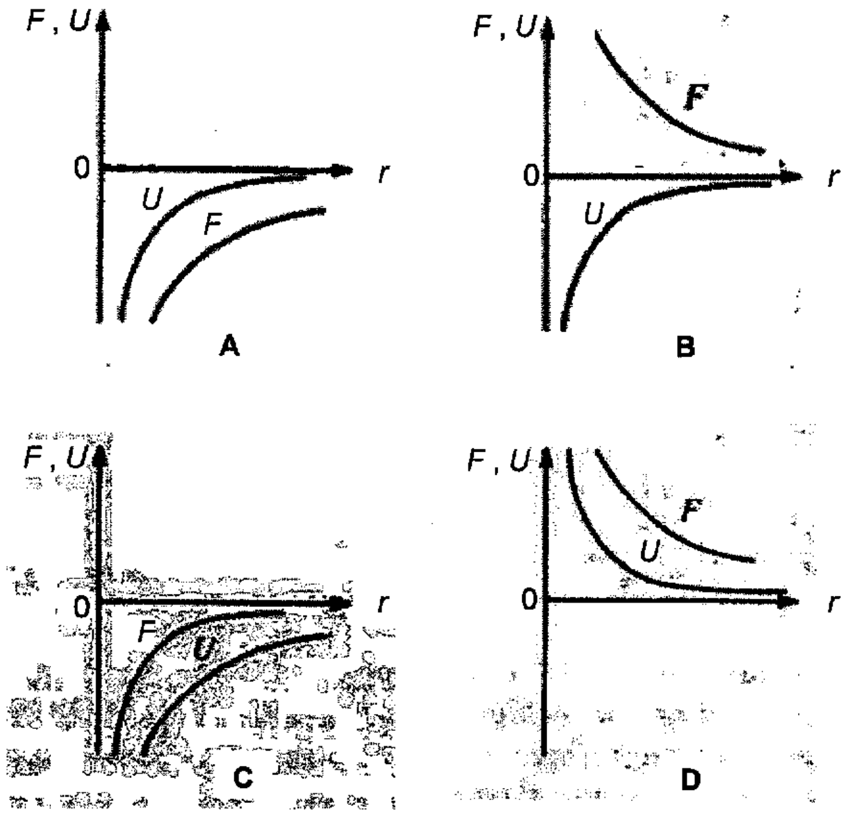
A The value of a at the equator is larger than that at the poles.

B If the rate of rotation of the Earth decreases, the value of$a$ at the equator increases.

C If the radius of the Earth increases with its density remaining unchanged, the value of$a$ at the poles decreases.

D If the radius of the Earth increases with its density remaining unchanged, the value of$a$at the equator decreases.

11 Which one of the following diagrams shows the variation of gravitational force F on a point mass and gravitational potential energy U of the mass at a distance r from another point mass?



12 The temperature of an ideal gas is raised from 32.1 °C to 40.5 °C.

What is the percentage increase in the r.m.s. speed of its gas particles?

A 1.4 %

B 2.8 %

C 11%

D 12%

13 The specific latent heat of vaporisation of water at 20°C is appreciably greater than the value at 100°C. This is because

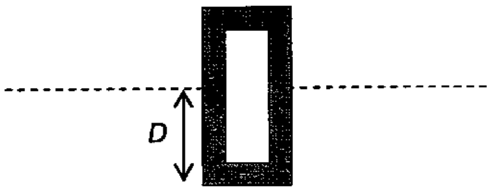
A the specific latent heat at 20°C includes the energy to raise the temperature of one kilogram of water from 20°C to 100°C.

B more work must be done in expanding the water vapour against atmospheric pressure at 20°C than at 100°C.

C the molecules in the liquid are more tightly bound to one another at 20°C than at 100 °C.

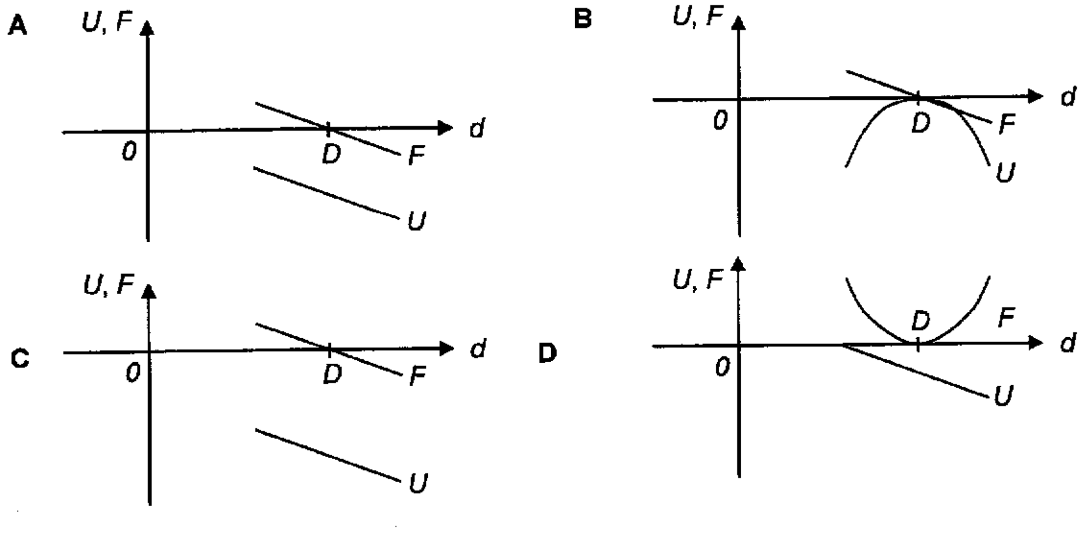
D vaporisation of water can only take place at 100°C.

14 A hollow metal cylinder floats upright in a body of water with the bottom of the cylinder at a depth D below the water surface as shown.

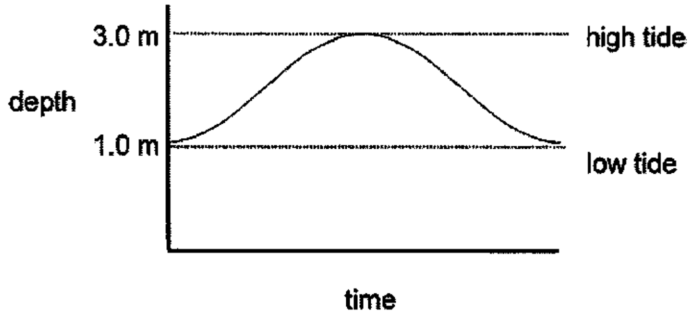


The cylinder is pressed further down into the water and upon release, performs simple harmonic motion.

Which of the following graphs (all drawn to scale) shows how the upthrust U and resultant force F acting on the cylinder vary with the depth d of the bottom of the cylinder below the water surface?



15 The rise and fall of water in a harbour is simple harmonic. The depth varies between 1.0 m at low tide and 3.0 m at high tide. The time between successive low tides is 12 hours



A boat, which requires a minimum depth of water of 1.5 m, approaches the harbour at low tide. How long will the boat have to wait before entering?

A0.5 hours **B**1.0 hours **C**2.0 hours **D**2.5 hours

16 When coherent monochromatic light falls on double slits, an interference pattern is observed on a screen some distance from the slits.

The fringe separation can be increased by

A decreasingthe distance between the screen and the slits.

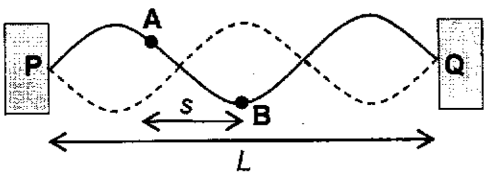
B increasingthe distance between the slits.

C usingmonochromatic light of lower frequency.

D immersingthe whole set up in water.

17 A guitar string of length *L*is stretched between two fixed points **P** and **Q** and made to vibrate transversely as shown below.

[Turn over



Two pointsA and **B** on the string are separated by a distance s. The maximum kinetic energies of points **A** and **B** are K_A and K_B respectively.

Which of the following gives the correct phase difference and relationship between maximum kinetic energies of the points?

	phase difference	maximum kinetic energy
A	$\frac{3s}{2L}$ □ 360°	$K_A < K_B$
B	$\frac{3s}{2L}$ □ 360°	same
C	180°	$K_A < K_B$
D	180°	same

18 The images of two sources are just resolved.

Which of the following is a correct statement of theRayleigh criterion for this situation?

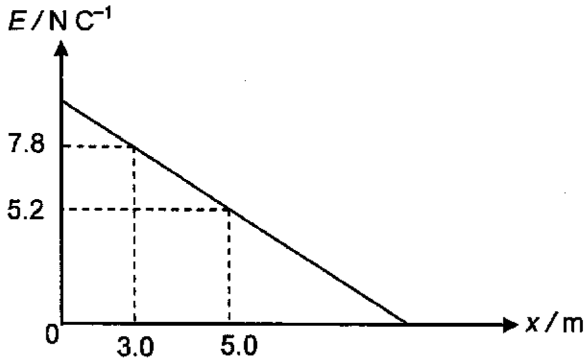
A The central maximum of the diffraction pattern of one source must coincide with the centralmaximum of the diffraction pattern of the other source.

B Light from the sources must pass through a circular aperture.

C Light from the sources must be coherent.

D The first minimum of the diffraction pattern of one source must coincide with the centralmaximum of the diffraction pattern of the other source.

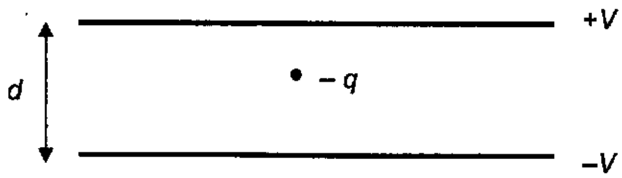
19 The graph shows how the electric field strength E varies with displacement x from a point A.



What is the change in potential for an electron if it is moved from x = 3.0 m to x = 5.0 m?

A 13 V **B** – 13 V **C** 1.3 V **D** – 1.3 V

20 An oil droplet has a charge $-q$ and is situated between two parallel horizontal metal plates as shown in the diagram.



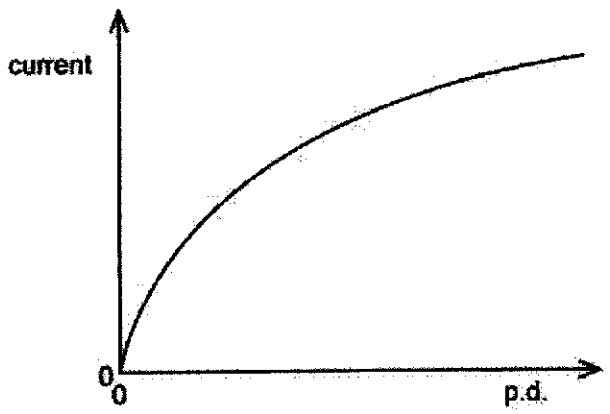
The separation of the plates is d. The droplet is observed to be stationary when the upper plate is at potential $+V$ and the lower at potential $-V$.

For this to occur, the weight of the droplet is equal in magnitude to

A $\frac{Vq}{d}$ **B** $\frac{2Vq}{d}$ **C** $\frac{Vd}{q}$ **D** $\frac{2Vd}{q}$

[Turn over

21 The graph shows how the current through a lamp filament varies with the potential difference (p.d.) across it.



Which statement explains the shape of this graph?

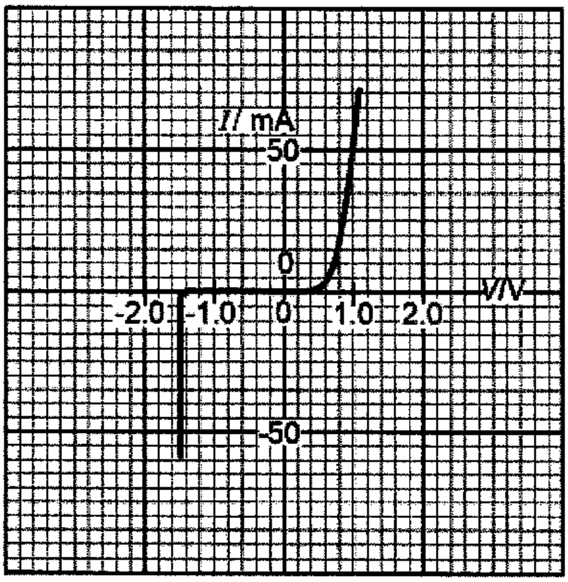
A As the filament temperature rises, electrons can pass more easily through the filament.

B It takes time for the filament to reach its working temperature.

C The power output of the filament is proportional to the square of the current through it.

D The resistance of the filament increases with a rise in temperature.

22 The variation with potential difference V of the current I in a semiconductor diode is shown below.

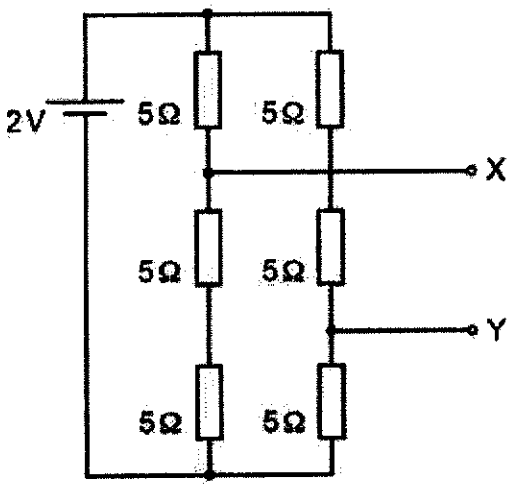


What is the resistance of the diode for applied potential differences of +1.0 V and –1.0 V?

	+1.0 V	–1.0 V
A	20 Ω	infinite
B	20 Ω	zero
C	0.05 Ω	infinite
D	0.05 Ω	zero

[Turn over

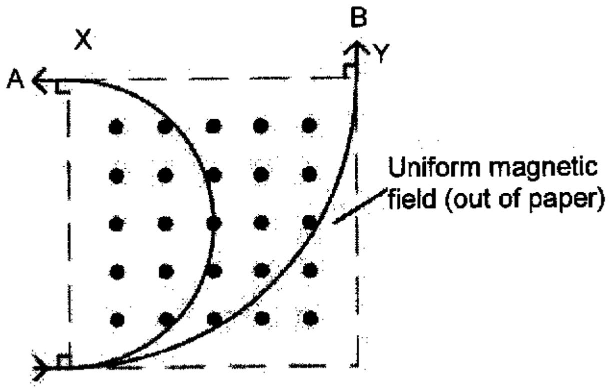
23 Six resistors, each of resistance 5 Ω, are connected to a 2 V cell of negligible internal resistance.



What is the potential difference between terminals X and Y?

A 0.67 V **B** 0.89 V **C** 1.3 V **D** 2.0 V

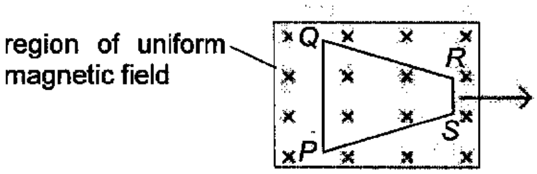
24 Particles *A* and *B*, both moving at the same speed, enter a square region of uniform magnetic field as shown in the figure below. Particle *A* leaves at *X* while particle *B* leaves at *Y*.



If the ratio of charge to mass of particle *A* is *k*, what is that of particle *B*?

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

25 A trapezoidal coil *PQRS* is movingwithconstant velocity in a direction perpendicularto a uniform magnetic field as shown in the figure below.



At the instant shown, which of the following statements is correct?

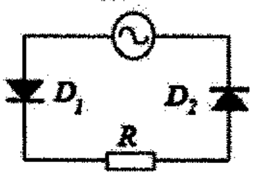
A An induced current it flowing in the coil in the clockwise direction.

B An induced current is flowing in the coil in the anticlockwise direction.

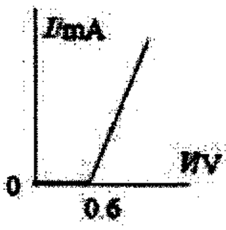
C There is no induced current flowing in the coil.

D An electromagnetic force acts on the side *PQ* in a direction opposing its motion.

26 The circuit below shows the rectification of a sinusoidal a.c. supply using two identical diodes D_1 and D_2.



Each of the diodes has the *I*-*V* characteristics as shown.



For a current to flow through*R*, the value ofE_0must be at least

A 0.3 V

B $0.3\sqrt{2}$ V

C $0.6\sqrt{2}$ V

D $1.2\sqrt{2}$ V

[Turn over

27 Which piece of evidence about the photoelectric effect cannot be explained using a wave model?

A Increasing the intensity of the illumination increases the rate at which electrons are ejected.

B Shining ultraviolet radiation onto a zinc surface ejects electrons.

C Increasing the frequency of the radiation increases the kinetic energy of the ejected electrons.

D There is a minimum frequency of radiation below which no electrons are ejected from the metal surface despite increasing the intensity of radiation.

28 What is the de Broglie wavelength of an electron having a kinetic energy of 54 eV?

A $3.7 \square 10^{\square 27}$ m　　**B** $6.7 \square 10^{\square 20}$ m　　**C** $1.7 \square 10^{\square 10}$ m　　**D** $2.3 \square 10^{\square 8}$ m

29 The table shows the ionizing effect of different types of radiation.

	X	**Y**	**Z**
ionising effect	strong	weak	very weak

What are the radiations **X**, **Y** and **Z**?

	X	**Y**	**Z**
A	Gamma	Beta	Alpha
B	Beta	Alpha	Gamma
C	Alpha	Beta	Gamma
D	Gamma	Alpha	Beta

30 Which statement concerning α-particles is correct?

A An α-particle has charge +4e.

B An α-particle is a helium atom.

C An α-particle has mass $4u$.

D When α-particles travel through a sheet of gold foil, they make the gold radioactive.

End of Paper

BLANK PAGE

BLANK PAGE

NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2 Preliminary Examination

Higher 2

CANDIDATE NAME

SUBJECT CLASS

REGISTRATION NUMBER

PHYSICS **9749/02**

Paper 2 Structured Questions

29 August 2019

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THE INSTRUCTION FIRST

Write your subject class, registration number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a HB pencil for any diagrams or graphs.

Do not use staples, paper clips, glue or correction fluid.

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

Answers all questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

This document consists of 24 printed pages.

For Examiner's Use	
1	/ 8
2	/ 10
3	/ 12
4	/ 10
5	/ 10
6	/ 10
7	/ 20
Total(80m)	

[Turn over

Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(1/(36\pi)) \times 10^{-9}\,\mathrm{F\,m^{-1}}$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
unified atomic mass constant	$u = 1.66 \times 10^{-27}\,\mathrm{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

[Turn over

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -Gm/r$
temperature	$T/K = T/°C + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}<c^2>$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $= \pm \omega \sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

[Turn over

1 **(a)** The speed v of sound in a gas is given by the expression

$$v = \sqrt{\frac{\square P}{\square}}$$

where P is the pressure of the gas of density ρ and γ is a constant.

(i) State the S.I. base units of pressure.

base units: .... [1]

(ii) Show that γ has no unit.

[2]

(b) A student conducted an experiment to determine the speed of sound v in air which he found to be 328.85 m s^{-1}.

(i) He used a pressure gauge with a precision of 5 kPa to measure the pressure P of air which he found to be 105 kPa.

Calculate the fractional error of P.

fractional error = ... [1]

[Turn over

(ii) The density ρ of air is measured to be (1.2 ± 0.1) kg m^{-3}.

1. Calculate the absolute uncertainty in v.

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

2. State the value of v and its absolute uncertainty to the appropriate number of significant figures.

v = ... ± .... m s^{-1} [1]

(c) The student repeated the experiment in **(b)** and obtained several values for the speed of sound v

330 m s^{-1}, 326 m s^{-1}, 334 m s^{-1}, 328 m s^{-1}, 332 m s^{-1}

The theoretical value of v is 340 m s^{-1}.

Explain whether there was a systematic error in the experiment.

....

.... [1]

[Total: 8]

[Turn over

2 A long bar magnet is suspended from the free end of a helical spring. One pole of the magnet lies within a coil of wire, as shownin Fig. 2.1.

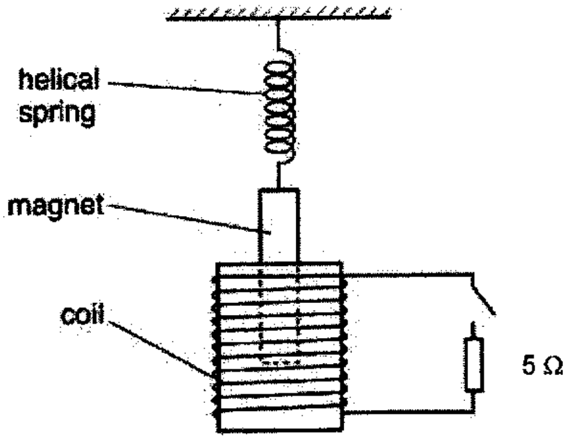


Fig. 2.1

The coil is connected in series with a switch and a 5 Ω resistor. The switch is open.

The magnet is displaced vertically and then released.

As the magnet passes through its rest position, a timer is started. The variation with time t of the vertical displacement y of the magnet from its rest position is shown in Fig. 2.2.

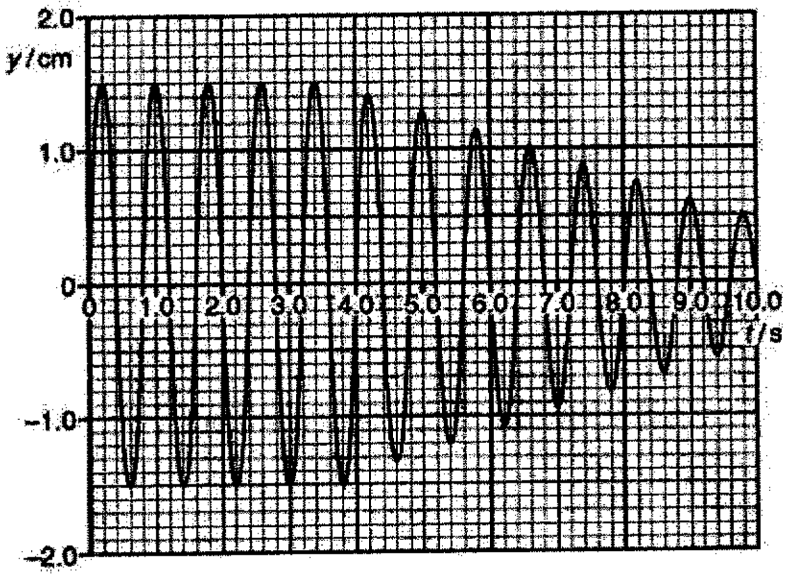


Fig. 2.2

At time t = 4.0 s, the switch is closed.

(a) Explain why, after time $t = 4.0$ s, the amplitude of oscillation of the magnet decreases.

....

....

....

....

....

....

.... [4]

(b) The spring is removed and an oscillator is attached to the magnet so that the magnet undergo a periodic motion in the coil.

The switch is closed. The potential difference V measured across the resistor is given by

$$V = 27.0 \cos (15.7\, t)$$

V is in millivolts and the time t is in seconds.

(i) Determine the mean power dissipated from the 5 Ωresistor.

mean power = ... W [3]

(ii) Sketch the variation with time t of the power P dissipated from the resistance in

[Turn over

Fig. 2.3. (Include appropriate values in your graph.)

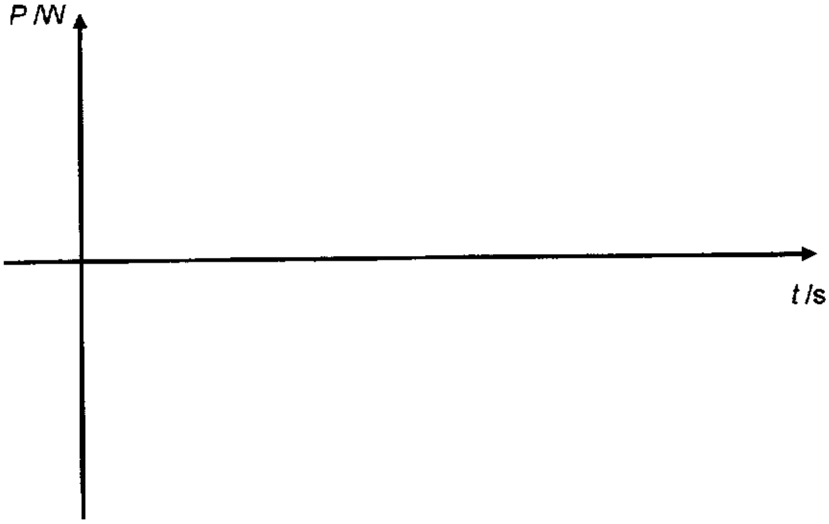


Fig 2.3

[3]

[Total: 10]

[Turn over

Question 3 begins over the page.

3 **(a)** State what is meant by *coherent sources*.

[Turn over

....

.... [1]

(b) Two coherent microwave emitters S_1 and S_2 are in phase with one another. They emit waves of equal frequency, equal intensity and with the same direction of polarisation.A microwave detector is placed at point P, as shown in Fig. 3.1.

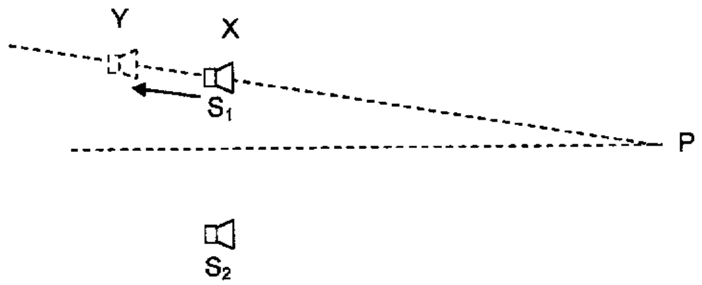


Fig. 3.1

The initial distances of S_1 and S_2 from P are equal. The intensity of the individual microwaves from S_1 and S_2 at P is I.

(i) S_1 is moved slowly away from P along the line PXY as shown.

Explain why the intensity of the microwave detected at P fluctuates.

....

....

....

....

.... [3]

(ii) $S_1$is moved from point X to Y andthe intensity of the microwave at P changes from a maximum to a minimum. The distance XYis 8.2cm.

Calculate the frequency of the microwaves emitted by the sources.

frequency = ... Hz [2]

(iii) S_1remains at point Y.

[Turn over

A polariser is placed between $S_1$and P. The direction of polarisation of the microwave from $S_1$is changed by 40°. The power of S_1 is adjusted such that the intensity of the microwave from S_1 at P remains as I.

Explain, without numerical calculation, the intensity of the microwave at P.

....

....

....

.... [2]

(c) Fig. 3.2 shows the variation with time of the displacement of the microwave from S_2 at P.

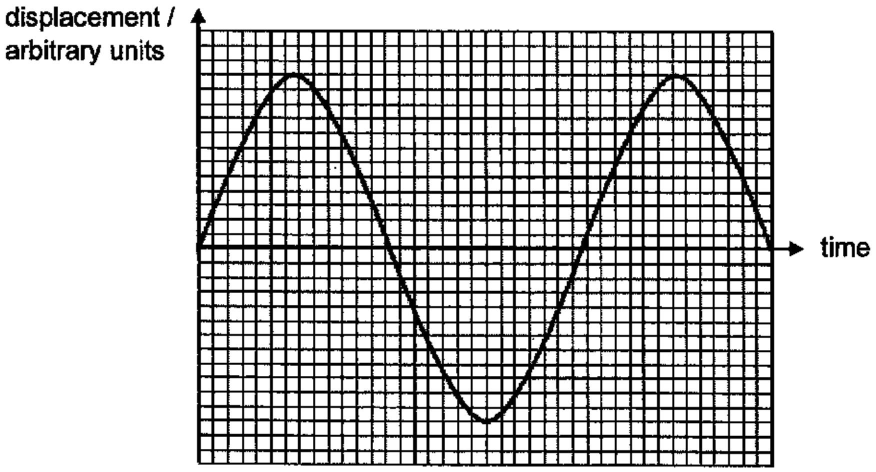


Fig. 3.2

(i) The polariser in **(b)(iii)** is removed and the intensity of the microwave from S_1 at P is reduced to $\frac{1}{2}I$.

Show that the amplitude of the microwave from S_1 at P is approximately 8.5 units.

[2]

(ii) Sketch the variation with time of the displacement of the microwave from S_1 at P in Fig 3.2. [2]

[Total: 12]

4(a)(i) State the *first law of thermodynamics*.

[Turn over

....

....[1]

(ii) Suggest why there is a considerable difference in magnitude between the specific latent heat of fusion and vaporisation.

....

....

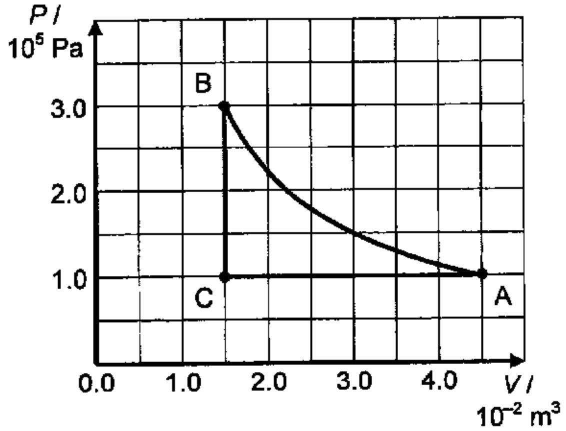
....

....

....

....[3]

(b) The diagram below shows the *P*–*V* graph of a fixed mass of ideal gas undergoing changes between the three states A, B and C.



(i) Show that the change A→B is an isothermal (constant temperature) process.

[2]

(ii) Describe qualitatively, with reference to molecular movement, how the changes A → B and C→B differ in the manner the pressure of the gas is increased.

[Turn over

....

....

....

....[2]

(iii) Estimate the heat removed fromthe gas in the change A→B.

heat removed = ...J [2]

[Total: 10]

5 In a proposed fusion reactor, one possible reaction is

[Turn over

$${}^{4}_{2}He + {}^{9}_{4}Be \rightarrow {}^{12}_{6}C + {}^{1}_{0}n$$

The binding energy per nucleon are given as follows

	binding energy per nucleon / MeV
${}^{4}_{2}He$	7.075175
${}^{9}_{4}Be$	6.462767
${}^{12}_{6}C$	7.675310

(a) **(i)** Explain what is meant by *binding energy.*

....

....

....[1]

(ii) Calculate the energy released during this process.

energy released = ... MeV [3]

(b) Uranium (U) has at least fourteen isotopes. Uranium-238(${}^{238}_{92}U$)is an isotope and themean radius of its nucleus is 8.9×10^{-15} m.

[Turn over

(i) Explain what is meant by an *isotope*.

....

....

....[1]

(ii) For a uranium-238 nucleus, show that

1. its mass is 3.95×10^{-25} kg,

mass = ... kg [1]

2. its mean density is 1.3×10^{17} kg m^{-3}.

density = ... kg m^{-3} [2]

(iii) The density of a lump of uranium is 1.9×10^{4} kg m^{-3}.

Using your answer to **(b)(ii)(2)**, suggest what can be inferred about the structure of the atom.

....

....

....

....[2]

[Total: 10]

6 A photodiode is a circuit component used to convert a light signal into an electrical one.Fig. 6.1 shows an enlarged cross-section through a photodiode to illustrate how it isconstructed.

[Turn over

Light incident on the thin transparent conducting surface layer of the diode passes through it to be absorbed in the insulating layer. The energy of each photon is sufficient to release one electron in the insulating layer. The potential difference V,applied across the insulating layer, causes these electrons to move to one of the conducting layers.

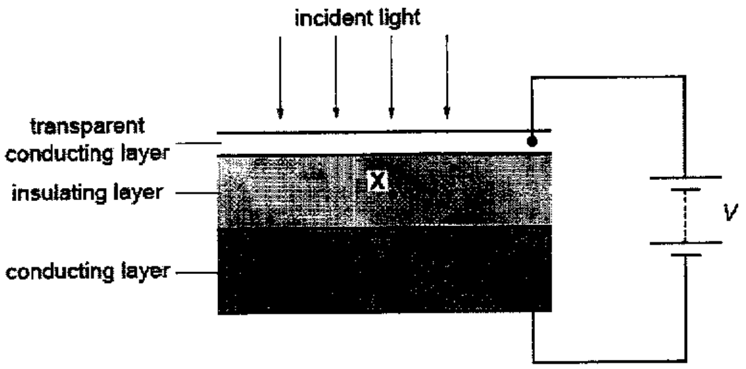


Fig. 6.1

In one particular application, red light of wavelength 6.33×10^{-7} m, from a helium-neon laser, is incident on the photodiode. The power of the laser beam is 1.0 mW.

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

....

....[1]

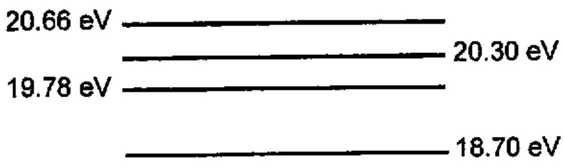
(b) Calculate the energy of one photon emitted by the helium-neon laser.

energy = ...J [2]

(c) Show that about 3×10^{15} photons are emitted by the helium-neon laser each second.

[1]

(d) The energy level diagram of the neon atom is shown in Fig. 6.2.



[Turn over

On Fig 6.2, draw an arrow to indicate the transition that gave rise to the photon of wavelength 6.33□10□ m emitted by the helium-neon laser. [1]

(e) **(i)** On Fig. 6.1, draw an arrow to show the direction of motion of an electron released at point **X** in the centre of the insulating layer.[1]

(ii) Experiments show that only 20% of the red light photons incident on the photodiode release electrons in the insulating layer.

Calculate the current through the photodiode.

current = ... A [3]

(iii) Suggest one reason why the efficiency of the photodiode is less than 100%.

....

....

....

.... [1]

[Total: 10]

[Turn over

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

Law of Gravitation and Celestial Mechanics

For thousands of years, Man has studied the night sky and some ancient buildings provide evidence of careful and patient astronomical observations by people of many different cultures. As instrumentation has improved, so has the precision with which astronomical observations could be made. Between 1576 and 1597, Danish astronomer Tycho Brahe wanted to determine how the heavens were constructed and pursued a project to determine the positions of both stars and planets.

German astronomer Johannes Kepler was Brahe's assistant for a short while before Brahe's death, whereupon he acquired his mentor's astronomical data and spent 16 years trying to deduce a mathematical model for the motion of the planets.

Kepler deduced three laws:

1. All planets move in elliptical orbits with the Sun at one focus.
2. The radius vector drawn from the Sun to a planet sweeps out equal areasin equal time intervals.
3. The square of the circular orbital period of any planet is proportional to the cube of the radius of the circle.

As a result of Kepler's work, Newton formulated the law of gravitation.

(a) **(i)** *Newton's law of gravitation* partially states that the force between two masses is inversely proportional to the square of their distance apart.
Using concepts on an object moving in *circular motion*, explain how this statement can be deduced from Kepler's third law.

....

....

.... [2]

(ii) Using Newton's laws, show that, for a circular orbit of an object about a planet,

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

where T is the orbital period of the body,
M is the mass of the planet, and
r is the distance between the centre of mass of the body and the planet.

(b) The planet Jupiter has several moons. Data for some of these moons are shown in Table 7.1.

Table 7.1

moon	**period T / days**	**mean distance from centre of Jupiter r / 10^9m**	**$\log_{10}$ (T / days)**	**$\log_{10}$ (r / m)**
Sinope	758	23.7	2.88	10.37
Leda	239	11.1		
Callisto	16.7	1.88		
Io	1.77	0.422		
Metis	0.295	0.128	-0.53	8.11

(i) Complete Table 7.1 for the moons– Leda, Callisto and Io. [2]

(ii) On the axes of Fig. 7.1, plot a graph of $\log_{10}$ (T/days) against $\log_{10}$ (r/m). [3]

(iii) Determine the gradient of the graph in Fig. 7.1. [3]

[Turn over

gradient = ...[2]

(iv) Hence, discuss whether the data in Table 7.1 support the relation given in **(a)(ii)**.

....

....

....

....

.... [2]

[Turn over

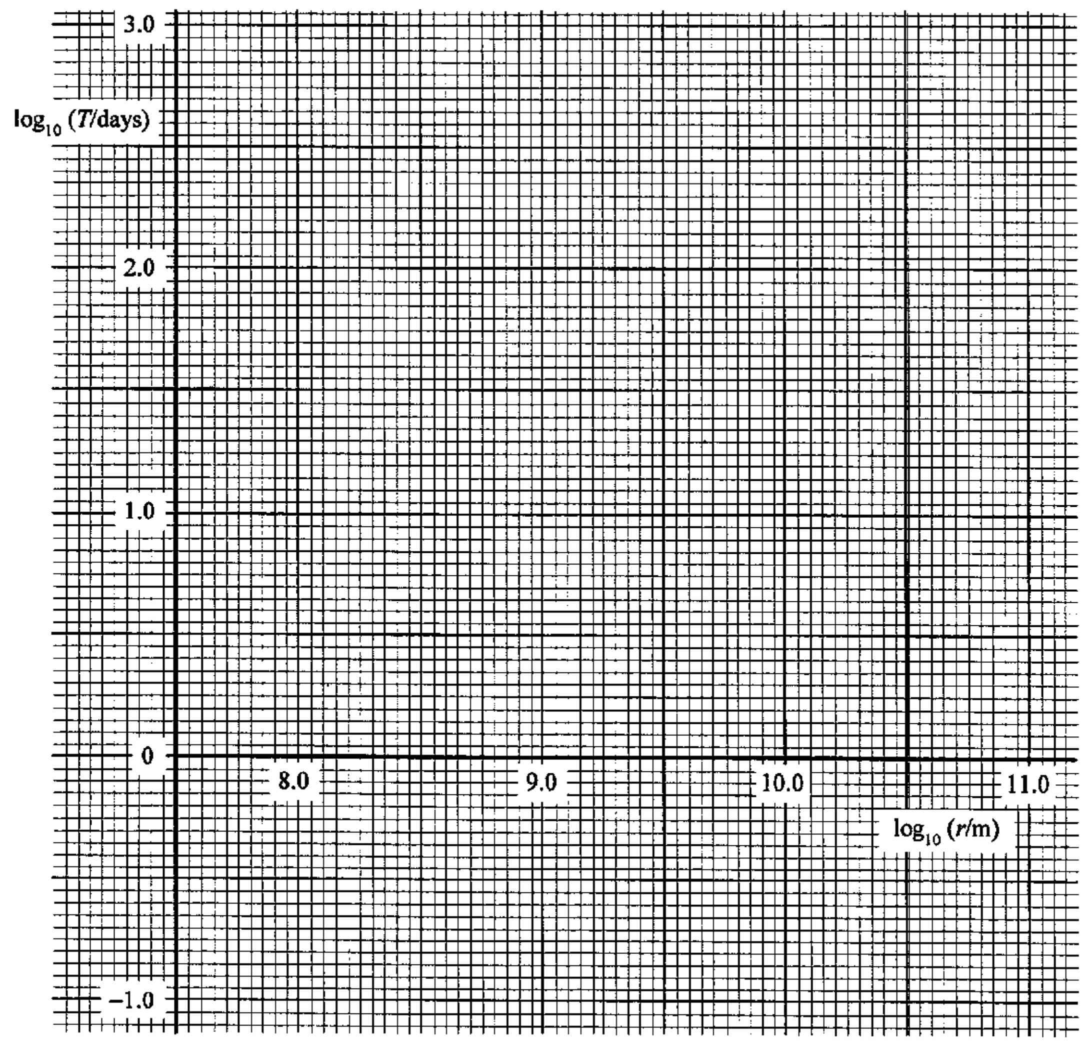


Fig. 7.1

(c) Observation shows that the moon Ganymede orbits Jupiter with a period of 7.16 days.

Use Fig. 7.1 to estimate the orbital radius of Ganymede.

orbital radius = ... m [2]

[Turn over

(d) It is reported in the media that the moon Thebe is discovered to orbit Jupiter once every 16.2 hours at a height of $2.22 \square 10^5$ km above the surface of Jupiter.

Comment on the accuracy of this media report.

....

....

....

....
[2]

(e) Suggest whether Fig. 7.1 could be used to check data on the orbital radii and periods of the moons of another planet (e.g. Saturn).

....

....

....

.... [2]

[Total: 20]

ᘛ End of Paper ᘚ

[Turn over

BLANK PAGE

[Turn over

BLANK PAGE

[Turn over

NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2 PRELIMINARY EXAMINATIONS

Higher 2

CANDIDATE NAME	

SUBJECT CLASS		REGISTRATION NUMBER	

PHYSICS **9749/03**

Paper 3Longer Structured Questions**(Section A)**

3September 2019

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

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

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

Section A
Answers **all** questions.

Section B
Answer **one** question only.

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

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	/12
2	/6
3	/7
4	/9
5	/12
6	/7
7	/7
8	/ 20
9	/ 20
Total (60m)	

This document consists of 25printed pages.

[Turn over

Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(1/(36\pi)) \times 10^{-9}\,\mathrm{F\,m^{-1}}$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
unified atomic mass constant	$u = 1.66 \times 10^{-27}\,\mathrm{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on / by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -Gm/r$
temperature	$T/\text{K} = T/{}^\circ\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $= \pm \omega \sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current / voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

[Turn over

Section A (60 marks)

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

1 A ball is thrown horizontally from the top of a building, as shown in Fig. 1.1.

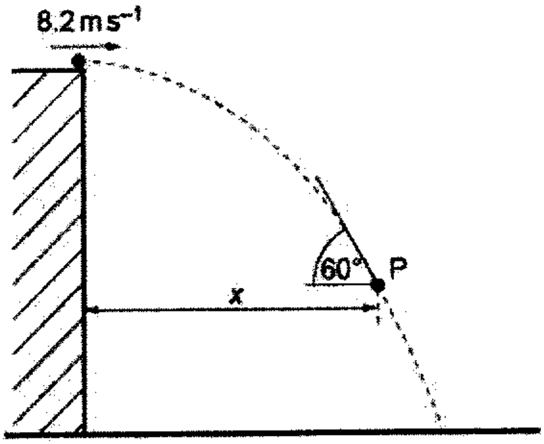


Fig. 1.1

The ball is thrown with a horizontal speed of 8.2 m s^{-1}. The side of the building is vertical. At point P on the path of the ball, the ball is at a distance x from the building and is moving at an angle of 60° to the horizontal. Air resistance is negligible.

(a) For the ball at point P,

(i) show that the vertical component of its velocity is 14.2 m s^{-1},

[2]

(ii) determine the vertical distance through which the ball has fallen,

verticaldistance = ... m [2]

(iii) determine the horizontal distance x.

distance x = ... m [2]

(b) The path of the ball in **(a)**, with an initial horizontal speed of 8.2 m s^{-1}, is shown again in Fig. 1.2.

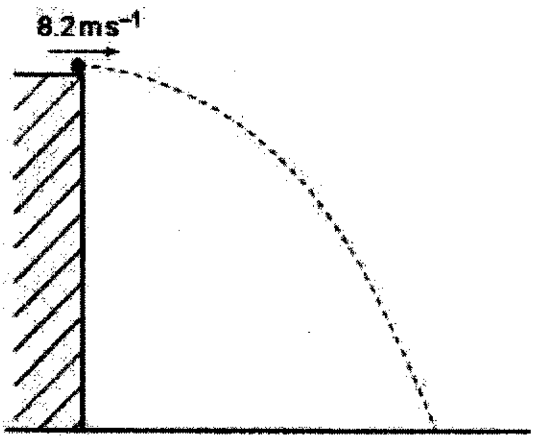


Fig. 1.2

On Fig. 1.2, sketch the new path of the ball for the ball having an initial horizontal speed

(i) greater than 8.2 m s^{-1} and with negligible air resistance.Label this path G. [2]

(ii) equal to 8.2 m s^{-1} but with air resistance.Label this path A. [2]

(c) State and explain in which case, **b(i) or b(ii)**, the ball will reach the bottom of the building first.

....

....

....

.... [2]

[Total: 12]

[Turn over

2 A ball B of mass 1.2 kg travelling at constant velocity collides head-on with a stationary ball S of mass 3.6 kg, as shown in Fig. 2.1.

Fig. 2.1

Frictional forces are negligible.

The variation with time *t* of the velocity *v* of ball B before, during and after colliding with ball S is shown in Fig. 2.2.

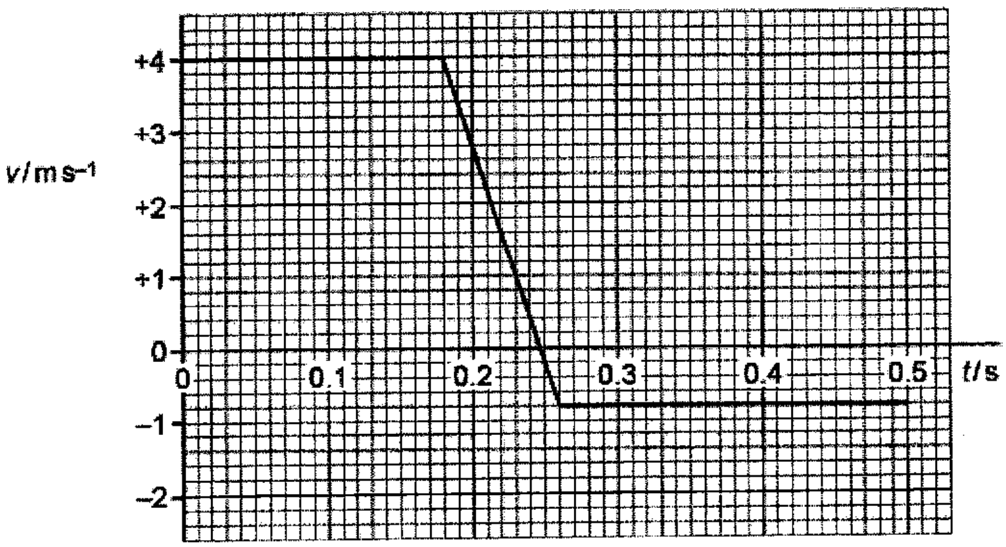


Fig. 2.2

Using Fig. 2.2, for ball B during the collision with ball S,

(a) **(i)** show thatthe change in momentum of ball B is 5.76 N s,

[1]

(ii) calculate the speed of ball S after the collision,

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

(b) Using your answer in **(a)(ii)** and information from Fig. 2.2, deduce whether the collision is elastic or inelastic. Support your answer with working.

....

....

....
[3]

[Total: 6]

[Turn over

3 A train ride for kids in an amusement park can vary between two power setting – *High* or *Low*. The power at *High*setting is double that of *Low*.

The total mass of the train and the passengers is 4000 kg. The frictional force acting on the trainis constant at 700 N.

(a) When the train is travelling at 8.0 m s^{-1} and the power provided by the train is set to *High*, the train accelerates at 0.30 m s^{-2}.

Show that the power provided by the train is 15200 W.

[2]

(b) When the power provided by the train is set to *Low*,

(i) determine its maximum speed,

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

(ii) determine the maximum speed when it is climbing up a slope that rises 1 m for every 25 m of road travelled.

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

[Total: 7]

Question 4 begins over the page

[Turn over

4 An amusement park ride spins customers so fast that they are 'held' to the sides of a vertical wall as shown in Fig. 3.1.

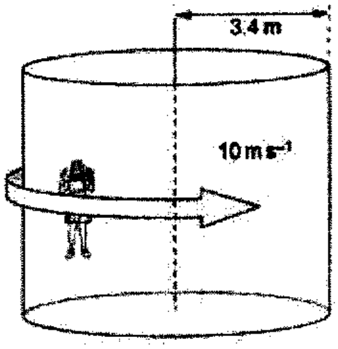


Fig. 3.1

A girl of mass 60 kg is spun around at a constant speed of 10 ms^{-1} in a circular path of radius 3.4 m.

(a) Explain why the girl is accelerating even though her speed is constant.

....

....

....

.... [2]

(b) (i) Calculate the centripetal force on the girl.

centripetal force = ...N [2]

(ii) The wall of the ride exerts a frictional force *f* on the girl given by

$$f = \mu N$$

where N is the normal contact force exerted by the wall on the girl and μ is a constant that depends on the roughness of the wall.

Determine the value of μ. Explain your working.

μ= .... [3]

(c) In another similar ride, the wall of the ride is tilted at an angle θ to the vertical, as shown in Fig 3.2.

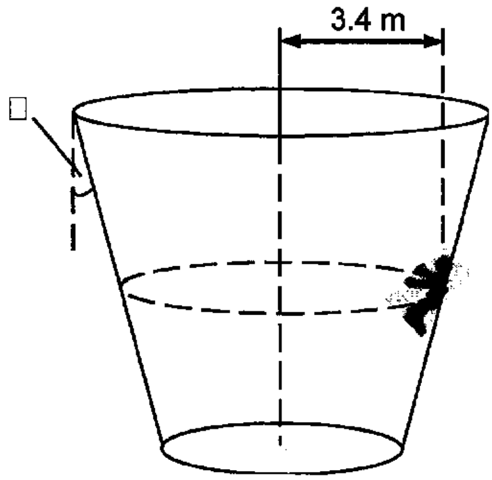


Fig. 3.2

The same girl is being spun around at the same constant speed of 10 ms^{-1} in a circular path of radius 3.4 m. The girl's feet is not touching the floor of the ride.

Explain whether the girl can remain at constant height while the ride is spinning, if the wall is frictionless.

....

....

....

....[2]

[Total: 9]

5 Two vertical springs, each having spring constant k, support a mass. The lower spring

[Turn over

isattached to an oscillator as shown in Fig. 5.1.

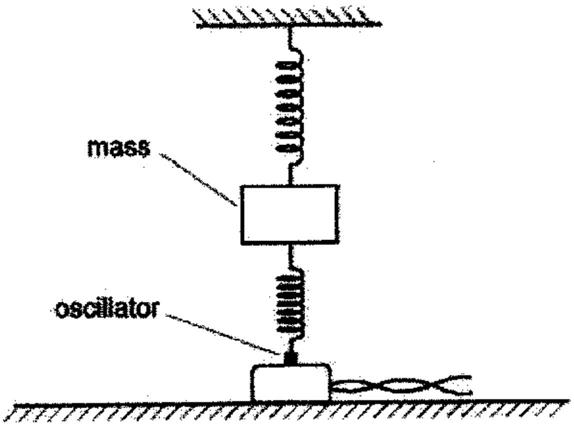


Fig. 5.1

The oscillator is switched off. The mass is displaced vertically and then released so that it vibrates. During these vibrations, the springs remain extended. The vertical acceleration *a* of the mass *m* is given by the expression

$$a = \frac{\square 2kx}{m}$$

wherex is the vertical displacement of the mass from its equilibrium position.

(a) **(i)** Define *Simple Harmonic Motion*

....

....

....[2]

(ii) Show that, for a mass of 240 g and springs with spring constant 3.0 N cm^{-1}, the frequency of vibration of the mass is approximately 8.0 Hz.

[4]

(b) The oscillator is switched on and the frequency *f* of the vibrations is gradually increased. Theamplitude of vibration of the oscillator is constant. Fig. 5.2 shows the variation with *f* of the amplitude *A* of vibration of the mass.

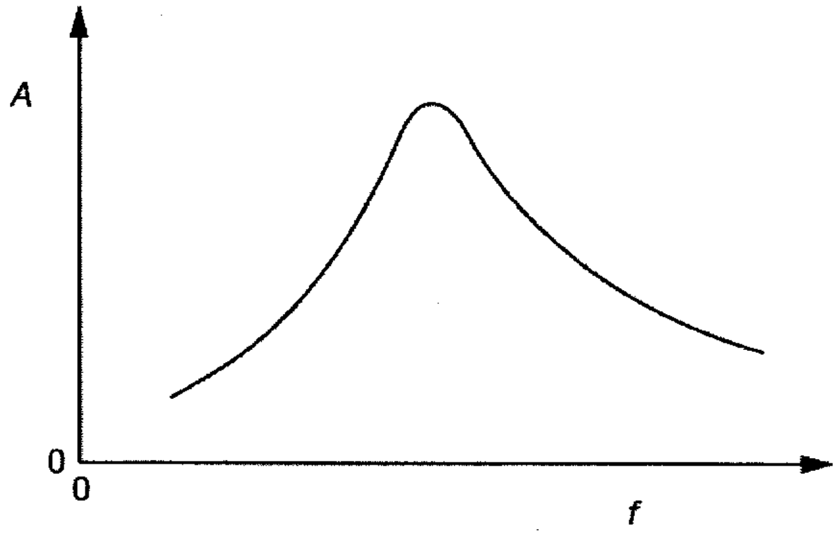


Fig.5.2

(i) State

1.the name of the phenomenon illustrated in Fig. 5.2,

....[1]

2.the frequency f_0 at which maximum amplitude occurs.

frequency = ... Hz [1]

(ii) Explain, in terms of energy,the reason why the maximum amplitude occurs at the frequency stated in **(i) 2**.

....

.... [1]

(iii) Suggest and explain how the apparatus in Fig. 5.1 could be modified to make the peakon Fig. 5.2 flatter, without significantly changing the frequency f_0 at which the peak occurs.

....

....

....

....

.... [3]

[Total: 12]

6 (a) Positive ions are travelling through a vacuum in a narrow beam. The ions enter a region of uniform magnetic field and are deflected in a semi-circular arc, as shown in

[Turn over

Fig. 6.1.

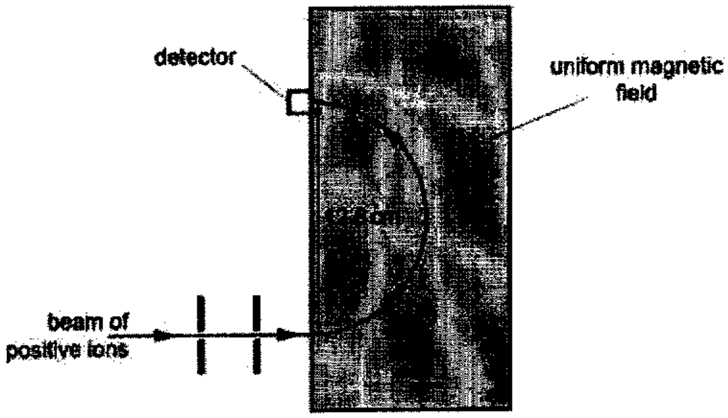


Fig. 6.1

The ions, travelling at a constantspeed 1.40×10^{5} m s^{-1}, are detected at a detector when the diameter of the arc in the magnetic field is 12.8 cm.

(a) With reference to Fig. 6.1, state the direction of the magnetic field.

.... [1]

(b) The ions have mass 20*u* and charge $+1.60 \times 10^{-19}$ C (where *u* is the unified atomic mass unit.)

Show that the magnetic flux density is 0.454 T. Explain your working.

[3]

(c) Ions of mass 22*u* with the same charge and speed as those in **(b)** are also present in the beam.

(i) On Fig. 6.1, sketch the path of these ions in the magnetic field of magnetic fluxdensity 0.454 T.[1]

(ii) In order to detect these ions at the fixed detector, the magnetic flux density ischanged. Calculate this new magnetic flux density.

magnetic flux density = ...T [2]

[Total: 7]

[Turn over

7 A cubical container, shown in Fig. 7.1, is filled with an ideal gas.

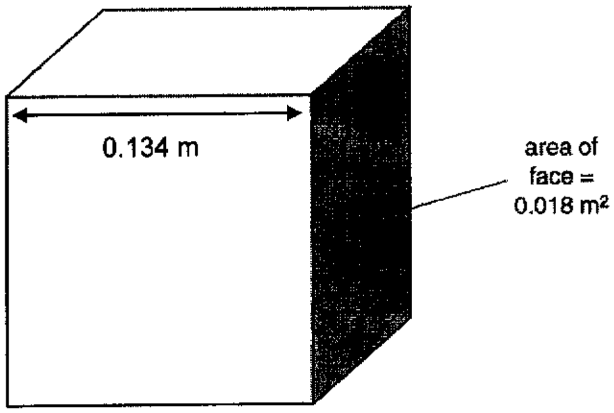


Fig. 7.1

When an ideal gas atom makes an elastic collision perpendicular to a face of the container, it experiences a change of momentum of 1.85×10^{-23} N s.

(a) In one second there are the equivalent of 1.49×10^{24} collisions perpendicular to each face of the container.

Calculate the force exerted by the gas on one face of the container.

force =..T [2]

(b) Calculate the pressure exerted by the gas.

pressure = ...Pa [1]

(c) The temperature of the ideal gas in the container is 27°C.

Determine the number of ideal gas molecules present in the container.

number of molecules = ... [2]

(d) The mass of one ideal gas molecule is 6.86×10^{-27} kg.

Calculate the root-mean-square (r.m.s.) speed of the gas molecules.

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

Section B

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

8 An engineer designs a resistor made from a thin layer of graphite mounted on an insulating base. Fig. 8.1shows the arrangement.

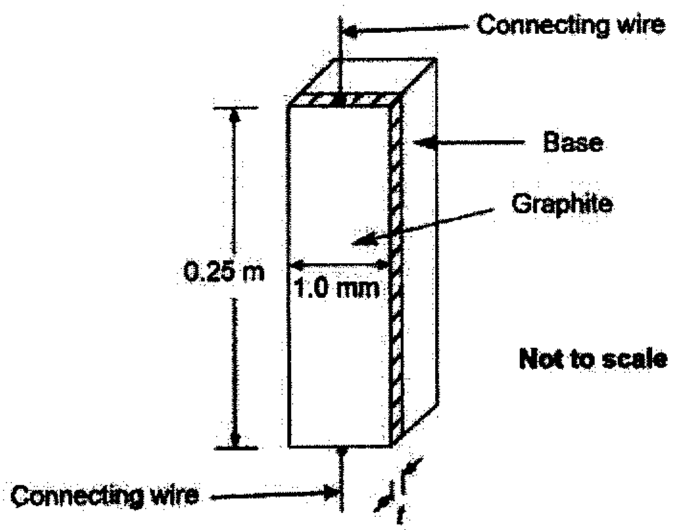


Fig. 8.1

(a) The graphite layer has a length of 0.25 m, a width of 1.0 mm, and a resistance of 1.2 kΩ. The resistivity of graphite is 15.0×10^{-5} Ω m. The number density of electrons in graphite is 2.2×10^{28} m^{-3}.

(i) Calculate the thickness *t* of the graphite layer.

t = ... m [2]

(ii) A potential difference of 9.0 V is applied to the connecting wires.
Determine the drift velocity of the electrons in the graphite.

drift velocity = ... m s^{-1} [3]

(b) The engineer has also some connecting wires and a cell. The cell has negligible internal resistance. He wants to connect a circuit to provide a potential difference which is dependent on illumination.

(i) State another electrical component that he needs to complete the circuit.

.... [1]

(ii) With the electrical component in **(b)(i)**and the newly designed resistor, draw a circuit diagram to show how this circuit should be connected.

Your diagram should show clearly the cell and the potential difference output.

[2]

(iii) Explain how your circuit in **(b)(ii)** provides a varying potential difference which is dependent on illumination.

....

....

....

....

....

....[3]

(c) Two of these newly designed resistorsare connected in a circuit with 2 cells and an ammeter. The electromotive force e.m.f. of the cells are 5.0 V and 12.0 V as

[Turn over

shown in Fig 8.2. The cells have negligible internal resistance, and the ammeter isconsidered ideal.

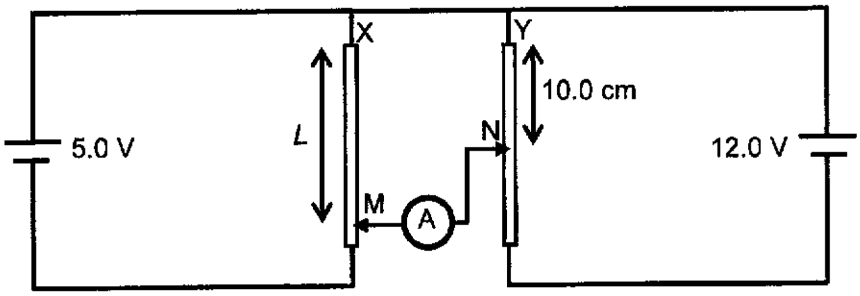


Fig. 8.2

The reading of the ammeter is zero.

(i) Distinguish between electromotive force and potential difference.

....

....

....[2]

(ii) Explain how the potential difference across XM is compared to YN such that the ammeter reading is zero.

....

....

....[2]

(iii) Determine the length *L*.

L= .... m [2]

(iv) Explain how length *L*should be changed such that the ammeter continues to reads zero current, if the 12.0 V cell has internal resistance, but not the 5.0 V cell.

....

....

....

....

....[3]

[Total: 20]

9 **(a)** State the *principle of moments*.

....

....

.... [2]

(b) Fig. 9.1.shows mass A and a negatively charged sphere X balanced on a rod of negligible mass. The rod is free to rotate about the pivot P which is at the center of the rod.

Another negatively charged sphere Y is placed near sphere X.

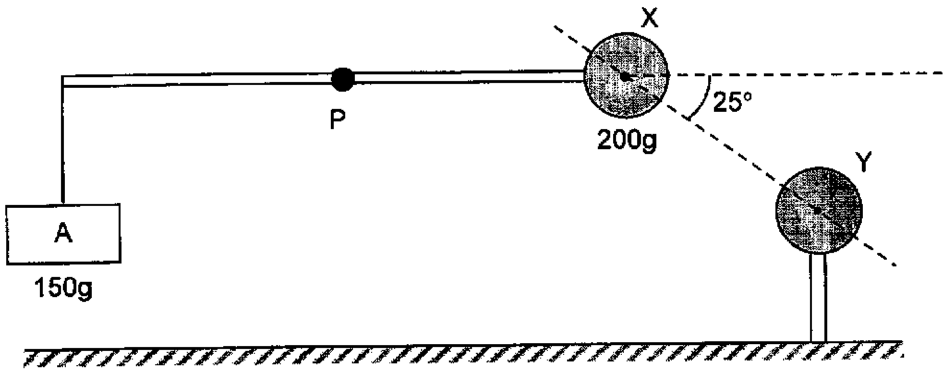


Fig. 9.1

Mass A is 150 g and the mass of sphere X is 200g.

(i) Explain why sphere Y must be negatively charged for the rod to be horizontal, as shown in Fig. 9.1.

....

....

....

.... [2]

(ii) The dotted line XY shows the axis joining the centers of charge of sphere X and sphere Y. The axis XY is 25° below the horizontal. Spheres X and Y are assumed to be point charges.

Calculate the electric force on sphere X

force = ...N [3]

(iii) Sketch the contact force on the rod by pivot P on Fig. 9.1. Label this force N. [1]

(c) Sphere X is now mounted on a rigid rod as shown in Fig. 9.2. The negative charge on sphere X is greater than the negative charge on Y

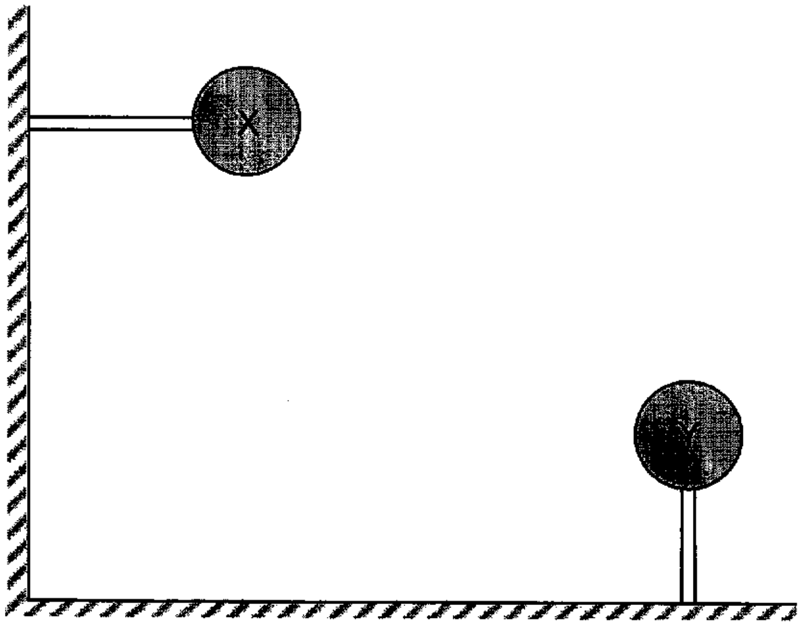


Fig. 9.2

Sketch the electric field between spheres X and Y on Fig. 9.2. [2]

(d) The distance *d* from the centre of charge of sphere X to a point along the line joining the centres of the two spheres is shown in Fig. 9.3.

[Turn over

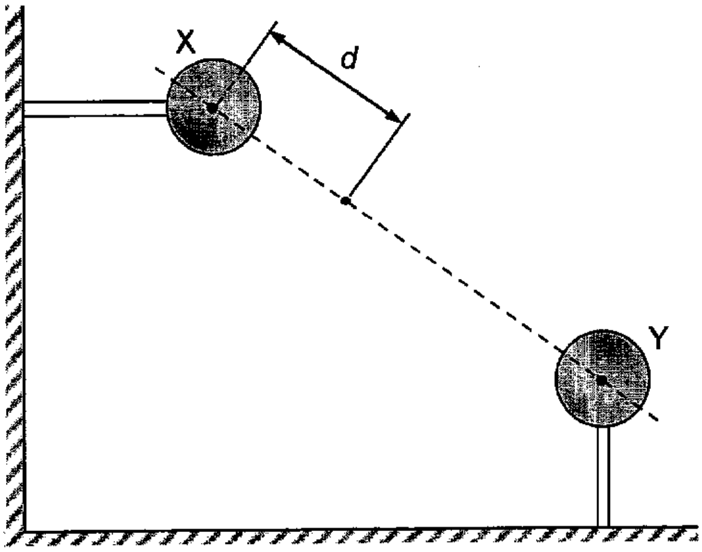


Fig. 9.3

Fig. 9.4shows the variation with the distance *d* of the electric potential due to sphere X and the electric potential due to sphere Y.

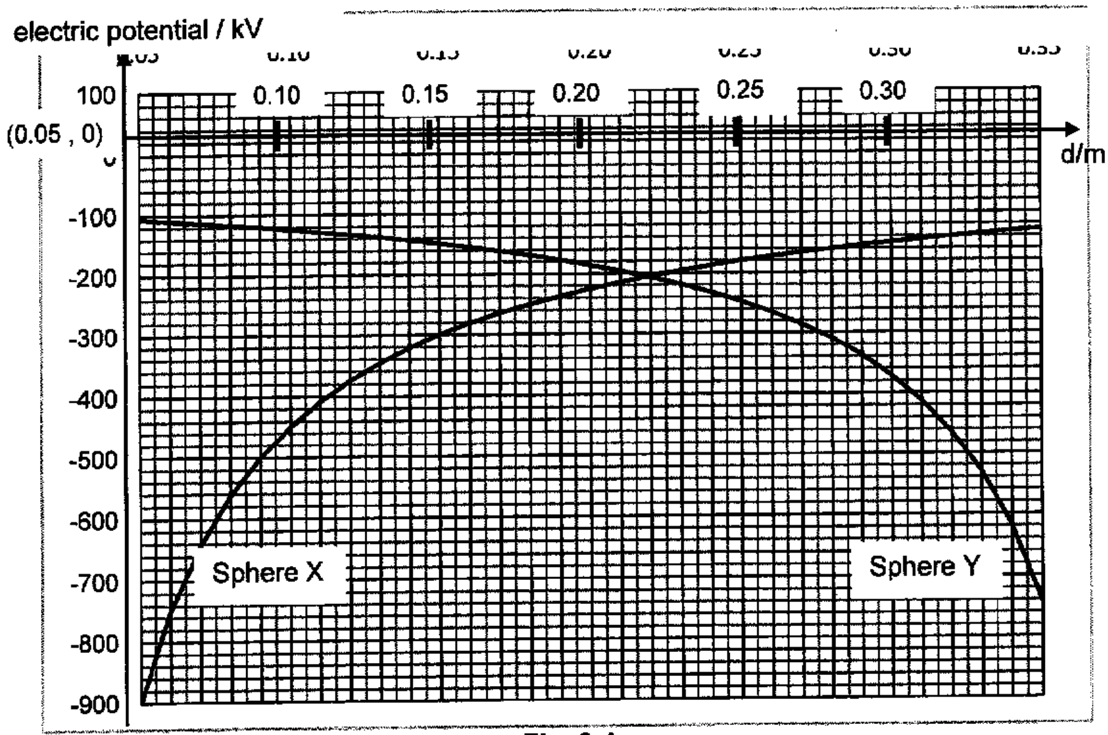


Fig. 9.4

(i) An electron moves along the line joining the centres of both spheres.

Describe how the electric potential energy of the electron changes as it moves from d = 0.05 m to d = 0.35 m.

....

....

....

....

.... [3]

(ii) Determine the potential energy of an electron at d = 0.30 m.

potential energy = ...J [3]

(iii) At a particular distance between the charged spheres, the net electric force on the electron is zero. Explain the relative magnitude and direction of the potential gradient of sphere X to the potential gradient of sphere Y at this point.

....

....

....

....

....

....

.... [4]

[Total: 20]

END OF PAPER

NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2PRELIMINARY EXAMINATION

Higher 2

CANDIDATE NAME

SUBJECT CLASS

REGISTRATION NUMBER

PHYSICS
Paper 4Practical

9749/04

Candidate answers on the Question Paper.
Additional Materials: As listedon Instructions.

22August 2019
2 hours 30 minutes

Shift
Laboratory

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

Answers **all** questions.

You will be allowed a maximum of one hour to work with the apparatus for Questions 1 and 2, and a maximum of one hour for Question 3. You are advised to spend approximately 30 minutes on Question 4.

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

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

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	/ 16
2	/ 6
3	/ 21
4	/ 12
Total (55m)	

This document contains 20 printed pages, including this cover page.

1 In this experiment you will investigate the behaviour of a sphere rolling across a sloping board.

(a) Place the thread over the top of the board and clip it in place with the spring clip.

Set up the apparatus as shown in Fig. 1.1, with the board at an angle of approximately 45° to the bench. The length of the thread between the spring clip and the sphere should be approximately 20 cm.

Do not remove the clamp from your bench.

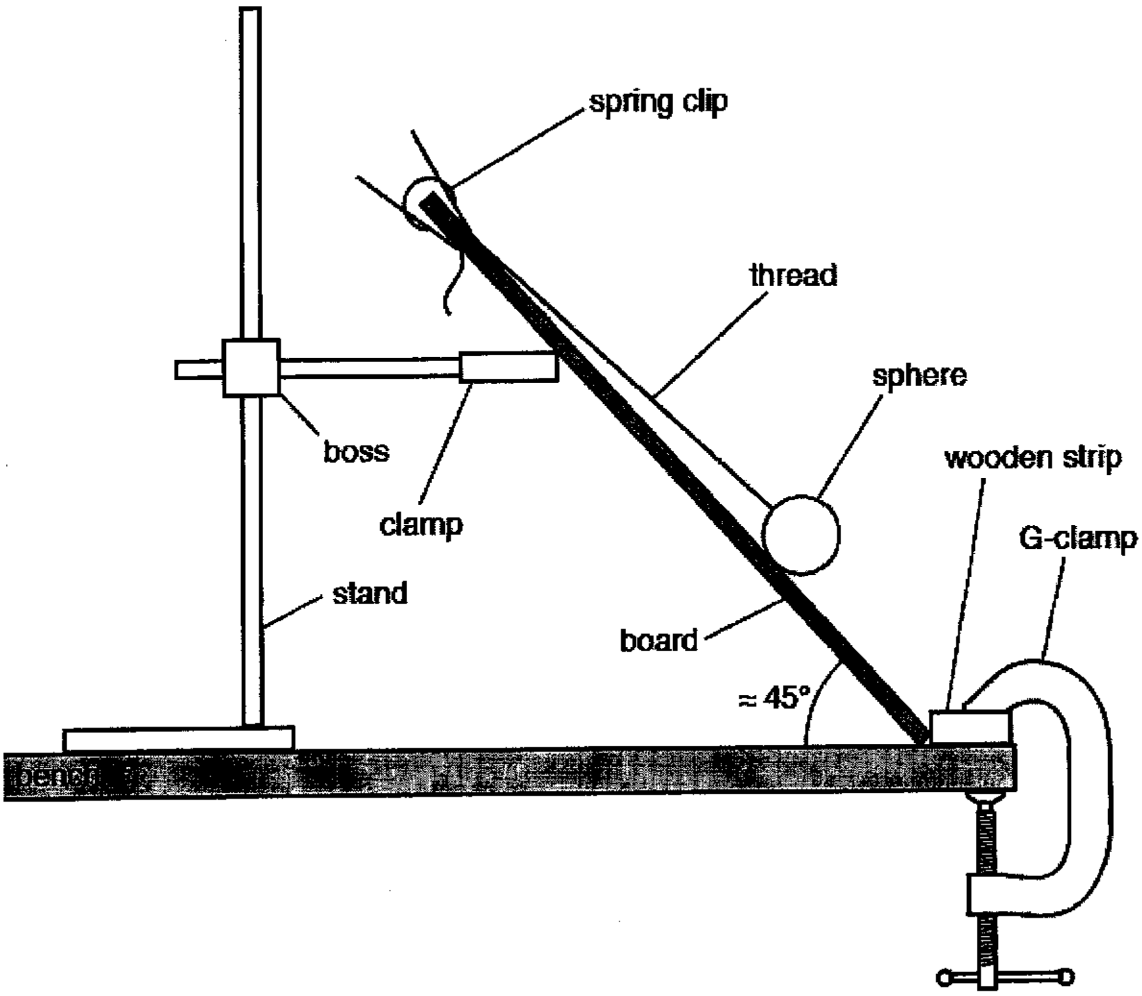


Fig. 1.1 (not to scale)

(b) **(i)** Measure and record the angle θ between the board and the bench, as shown in Fig. 1.2.

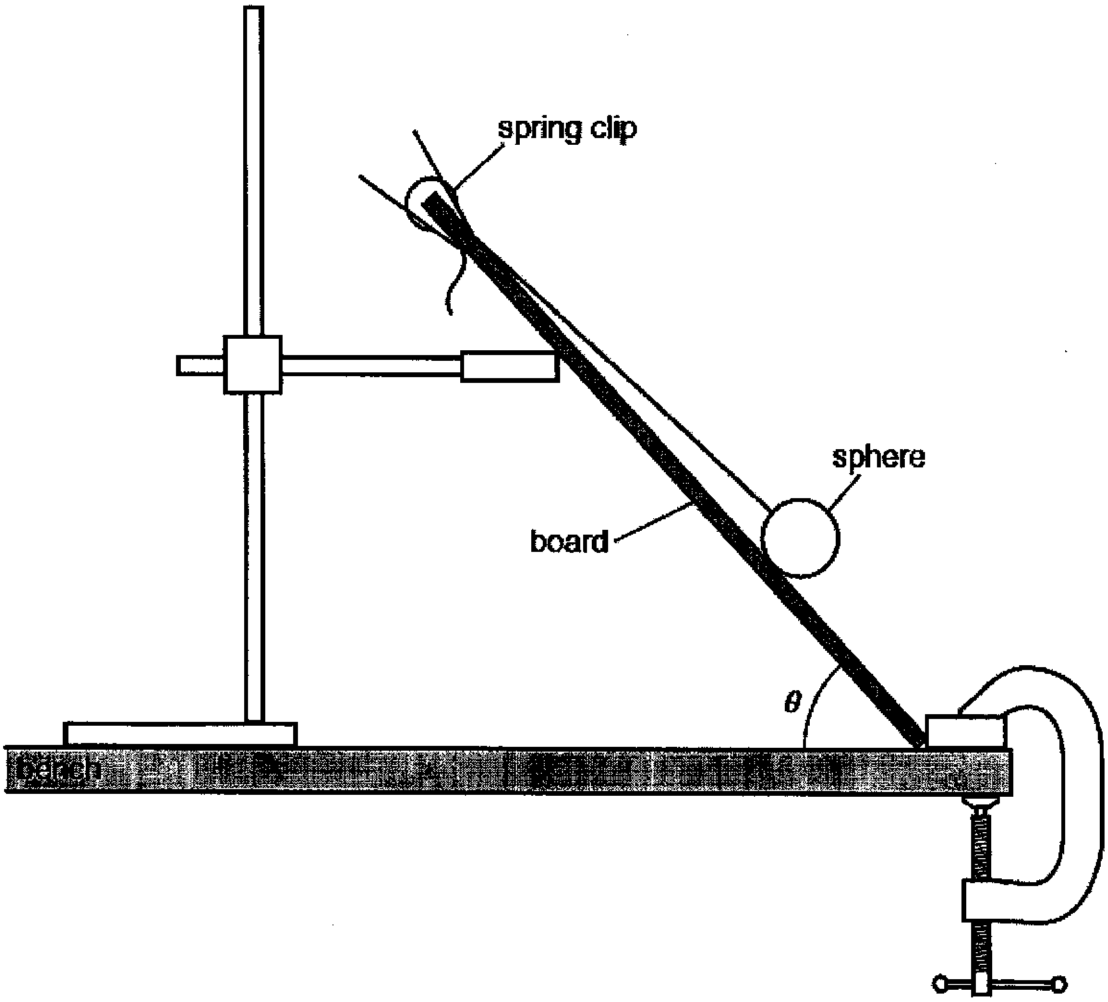


Fig. 1.2 (not to scale)

45° Value of θ from $40°$ *to* $50°$, to nearest degree, with unit

θ = ... [1]

(ii) Push the sphere to one side. Release the sphere so that it oscillates from side to side.

(iii) Take measurements to find the period *T* of the oscillations.

Record *T*.

For 5 oscillations, $t_1 = 6.14\,s$, $t_2 = 6.32\,s$

$$T = \frac{6.14 + 6.32}{2 \times 5} = 1.25\,s$$

Value of T from 1.0 to 2.0 s, with unit

Evidence of repeat readings

T = ... [2]

(c) Change θ by moving the boss and clamp and repeat **(b)** to take further values of θ and T.

Do **not** change the length of the thread between the sphere and the spring clip.

$\theta/°$	n (no. of osc)	t_1/s	t_2/s	T/s	T^{-3}/s^{-3}
60	5	5.55	5.60	1.12	0.721
55	5	5.66	5.72	1.14	0.679
50	5	5.98	5.98	1.20	0.585
45	5	6.14	6.32	1.25	0.517
40	5	6.67	6.75	1.34	0.414
35	5	6.92	6.93	1.39	0.376

6 readings

θvalues must include 35° or less and 55° or more

Column headings with correct presentation and units (column for T not required)

d.p.: t_1 and t_2 to nearest 0.01 s

s.f.: correct s.f.for T^{-3}, depending on s.f. of t_1 and t_2 (same no. or one greater than)

Calculation :T^{-3} calculated correctly

[7]

(d) θ and T are related by the expression

$$\square = \frac{a}{T^3} + b$$

where a and b are constants.

Plot a suitable graph to determine the values of a and b.

Plot θ against $\frac{1}{T^3}$ where a is the gradient and b the y-intercept

Using points (0.70, 57) and (0.40, 38)

Gradient = $\frac{58.5-36.5}{0.70-0.40} = 73.3$ [1] (gradient triangle must be more than half the drawn line, coordinates of points read to half a small square)

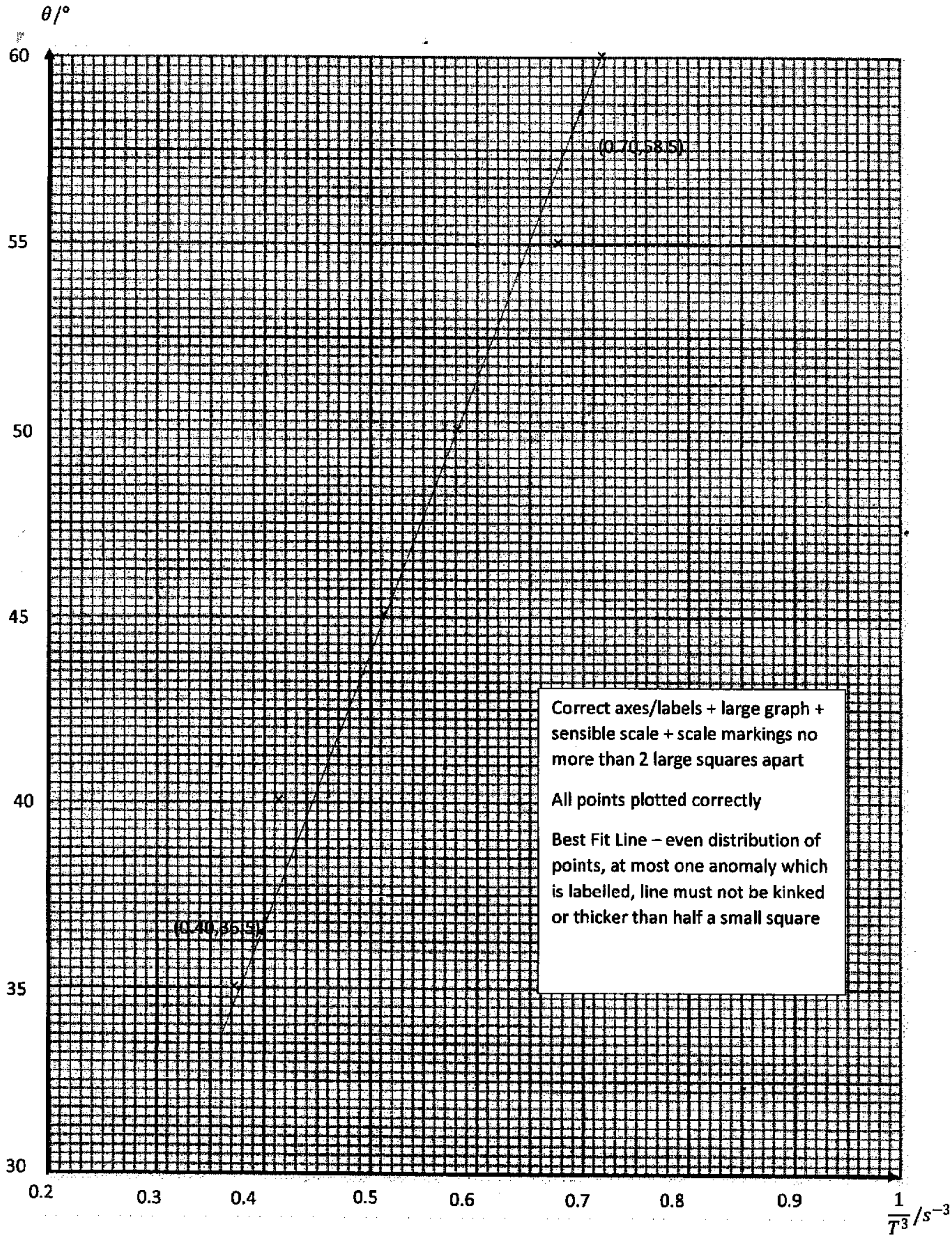
a = 73.3°s^3 correct calculation and units

y-intercept = $58.5 - 0.70 \times 73.3 = 7.2$ (points used must be read to nearest half a small square)

b = 7.2° correct calculation and units

a = ...

b = ... [6]


θ/°
60
55
50
45
40
35
30
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1/T³ /s⁻³
(0.70,58.5)
(0.40,36.5)
Correct axes/labels + large graph + sensible scale + scale markings no more than 2 large squares apart
All points plotted correctly
Best Fit Line – even distribution of points, at most one anomaly which is labelled, line must not be kinked or thicker than half a small square

[Total: 16]

2 In this experiment you will investigate an electrical circuit.

(a) **(i)** You have been provided with a resistor A of unknown resistance, an electrical component B and a switch.

Connect the circuit as shown in Fig. 2.1.

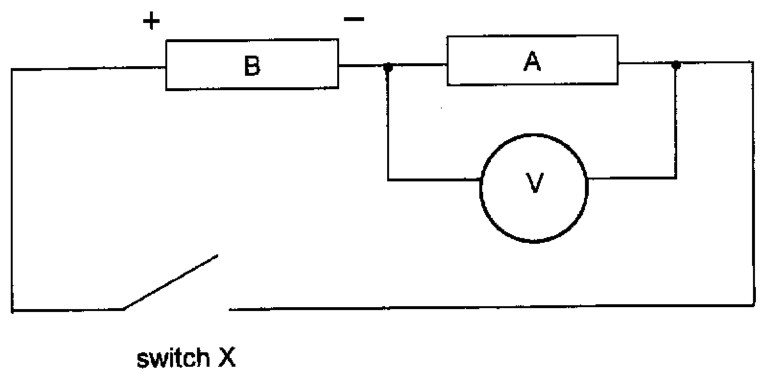


Fig. 2.1

The positive and negative terminals of component Bare indicated on component B and **must** be connected as shown in the Fig. 2.1.

(ii) Switch the voltmeter to the 20 V range and close switch X.

(iii) Open switch X when the reading on the voltmeter is 0.01 V or less.

(iv) If the readings for this question needs to be re-taken, you should repeat the procedure starting from**(a)(i)** before taking the readings again.

(b) **(i)** Connect the battery cell to the circuit as shown in Fig. 2.2.

⚡Switch Y and Switch X must **not** be closedtogether as this will lead to a short circuit and a large current. ⚡

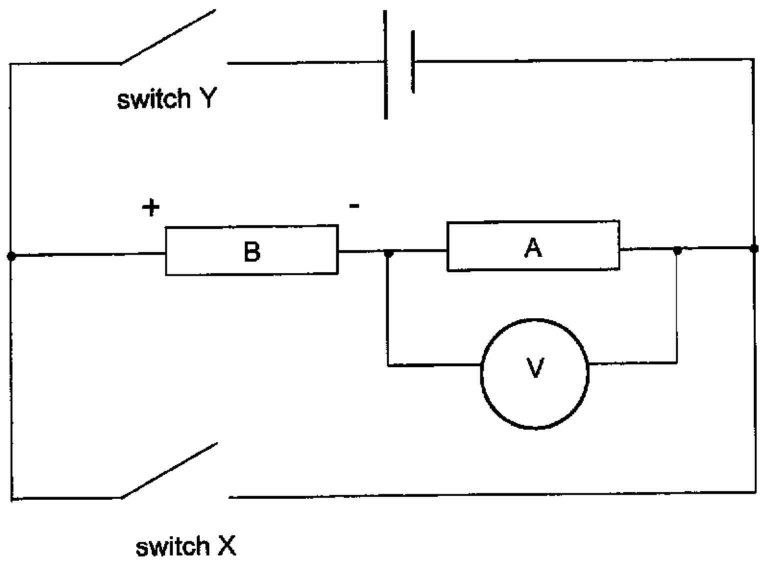


Fig. 2.2

(ii) Close switch Y and start the stopwatch. Switch X must be **open**.

(iii) Record the numericalvalue of the potential difference V_0 across resistor A when the stopwatch is first started. This should be the highest value observed on the voltmeter when carrying out the steps **(b)(i)** to **(b)(iv)**.

1.44 V

V_0= ....

(iv) Record the numericalvalue of the potential difference V across resistor A when the time on the stopwatch reaches 10 s.

Note that the value of the potential difference should be decreasing continuously for the 10 s.

0.22 V (2d.p.and correct unit)

V = ... [1]

(v) Allow switch Y to be closed for 1 minute.

(vi) Open switch Y.

(c) **(i)** Close switch X and start the stopwatch. Switch Y must be **open**.

(ii) Record thenumericalvalue of the potential difference V_0 across resistor A when the stopwatch is first started. This should be the highestvalue observed on the voltmeter when carrying out the steps **(c)(i)** to **(c)(iii)**.

1.44 V

V_0= ....

(iii) Record thenumericalvalue of the potential difference V across resistor A when the time on the stopwatch reaches 10 s.

0.24 V (2d.p.and correct unit)

V = ... [1]

(d) Theory suggests that

$$V = V_0 e^{-\frac{10000}{R}}$$

where$R$ is the resistance of resistor A and $V_0$the e.m.f. of the battery cell.

(i) Calculate the average value of R.

$$ln\frac{V}{V_0} = -\frac{10000}{R}$$

$$R = \frac{-10000}{\ln(V/V_0)}$$

1st value of R = $\frac{-10000}{\ln(0.22/1.44)} = 5300\Omega$

2nd value of R = $\frac{-10000}{\ln(0.24/1.44)} = 5600\Omega$

(correct calculation of both values of R)

Average R = $\frac{5300+5600}{2}$ = 5500Ω (correct calculation of average, 2 to 3 s.f.) .... [2]

(ii) If you were to repeat this experiment with other battery cells of different e.m.f., describe the graph that you would plot to determine *R*.

$$V = V_0 e^{-\frac{10000}{R}}$$

$lnV = lnV_0 - \frac{10000}{R}$ (show linearization)

Plot ln V against ln V_0

[2]

[Total: 6]

Question 3 begins on the next page

3 In this experiment, you will investigate the appearance of a line viewed through a beaker of water.

(a) You have been provided with an empty beaker.

The thickness of the beaker is *t*.

Measure and record *t*.

$t_1 = 0.192cm, t_2 = 0.217cm$

$t = 0.205cm$ (repeated values, t to nearest 0.001 cm, 0.1 to 0.3 cm)

t= .... [1]

(b) **(i)** The outer diameter of the beaker is *d* as shown in Fig. 3.1.

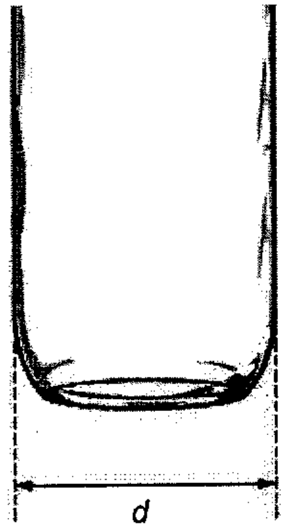


Fig. 3.1

Measure and record *d*.

$d = 6.99\ cm$ (d to nearest 0.01 cm, correct unit)

d = ... [1]

(ii) Calculate the inner diameter *D* of the beaker where

$$D = d - 2t$$

$D = 6.99 - 2 \times 0.205 = 6.58cm$

D = ...

(c) **(i)** Add water to the beaker until it is approximately three-quarters full.

(ii) The height *h* of water in the beaker is shown in Fig. 3.2.

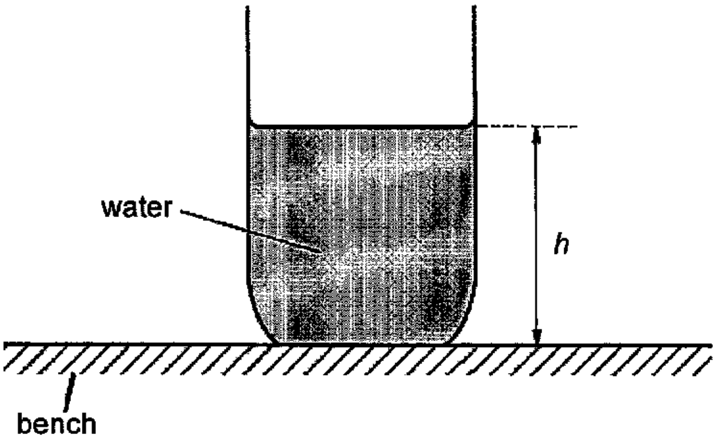


Fig. 3.2

Measure and record *h*.

h = 6.5 cm (h to nearest 0.1 cm, correct unit)

h = ... [1]

(iii) Calculate the approximate volume *V* of water in the beaker using

$$V = \frac{\square D^2 h}{4}$$

$$V = \frac{\pi 6.58^2 \times 6.5}{4} = 220cm^3$$

Correct calculation with correct unit

V = ... [1]

(iv) Justify the number of significant figures that you have given for your value of *V*.

V is calculated using d, t and h.

s.f of h is the smallest which is 2 s.f. Hence V is 2 s.f.

.... [1]

(d) Draw a straight line of approximate length 25 cm in the centre of the A4 sheet of paper.

(e) **(i)** Place the beaker centrally on the line as shown in Fig. 3.3.

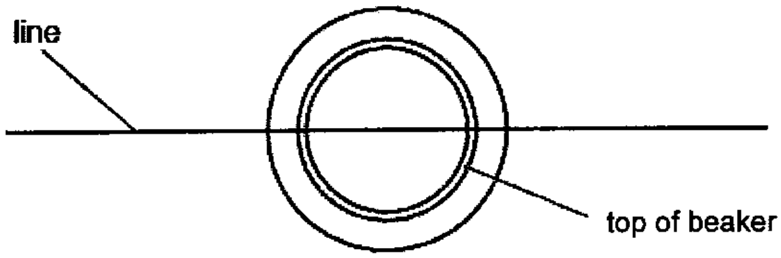


Fig. 3.3

Look down on the beaker from directly above. The line should appear to pass through the centre of the beaker as an unbroken straight line.

(ii) Move your head backwards and forwards.

When viewed through the water, the line (shown dotted) appears to move, as shown in Fig. 3.4.

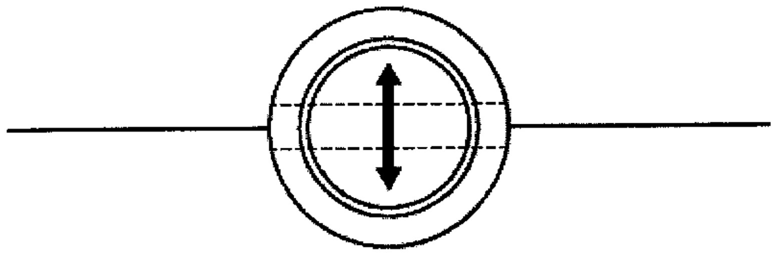


Fig. 3.4

(iii) Place the nails on the line either side of the beaker, as shown in Fig. 3.5.

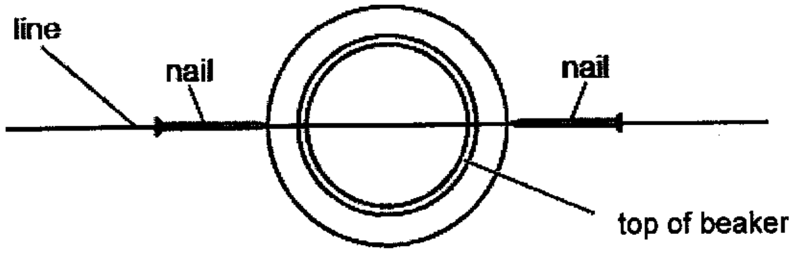


Fig. 3.5

(iv) For a particular height of the nails, the nails and the line viewed through the water appear to move together when you move your head backwards and forwards.

Raise the nails to this height.

(v) The distance between the surface of the water and the nails is y as shown in Fig. 3.6.

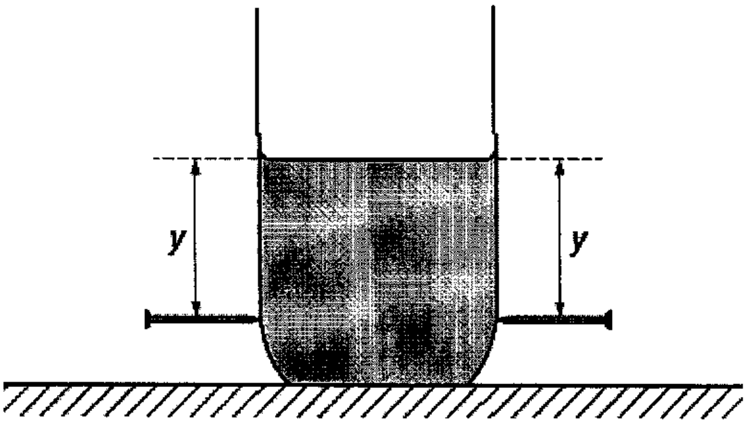


Fig. 3.6

Measure and record y.

$y_1 = 4.7\ cm, y_2 = 4.6\ cm$

y = 4.7 cm (repeated data, nearest 0.1 cm, correct unit)

y = ... [1]

(f) Estimate the percentage uncertainty in your value of y.

$\Delta y = 0.5\ cm$(accept from 0.2 to 0.8 cm)

Percentage uncertainty = $\frac{0.5}{4.7} \times 100\% = 11\%$ (2 s.f.)

percentage uncertainty = ... [1]

(g) Pour water out of the beaker until it is approximately half full.

Repeat **(c)(ii)**, **(c)(iii)** and **(e)**.

$h = 4.7\ cm$ (lower value)

$V = 160\ cm^3$ (correct calculation)

$y_1 = 3.5cm$

$y_2 = 3.2\ cm$

$y = 3.4\ cm$ (lower value)

h = ...

V = ...

$y =$ .... [3]

(h) It is suggested that the relationship between y and V is

$$y = kV$$

where k is a constant.

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

$$k_1 = \frac{y}{V} = \frac{4.7}{220} = 0.021cm^{-2}$$

$$k_2 = \frac{y}{V} = \frac{3.4}{160} = 0.021cm^{-2}$$

Two values of k calculated correctly (units not required)

first value of $k =$ ....

second value of $k =$ .... [1]

(ii) Statewhether your results support the suggested relationship.

Justify your conclusion by referring to your value in **(f)**.

Percentage difference $= \frac{0.021-0.021}{(0.021+0.021)/2} \times 100\% = 0\%$

As the percentage difference is smaller than the percentage error in (f), the relationship is supported.

(Calculation of percentage difference, test against criterion in (f), concluding statement)

....

.... [1]

(i) (i) Suggest **two**significant sources of errors in this experiment.

1. Too few readings/only 2 readings <u>not enough to draw a valid conclusion</u>
2. Difficult to measure t with reason (curved surface, thickness not the same)
3. Difficult to judge correct position of nails (nails are too thick)
4. Difficult to measure y with reason e.g. holding the nail and rule both in position

....

....

....

.... [2]

(ii) Suggest **two** improvements that could be made to this experiment to address the sources of errors identified in **(i)(i)**. You may suggest the use of other apparatus or a different procedure.

1. Take more readings (for different volumes) <u>and</u> plot a graph/ take more values of k and compare
2. Use travelling microscope to measure t, take more values of t
3. Use optical pins/thinner nails
4. Have scale on side of jar/ place nails on lab jacks/use marker pen instead of nails/ clamp rule/use a marker to mark position of nail

....

....

....

.... [2]

(j) The apparent position of the line beneath the beaker depends on the properties of the fluid in the beaker.

It is suggested that, if the water is replaced with a sugar solution, the distance y is inversely proportional to the density ρ of the sugar solution.

Explain how you would investigate this relationship using the same apparatus. You may use additional equipment that can be found in a school laboratory.

Your account should include:

- your experimental procedure
- control of variables
- how you would use your results to show that y is inversely proportional to ρ.

1. Use an electronic balance to measure the mass of the beaker M.
2. Stir some sugar into water and use a measuring cylinder to measure the volume V of the sugar solution. (original method of estimating V is acceptable.)
3. Pour the sugar solution into the beaker until it is about three quarters full and measure the mass of the plastic container and sugar solution using an electronic balance to determine the mass m of the sugar solution.
4. The density of the sugar solution is given by $\rho = \frac{m}{V}$
5. Place the beaker with the sugar solution centrally over the drawn line and repeat the same procedure using the nails to determine the distance y.
6. Pour more sugar into the sugar solution and repeat steps 3 to 5 for 10 more sets of readings.
7. A ruler should be used to check that the height of the sugar solution and its volume stays constant.
8. Tabulate m, V, ρ, y and $\frac{1}{y}$
9. Plot $\frac{1}{y}$ against ρ
10. If a straight line graph passing close to the origin is obtained, y is inversely proportional to ρ.

[5]

[Total:21]

4 A fairground ride carries passengers in chairs which are attached by metal rods to a rotating central pole, as shown in Fig. 4.1. When the pole rotates with angular velocity ω, the rods make an angle θ to the vertical.

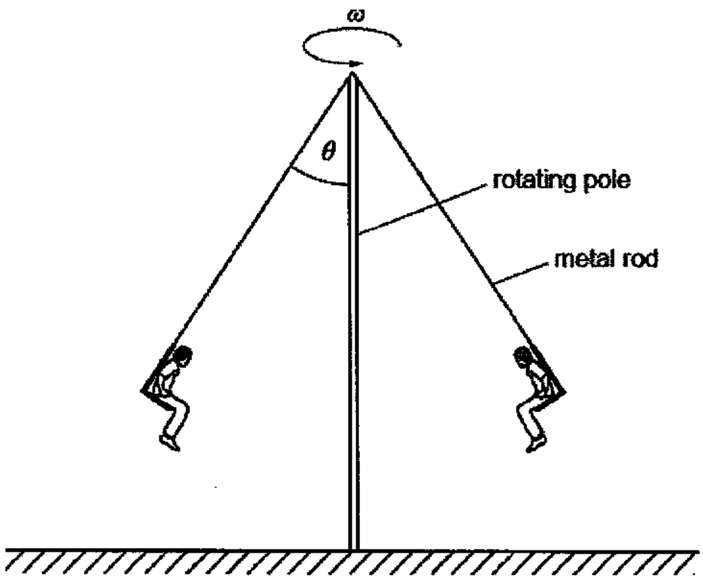


Fig 4.1

It is suggested that

$$\cos\theta = \frac{g}{l\omega^2}$$

where g is the acceleration of free fall and l is a constant.

Design a laboratory experiment, using a small object to represent an occupied chair, to determine the value of l.

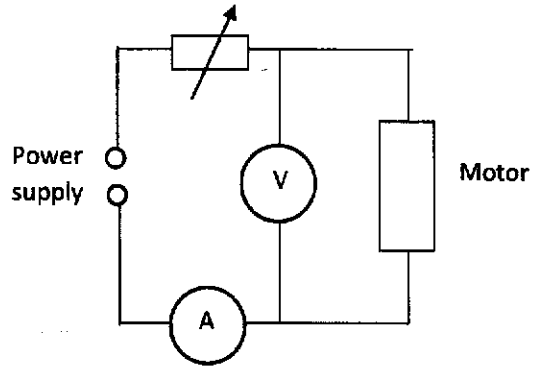
You should draw a diagram to show the arrangement of your apparatus and pay particular attention to

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

Diagram

[12]

- END OF PAPER –



Aim: To determine l

Independent variable: angular velocity ω (*or frequency or period of rotation*)

Dependent variable: angle between rigid rod and pole, θ

Fixed variables: length of rod (ignore reference to mass)

Procedure

1. Set up the apparatus as shown above.
2. Measure the length x of the rigid rod with a metre rule.
3. Measure the height h_0 of the top end of the pole from the bench with a metre rule.
4. Switch on the motor.
5. The metal bob will start to turn. Allow the metal bob to stabilize at a fixed height.
6. Use a metre rule to measure the height h of the metal bob from the bench.
7. Angle θ can be found using the following equation: $cos\theta = \frac{h_0 - h}{x}$
8. Count a fixed number of revolutions n made by the metal bob and use the stopwatch to record the time t taken for n revolutions.
9. The period T is t/n.
10. The angular velocity $\omega = \frac{2\pi}{T}$.
11. Adjust the power to motor by changing the resistance of the variable resistor to change the angular velocity of the motor and repeat steps 6 to 8 for 10 readings

Analysis

1. Tabulate $h, cos\theta, T, \omega$ and $1/\omega^2$
2. Plot a graph of $cos\theta$against $1/\omega^2$.
3. A straight line passing close to the origin should be obtained, where the gradient = $\frac{g}{l}$ and l can then be calculated from the gradient.

Safety Precautions

1. Use a protective screen in case mass detaches from the pole.
2. Ensure speed of mass is not too fast such that it flies off the pole.

Additional Details

1. Preliminary experiment could be conducted to ensure there is a large motor speed to produce a measurable θ.
2. Projection method, slow motion freeze frame video, camera with detail, i.e. what to measure using these methods to obtain θ
3. $cos\theta = \frac{h_0 - h}{x}$ or equivalent trigonometric method
4. Use set-square (or other methods) to check pole is vertical
5. Wait for motion to be stable before measurements
6. When measuring angular velocity, at least 10 rotations should be used or timing of rotations should be long enough.
7. When counting rotations, a mark or light gates perpendicular to the motion of objects can be used to assist with the counting and increase accuracy of the timing t.
8. Repeated measurements of timing t could be taken to increase accuracy.

NATIONAL JUNIOR COLLEGE
SENIOR HIGH 2 Preliminary Examination
Higher 2

CANDIDATE NAME

SUBJECT CLASS

REGISTRATION NUMBER

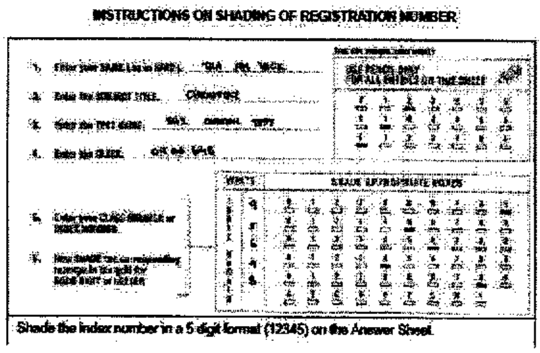
PHYSICS **9749/01**

Paper 1 Multiple Choice

Additional Materials: Multiple Choice Answer Sheet

19 September 2019
1 hour

READ THE INSTRUCTION FIRST
Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, subject class and registration number on the Answer Sheet in the spaces provided unless this has been done for you.
There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Optical Mark Sheet.
Read the instructions very carefully.
Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.



OAS index number is in 5-digit format.

5 digit format: **2nd digit** and the **last four digits** of the Reg Number.

This document consists of 21 printed pages.

Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1} = $(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J $K^{-1}mol^{-1}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}
acceleration of free fall	$g = 9.81$ m s^{-2}

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$, $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -GM/r$
temperature	$T/K = T/°C + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ and $v = \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \cdots$
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	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

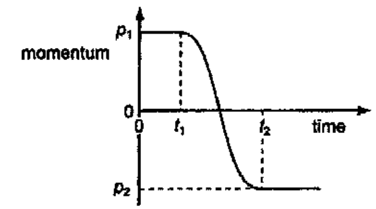
1	A man is standing still on the ground. What is an appropriate value for the pressure his feet exerts on the ground?	
	A	120 Pa
	B	1 200 Pa
	C	12 000 Pa
	D	120 000 Pa

	Ans: C – Assume area of feet is 10 cm by 25 cm. Area is 0.050 m^2. Take weight of man to be 65 kg.

2	Ball A is projected horizontally at 2.0 m s^{-1} from the top of a vertical cliff while Ball B is released from rest 1 s later from the same point. It took Ball B 3.5 s to reach the base of the cliff. How far from the base of the cliff will Ball A hit the ground?	
	A	7.0 m
	B	9.0 m
	C	53 m
	D	67 m

	Ans: A Both A and B will take the same amount of time and thus 3.5 s. Hence, horizontal distance = 3.5 x 2 = 7.0 m

3 The graph shows the variation with time of the momentum of a ball as it is kicked in a straight line.

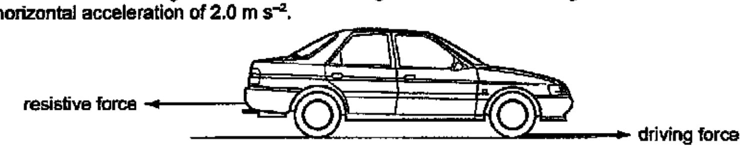


Initially, the momentum is p_1 at time t_1. At time t_2 the momentum is p_2.
What is the magnitude of the average force acting on the ball between times t_1 and t_2?

A	$\frac{p_1 - p_2}{t_2}$
B	$\frac{p_1 - p_2}{t_2 - t_1}$
C	$\frac{p_1 + p_2}{t_2}$
D	$\frac{p_1 + p_2}{t_2 - t_1}$

	Ans: D. <F> = Δp/Δt = $p_f - p_i$ / ($t_2 - t_1$) = $-p_2 - p_1$ / ($t_2 - t_1$) = – ($p_2 + p_1$) / ($t_2 - t_1$). For magnitude only, thus [D] is the ans. (p_2 should be interpreted as scalar by convention since it is italicized and not bold.)

4 A car of mass 750 kg has a horizontal driving force of 2.0 kN acting on it. It has a forward horizontal acceleration of 2.0 m s^{-2}.



What is the resistive force acting horizontally?

A	0.5 kN
B	1.5 kN
C	2.0 kN
D	3.5 kN

Ans: A – F = ma
2000 – f = 750 (2)
F = 500 N

5 An object, made from two equal spherical masses joined by a light rod, falls with uniform speed through air.

The rod remains horizontal.

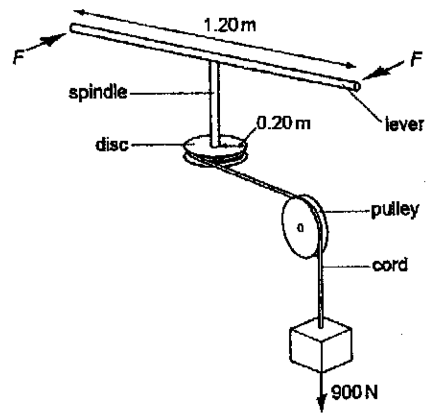
Which statement about the equilibrium of the system is correct?

A	It is not in equilibrium because it is falling steadily.
B	It is not in equilibrium because it is in motion.
C	It is not in equilibrium because there is a resultant torque.
D	It is in equilibrium because there is no resultant force and no resultant torque.

Ans: D

6 One end of a spindle is attached to the centre of a lever of length 1.20 m and its other end is attached to the centre of a disc of radius 0.20 m as shown in the figure below.

A cord is wrapped around the disc, passes over a pulley and is attached to a 900 N weight at one end.



The mass of the lever, spindle, disc, cord and pulley is assumed to be negligible. Equal and opposite forces of magnitude F is applied to each end of the lever.

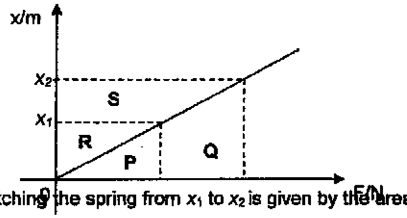
Ignoring frictional forces, what is the minimum value of F needed to balance the 900 N weight?

A	75 N
B	150 N
C	300 N
D	950 N

Ans: B

Tension in the cord = 900 N
Torque on disc = 900 x 0.20 = 180 Nm
Torque due to F = F x 1.20 = 180
F = 180/1.2 = 150 N

7 The variation with force of the extension of a spring is shown in the figure below.



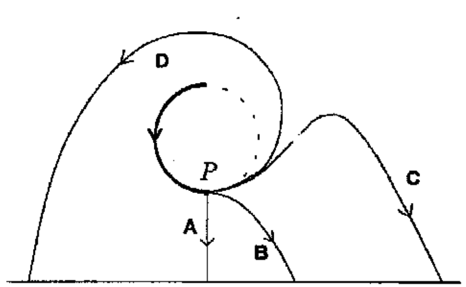
The work done in stretching the spring from x_1 to x_2 is given by the area

A	P + Q
B	S
C	R + S
D	Q

Ans: B

Area under F-x graph and thus answer is S

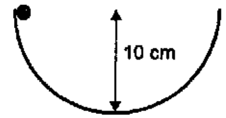
8 A stone, tied to a piece of string, is whirled in a vertical circle as shown in the figure below. The string suddenly breaks at *P*.



Which of the paths (A to D) represents a possible path for the stone from just before the string breaks until the stone hits the ground?

Ans: B

9 A small object of mass 0.050 kg is released from rest at the rim of a heavy, smooth semi-spherical bowl of radius 10 cm as shown in the figure below.



When the object passes the bottom of the bowl, what is the normal force exerted on it by the bowl?

A	0.49 N
B	0.98 N
C	1.5 N
D	2.0 N

Ans: C

From energy conservation:
$\frac{1}{2}mv^2 = mgh$
$v^2 = 2gh = 2gr$

At the bottom:
$N - mg = \frac{mv^2}{r}$
$N = mg + \frac{mv^2}{r} = mg + 2mg$
= 3mg

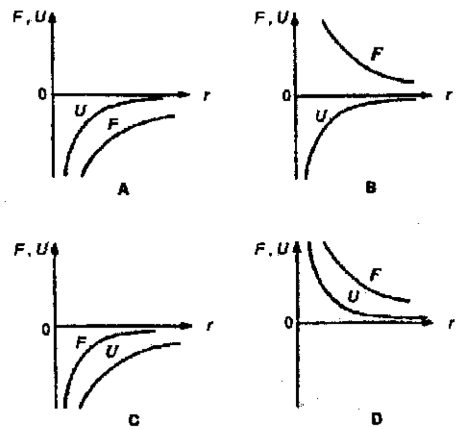
10 Taking the Earth to be a perfect sphere of uniform density rotating about its polar axis, which of the following statements concerning the observed acceleration due to free fall, *a*, at the surface of the Earth is true?

A	The value of *a* at the equator is larger than that at the poles.
B	If the rate of rotation of the Earth slows down, *a* at the equator increases.
C	If the radius of the Earth increases with its density remaining unchanged, *a* at the poles decreases.
D	If the radius of the Earth increases with its density remaining unchanged, *a* at the equator decreases.

Ans: B

$a = g - r\omega^2$

11 Which one of the following diagrams shows the variation of gravitational force F on a point mass and gravitational potential energy U of the mass at a distance r from another point mass?



Ans: C

F = -dU/dr and since r is usually large, F is numerically smaller.

12 The temperature of a ideal gas is raised from 32.1 °C to 40.5 °C. What is the percentage increase in the r.m.s. speed of its gas particles?

A	1.4 %
B	2.8 %
C	12 %
D	13 %

Ans: A

$v_{rms} \alpha \sqrt{T}$

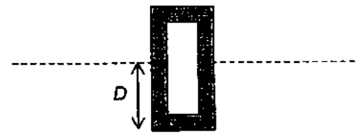
% change = (√305.1 - √313.5)/ √305.1 = 1.4%

13 The specific latent heat of vaporisation of water at 20 °C is appreciably greater than the value at 100 °C. This is because

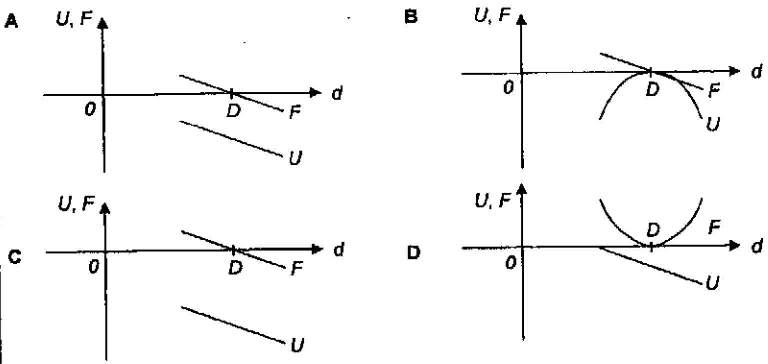
A	the specific latent heat at 20 °C includes the energy necessary to raise the temperature of one kilogram of water from 20 °C to 100 °C.
B	more work must be done in expanding the water vapour against atmospheric pressure at 20 °C than at 100 °C.
C	the molecules in the liquid are more tightly bound to one another at 20 °C than at 100 °C.
D	vaporisation of water can only take place at 100 °C.

Ans: C

14 A hollow metal cylinder floats upright in a body of water with the bottom of the cylinder at a depth of D below the water surface as shown in the figure below.

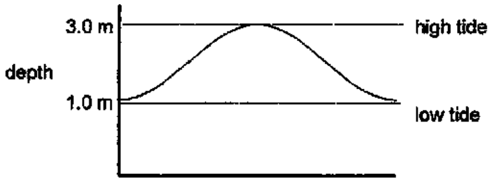


The cylinder is pressed further down into the water and upon release, performs simple harmonic motion. Which of the following graphs (all drawn to scale) shows how the upthrust U and net force F acting on the cylinder vary with d, the depth the bottom of the cylinder below the water surface?



Ans: A
Both must be linear and U = 0 when d = 0

15 The rise and fall of water in a harbour is simple harmonic. The depth varies between 1.0 m at low tide and 3.0 m at high tide. The time between successive low tides is 12 hours.



A boat, which requires a minimum depth of water of 1.5 m, approaches the harbour at low tide. How long will the boat have to wait before entering?

A	0.5 hours
B	1.0 hours
C	2.0 hours
D	2.5 hours

Ans: C

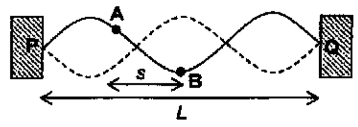
-0.5 = cos (2π/12)t and thus t = 2.0 hrs

16 When coherent monochromatic light falls on double slits, an interference pattern is observed on a screen some distance from the slits. The fringe separation can be increased by

A	Decreasing the distance between the screen and the slits.
B	Increasing the distance between the slits.
C	Using monochromatic light of lower frequency.
D	Immersing the whole set up in water.

Ans: C, $x = \frac{\lambda D}{a}$, hence decreasing D, increasing a causes x to be lower. Lower frequency means higher λ resulting in higher x. Immersing set up in water causes speed of light to decrease which in turn causes wavelength to decrease (frequency stays the same) resulting in lower x.

17 A guitar string of length *L* is stretched between two fixed points **P** and **Q** and made to vibrate transversely as shown below.



Two points **A** and **B** on the string are separated by a distance *s*. The maximum kinetic energies of points A and B are K_A and K_B respectively. Which of the following gives the correct phase difference and relationship between maximum kinetic energies of the points?

	Phase difference	Maximum kinetic energy
A	$\frac{3s}{2L} \times 360°$	$K_A < K_B$
B	$\frac{3s}{2L} \times 360°$	same
C	180°	$K_A < K_B$
D	180°	same

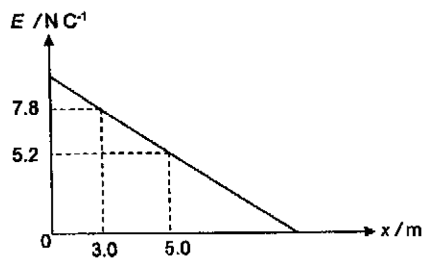
Ans: C
The adjacent segments of a stationary wave on a string are in antiphase. Point B has a larger amplitude of vibration than point A. Thus the maximum kinetic energy that point B can have during the vibration is greater than A.

18 The images of two sources are just resolved. Which of the following is a correct statement of the Rayleigh criterion for this situation?

A	The central maximum of the diffraction pattern of one source must coincide with the central maximum of the diffraction pattern of the other source.
B	Light from the sources must pass through a circular aperture.
C	Light from the sources must be coherent.
D	The first minimum of the diffraction pattern of one source must coincide with the central maximum of the diffraction pattern of the other source.

Ans: D

19 The graph below shows how the electric field strength E varies with displacement x from a point A. What is the change in potential for an electron if it is moved from a point 3.0 m away from A to another point 5.0 m away from A?



A	13 V	**B**	– 13 V	**C**	1.3 V	**D**	– 1.3 V

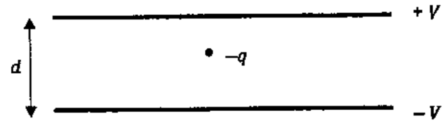
Ans: B

Electric Field Strength, $E = -\dfrac{dV}{dr}$

$\Delta V = -\int E\,dr$ Hence *magnitude* of the change in potential is the area under this graph.
Because E is positive here, the change in potential must be negative (a decrease)

$$dv = \frac{1}{2}(7.8+5.2)(5.0-3.0) = 13\text{ V (a decrease in the positive x direction)}$$

20 An oil droplet has a charge $-q$ and is situated between two parallel horizontal metal plates as shown in the diagram.



The separation of the plates is d. The droplet is observed to be stationary when the upper plate is at potential $+V$ and the lower at potential $-V$.

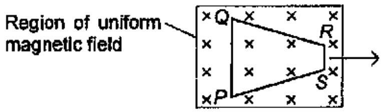
For this to occur, the weight of the droplet is equal in magnitude to

A	$\frac{Vq}{d}$
B	$\frac{2Vq}{d}$
C	$\frac{Vd}{q}$
D	$\frac{2Vd}{q}$

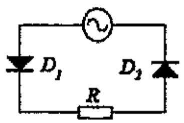
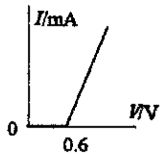
Ans:B

$$E = \frac{\Delta V}{d} = \frac{2V}{d}$$

Weight = electric force = $qE = \frac{2Vq}{d}$

25	A trapezoidal coil *PQRS* is driven with constant velocity in a direction perpendicular to a uniform magnetic field as shown in the figure below.  At the instant shown, which of the following statements is correct?	
	A	An induced current it flowing in the coil in the clockwise direction.
	B	An induced current is flowing in the coil in the anticlockwise direction.
	C	There is no induced current flowing in the coil.
	D	An electromagnetic force acts on the side *PQ* in a direction opposing its motion.

	Ans: C

26	The circuit below shows the rectification of a sinusoidal a.c. supply using two identical diodes D_1 and D_2. $E = E_0 \sin(\omega t)$  Each of the diodes has the *I-V* characteristics as shown.  For a current to flow through *R*, the value of E_0 must be at least	
	A	0.3 V
	B	$0.3\sqrt{2}$ V
	C	$0.6\sqrt{2}$ V
	D	$1.2\sqrt{2}$ V
	Ans: D. For A, B and C, the value of E can never be 1.2 V. So cannot be the answer.	

27	Which piece of evidence about the photoelectric effect cannot be explained using a wave model?	
	A	Increasing the intensity of the illumination increases the rate at which electrons are ejected.
	B	Shining ultraviolet radiation onto a zinc surface ejects electrons.
	C	Increasing the frequency of the radiation increases the kinetic energy of the ejected electrons.
	D	There is a minimum frequency of radiation below which no electrons are ejected from the metal surface despite increasing the intensity of radiation.

	Ans: D

28	What is the de Broglie wavelength of an electron having a kinetic energy of 54 eV?	
	A	3.7×10^{-27} m
	B	6.7×10^{-20} m
	C	1.7×10^{-10} m
	D	2.3×10^{-8} m

	Ans: C $k.e. = \frac{p^2}{2m} = 54 \times 1.6 \times 10^{-19} \Rightarrow p = 3.97 \times 10^{-24}$ $\lambda = \frac{h}{p} = 1.67 \times 10^{-10}$

29 The table shows the ionizing effect of different types of radiation.

	X	Y	Z
Ionising Effect	Strong	Weak	Very weak

What are the radiations X, Y and Z?

	X	Y	Z
A	Gamma	Beta	Alpha
B	Beta	Alpha	Gamma
C	Alpha	Beta	Gamma
D	Gamma	Alpha	Beta

Ans: C

30 Which statement concerning α-particles is correct?

A An α-particle has charge +4e.

B An α-particle is a helium atom.

C An α-particle has mass 4u.

D When α-particles travel through a sheet of gold foil, they make the gold radioactive.

Ans: C – An alpha particle is a helium nucleus with a charge of 2e and mass 4u.

ꕤ END OF PAPER ꕤ

NJC 2019 Prelim Paper 2

1	(a)	(i)	$\frac{kgms^{-2}}{m^2} = kgm^{-1}s^{-2}$	
		(ii)	Units of $v = ms^{-1}$ Units of $\rho = kgm^{-3}$ Units of $\gamma = \frac{(ms^{-1})^2 kgm^{-3}}{kgm^{-1}s^{-2}}$ = no units	
	(b)	(i)	Fractional error of P = $\frac{5}{105}$ = 0.048 (2s.f)	
		(ii)	1. $\frac{\Delta v}{v} = \frac{1}{2}\frac{\Delta P}{P} + \frac{1}{2}\frac{\Delta\rho}{\rho} = \frac{1}{2} \times 0.048 + \frac{1}{2} \times \frac{0.1}{1.2} = 0.066$ $\Delta v = 0.66 \times 328.85 = 21.7 \approx 20\ ms^{-1}$ 2. $v = (330 \pm 20)ms^{-1}$	
	(c)		Yes as all the obtained values are all lower than the theoretical value.	

2	(a)		Oscillating magnet causes a rate of change of magnetic flux linkage in the coil, by Faraday's Law, an EMF is induced. Since circuit is closed, by Lenz's Law, an induced current flows such that it produce a magnetic field to oppose the change in magnetic flux that causes it. <u>AND:</u> This magnetic field thus opposes the motion of the oscillating magnet. Since the motion is opposed, the amplitude is reduced. <u>Alternatively:</u> The induced current flows through the resistor causing a heating effect. This dissipate thermal energy which originated from the energy stored in the spring. Thus the motion of the magnet reduces in amplitude.	
	(b)	(i)	$V_{rms} = V_0 / \sqrt{2} = 27.0 / \sqrt{2}$ = 19.092 mV Therefore, <P> = 19.092^2 / 5 = 73 μW	
		(ii)	T = 2π / ω = 2(3.14)/15.7 = 0.4 s Labelled cosine square graph $P_o = V_0^2/R = (27 \times 10^{-3})^2 / 5$ = 146 μW OR 2<P> = 146 μW	

3	(a)		Coherence means that the <u>phase difference</u> between two waves remain <u>constant</u> and do not vary with time.	
	(b)			
		(i)	The microwaves waves from the two sources undergo interference. The <u>path/phase difference</u> at P is <u>changing</u> as S_1 moves. When the waves are in phase at P such that the <u>path difference</u> between the sources is an <u>integer number of wavelengths</u> (or equivalent statement about phase difference); <u>constructive interference</u> occurs at P resulting in <u>maximum intensity</u>. When the waves are anti-phase at P when the <u>path difference</u> is an <u>integer number of wavelengths plus half a wavelength</u> (or equivalent statement about phase difference), <u>destructive interference</u> occurs at P resulting in <u>minimum/zero intensity</u>.	
		(ii)	path difference = XY = $\frac{\lambda}{2}$ λ = 0.164 m $v = f\lambda$ $f = \frac{3.0\times10^8}{0.164} = 1.8 \times 10^9\ Hz$	
		(iii)	As the microwaves from S1 and S2 are no longer have the same axis of polarization, destructive interference does not take place (or the waves do not cancel out). Hence, the intensity of the microwave at P is now between the minimum and the maximum.	
	(c)			
		(i)	Original amplitude of S_1 = 12 units As intensity is proportional to the square of the amplitude New amplitude of $S_1 = \sqrt{\frac{I/2}{I}} \times 12$ = 8.5 units.	
		(ii)	Wave in antiphase with original but with only 8.5 units	

4	(a)	(i)	The increase in internal energy of a system is equal to the sum of heat (or thermal energy) supplied to the system (or heating) and the work done on the system.	
		(ii)	Increase in volume (or intermolecular separation) is more significant in vaporisation compared to melting Hence, the increase in internal energy and work done by the substance in expanding against atmospheric pressure is greater in vaporisation compared to melting resulting in a larger specific latent heat of vaporisation compared to specific latent heat of fusion for the same substance.	
	(b)	(i)	At point A: $p_A V_A = 1.0 \times 10^5 \times 4.5 \times 10^{-2} = 4500$ At point B: $p_B V_B = 3.0 \times 10^5 \times 1.5 \times 10^{-2} = 4500$ Since (from the equation of state of an ideal gas) pV is directly proportional to the thermodynamic temperature of the gas, it follows that $p_A V_A = p_B V_B$ means the temperature at A and B are the same and hence A→B is an isothermal process	

(ii) pressure $= \frac{Force}{Area}$ and Force $= \Delta v \frac{Nm}{t} = (m\Delta v)\left(\frac{N}{t}\right) = (\Delta p)\left(\frac{N}{t}\right)$

From A→B, the temperature is constant, increase in pressure is due to the increase in the rate of collision between the gas molecules and the walls of the container due to the decrease in the volume of the gas.
From C→B, the volume of the gas is constant while temperature of the gas is increased resulting in the increase in mean square speed of the gas molecules. This increases the rate of collision as well as the change in momentum of each molecule as it collides with the wall.

(iii) Area under the graph $\approx \frac{1}{2}(1 + 2.25) \times 10^5 \times (4.5 - 1.5) \times 10^{-2} = 4900$ J
Since $q + w = 0$ $q = -w = -4900$ J
Heat removed = 4900 J (accept 4000 to 5500 J)

5 (a) (i) Amount of work needed to take all its constituent nucleons apart so that they are separated an infinite distance from one another.

(ii) Total binding energy of He-4 = 7.075175 × 4 = 28.30070 MeV
Total binding energy of Be-9 = 6.462767 × 9 = 58.16490 MeV
Total binding energy of C-12 = 7.675310 × 12 = 92.10372 MeV
(2m, any one wrong will be awarded 1 m only for the question)

Energy released = 92.10372 – (28.30070 + 58.16490) = 5.638120 MeV

(b) (i) Nuclei/Atoms with same proton number/atomic number, but contain different numbers of neutrons/different atomic mass.

(ii) 1.
mass $= 238 \times 1.66 \times 10^{-27}$
$= 3.95 \times 10^{-25}$ kg

2.
Volume $= 4/3\,\pi \times (8.9 \times 10^{-15})^3 = 2.95 \times 10^{-42}$

density $= (3.95 \times 10^{-25})/(2.95 \times 10^{-42})$
$= 1.3 \times 10^{17}$ kg m^{-3}

(iii) The nucleus contains most of mass of atom.
either The nuclear's diameter/volume is very much less than that of atom
or The atom is mostly (empty) space.

6 (a) A photon is a quantum (packet) of electromagnetic radiation / wave / field.

(b) $E = \frac{hc}{\lambda} = \frac{6.63\times10^{-34}\times3\times10^{8}}{6.33\times10^{-7}} = 3.14 \times 10^{-19}$ J

(c) $P = \frac{Nhf}{t}$ $\frac{N}{t} = \frac{P}{hf} = \frac{1\times10^{-3}}{3.14\times10^{-19}} = 3.2 \times 10^{15}$

(d)

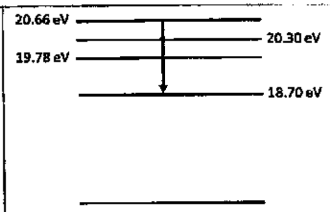


Fig 6.2

(e) (i) UP

(ii) Number of photoelectrons emitted per unit time $= \frac{20}{100} \times 3 \times 10^{15}$
$= 6 \times 10^{14}$

Current, $I = \frac{Ne}{t} = 6 \times 10^{14} \times 1.6 \times 10^{-1}$

$= 9.6 \times 10^{-5}$ A

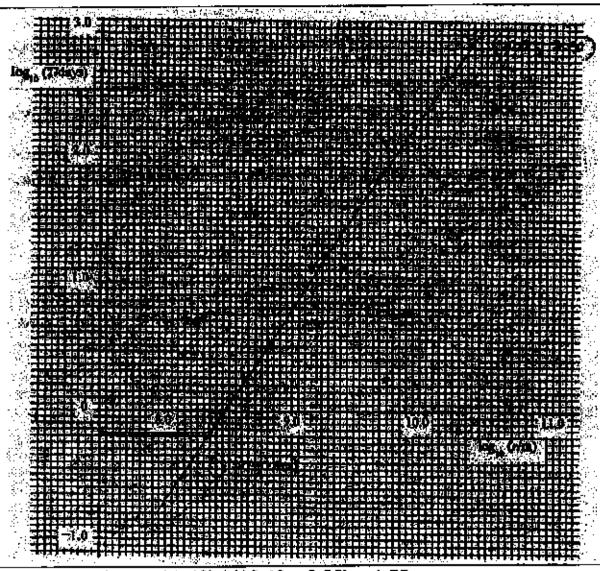
(iii) Most of the incident photons are reflected by the photodiode.

7 (a) (i) $T^2 \propto r^3$
$(2\pi r/v)^2 \propto r^3$
$r^2 / v^2 \propto r^3$
$a \propto 1/r^2$ and thus we can conclude F is inversely proportional to r^2 since F = ma

(ii) Gravitational force provides the centripetal force for circular motion to take place.
By Newton's 2nd Law,
F = ma
$GMm/r^2 = mr\omega^2$
$GM/r^3 = (2\pi/T)^2$
$T^2 = 4\pi^2 r^3/ GM$

(b) (i)

lg (T/days)	lg (r/m)
2.38	10.05
1.22	9.27
0.25	8.63

		(ii)		
		(iii)	Gradient = 2.90 – (-0.40) / (10.40 – 8.20) = 1.50	
		(iv)	$T^2 = 4\pi^2 r^3 / GM$ $T^2 = kr^3$, where $k = 4\pi^2 / GM$ (constant because all the moons are orbiting around Jupiter) lg T = (3/2) lg r + lg k If lg T is plotted against lg r, the gradient should be 1.5 and this corresponds with the graphically obtained value. Hence, the data support the relation.	
	(c)		T_G = 7.16, lg T_G = 0.85 From graph, lg (r_G) = 9.05, $r_G = 1.12 \times 10^9$ m	
	(d)		T_T = 16.2 / 24 days, lg T_T = -0.17 From graph, lg (r_G) = 8.35, $r_G = 2.24 \times 10^8$ m r_G calculated is the distance of the Thebe to the centre of Jupiter. We can only decide on the accuracy of the statement if the radius of Jupiter is known.	
	(e)		No, because the k value mentioned in (c)(ii) will be different. Orbital radii and periods of moons depend on the mass of the planet where the moons are orbiting.	

NJC 2019 Prelim Paper 3

1	(a)	(i)	horizontal speed constant at 8.2 m s^{-1} vertical component of speed = 8.2 tan 60° = 14.2 m s^{-1}	
		(ii)	14.2^2 = 2 × 9.8 × h vertical distance = 10.3 m	
		(iii)	time of descent = 14.2 / 9.8 = 1.45 s x = 1.45 × 8.2 = 11.9 m	
	(b)	(i)	smooth path curved and above given path hits ground at more acute angle	
		(ii)	smooth path curved and below given path hits ground at steeper angle	
	(c)		b(ii) will take a longer time as its KE at any point is lower and thus average velocity is lower. Since, vertical distance is same, the time take is lower.	

2	(a)	(i)	$\Delta p = \Delta(mv) = m\Delta v = m(v_f - v_i)$ $= 1.2(-0.8 - 4)$ $= -5.76$ kg m s^{-1}	
		(ii)	Ball S must have a change of momentum of 5.76 kg m s^{-1} as well, thus 5.76 = m ($v_f - v_i$) = 3.6 (v_f – 0) v_f = 1.6 m s^{-1}	
	(b)		Relative speed of approach = $u_1 - u_2$ = 4 – 0 = 4 m s^{-1} relative speed of separation = $v_2 - v_1$ =1.6 – (-0.8) = 2.4 m s^{-1} Since they are different, this is an inelastic collision. (accept ans using KE conservation. KE_i = 9.60 J, KE_f = 4.99 J)	

3	(a)		Resultant Force, F_R = ma = 4000 (0.30) = 1200 N Applied force, F = F_R + f = 1200 + 700 = 1900 N Therefore power = 1900 (8.0) = 15200 W	
	(b)	(i)	Applied force, P = Fv 7600 = 700 v F = f, since max speed, a = 0 V = 10.9 m s^{-1}	
		(ii)	sin□□ = 1/25 Total opposing force f_T = f + mg sin □ = 700 + 39240 (0.04) = 2270 N P = Fv v = 7600 / 2270 = 3.35 m s^{-1}	

4	(a)		Direction of girl's velocity is changing Acceleration is the rate of change of velocity	
	(b)	(i)	$F = \frac{mv^2}{r} = \frac{(60)(10^2)}{3.4}$ = 1760 N	
		(ii)	N = centripetal force = 1760 N $f = mg = (60)(9.81)$ $\mu = 0.33$	
	(c)		Vertical component of the normal force is directed upwards it can balance the weight of the girl hence no need for friction	

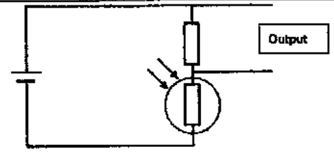
5	(a)	(i)	Simple harmonic motion is defined as the motion of a particle about a fixed point such that its acceleration **a** is proportional to its displacement **x** from a fixed point, and is directed towards the fixed point.	
		(ii)	use of a = $-\omega^2$x clear either ω = √(2k/m) or ω^2 = (2k/m) ω = 2 πf f = (1/2 π)√(2 x 300)/0.240) = 7.96 = 8 Hz	
	(b)	(i)	1. resonance 2. 8 Hz	
		(ii)	There is maximum energy transfer from the driver to the oscillating mass during resonance.	
		(iii)	(increase amount of) damping without altering (k or) m ...(some indirect reference is acceptable) sensible suggestion.	

6	(a)		Into the page / into the (plane of) paper. (Do not accept into the plane unless candidate specify which plane they are referring to)	
	(b)		Magnetic force (acting on ions) provides the centripetal force (or centripetal acceleraton) $Bqv = \frac{mv^2}{r}$ or $Bq(v\sin\theta) = \frac{m(v\sin\theta)^2}{r}$ $B = \frac{(20\times1.66\times10^{-27})(1.40\times10^5)}{(1.60\times10^{-19})(\frac{0.128}{2})}$ = 0.4539 ≈ 0.454 T (shown)	
	(c)	(i)	Proper semi-circle with **slightly larger** diameter	

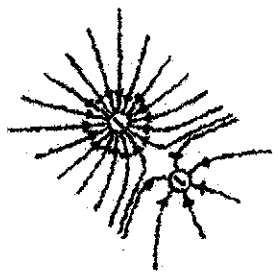
		(ii)	From $Bqv = \frac{mv^2}{r}$ $\quad B \propto m$ $\frac{B}{0.454} = \frac{22}{20}$ $B = 0.499$ T Or $\quad B = \frac{(22\times1.66\times10^{-27})(1.40\times10^{5})}{(1.60\times10^{-19})\left(\frac{0.128}{2}\right)}$ $\quad B = 0.499$ T	

7	(a)		$F = (\Delta v)\frac{Nm}{t} = (m\Delta v)\frac{N}{t} = 1.85\times10^{-23}\times1.49\times10^{24}$ $= 27.6$ N	
	(b)		$p = \frac{F}{A} = \frac{27.6}{0.018} = 1530$ Pa $\quad$ (accept $p = \frac{27.6}{(0.134)^2}$)	
	(c)		From $pV = NkT$ $\quad N = \frac{pV}{kT}$ $N = \frac{(1530)(0.018\times0.134)}{(1.38\times10^{-23})(273+27)}$ $= 8.9\times10^{20}$	
	(d)		From $\frac{1}{2}mc_{rms}^2 = \frac{3}{2}kT$ $\quad c_{rms} = \sqrt{\frac{3kT}{m}}$ $c_{rms} = \sqrt{\frac{3(1.38\times10^{-23})(273+27)}{6.86\times10^{-27}}}$ $= 1350$ ms^{-1} Accept $\Delta p = 2mc_{rms}$ although this is not the preferred method unless student mentioned that based on the assumptions of kinetic theory of gases, the collision between the gas molecules and the container is perfectly elastic.	

8	(a)	(i)	R = ρl / A $1200 = 15.0\times10^{-6}(0.25) / (1\times10^{-3}\times t)$ $t = 3.13\times10^{-5}$ m	
		(ii)	V = IR 9 = I(1200) $I = 7.5\times10^{-3}$ A I = nAve $V = I/(nAe) = 7.5\times10^{-3} / (2.2\times10^{28}\times1\times10^{-3}\times3.13\times10^{-5}\times1.6\times10^{-19})$ $= 6.81\times10^{-5}$ m s^{-1}	
	(b)	(i)	Light Dependent Resistor ("LDR" not accepted)	

		(ii)		
		(iii)	The resistor and the light-dependent resistor are connected in series with the cell so that the cell's e.m.f. is shared between them. Thus, when the potential difference of one of the component increases, the other should decrease using the potential divider principle. The light dependent resistor characteristic is such that when the ambience light is bright, the resistance is low, thus the potential difference across it will be low and the potential difference across the resistor will be high, and vice versa.	
	(c)	(i)	E.m.f. of a source is defined as the amount of energy converted from other forms of energy to electrical energy when the source drives a unit charge round a complete circuit. Whereas for potential difference, it is energy converted from electrical to other forms of energy.	
		(ii)	Since there is not current in the ammeter, the potential difference across XM and YN must be the same, and the potential at X must be the same as Y.	
		(iii)	$V_{10} = 12\times10/25 = 4.8$ V Thus $V_L = 4.8 = 5\times L/25$ L = 24 cm	
		(iv)	If the 12 V cell has internal resistance, the EMF of the cell will have to drop some p.d. across the internal resistance. Thus the p.d. across V_{10} will decrease. For the ammeter to continue to have a null deflection, length L will need to be decreased. OR For the ammeter to continue to have a null deflection, thus the length between YP must increase	

9	(a)		The principle of moments states that for a body to be in (rotational) equilibrium, the sum of clockwise moments about any point must be equal to the sum of anti-clockwise moments about the same point. (Accept net/total moment about a fixed point is zero)	
	(b)	(i)	As sphere X is heavier than mass A, the clockwise moment due to the weight of sphere X about P is greater than the anticlockwise due to the weight of mass A about P. By the principle of moments, for mass A and sphere X to be balanced, the electric force on sphere X must provide an anti-clockwise moment. Sphere Y must be negatively charged to provide such an electric force on sphere X.	
		(ii)	Let the electric force be F and l the length of the rod. By the principle of moments, Clockwise moments about P = anti-clockwise moments about P $0.200\times9.81\times\frac{l}{2} = 0.150\times9.81\times\frac{l}{2} + F\sin25°\times\frac{l}{2}$ $F\sin25° = 0.4905\ N$ $F = 1.16N$	
		(iii)	Pointing upwards and to the right	

	(c)			
	(d)	(i)	The potential energy of the decreases as it is moved from d = 0.05 m and reaches a minimum potential energy in between d = 0.05 m to d = 0.35 m. It then increases as it is moved towards d = 0.35 m.	
		(ii)	Potential due to X = - 150kV Potential due to Y = - 370 kV Total potential = - 150 – 370 = - 520 kV Potential energy = qV = $-520000 \times (-1.6 \times 10^{-19}) = 8.32 \times 10^{-14} J$	
		(iii)	Negative potential gradient is the electric field strength Since net force is zero, the net electric field strength is zero. Hence, the magnitude of the potential gradient of X is equal to that of Y at this point The direction of the potential gradient of X is opposite to that of Y at this point.	

H

NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2 PRELIMINARY EXAMINATION

Higher 2

CANDIDATE NAME

SUBJECT CLASS | REGISTRATION NUMBER

PHYSICS **9749/04**

Paper 4 Practical

Candidate answers on the Question Paper.
Additional Materials: As listed on Instructions.

22 August 2019
2 hours 30 minutes

Shift
Laboratory

READ THESE INSTRUCTIONS FIRST

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

Answers **all** questions.

You will be allowed a maximum of one hour to work with the apparatus for Questions 1 and 2, and a maximum of one hour for Question 3. You are advised to spend approximately 30 minutes on Question 4.

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

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

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	/ 16
2	/ 6
3	/ 21
4	/ 12
Total (55m)	

This document contains 20 printed pages, including this cover page.

1 In this experiment you will investigate the behaviour of a sphere rolling across a sloping board.

(a) Place the thread over the top of the board and clip it in place with the spring clip.

Set up the apparatus as shown in Fig. 1.1, with the board at an angle of approximately 45° to the bench. The length of the thread between the spring clip and the sphere should be approximately 20 cm.

Do not remove the clamp from your bench.

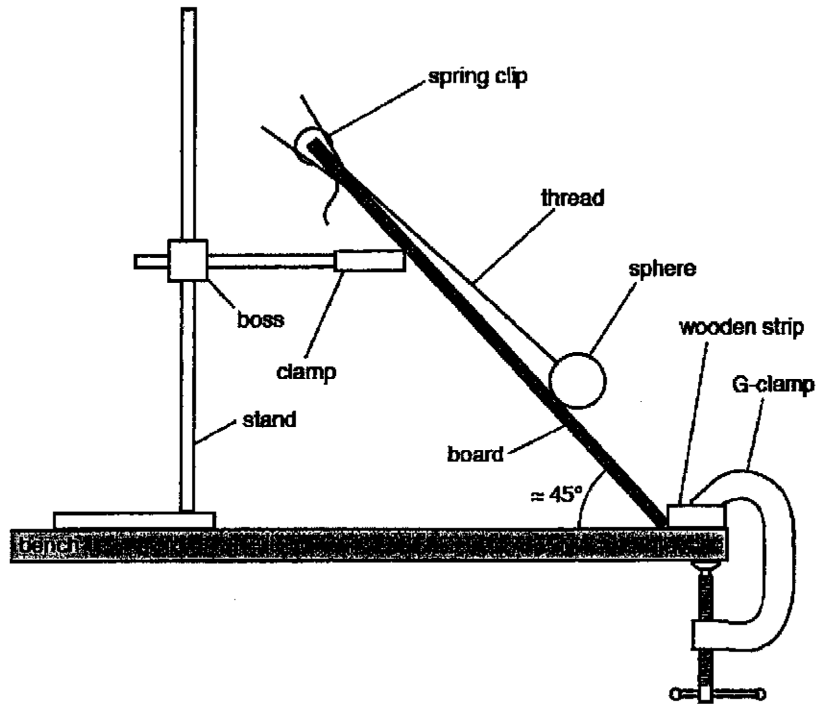


Fig. 1.1 (not to scale)

(b) **(i)** Measure and record the angle θ between the board and the bench, as shown in Fig. 1.2.

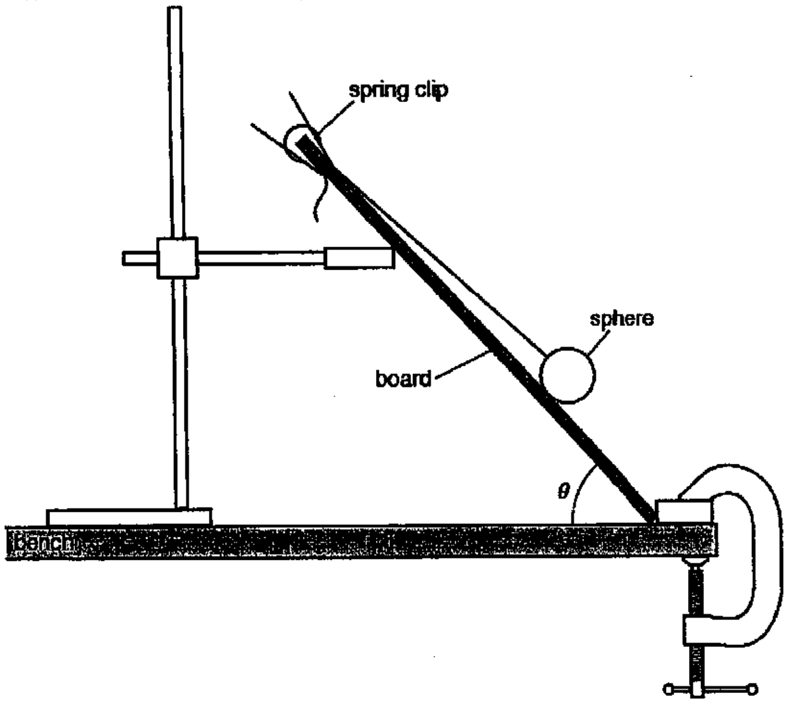


Fig. 1.2 (not to scale)

45° Value of θ from 40° to 50°, to nearest degree, with unit

θ = ... [1]

(ii) Push the sphere to one side. Release the sphere so that it oscillates from side to side.

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

Record T.

For 5 oscillations, $t_1 = 6.14\ s$, $t_2 = 6.32\ s$

$T = \frac{6.14+6.32}{2\times5} = 1.25\ s$

Value of T from 1.0 to 2.0 s, with unit

Evidence of repeat readings

T = ... [2]

(c) Change θ by moving the boss and clamp and repeat **(b)** to take further values of θ and T.

Do **not** change the length of the thread between the sphere and the spring clip.

$\theta/°$	n (no. of osc)	t_1/s	t_2/s	T/s	T^{-3}/s^{-3}
60	5	5.55	5.60	1.12	0.721
55	5	5.66	5.72	1.14	0.679
50	5	5.98	5.98	1.20	0.585
45	5	6.14	6.32	1.25	0.517
40	5	6.67	6.75	1.34	0.414
35	5	6.92	6.93	1.39	0.376

6 readings

θ values must include 35° or less and 55° or more

Column headings with correct presentation and units (column for T not required)

d.p.: t_1 and t_2 to nearest 0.01 s

s.f.: correct s.f. for T^{-3}, depending on s.f. of t_1 and t_2 (same no. or one greater than)

Calculation : T^{-3} calculated correctly

[7]

(d) θ and T are related by the expression

$$\theta = \frac{a}{T^3} + b$$

where a and b are constants.

Plot a suitable graph to determine the values of a and b.

Plot θ against $\frac{1}{T^3}$ where a is the gradient and b the y-intercept

Using points (0.70, 57) and (0.40, 38)

Gradient = $\frac{58.5-36.5}{0.70-0.40}$ = 73.3 [1] (gradient triangle must be more than half the drawn line, coordinates of points read to half a small square)

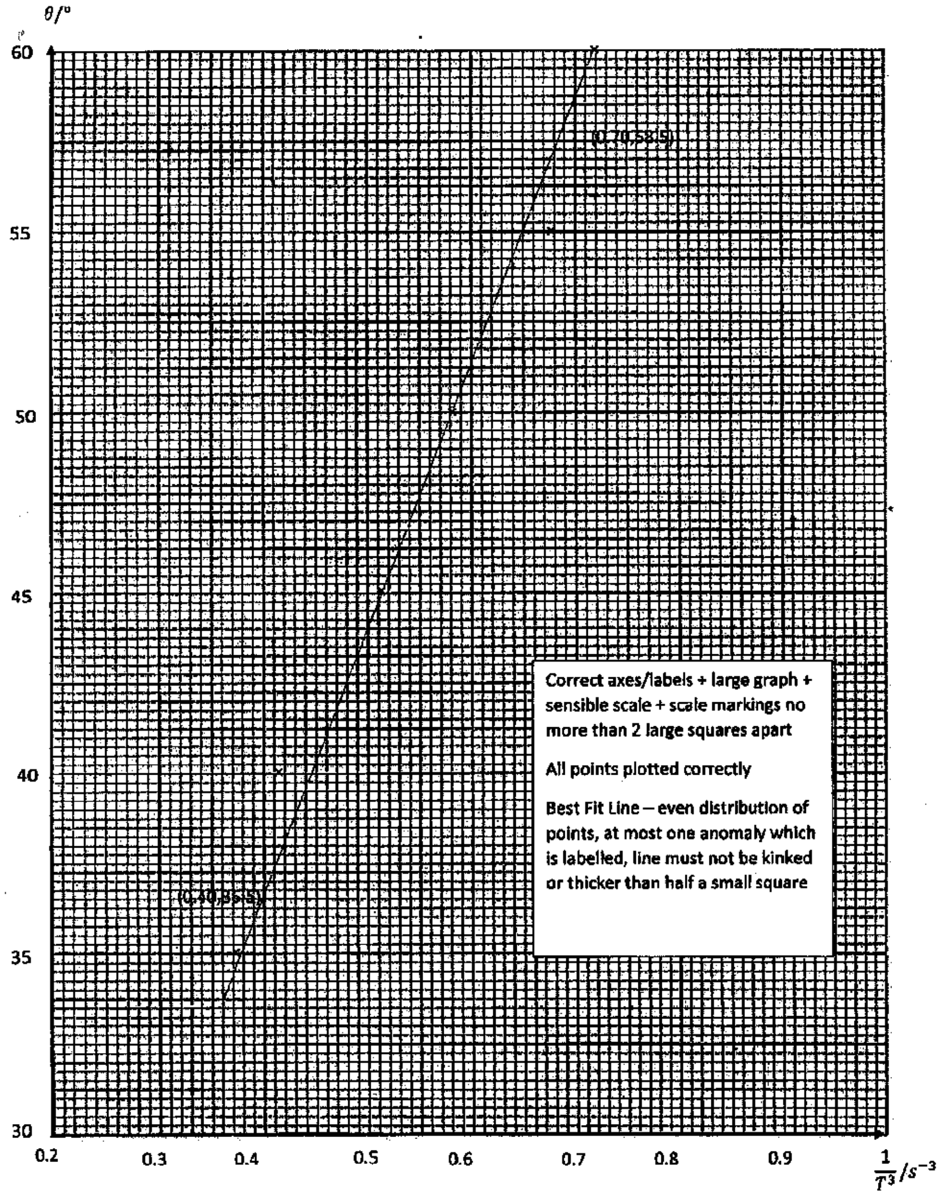
a = 73.3°s^3 correct calculation and units

y-intercept = 58.5 − 0.70 × 73.3 = 7.2 (points used must be read to nearest half a small square)

b = 7.2° correct calculation and units

a = ...

b = ... [6]



[Total: 16]

2 In this experiment you will investigate an electrical circuit.

(a) (i) You have been provided with a resistor A of unknown resistance, an electrical component B and a switch.

Connect the circuit as shown in Fig. 2.1.

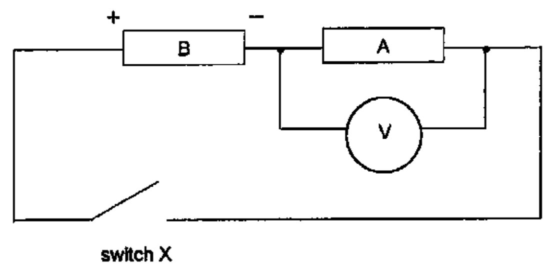


Fig. 2.1

The positive and negative terminals of component B are indicated on component B and **must** be connected as shown in the Fig. 2.1.

(ii) Switch the voltmeter to the 20 V range and close switch X.

(iii) Open switch X when the reading on the voltmeter is 0.01 V or less.

(iv) If the readings for this question needs to be re-taken, you should repeat the procedure starting from **(a)(i)** before taking the readings again.

(b) (i) Connect the battery cell to the circuit as shown in Fig. 2.2.

⚡Switch Y and Switch X must **not** be closed together as this will lead to a short circuit and a large current. ⚡

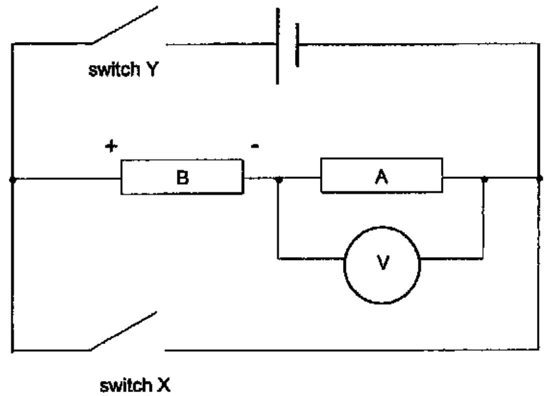


Fig. 2.2

(ii) Close switch Y and start the stopwatch. Switch X must be **open**.

(iii) Record the numerical value of the potential difference V_0 across resistor A when the stopwatch is first started. This should be the highest value observed on the voltmeter when carrying out the steps **(b)(i)** to **(b)(iv)**.

1.44 V

V_0 = ...

(iv) Record the numerical value of the potential difference V across resistor A when the time on the stopwatch reaches 10 s.

Note that the value of the potential difference should be decreasing continuously for the 10 s.

0.22 V (2 d.p. and correct unit)

V = ... [1]

(v) Allow switch Y to be closed for 1 minute.

(vi) Open switch Y.

(c) **(i)** Close switch X and start the stopwatch. Switch Y must be **open**.

(ii) Record the numerical value of the potential difference V_0 across resistor A when the stopwatch is first started. This should be the highest value observed on the voltmeter when carrying out the steps **(c)(i)** to **(c)(iii)**.

1.44 V

V_0 = ...

(iii) Record the numerical value of the potential difference V across resistor A when the time on the stopwatch reaches 10 s.

0.24 V (2 d.p. and correct unit)

V = ... [1]

(d) Theory suggests that

$$V = V_0 e^{-\frac{10000}{R}}$$

where R is the resistance of resistor A and V_0 the e.m.f. of the battery cell.

(i) Calculate the average value of R.

$ln\frac{V}{V_o} = -\frac{10000}{R}$

$R = \frac{-10000}{\ln(V/V_0)}$

1st value of R = $\frac{-10000}{\ln(0.22/1.44)} = 5300\Omega$

2nd value of R = $\frac{-10000}{\ln(0.24/1.44)} = 5600\Omega$

(correct calculation of both values of R)

Average R = $\frac{5300+5600}{2} = 5500\Omega$ (correct calculation of average, 2 to 3 s.f.)

.... [2]

(ii) If you were to repeat this experiment with other battery cells of different e.m.f., describe the graph that you would plot to determine R.

$V = V_0 e^{-\frac{10000}{R}}$

$lnV = lnV_0 - \frac{10000}{R}$ (show linearization)

Plot ln V against ln V_0

.... [2]

[Total: 6]

Question 3 begins on the next page

3 **In this experiment, you will investigate the appearance of a line viewed through a beaker of water.**

(a) You have been provided with an empty beaker.

The thickness of the beaker is *t*.

Measure and record *t*.

$t_1 = 0.192cm$, $t_2 = 0.217cm$

$t = 0.205cm$ (repeated values, t to nearest 0.001 cm, 0.1 to 0.3 cm)

t = ... [1]

(b) **(i)** The outer diameter of the beaker is *d* as shown in Fig. 3.1.

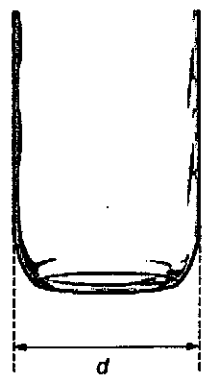


Fig. 3.1

Measure and record *d*.

$d = 6.99\ cm$ (d to nearest 0.01 cm, correct unit)

d = ... [1]

(ii) Calculate the inner diameter *D* of the beaker where

$$D = d - 2t$$

$D = 6.99 - 2 \times 0.205 = 6.58cm$

D = ...

(c) (i) Add water to the beaker until it is approximately three-quarters full.

(ii) The height *h* of water in the beaker is shown in Fig. 3.2.

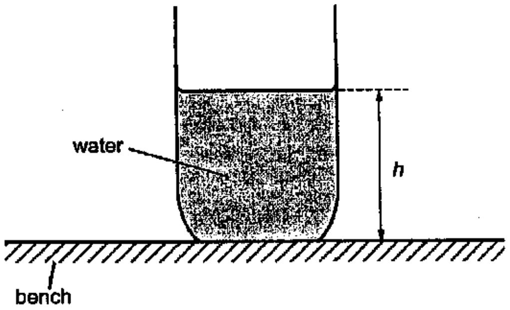


Fig. 3.2

Measure and record *h*.

h = 6.5 cm (h to nearest 0.1 cm, correct unit)

h = ... [1]

(iii) Calculate the approximate volume *V* of water in the beaker using

$$V = \frac{\pi D^2 h}{4}$$

$V = \frac{\pi 6.58^2 \times 6.5}{4} = 220 cm^3$
Correct calculation with correct unit

V = ... [1]

(iv) Justify the number of significant figures that you have given for your value of *V*.

V is calculated using d, t and h.
s.f of h is the smallest which is 2 s.f. Hence V is 2 s.f.

[1]

(d) Draw a straight line of approximate length 25 cm in the centre of the A4 sheet of paper.

(e) (i) Place the beaker centrally on the line as shown in Fig. 3.3.

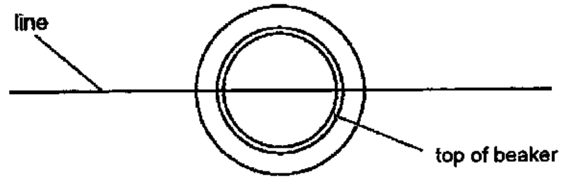


Fig. 3.3

Look down on the beaker from directly above. The line should appear to pass through the centre of the beaker as an unbroken straight line.

(ii) Move your head backwards and forwards.

When viewed through the water, the line (shown dotted) appears to move, as shown in Fig. 3.4.

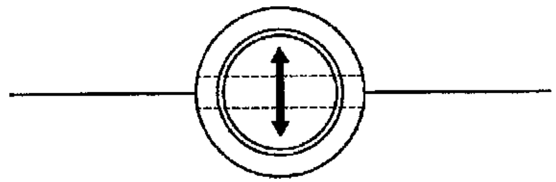


Fig. 3.4

(iii) Place the nails on the line either side of the beaker, as shown in Fig. 3.5.

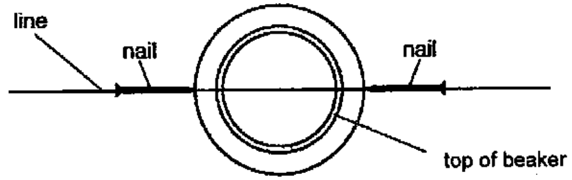


Fig. 3.5

(iv) For a particular height of the nails, the nails and the line viewed through the water appear to move together when you move your head backwards and forwards.

Raise the nails to this height.

(v) The distance between the surface of the water and the nails is *y* as shown in Fig. 3.6.

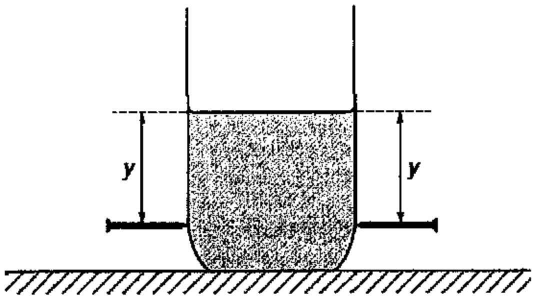


Fig. 3.6

Measure and record *y*.

$y_1 = 4.7\ cm, y_2 = 4.6\ cm$

y = 4.7 cm (repeated data, nearest 0.1 cm, correct unit)

y = ... [1]

(f) Estimate the percentage uncertainty in your value of *y*.

$\Delta y = 0.5\ cm$ (accept from 0.2 to 0.8 cm)

Percentage uncertainty = $\frac{0.5}{4.7} \times 100\% = 11\%$ (2 s.f.)

percentage uncertainty = ... [1]

(g) Pour water out of the beaker until it is approximately half full.

Repeat **(c)(ii)**, **(c)(iii)** and **(e)**.

$h = 4.7\ cm$ (lower value)

$V = 160\ cm^3$ (correct calculation)

$y_1 = 3.5cm$

$y_2 = 3.2\ cm$

$y = 3.4\ cm$ (lower value)

h = ...

V = ...

y = ... [3]

(h) It is suggested that the relationship between *y* and *V* is

$$y = kV$$

where *k* is a constant.

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

$k_1 = \frac{y}{V} = \frac{4.7}{220} = 0.021cm^{-2}$

$k_2 = \frac{y}{V} = \frac{3.4}{160} = 0.021cm^{-2}$

Two values of k calculated correctly (units not required)

first value of *k* = ...

second value of *k* = ... [1]

(ii) State whether your results support the suggested relationship.

Justify your conclusion by referring to your value in **(f)**.

Percentage difference = $\frac{0.021-0.021}{(0.021+0.021)/2} \times 100\% = 0\%$

As the percentage difference is smaller than the percentage error in (f), the relationship is supported.

(Calculation of percentage difference, test against criterion in (f), concluding statement)

.... [1]

(i) (i) Suggest **two** significant sources of errors in this experiment.

1. Too few readings/only 2 readings <u>not enough to draw a valid conclusion</u>

2. Difficult to measure t with reason (curved surface, thickness not the same)

3. Difficult to judge correct position of nails (nails are too thick)

4. Difficult to measure y with reason e.g. holding the nail and rule both in position

[2]

(ii) Suggest **two** improvements that could be made to this experiment to address the sources of errors identified in (i)(i). You may suggest the use of other apparatus or a different procedure.

1. Take more readings (for different volumes) <u>and</u> plot a graph/ take more values of k and compare

2. Use travelling microscope to measure t, take more values of t

3. Use optical pins/thinner nails

4. Have scale on side of jar/ place nails on lab jacks/use marker pen instead of nails/ clamp rule/use a marker to mark position of nail

[2]

(j) The apparent position of the line beneath the beaker depends on the properties of the fluid in the beaker.

It is suggested that, if the water is replaced with a sugar solution, the distance y is inversely proportional to the density ρ of the sugar solution.

Explain how you would investigate this relationship using the same apparatus. You may use additional equipment that can be found in a school laboratory.

Your account should include:

- your experimental procedure
- control of variables
- how you would use your results to show that y is inversely proportional to ρ.

1. Use an electronic balance to measure the mass of the beaker M.
2. Stir some sugar into water and use a measuring cylinder to measure the volume V of the sugar solution. (original method of estimating V is acceptable.)
3. Pour the sugar solution into the beaker until it is about three quarters full and measure the mass of the plastic container and sugar solution using an electronic balance to determine the mass m of the sugar solution.
4. The density of the sugar solution is given by $\rho = \frac{m}{V}$
5. Place the beaker with the sugar solution centrally over the drawn line and repeat the same procedure using the nails to determine the distance y.
6. Pour more sugar into the sugar solution and repeat steps 3 to 5 for 10 more sets of readings.
7. A ruler should be used to check that the height of the sugar solution and its volume stays constant.
8. Tabulate m, V, ρ, y and $\frac{1}{y}$
9. Plot $\frac{1}{y}$ against ρ
10. If a straight line graph passing close to the origin is obtained, y is inversely proportional to ρ.

[5]

[Total:21]

4 A fairground ride carries passengers in chairs which are attached by metal rods to a rotating central pole, as shown in Fig. 4.1. When the pole rotates with angular velocity ω, the rods make an angle θ to the vertical.

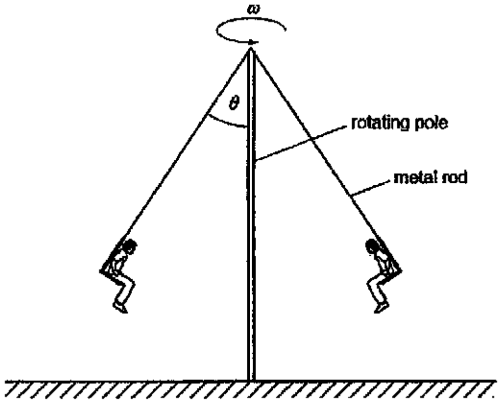


Fig 4.1

It is suggested that

$$\cos\theta = \frac{g}{l\omega^2}$$

where g is the acceleration of free fall and l is a constant.

Design a laboratory experiment, using a small object to represent an occupied chair, to determine the value of l.

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

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

Diagram

....

....

....

....

....

....

....

....

....

....

....

....

....

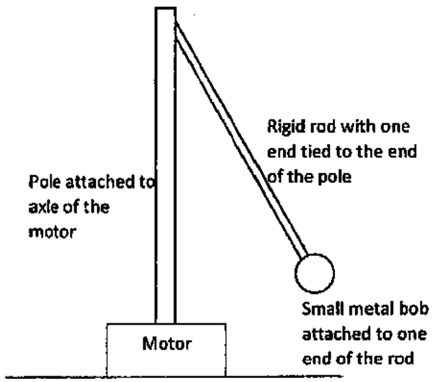
....

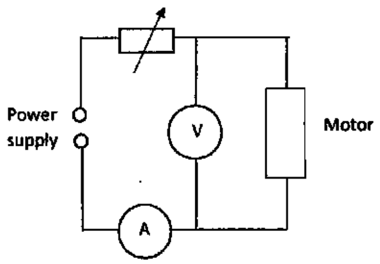
....

....

[12]

- END OF PAPER –





Aim: To determine l

Independent variable: angular velocity ω (*or frequency or period of rotation*)

Dependent variable: angle between rigid rod and pole, θ

Fixed variables: length of rod (ignore reference to mass)

Procedure

1. Set up the apparatus as shown above.
2. Measure the length x of the rigid rod with a metre rule.
3. Measure the height h_0 of the top end of the pole from the bench with a metre rule.
4. Switch on the motor.
5. The metal bob will start to turn. Allow the metal bob to stabilize at a fixed height.
6. Use a metre rule to measure the height h of the metal bob from the bench.
7. Angle θ can be found using the following equation: $\cos\theta = \frac{h_0 - h}{x}$
8. Count a fixed number of revolutions n made by the metal bob and use the stopwatch to record the time t taken for n revolutions.
9. The period T is t/n.
10. The angular velocity $\omega = \frac{2\pi}{T}$.
11. Adjust the power to motor by changing the resistance of the variable resistor to change the angular velocity of the motor and repeat steps 6 to 8 for 10 readings

Analysis

1. Tabulate $h, \cos\theta, T, \omega$ and $1/\omega^2$
2. Plot a graph of $\cos\theta$ against $1/\omega^2$.
3. A straight line passing close to the origin should be obtained, where the gradient = $\frac{g}{l}$ and l can then be calculated from the gradient.

Safety Precautions

1. Use a protective screen in case mass detaches from the pole.
2. Ensure speed of mass is not too fast such that it flies off the pole.

Additional Details

1. Preliminary experiment could be conducted to ensure there is a large motor speed to produce a measurable θ.
2. Projection method, slow motion freeze frame video, camera with detail, i.e. what to measure using these methods to obtain θ
3. $\cos\theta = \frac{h_0 - h}{x}$ or equivalent trigonometric method
4. Use set-square (or other methods) to check pole is vertical
5. Wait for motion to be stable before measurements
6. When measuring angular velocity, at least 10 rotations should be used or timing of rotations should be long enough.
7. When counting rotations, a mark or light gates perpendicular to the motion of objects can be used to assist with the counting and increase accuracy of the timing t.
8. Repeated measurements of timing t could be taken to increase accuracy.