Name:		Centre/Index Number:		Class:	

DUNMAN HIGH SCHOOL
Preliminary Examination
Year 6

H2 PHYSICS — 9749/02

Paper 2 Structured Questions

17 September 2021

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.

Answer **all** questions 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.

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

For Examiner's Use	
1	9
2	9
3	9
4	7
5	10
6	11
7	9
8	16
Total	80

This document consists of **21** printed pages and **1** blank page.

Data

speed of light in free space,	$c = 3.00 \times 10^{8}\ \mathrm{m\ s^{-1}}$
permeability of free space,	$\mu_o = 4\pi \times 10^{-7}\ \mathrm{H\ m^{-1}}$
permittivity of free space,	$\varepsilon_o = 8.85 \times 10^{-12}\ \mathrm{F\ m^{-1}}$
	$(1/(36\pi)) \times 10^{-9}\ \mathrm{F\ m^{-1}}$
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	=	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	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

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

1 **(a)** Length, mass and temperature are all SI base quantities.

State two other SI base quantities.

1. ....

2. .... [2]

(b) A small frictionless trolley of mass m is attached to a fixed point A by means of a spring, as shown in Fig. 1.1.

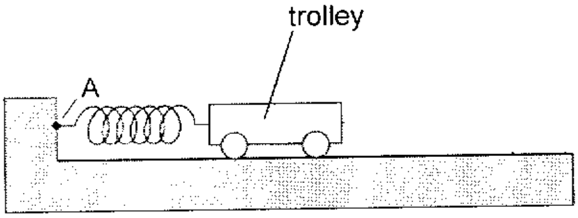

Fig. 1.1

The trolley is then displaced horizontally 5.0 cm and released.

The period T of the oscillations of the trolley is given by

$$T = 2\pi\sqrt{\frac{m}{k}}$$

where k is the spring constant of the spring.

Data for the oscillation is shown in Fig. 1.2.

quantity	magnitude	uncertainty
k / N m^{-1}	25	± 8 %
m / kg	200×10^{-3}	± 2 %

Fig. 1.2

(i) Determine the period T of the oscillations, with its uncertainty. Give your answer to an appropriate number of significant figures.

T = ... ± .... s [4]

(ii) 1. Derive an expression for total energy of the trolley in terms of T.

[2]

2. Calculate the total energy of the trolley using the period calculated in **b(i)**.

total energy = ... J [1]

2 **(a)** State the *principle of conservation of momentum*.

....

....

.... [2]

(b) Two blocks, A and B, are on a horizontal frictionless surface. The blocks are joined together by a spring, as shown in Fig. 2.1.

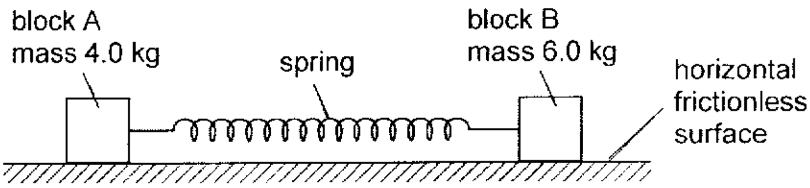

Fig. 2.1

Block A has mass 4.0 kg and block B has mass 6.0 kg. The two blocks are held apart so that the spring has an extension of 8.0 cm. The elastic potential energy of the spring at an extension of 8.0 cm is 0.48 J.

The blocks are released from rest at the same instant. When the extension of the spring becomes zero, block A has speed v_A and block B has speed v_B.

For the instant when the extension of the spring becomes zero,

(i) use the conservation of momentum to show that

$$\frac{\text{kinetic energy of block A}}{\text{kinetic energy of block B}} = 1.5$$

[3]

(ii) use the information in **(b)(i)** to determine the kinetic energy of block A. It may be assumed that the spring has negligible kinetic energy and that air resistance is negligible.

kinetic energy of block A = ...J [2]

(iii) The blocks are released at time = 0.

On Fig. 2.2, sketch a graph to show the variation with time of the momentum of block A, until the extension of the spring becomes zero.

Numerical values of momentum and time are not required.

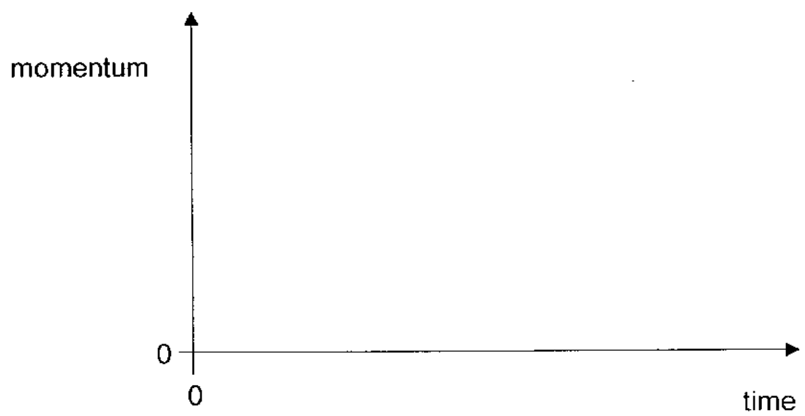

Fig. 2.2

[2]

3 **(a)** A block of mass 0.40 kg slides in a straight line with a constant speed of 0.30 m s^{-1} along a horizontal surface, as shown in Fig. 3.1.

Fig. 3.1

The block hits a spring and decelerates. The speed of the block becomes zero when the spring is compressed by 8.0 cm.

(i) Calculate the initial kinetic energy of the block.

kinetic energy = ... J **[1]**

(ii) The variation of the compression x of the spring with the force F applied to the spring is shown in Fig. 3.2.

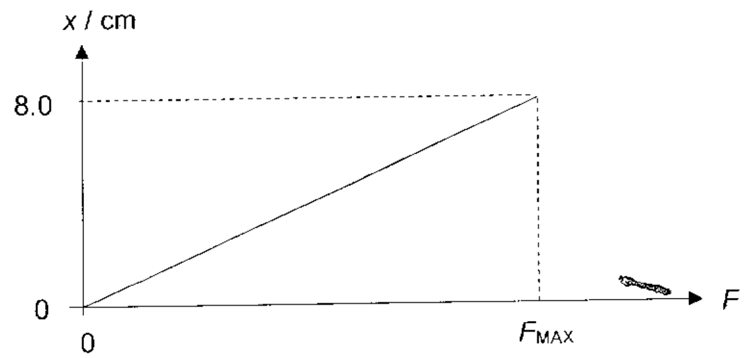

Fig. 3.2

Use your answer in **(a)(i)** to determine the maximum force F_{MAX} exerted on the spring by the block. Explain your working.

F_{MAX} = ...N [3]

(iii) Calculate the maximum deceleration of the block.

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

(iv) State and explain whether the block is in equilibrium

1. before it hits the spring,

....

....[1]

2. when its speed becomes zero.

....

....[1]

(b) The mass m of the block in **(a)** is now varied. The initial speed of the block remains constant and the spring continues to obey Hooke's law.

On Fig. 3.3, sketch the variation of the maximum compression x_0 of the spring with the mass m.

[2]

Fig. 3.3

4 **(a)** Sketch, on Fig. 4.1, a standing wave with 4 antinodes only.

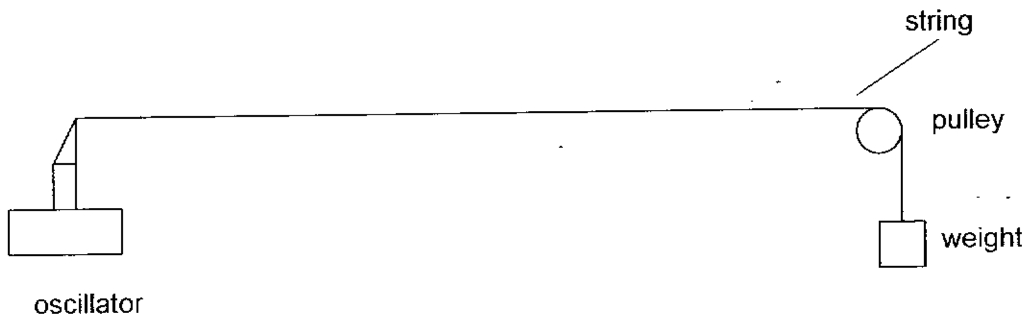

Fig. 4.1

[2]

(b) Draw, on Fig. 4.2, a wave that is 90° out of phase with the wave shown.

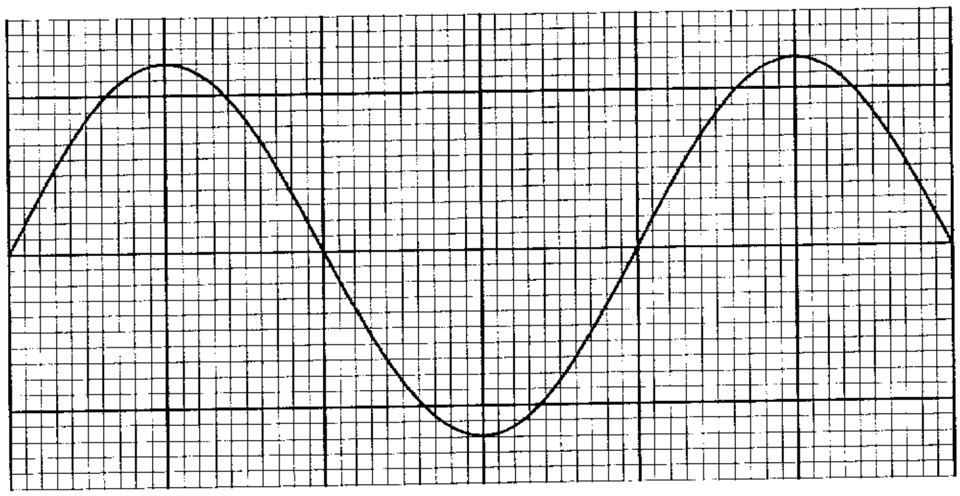

Fig. 4.2

[2]

(c) Sketch, on Fig. 4.3, the diffraction of a plane wave passing through a gap that is smaller than the wavelength of the wave.

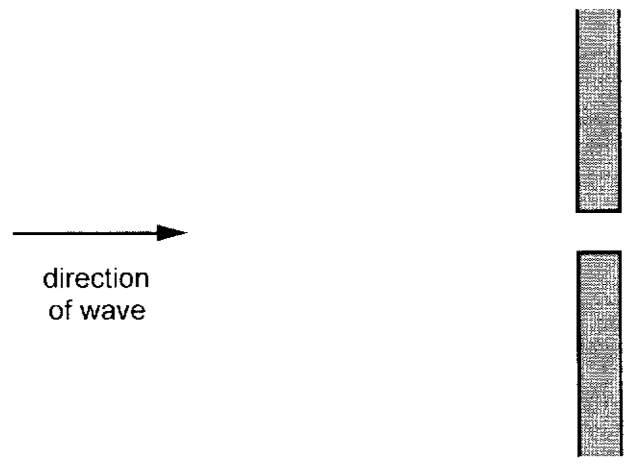

Fig. 4.3

[3]

5 **(a)** A cell of e.m.f. 2.50 V and internal resistance *r* is connected to two resistive wires in series as shown in Fig. 5.1.

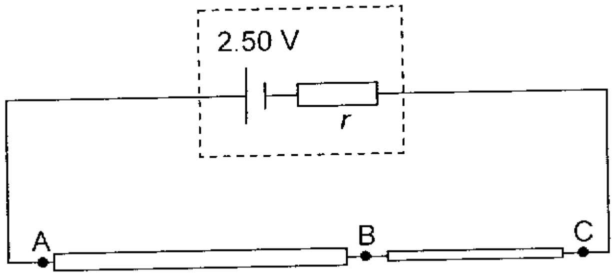

Fig. 5.1

The wires are made of the same material but have different lengths and diameters. Wire AB is 50.0 cm long and has a diameter d, whereas wire BC is 30.0 cm long and has a diameter 0.30 d. The connecting wires are assumed to have no resistance.

Show that $\frac{R_{AB}}{R_{BC}} = 0.15$.

[2]

(b) An ammeter is added to the circuit in **(a)**, along with a voltmeter connected across wire BC as shown in Fig. 5.2.

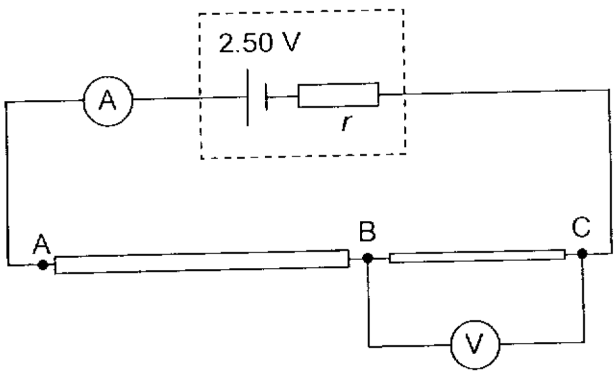

Fig. 5.2

If the ammeter shows a reading of 0.400 A and the voltmeter gives a reading of 2.00 V,

(i) show that the terminal potential difference of the cell is 2.30 V, terminal potential difference = ...V [2]

(ii) determine the internal resistance r of the 2.50 V cell,

r = ...Ω [2]

(iii) calculate the efficiency of the circuit.

efficiency = ...% [2]

(c) Suggest and explain whether your answer in **(b)(ii)** is an overestimate or underestimate if the ammeter is not ideal.

....

....

....[2]

6 An ideal transformer is shown in Fig. 6.1.

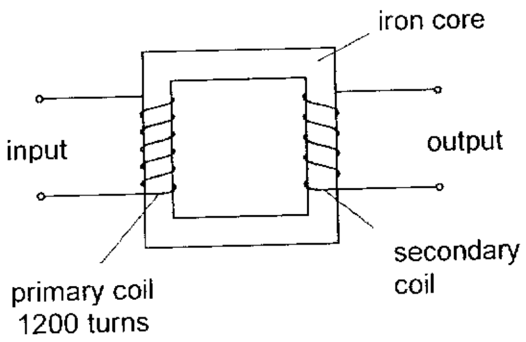

Fig. 6.1

(a) **(i)** State why the transformer has an iron core, rather than having no core.

....

.... [1]

(ii) Explain why an electromotive force (e.m.f.) is not induced at the output when a constant direct voltage is at the input.

....

....

.... [2]

(b) An alternating voltage of peak value 150 V is applied across the 1200 turns of the primary coil. The variation with time t of the e.m.f. E induced across the secondary coil is shown in Fig. 6.2.

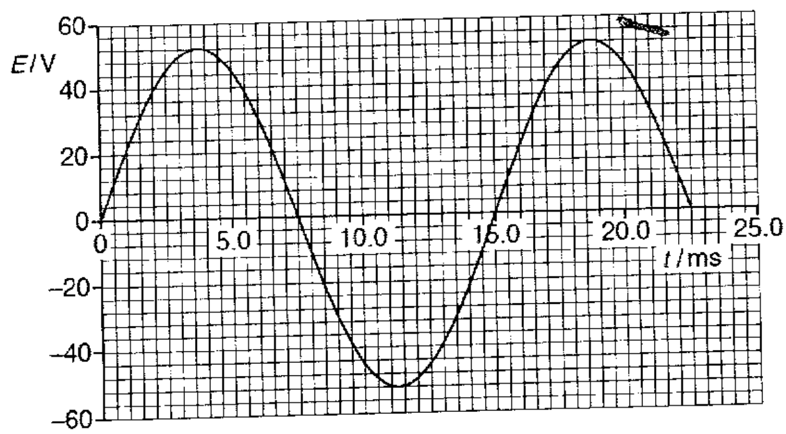

Fig. 6.2

Use the data from Fig. 6.2 to

(i) calculate the number of turns of the secondary coil,

number = ... [2]

(ii) state one time when the magnetic flux linking the secondary coil is a maximum.

time = ... ms [1]

(c) A resistor is connected between the output terminals of the secondary coil. The mean power dissipated in the resistor is 1.2 W. It may be assumed that the varying voltage across the resistor is equal to the varying e.m.f. E shown in Fig. 6.2.

(i) Calculate the resistance of the resistor.

resistance = ... Ω [2]

(ii) On Fig. 6.3, sketch the variation with time t of the power P dissipated in the resistor for t = 0 to t = 22.5 ms.

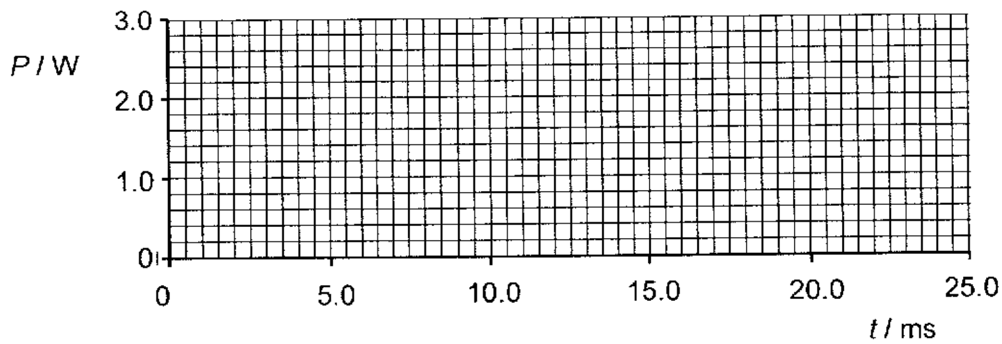

Fig. 6.3

[3]

7 A cyclotron is a device used to accelerate ions to very high speeds. Fig. 7.1 shows a top-view diagram of a cyclotron. It is composed of two hollow, semi-circular electrodes called "Dees". The "Dees" are encased inside a vacuum chamber and exposed to a perpendicular uniform magnetic field. An ion source lies in between the "Dees" at point A. An alternating voltage supply is connected across the "Dees" such that the voltage changes between $+V$ and $-V$ after a constant time duration.

During operation, the voltage supply produces an alternating electric field in the small gap between the "Dees". This is to ensure that the ions are accelerated each time they cross the gap. On entering the "Dees", the uniform magnetic field causes the ions to move in a circular path. As the ions speed up, they travel in ever larger circles within the "Dees". Once the ions reach a sufficiently large speed, they exit through an outlet in one of the "Dees" which is aimed at a target.

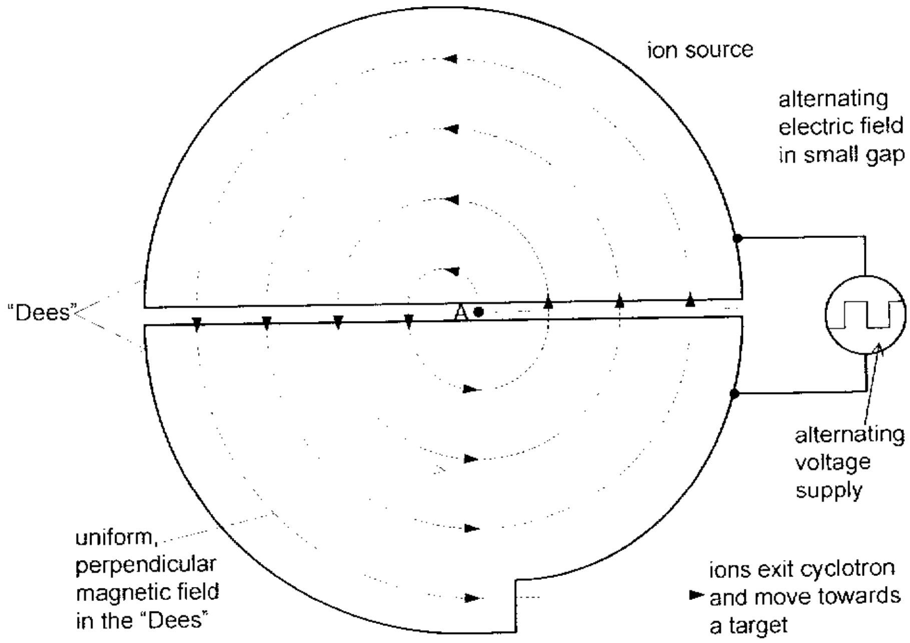

Fig. 7.1

At any time when an ion of mass m and charge q accelerates across the small gap, the potential difference between the "Dees" is V. The ion then travels in a circular path in the "Dees" where a uniform magnetic field of flux density B is applied perpendicularly.

(a) Show that the time T for the ion to complete one revolution in the cyclotron is independent of the radius of its circular path r.

State an assumption you made.

[3]

(b) A helium nucleus of mass 6.68 x 10^{-27} kg and charge $2e$ (where e is the elementary charge) is accelerated in the cyclotron by applying an alternating potential difference of 450 V across the "Dees". The magnetic flux density through the "Dees" is 0.850 T.

(i) Calculate the time T to complete one revolution for the helium nucleus.

T = ...s [2]

(ii) Determine the frequency f of the alternating voltage supply so that the helium nucleus is accelerated each time it crosses the gap between the "Dees". Explain your answer.

f = ...Hz [2]

(iii) Explain why the expression for the gain in kinetic energy of the helium nucleus after one revolution is $4eV$.

....

....

.... [2]

8 When the structure of the Earth near the surface is surveyed in prospecting for oil or minerals, one frequently used method is that of seismic reflection surveying. The process can be very complex because the strata in the Earth's crust are by no means regular, and also the quantity of data that is usually received is very large. Some of the principles behind the practice of seismic reflection surveying are explained and used in this question. The data have, however been simplified.

In a place where there is horizontal change in rock type at a certain depth, an explosion is set off. Fig. 8.1 shows an arrangement of eight detectors (D_1 – D_8) to detect vibrations from the explosion at source S, a short time after the explosion.

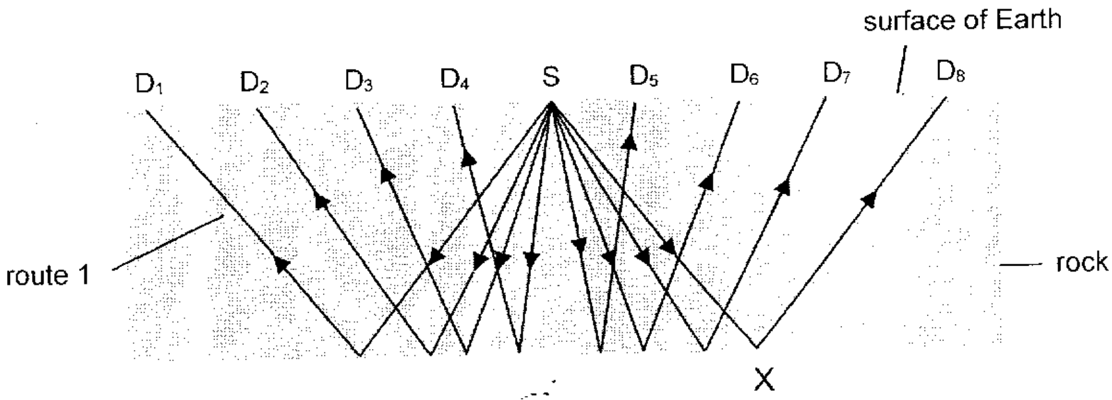

Fig. 8.1

Fig. 8.2 shows the traces received from the eight detectors printed alongside one another. Time t = 0 is the time the explosion commences.

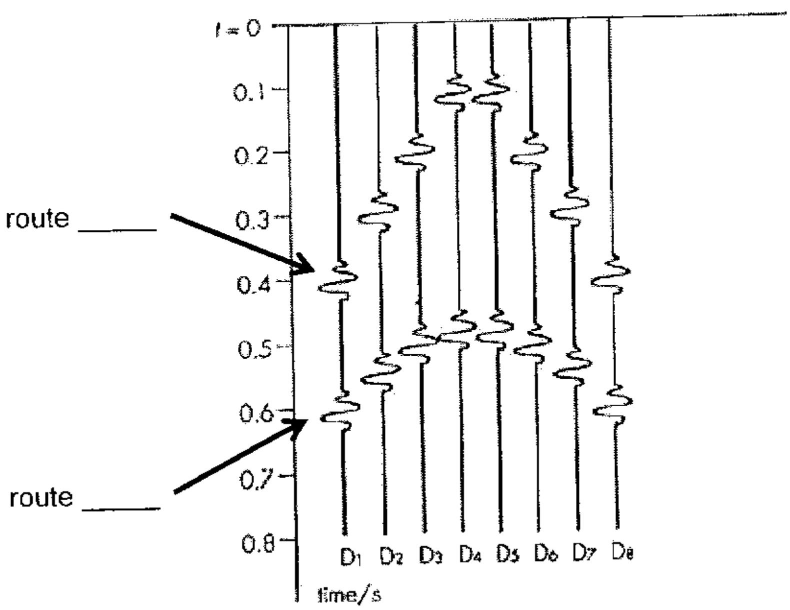

Fig. 8.2

The rock through which the waves are travelling is known to have a density of 2700 kg m^{-3} and in the rock of this density, the speed of P-waves is 3.1 km s^{-1}. P-waves are longitudinal waves and are responsible for the pulses shown in Fig. 8.2.

Answer the following questions, taking data from the diagrams where necessary.

(a) Explain what is meant by a *longitudinal wave*.

....

....[1]

(b) The speed v of a P-wave is given by

$$v = \sqrt{\frac{A}{\rho}}$$

where A is a constant and ρ is the density of the rock.

Determine the value and unit of A.

value = ... [1]

unit of A = ... [1]

(c) Apart from route 1 shown in Fig. 8.1, draw, *on the same figure*, another shorter route P-waves can take to get from S to detector D_1. Label it route 2. [1]

(d) For the detector D_1 shown in Fig. 8.2, indicate the route number corresponding to the two routes in which the P-waves arrive at the detector in **(c)**. [1]

(e) The amplitude for each pulse of the same detector in Fig. 8.2 should **not** be the same. Suggest why this is so.

....

....

....[2]

(f) Determine

(i) the distance SD_8 and

distance = ... km [1]

(ii) the distance SXD_8.

distance = ... km [1]

(g) Use your answer in **(f)** to determine the depth of the rock in Fig. 8.1.

depth = ... km [2]

(h) S-waves are transverse waves and always arrive after the P-waves. In Fig. 8.2, the arrow patterns develop when the eight detectors are used.

(i) Sketch, on Fig. 8.3, the arrow patterns obtained when S-waves, travelling at 2.4 km s^{-1} are added. [2]

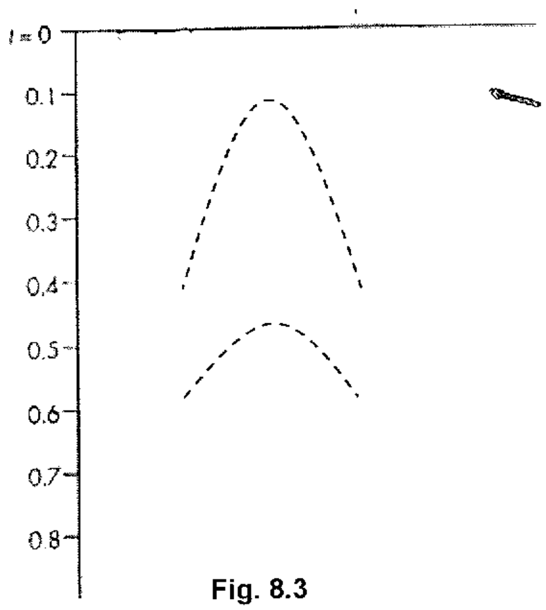

Fig. 8.3

(ii) Sketch, on Fig. 8.5, the arrow patterns obtained when P-waves travelled through a rock of uneven depth as shown in Fig.8.4. [2]

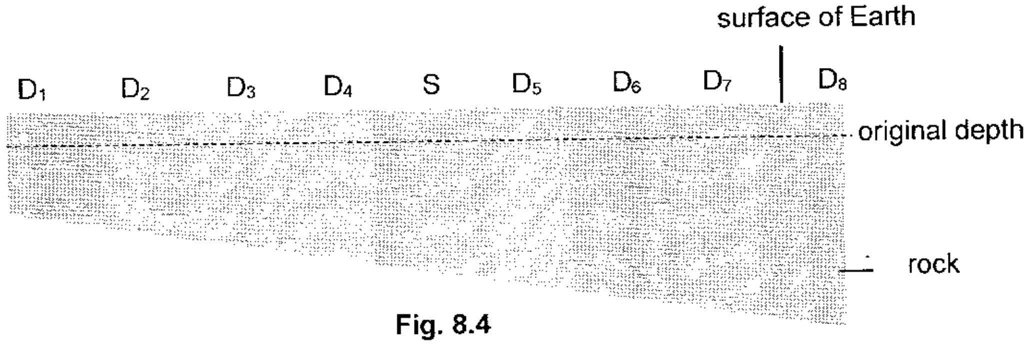

Fig. 8.4

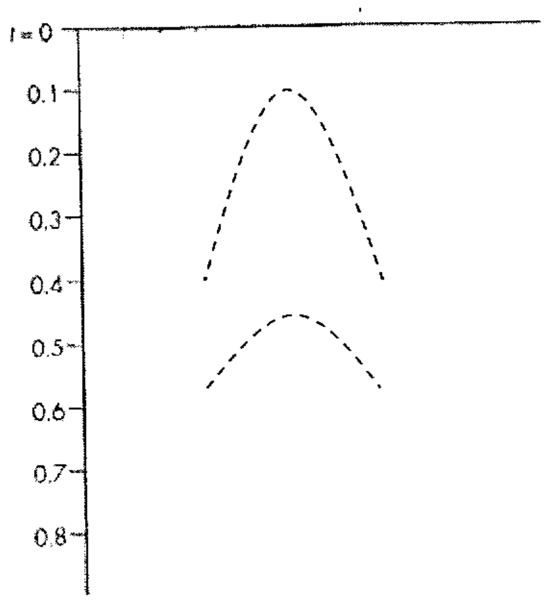

Fig. 8.5

(iii) State another factor, besides the speed of the waves and the depth of the rock, which may affect the traces shown in Fig. 8.2.

....

....[1]

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2021 DHS H2 Physics Prelim Paper 2 Suggested Solutions

1 (a) time **B2**

(electric) current

allow amount of substance

allow luminous intensity

any two of the above quantities, 1 mark each

(b) (i) $T = 2\pi \times \sqrt{\dfrac{200 \times 10^{-3}}{25}}$

= 0.562 s **A1**

percentage uncertainty = (2% + 8%) / 2 (= 5%) **C1**

or

fractional uncertainty = (0.02+0.08) / 2 (= 0.05)

ΔT = 0.562 x 0.05

= 0.028 s **C1**

T = (0.56 ± 0.03) s **A1**

(ii) 1. total energy = max kinetic energy

= ½ (200 x 10^{-3})($2\pi/T$)^2(5.00 x10^{-2})^2 **M1**

= $\dfrac{9.87 \times 10^{-3}}{T^2}$ **A1**

2. total energy = $\dfrac{9.87 \times 10^{-3}}{0.56^2}$

= 3.15 x 10^{-2} J **A1**

2 **(a)** sum / total momentum of bodies is constant **B1**

or

sum / total momentum of bodies before = sum / total momentum of bodies after

for an isolated / closed system / no (resultant) external force **B1**

(b) **(i)** $4.0\ v_A = 6.0\ v_B$ **C1**

$E_K = ½mv^2$ **C1**

$$\text{ratio} = \frac{(0.5)(4.0)(6.0)^2}{(0.5)(6.0)(4.0)^2}$$ **M1**

= 1.5 **A0**

(ii) $0.48 = E_K$ of A + E_K of B

= E_K of A + (E_K of A / 1.5) = 5/3 × E_K of A **C1**

E_K of A = 0.29 (0.288) J **A1**

(iii) curve starts from origin and has decreasing gradient **M1**

final gradient of graph line is zero **A1**

3 **(a)** **(i)** $E_K = ½mv^2$

$= 0.5 \times 0.40 \times 0.30^2$

$= 1.8 \times 10^{-2}$ J **A1**

(ii) (change in) kinetic energy = work done on spring / (change in)

elastic potential energy **C1**

$1.8 \times 10^{-2} = ½ \times F \times 0.080$ **C1**

$F_{MAX} = 0.45$ N **A1**

(iii) a = F / m = 0.45 / 0.40

$= 1.1\ \text{m s}^{-2}$ **A1**

(iv) 1. constant velocity / resultant force is zero, so in equilibrium **B1**

2. decelerating / resultant force is not zero, so not in equilibrium **B1**

(b) curved line from the origin **M1**

with decreasing gradient **A1**

4	(a)	two sine waves in antiphase (one dotted, one solid line)	B1
		4 antinodes and 5 nodes shown	B1
	(b)	a second sine wave of same wavelength on same axis	B1
		separated by a quarter of the wavelength	B1
	(c)	plane parallel wavefronts before the opening	B1
		circular wavefronts showing diffraction after the opening with same wavelength and	B1
		greater than the gap width	B1

5 (a)

$$R = \rho\frac{L}{A} = \rho\frac{L}{\left(\pi d^2/4\right)} = \frac{4\rho}{\pi}\frac{L}{d^2}$$ M1

$$\frac{R_{AB}}{R_{BC}} = \frac{L_{AB}}{d_{AB}^2}\times\frac{d_{BC}^2}{L_{BC}} \quad \text{OR} \quad \frac{L_{AB}}{L_{BC}}\times\frac{d_{BC}^2}{d_{AB}^2}$$

$$= \frac{50.0}{d^2}\times\frac{(0.3d)^2}{30.0}$$ M1

$$= 0.15$$ A0

(b) From **(a)**

(i)

$$\frac{R_{AB}+R_{BC}}{R_{BC}} = \frac{R_{AB}}{R_{BC}}+1$$

$$\rightarrow \frac{R_{AC}}{R_{BC}} = \frac{R_{AB}}{R_{BC}}+1 = 0.15+1 = 1.15$$ C1

$$\rightarrow \frac{V_{AC}}{V_{BC}} = 1.15$$

$$V_{AC} = 1.15(2.00) = 2.30 \text{ V}$$ A1

(ii)

$$E = V_{AC} + Ir$$

$$2.50 = (2.30) + (0.400)r$$ C1

$$r = 0.500\ \Omega$$ A1

(iii)

$$\text{Efficiency} = \frac{IV_{AC}}{IE}\times 100\%$$ C1

$$= \frac{2.30}{2.50}\times 100\% = 92.0\%$$ A1

(c) Over-estimate. 0.20 V is actually the p.d. across the internal resistance cell r as well as that of the ammeter. **B1**

$$E - V_{AC} = I(r + R_A)$$ **B1**

$$r + R_A = 0.500\ \Omega \quad \Rightarrow \quad r < 0.500\ \Omega$$

6 (a) (i) to increase flux linkage (with secondary coil) **B1**

(ii) e.m.f. (induced only) when flux (in core/coil) is changing **B1**

constant / direct voltage gives constant flux / field **B1**

(b) (i) $N_S / N_P = V_S / V_P$
C1

$N_S = (52 / 150) \times 1200$

$= 416$ turns **A1**

(ii) 0 ms or 7.5 ms or 15.0 ms or 22.5 ms **A1**

(c) (i) *either*

mean power = $V^2 / 2R$ and $V = 52$ (V) **C1**

$R = 52^2 / (2 \times 1.2)$

$= 1100\ (1127)\ \Omega$ **A1**

or

mean power = V^2 / R and $V = 52 / \sqrt{2}$ (= 36.8 V) **C1**

$R = 36.8^2 / 1.2$

$= 1100\ \Omega$ **A1**

(ii) sinusoidal shape with troughs at zero power **B1**

only 3 'cycles' **B1**

each 'cycle' is 2.4 W high and zero power at correct times **B1**

7 (a) In the magnetic field, the magnetic force acting on the ion provides the centripetal force for the ion to move in uniform circular motion. Thus **B1**

$$Bqv = \frac{mv^2}{r} \Rightarrow r = \frac{mv}{Bq}$$

Since $T = \frac{2\pi r}{v}$,

$$\therefore T = \frac{2\pi}{v}\left(\frac{mv}{Bq}\right) \Rightarrow T = \frac{2\pi m}{Bq}$$ **B1**

which is independent of r.

Assume that the time taken by the ion to cross the gaps is negligible compared to the time taken by the ion to travel in the magnetic field. **B1**

(b)(i) **C1**

$$\therefore T = \frac{2\pi(6.68 \times 10^{-27})}{0.85 \times 2 \times 1.6 \times 10^{-19}}$$ **A1**

$= 1.54 \times 10^{-7}$ s

(b)(ii) In order for the nucleus to accelerate when it crosses the gap, freq. of the alternating voltage = orbital freq. of the nucleus **B1**

$$\therefore f = \frac{1}{1.54 \times 10^{-7}} = 6.49 \times 10^{6} \text{ Hz}$$ **A1**

(b)(iii) The **work done by the magnetic force on the ion is zero** since the **magnetic force is always perpendicular to the velocity of the ion**. **A1**

Each time the ion crosses the gap, it **gains a kinetic energy of *qV*** due to the work done on it by the electric field given by $Fd = qEd = q(V/d)d$ where F is the electric force acting on the ion, d is the separation between the gaps and E is the strength of the uniform electric field between the gaps. In **one revolution**, the ion will cross the gap **two times**. **A1**

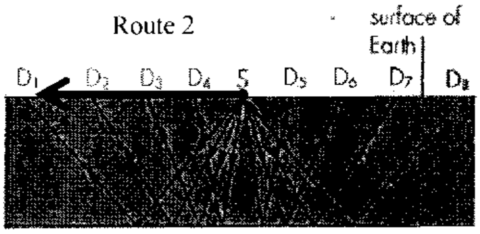
Thus, the total gain in its kinetic energy is $2qV = 4eV$, since the charge of the helium nucleus is $2e$.

8 **(a)** A longitudinal wave is one in which the oscillation of the molecules of the wave is along the direction of transfer of energy of the wave. **A1**

(b) $A = \rho v^2 = (2700)(3100)^2 = 2.59 \times 10^{10}$ **A1**

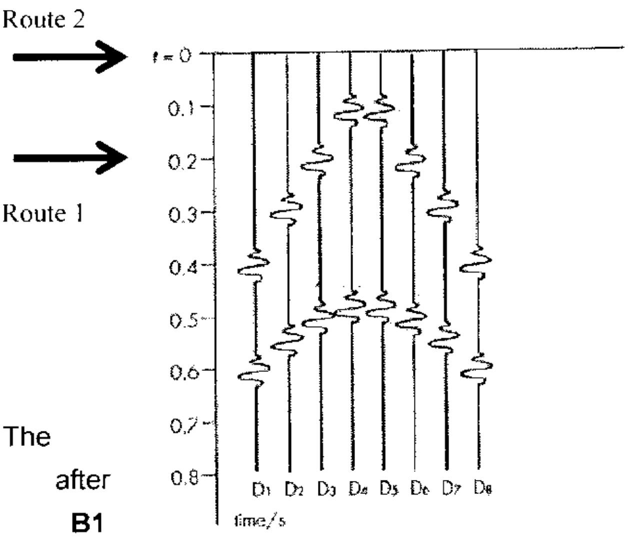
Units of $A = (\text{kg m}^{-3})(\text{m s}^{-1})^2 = \text{kg m}^{-1}\ \text{s}^{-2} = \text{Pa}$ **A1**

(c)



A1

(d)



A1

(e) The waves should be weaker after traveling longer distances, **B1** hence direct waves should show larger amplitude than reflected waves. **B1**

(f) **(i)** SD_8, $t = 0.40$ s

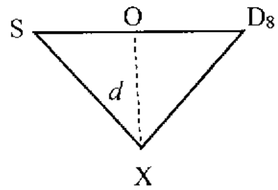
$SD_8 = (3.1)(0.40) = 1.24$ km **A1**

(ii) SXD_8, $t = 0.60$ s

$SXD_8 = (3.1)(0.60) = 1.86$ km **A1**

(g) Assume SX = XD_8

Using Pythagoras Theorem,



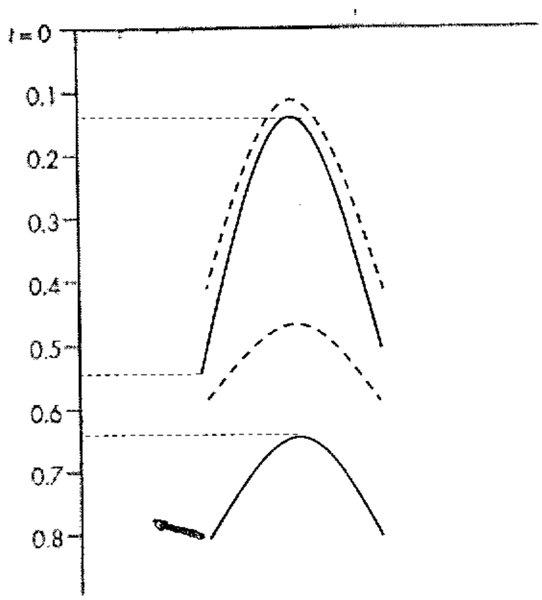
depth d = $\sqrt{(XD_8)^2 - (OD_8)^2}$

$= \sqrt{\left(\frac{SXD_8}{2}\right)^2 - \left(\frac{SD_8}{2}\right)^2}$ **M1**

$= \sqrt{\left(\frac{1.89}{2}\right)^2 - \left(\frac{1.27}{2}\right)^2}$

= 0.70 km **A1**

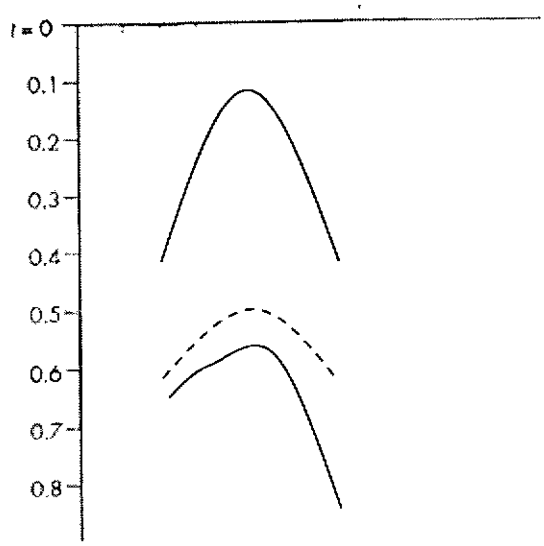
(h) (i)



Graph is lower, **B1**

Any peak value at a time factor about (3.1/2.4) = 1.3 times later **B1**

(ii)



Top graph is same, **B1**

Lower graph is lower and asymmetric as shown **B1**

(iii) Any one of the following:

- An extra layer of rock halfway down that can cause partial reflection
- Double reflection before reaching detector
- Some refraction takes place at intermediate level

(as a result of density changes) **B1**

- THE END -