Name:		Centre/Index Number:		Class:	

DUNMAN HIGH SCHOOL
Preliminary Examination
Year 6

H2 PHYSICS

9749/03

Paper 3 Longer Structured Questions

22 September 2022

2 hours

Candidates answer on the Question Paper

READ THESE INSTRUCTIONS FIRST

Write your centre number, index number, name and class at the top of this page.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer any **one** question.

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.

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

For Examiner's Use	
Section A	
1	/ 4
2	/ 10
3	/ 10
4	/ 9
5	/ 8
6	/ 8
7	/ 11
Section B	
8 / 9	/ 20
Total	/ 80

This document consists of **24** printed pages and **2** blank pages.

Data

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

Formulae

uniformly accelerated motion,	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas,	W	=	$p\Delta V$
hydrostatic pressure,	p	=	ρgh
gravitational potential,	ϕ	=	$-Gm/r$
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	=	$v_0 \cos \omega t$
		=	$\pm\omega\sqrt{x_o^2 - x^2}$
electric current,	I	=	$Anvq$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current / voltage,	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire,	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil,	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid,	B	=	$\mu_0 nI$
radioactive decay,	x	=	$x_0 \exp(-\lambda t)$
decay constant,	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

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

1 **(a)** Make estimates of

(i) the mass, in kg, of a wooden metre rule,

mass = …………………… kg [1]

(ii) the volume, in cm^3, of a tennis ball.

volume = …………………… cm^3 [1]

(b) The energy *E* stored in an electrical component is given by

$$E = \frac{Q^2}{2C}$$

where *Q* is charge and *C* is a constant.

Use this equation to determine the SI base units of *C*.

SI base units of *C* = ... [2]

[Total: 4]

2 **(a)** A lump of pure ice floats on pure water in a beaker, as shown in Fig. 2.1.

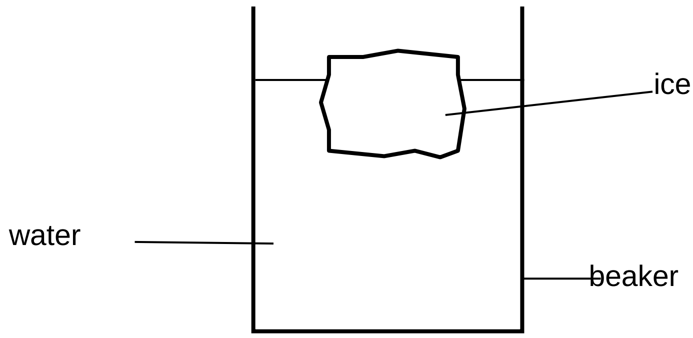

Fig. 2.1

(i) State, qualitatively, the relation between

1. the mass of the ice and the mass of the displaced water,

.... [1]

2. the density of ice and the density of water.

.... [1]

(ii) A student marks the level of water surface in the beaker and then observes the level as the ice melts. State and explain qualitatively the change, if any, in this level during the melting. Ignore the effects of evaporation.

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....

....

.... [3]

(b) A heavy anchor of volume 0.50 m^3 and density 7800 kg m^{-3} lies at the bottom of the seabed. A fisherman intends to use a lifting bag to raise the anchor from the seabed. Take the density of sea water to be 1030 kg m^{-3}.

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

…..…………………………………………………………………………………...

………………………………………………………………………………………….. [1]

(ii) Determine the upthrust acting on the anchor.

upthrust = ………………………………. N [2]

(iii) Determine the volume of air that needs to be released into the lifting bag suddenly in order that the initial acceleration of the anchor is 2.50 m s^{-2}.

volume of air = ………………………………. m^3 [2]

[Total: 10]

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3 A trolley on a track is attached by springs to fixed blocks X and Y, as shown in Fig. 3.1. The track contains many small holes through which air is blown vertically upwards. This results in the trolley resting on a cushion of air rather than being in direct contact with the track.

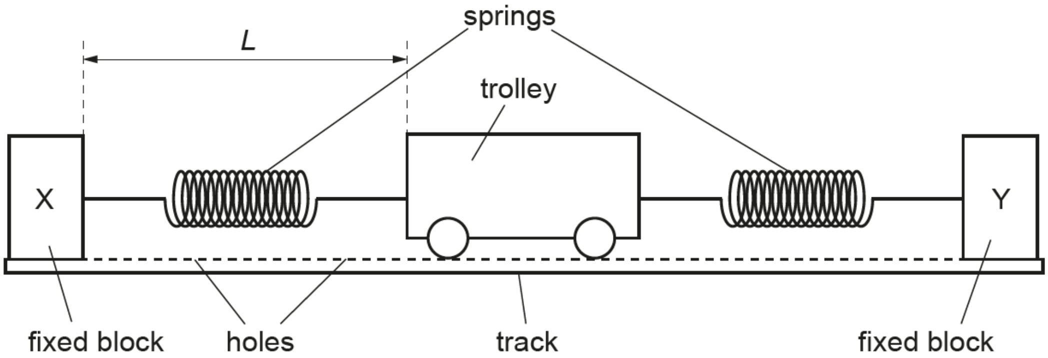

Fig. 3.1

The trolley is pulled to one side of its equilibrium position and then released so that it oscillates initially with simple harmonic motion. After a short time, the air blower is switched off. The variation with time t of the distance L of the trolley from block X is shown in Fig. 3.2.

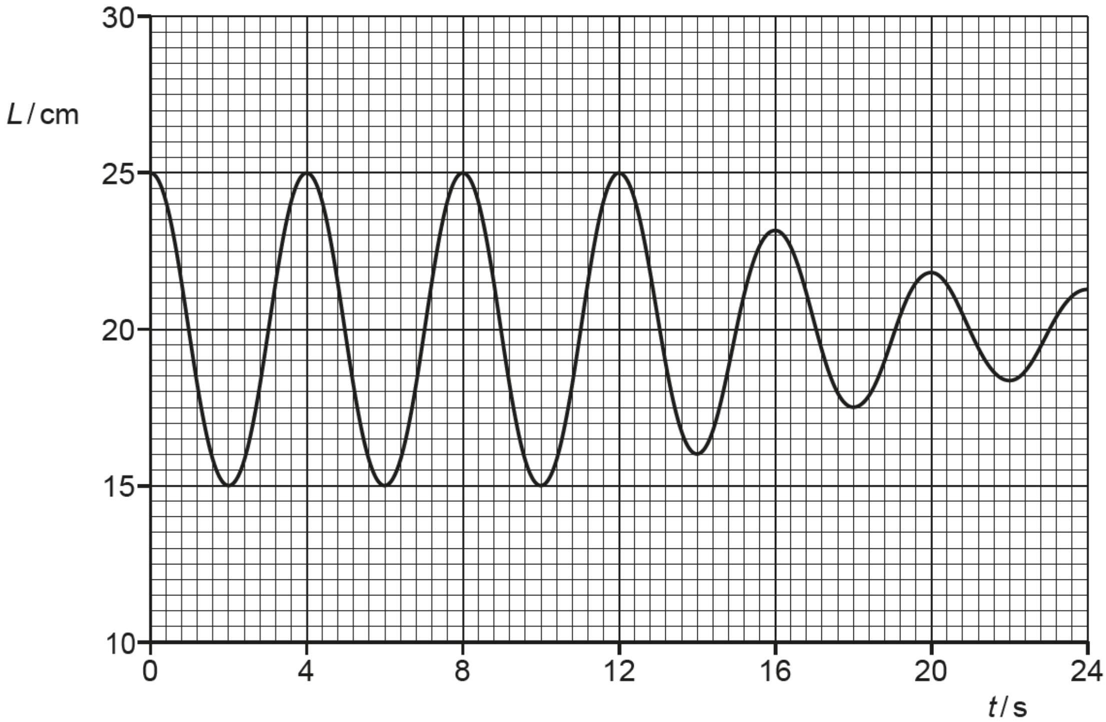

Fig. 3.2

(a) Use Fig. 3.2 to determine:

(i) the initial amplitude of the oscillations,

amplitude = ... cm [1]

(ii) the angular frequency ω of the oscillations,

ω = ... rad s^{-1} [2]

(iii) the maximum speed v_0, of the oscillating trolley.

v_0 = ... cm s^{-1} [2]

(b) Apart from the quantities in **(a)**, describe what may be deduced from Fig. 3.2 about the motion of the trolley between time t = 0 and time t = 24 s. No calculations are required.

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....

.... [3]

(c) On Fig. 3.3, sketch the variation with L of the velocity v of the trolley for its first complete oscillation.

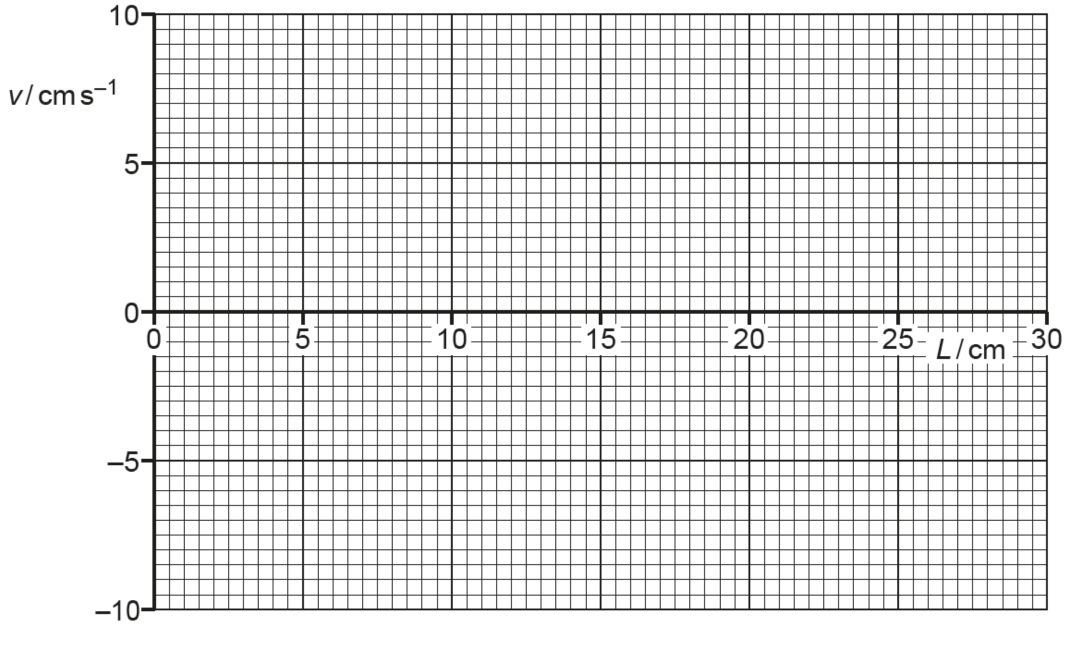


Fig. 3.3

[2]

[Total: 10]

4 An arrangement for producing stationary waves in air in a tube that is closed at one end is shown in Fig. 4.1

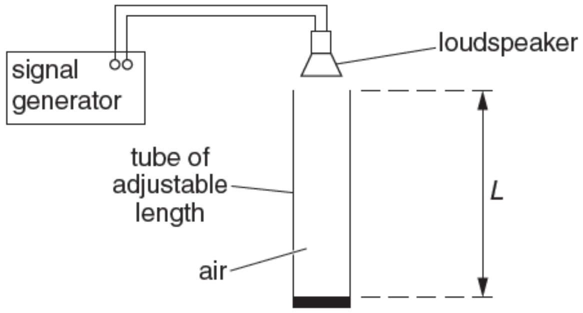


Fig. 4.1

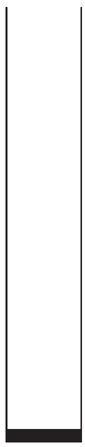
A loudspeaker produces sound waves of wavelength 0.680 m in the tube. For some values of the length L of the tube, stationary waves are formed.

(a) The length L is adjusted between 0.200 m and 1.00 m.

(i) Determine the two values of L for which stationary waves are formed.

L = …………………… m and …………………… m [2]

(ii) On Fig. 4.2, label the positions of all the antinodes with an **A** and the nodes with an **N** for the smallest value of L for which a stationary wave is formed.



[1]

Fig. 4.2

(b) A light wave from a laser has a wavelength of 460 nm in a vacuum. The light is incident normally on a diffraction grating.

Describe the diffraction of the light waves at the grating.

…………………………………………………………………………………………..……………...

…………………………………………………………………………………………..……………...

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

(c) A diffraction grating is used with different wavelengths of visible light. The angle θ of the **fourth**-order maximum from the zero-order (central) maximum is measured for each wavelength. The variation with wavelength λ of $\sin\theta$ is shown in Fig. 4.3.

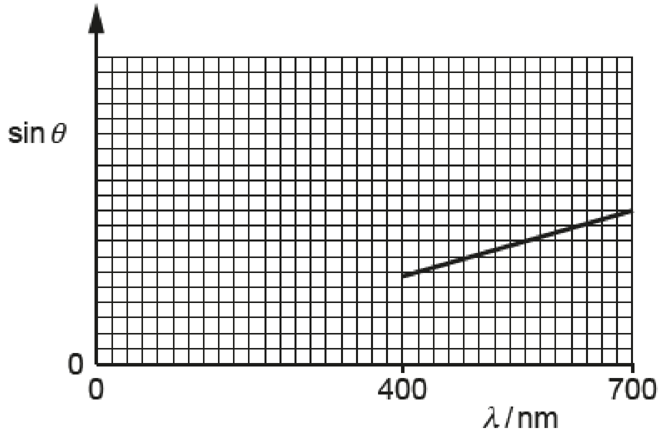


Fig. 4.3

(i) The gradient of the graph is G.
Determine an expression, in terms of G, for the distance d between the centres of two adjacent slits in the diffraction grating.

d = …………………… m [2]

(ii) On Fig. 4.3, sketch a graph to show the results that would be obtained for the **second**-order maxima. [2]

[Total: 9]

5 **(a)** Fig. 5.1 shows a proton moving at velocity v in a uniform magnetic field of flux density B.

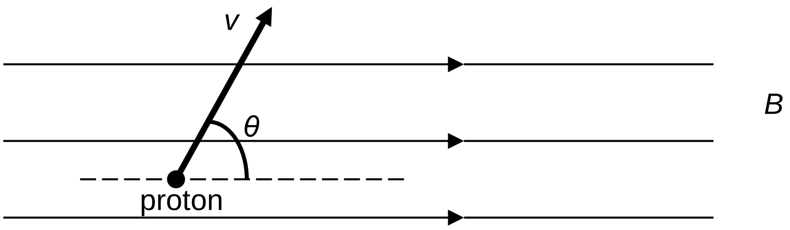


Fig. 5.1

The initial direction of the proton is at an angle θ to the direction of the magnetic field.

By considering the components of the velocity parallel to the magnetic field and at right-angles to the magnetic field, describe and explain qualitatively the motion of the proton in the field.

....

....

....

....

....

....

.... [4]

(b) A *magnetic bottle* may be created in the laboratory using two identical parallel circular coils placed along a central axis passing through the centre of each, as shown in Fig. 5.2.

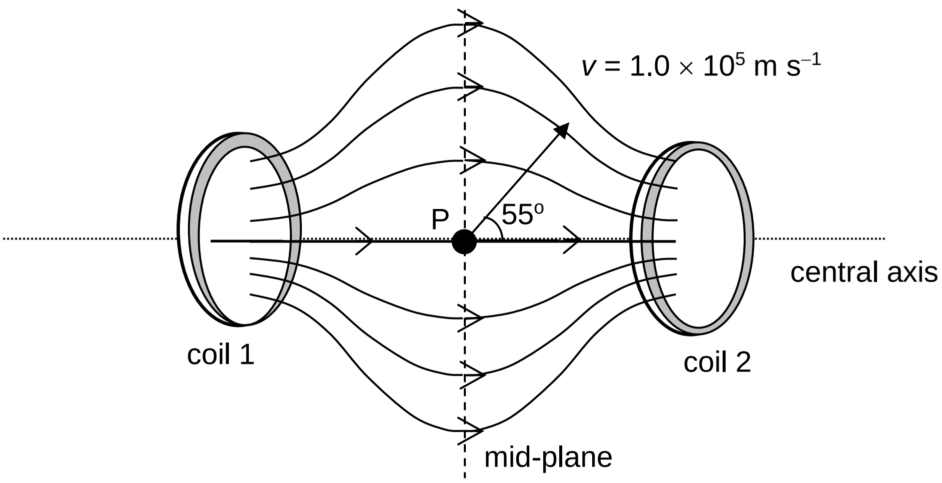


Fig. 5.2 (not to scale)

The magnetic field produced has a minimum value of 3.8×10^{-4} T halfway between the coils (along the mid-plane) and increases symmetrically to a maximum value of 170×10^{-4} T at the locations of the coils.

(i) On Fig. 5.2, draw the direction of the current passing through each coil. [1]

(ii) A proton P was detected moving with a velocity $v = 1.0 \times 10^5$ m s^{-1} at 55^o to the horizontal when it was at the mid-plane and along the central axis of these coils as shown in Fig. 5.2. At that point, the magnetic field line is horizontal.

Calculate the magnitude of the magnetic force acting on the proton at that point.

magnetic force = ……………………… N [2]

(iii) On Fig. 5.3, sketch a graph to show the variation with distance of the magnitude of the magnetic flux density along the central axis between the coils.

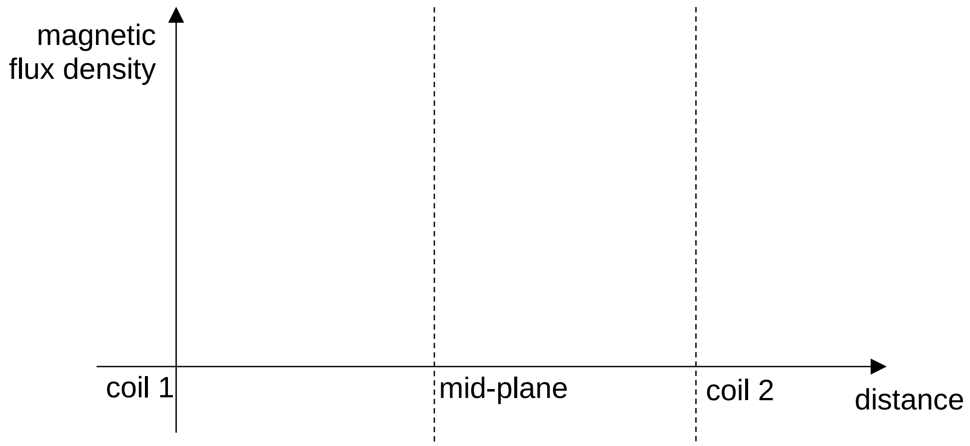


Fig. 5.3

[1]

[Total: 8]

6 **(a)** A solenoid is connected in series with a battery and a switch, as illustrated in Fig. 6.1.

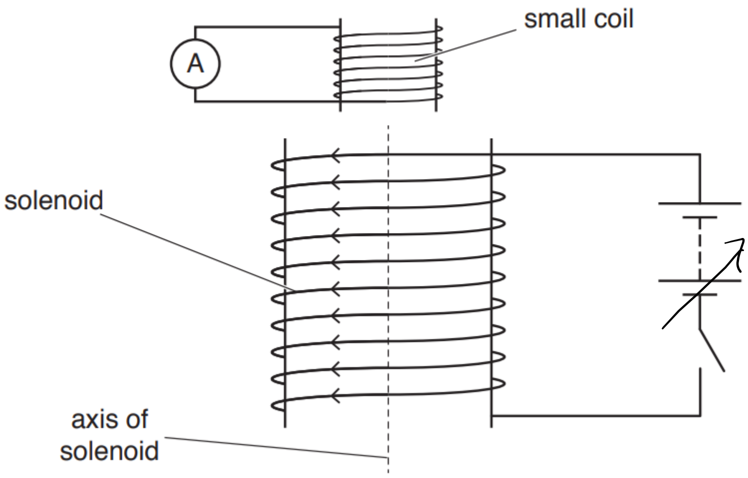


Fig. 6.1

A small coil, connected to a sensitive ammeter, is situated near one end of the solenoid. As the current in the solenoid is switched on, there is a deflection in the ammeter.

(i) State *Lenz's law*.

………………………………………………………………………………………………

………………………………………………………………………………………………

……………………………………………………………………………………………… [1]

(ii) Use Lenz's law to state and explain the direction of the magnetic field in the small coil.

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

……………………………………………………………………………………………… [3]

(iii) On Fig. 6.1, mark the direction of the induced current in the small coil. [1]

(b) The small coil has an area of cross-section 7.0×10^{-4} m^2 and contains 75 turns of wire. A constant current in the solenoid produces a uniform magnetic flux of flux density 1.4mT throughout the small coil. The current is switched off in a time of 0.12s.

Calculate the average e.m.f. induced in the small coil.

e.m.f. = ...V [3]

[Total: 8]

7 **(a)** The ^{226}Ra nucleus undergoes alpha decay according to

$$^{226}_{88}\text{Ra} \rightarrow {}^{222}_{86}\text{Rn} + {}^{4}_{2}\text{He}$$

Data for the nuclei in the reaction are given in Fig. 7.1.

nucleus	mass / *u*
$^{226}_{88}\text{Ra}$	226.0254
$^{222}_{86}\text{Rn}$	222.0176
$^{4}_{2}\text{He}$	4.0026

Fig. 7.1

(i) Show that the energy released in this decay, Q, is 4.86 MeV.

[2]

(ii) This energy, Q, must be shared by the alpha particle and the daughter nucleus.

Use conservation of energy and momentum to show that

$$Q = K_\alpha\left(1 + \frac{M_\alpha}{M}\right)$$

where K_α is the kinetic energy of the alpha particle, M_α is the mass of the alpha particle, and M is the mass of the daughter nucleus.

[3]

(iii) **1.** Hence calculate the kinetic energy of the alpha particle emitted in this decay process.

kinetic energy = ... MeV [2]

2. Comment on your answer in **(a)(iii)1.** with reference to **(a)(i)**.

……………………………………………………………………………………….. [1]

(b) The alpha particle produced in this decay travelled 25 mm in a cloud chamber. Given that, on average, an alpha particle creates 5.0×10^3 ion pairs per mm of track in the cloud chamber, determine the energy required to produce an ion pair.

Energy required to produce an ion pair = ... J [3]

[Total: 11]

Section B

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

8 **(a)** A cube of length L contains N molecules of an ideal gas. A molecule of mass m moves with velocity u towards the face of the box that is shaded in Fig. 8.1.

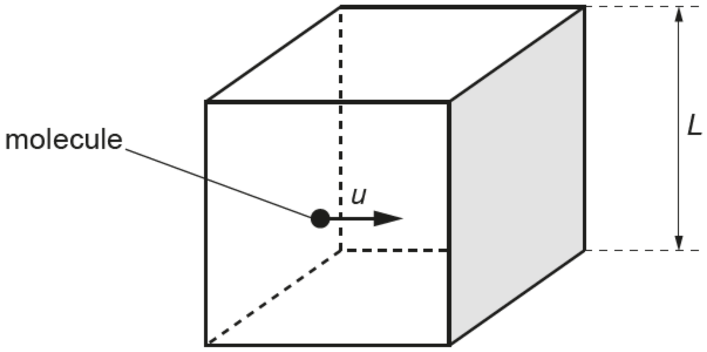


Fig. 8.1

The molecule collides elastically with the shaded face and the face opposite to it alternately.

Deduce expressions, in terms of N, m, u and L, for:

(i) the magnitude of the change in momentum of the molecule on colliding with a face,

change in momentum = ... [1]

(ii) the time between consecutive collisions of the molecule with the shaded face,

time = ... [1]

(iii) the average force exerted by the molecules on the shaded face,

force = ... [1]

(iv) the pressure on the shaded face.

pressure = ... [1]

(b) **(i)** When the model described in **(a)** is extended to three dimensions, it can be shown that

$$pV = \frac{1}{3} Nm <c^2>$$

where p is the pressure exerted by the gas, V is the volume of the gas and $<c^2>$ is the mean square speed of the molecules,

Explain how your answer in **(a)(iv)** leads to the above equation.

[3]

(ii) Use this expression to show that the average translational kinetic energy E_K of a molecule of an ideal gas is given by

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

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

[2]

(c) The mass of a hydrogen molecule is 3.34×10^{-27} kg.

Use the expression for E_K in **(b) (ii)** to determine the root-mean-square (r.m.s.) speed of the molecules of hydrogen gas at 25 °C.

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

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

…..…………………………………………………………………………………………………….

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

(e) The gas in **(a)** is supplied with thermal energy Q.

(i) Explain, with reference to the first law of thermodynamics, why the increase in internal energy of the gas is Q.

…..……………………………………………………………………………………………….

…..……………………………………………………………………………………………….

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

(ii) Define *specific heat capacity.*

…..……………………………………………………………………………………………….

…..……………………………………………………………………………………………….

…..…………………………………………………………………………………………… [1]

(iii) Use the expression in **(b) (ii)** and the information in **(e) (i)** to show that the specific heat capacity c of the gas is given by

$$c = \frac{3k}{2m}$$

[2]

(f) The container in **(a)** is now replaced with one that does not have a fixed volume. Instead, the gas is able to expand, so that the pressure of the gas remains constant as thermal energy is supplied.

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

……………………………………………………………………………………………………

…………………………………………………………………………………………………… [2]

[Total: 20]

9 **(a)** State one similarity and one difference between the fields of force produced by an isolated point charge and by an isolated point mass.

similarity: ……………………………………………………………………………………………

……………………………………………………………………………………………………

difference: ……………………………………………………………………………………………

…………………………………………………………………………………………………… [2]

(b) Two horizontal metal plates are separated by a distance of 1.8 cm in a vacuum.
A potential difference of 270 V is maintained between the plates, as shown in Fig. 9.1.

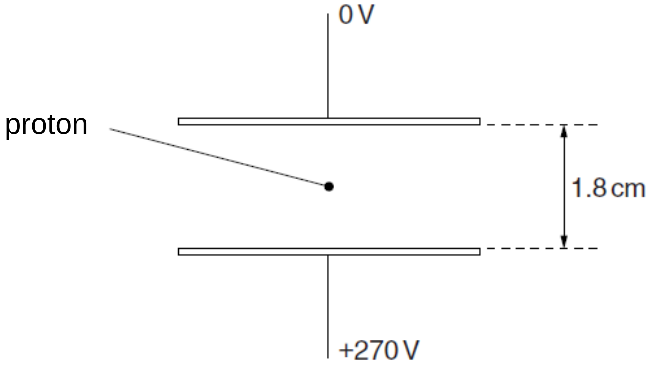


Fig. 9.1

A proton is in the space between the plates.

Explain quantitatively why, when predicting the motion of the proton between the plates, the gravitational field is not taken into consideration.

[4]

(c) Two point charges P and Q are placed 0.120 m apart as shown in Fig. 9.2.

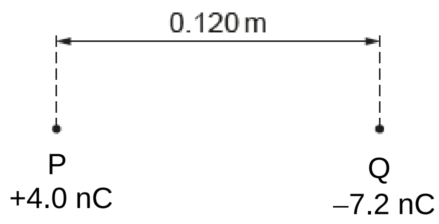


Fig. 9.2

(i) The charge at P is +4.0 nC and the charge at Q is –7.2 nC.

Determine the distance from P of the point on the line joining the two charges where the electric potential is zero.

distance = …………………… m [2]

(ii) State and explain, without calculation, whether the electric field strength is zero at the same point at which the electric potential is zero.

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………………… [2]

(iii) An electron is positioned at point X, equidistant from both P and Q, as shown in Fig. 9.3.

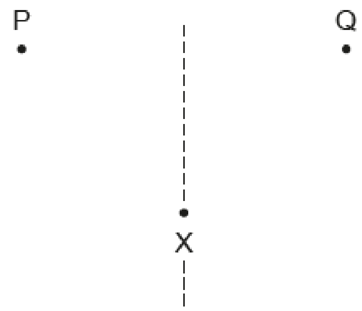


Fig. 9.3

On Fig. 9.3, draw an arrow to represent the direction of the resultant force acting on the electron. [1]

(d) State the relationship between *gravitational potential* and *gravitational field strength*.

………

…… [1]

(e) A moon of mass M and radius R orbits a planet of mass $3M$ and radius $2R$. At a particular time, the distance between their centres is D, as shown in Fig. 9.4.

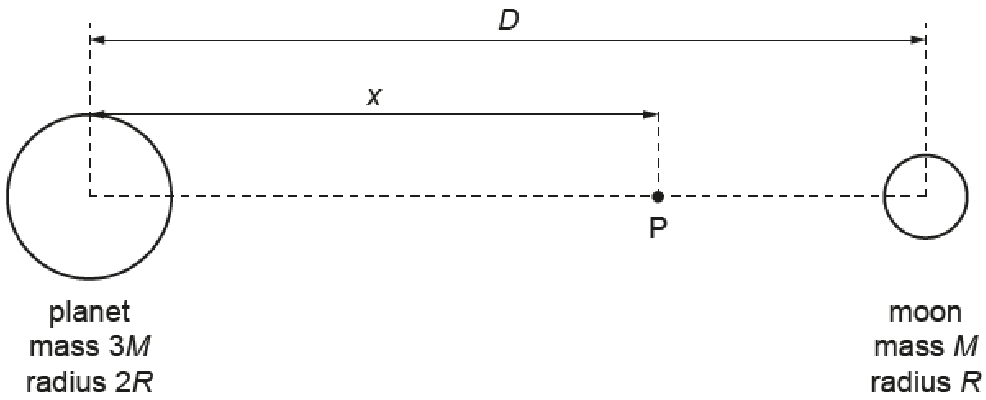


Fig. 9.4

Point P is a point along the line between the centres of the planet and the moon, at a variable distance x from the centre of the planet.

The variation with x of the gravitational potential ϕ at point P, for points between the planet and the moon, is shown in Fig. 9.5.

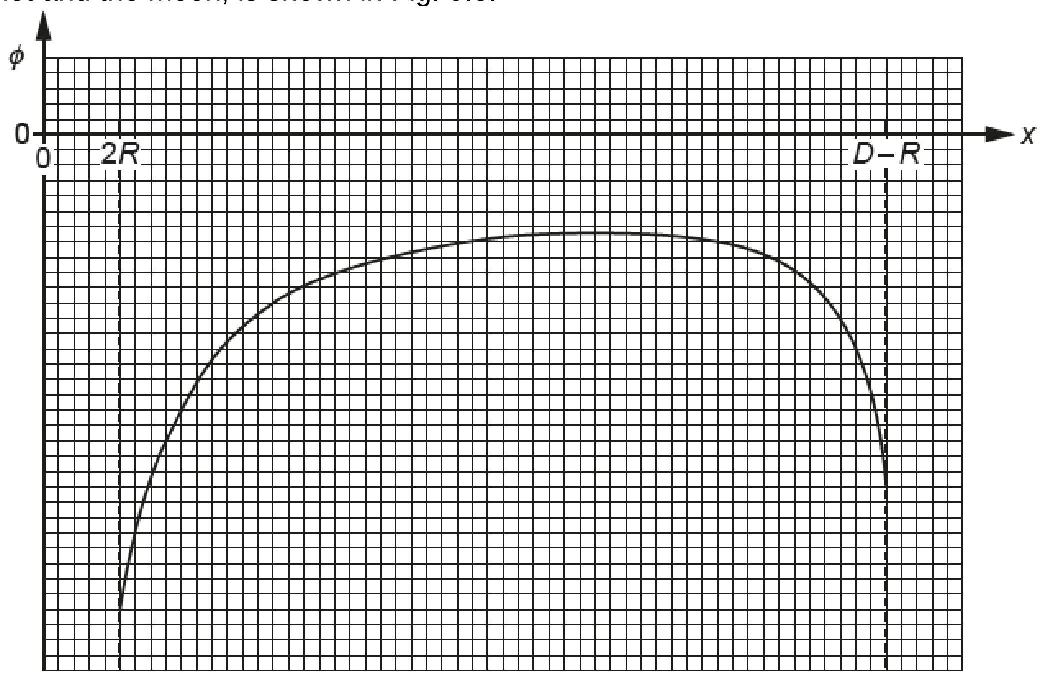


Fig. 9.5

(i) Explain why ϕ is negative throughout the entire range $x = 2R$ to $x = D - R$.

....

....

....

.... [3]

(ii) One of the features of Fig. 9.5 is that ϕ is negative throughout.

Describe two other features of Fig. 9.5.

1. ....

....

2. ....

.... [2]

(iii) On Fig. 9.6, sketch the variation with x of the gravitational field strength g at point P between $x = 2R$ and $x = D - R$.

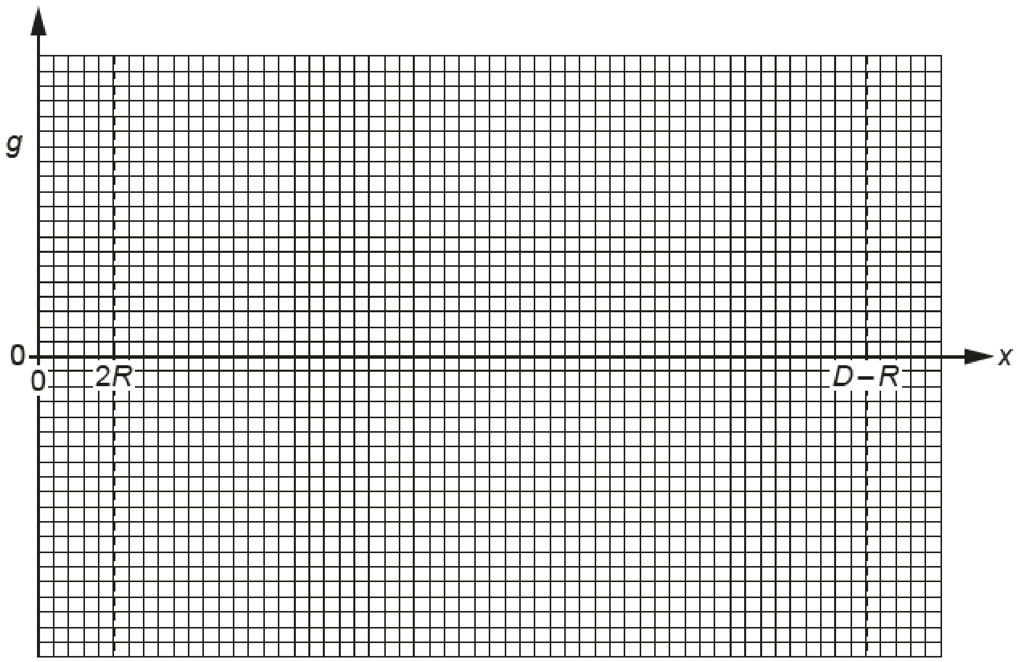


Fig. 9.6

[3]

[Total: 20]

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