TAMPINES MERIDIAN JUNIOR COLLEGE

JC2 MID-YEAR EXAMINATION

CANDIDATE NAME	( )
CIVICS GROUP	

H2 PHYSICS 9749

28 June 2024

2 hours 30 mins

Candidates answer on the Question Paper.

No Additional Materials are required.

Section B: Structured Questions

READ THESE INSTRUCTIONS FIRST

Write your name and Civics Group in the spaces at the top of the page.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.
The use of an approved scientific calculator is expected, where appropriate.

Answer **all** questions.

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

You are to spend **2 hours 30 mins** on Section B.

For Examiner's Use		Percentage
Section A	/ 15	
Section B		
1	/ 10	
2	/ 10	
3	/ 9	
4	/ 16	
5	/ 10	
6	/ 10	
7	/ 15	
8	/ 10	
9	/ 10	
Deductions		
Subtotal Section A&B	/ 115	/ 100

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
		=	$(1/(36\pi)) \times 10^{-9}$ 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	=	$-\dfrac{GM}{r}$
temperature	T /K	=	T /°C + 273.15
pressure of an ideal gas	p	=	$\dfrac{1}{3}\dfrac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	E	=	$\dfrac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
		=	$\pm\, \omega\sqrt{x_o^{\,2} - x^2}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential	V	=	$\dfrac{Q}{4\pi\varepsilon_0 r}$
alternating current / voltage	X	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\dfrac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\dfrac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\dfrac{\ln 2}{t_{\frac{1}{2}}}$

Section B: Structured Questions

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

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

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(b) A moon is in a circular orbit of radius *r* about a planet of mass *M*.

Assume that the planet and the moon are point masses isolated in space.

Show that the orbital period *T* of the moon is given by the expression

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

where *G* is the gravitational constant. Explain your working.

[2]

(c) Fig. 1.1 shows the planet Mars and the orbits of its two moons, Phobos and Deimos. Deimos has an orbital radius of 23 500 km and takes 30.3 hours to orbit Mars, while Phobos takes 7.7 hours to orbit Mars. Assume the moons orbit Mars with circular orbits.

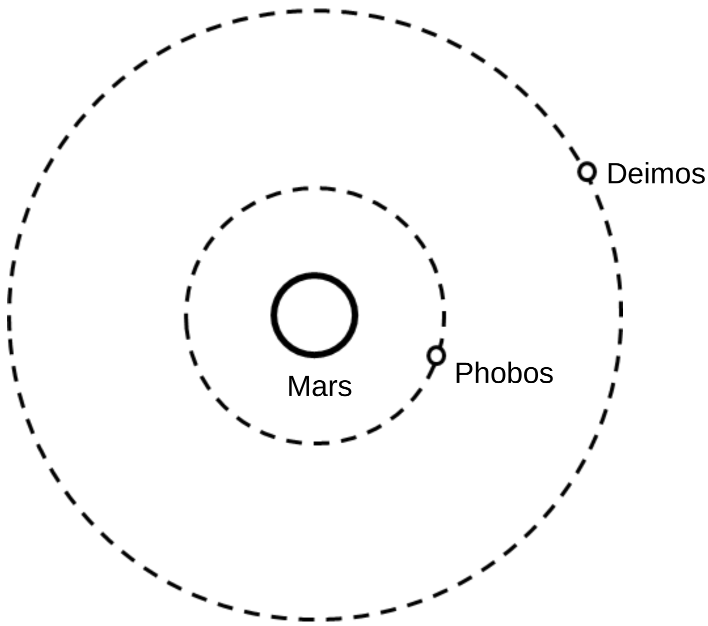


Fig. 1.1 (not to scale)

(i) Determine the orbital radius of Phobos.

orbital radius = ……………………. m [2]

(ii) Hence, or otherwise, determine the orbital speed of Phobos.

orbital speed = ………………… m s^{-1} [2]

(d) The mass of Phobos is 9.6×10^{15} kg and the mass of Mars is 6.4×10^{23} kg.

Determine the total energy of Phobos in its circular orbit around Mars.

total energy = ………………… J [2]

(e) The total energy of Phobos is gradually decreasing due to a gravitational interaction between Phobos and the surface of Mars.

State how this decrease in the total energy will affect the kinetic energy of Phobos.

……………………………………………………………………………………………

……………………………………………………………………………………………

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

2 An experiment set-up to determine the speed of sound in air is shown below in Fig. 2.1. A loudspeaker connected to a variable frequency signal generator produce sound waves that are directed towards a metal reflector. A microphone connected to a C.R.O is used to detect positions of nodes and antinodes.

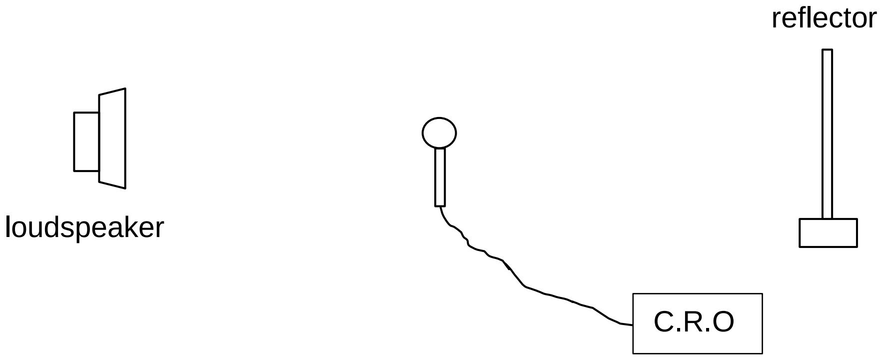


Fig. 2.1

(a) Explain why a stationary wave is formed between the loudspeaker and reflector.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(b) Explain why a node is formed at the position of the reflector.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(c) It is assumed that an antinode is formed at the position of the loudspeaker.

On Fig. 2.1, sketch a possible stationary wave profile with the position of the microphone being a node.

[2]

(d) At a certain frequency, the microphone detected two adjacent nodes to be 0.200 m apart. When the frequency increased by 480 Hz, the distance between two adjacent nodes decreased to 0.125m.

Calculate the speed of sound in this experiment.

speed = ……………… m s^{-1} [3]

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

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

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

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

(b) A liquid of mass 3.6 kg and specific heat capacity 156 J kg^{-1} K^{-1} is heated from its initial temperature of 60 °C until it just reaches its boiling point temperature of 86 °C. The mass and volume of the liquid remains constant during the heating.

(i) Calculate the heat supplied to the liquid.

heat supplied = ………………… J [2]

(ii) State the increase in internal energy of the liquid.

increase in internal energy = ………………… J [1]

(c) The liquid in **(b)** is heated at its boiling point until all the liquid is turned into vapour. The process takes place at a constant atmospheric pressure of 1.01×10^5 Pa. The density of the liquid and the vapour is 840 kg m^{-3} and 65 kg m^{-3} respectively. The specific latent heat of vaporisation is 1.32×10^4 J kg^{-1}.

For this boiling process,

(i) calculate the work done against the atmosphere.

work done = ………………… J [2]

(ii) determine the increase in internal energy.

increase in internal energy = ………………… J [2]

4 **(a)** Distinguish between electromotive force (e.m.f.) and potential difference (p.d.).

………………………………………………………………………………………………

………………………………………………………………………………………………

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

(b) An ideal battery of e.m.f. 2.0 V is connected to a resistor of resistance *R* and a resistor of resistance *S* as shown in Fig. 4.1.

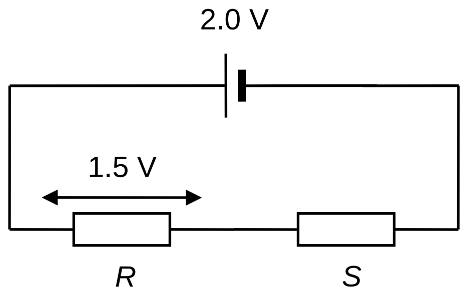


Fig. 4.1

The p.d. across *R* is 1.5 V. A charge of 4.0 C flows in the circuit for 25 s.

During the 25 s,

(i) calculate the chemical energy converted to electrical energy,

energy = ………………… J [2]

(ii) calculate the rate of heat generated in *R*,

rate of heat generated = ………………… W [2]

(iii) show that the resistance of S is $\frac{R}{3}$.

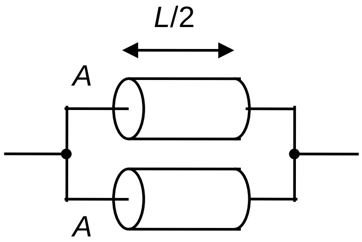
………………………………………………………………………………………

……………………………………………………………………………… [2]

The resistor R is a solid cylinder of cross-sectional area A and length L as shown in Fig. 4.2.

Fig. 4.2

The cylinder is cut in half, with each half of cross-sectional area A and length $L/2$. The halves are connected in parallel as shown in Fig. 4.3. The effective resistance of the combination is R_2.



effective resistance R_2

Fig. 4.3

(iv) Express the resistance R_2 in terms of R.

R_2 = ………………… [2]

(v) The resistor R in Fig. 4.1 is replaced by the combination R_2.

Calculate the p.d. across R_2.

p.d. = ………………… V [2]

(c) In the circuit shown in Fig. 4.4, the resistance wire XY has length 100 cm. The driver cell has e.m.f. 9.0 V and negligible internal resistance. The secondary cell has e.m.f. 5.0 V and negligible internal resistance. The galvanometer shows no deflection when the movable jockey J is placed a distance L_{XJ} from X.

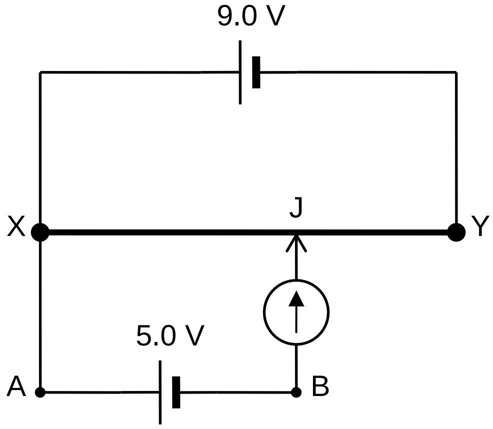


Fig. 4.4

(i) Calculate the balance length L_{XJ}.

length L_{XJ} = ………………… cm [2]

(ii) If the secondary cell has some internal resistance, state the effect of the internal resistance on the balance length L_{XJ}: does the length increase, decrease or stay the same.

……………………………………………………………………………………… [1]

(iii) The secondary cell acquires an internal resistance r. A resistor of resistance 3.0 Ω is connected to the secondary cell as shown in Fig. 4.5.

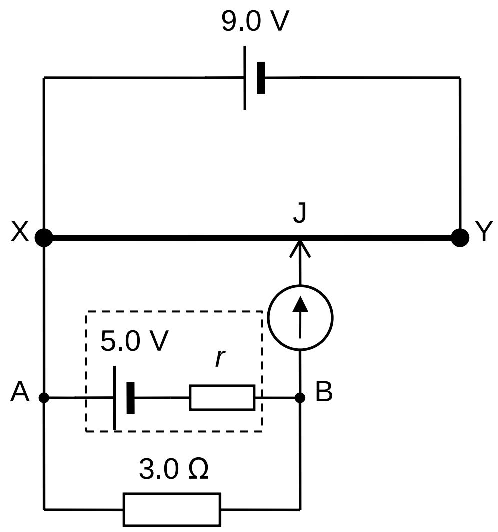


Fig. 4.5

The balance length L_{XJ} is found to be 39.7 cm.

Calculate r.

r = ………………… Ω [2]

5 Two vertical parallel plates, each of length 8.0 cm, are set 0.50 cm apart in a vacuum as shown in Fig. 5.1. One of the plates is at a potential of +300 V while the other plate is at a potential of −300 V.

An electron of speed 3.1×10^7 m s^{-1} enters the uniform electric field vertically, midway between the plates.

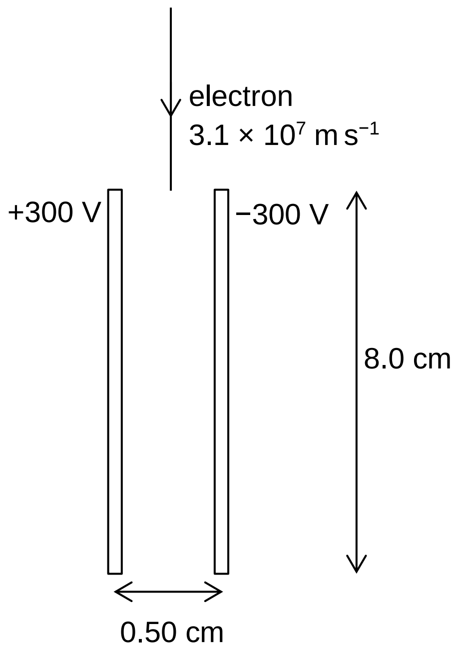


Fig. 5.1 (not to scale)

(a) On Fig. 5.1, sketch 5 arrows to represent the electric field lines within the plates.

[1]

(b) Show that magnitude of the electric field strength between the plates is 1.2×10^5 V m^{-1}.

[1]

(c) Calculate, with clear working, the speed of the electron when it hits one of the plates.

Explain, with suitable calculations, why the effect of gravitational field is not considered in your solution.

……………………………………………………………………………………………

……………………………………………………………………………………………

speed = ………………… m s^{-1} [5]

(d) Describe the motion of the electron in terms of its acceleration and velocity within the region of the electric field.

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……………………………………………………………………………………………

……………………………………………………………………………………………

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

(e) Without further calculation, predict one way that the motion of the particle would change if a proton was used instead of an electron.

……………………………………………………………………………………………

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

6 A light single-turn square-shaped coil PQRS of sides 40 cm is suspended from a well-insulated light spring. The coil is partially in a region of uniform magnetic field of flux density 3.0 T, as shown in Fig. 6.1.

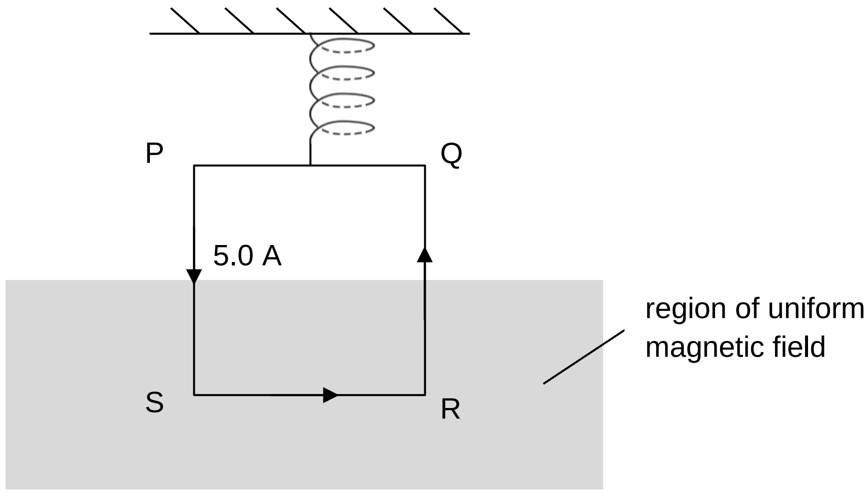

Fig. 6.1

A current of 5.0 A is passed through the square coil and the spring compresses by 8.0 mm.

(a) State and explain the direction of the magnetic field.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(b) Calculate the spring constant of the spring.

spring constant = ………………… N m^{-1} [2]

(c) The spring is now replaced by a string that pivots the coil PQRS to freely rotate about its vertical axis. The magnetic field is now applied rightwards and coil PQRS is fully in the region of the magnetic field, as shown in Fig. 6.2.

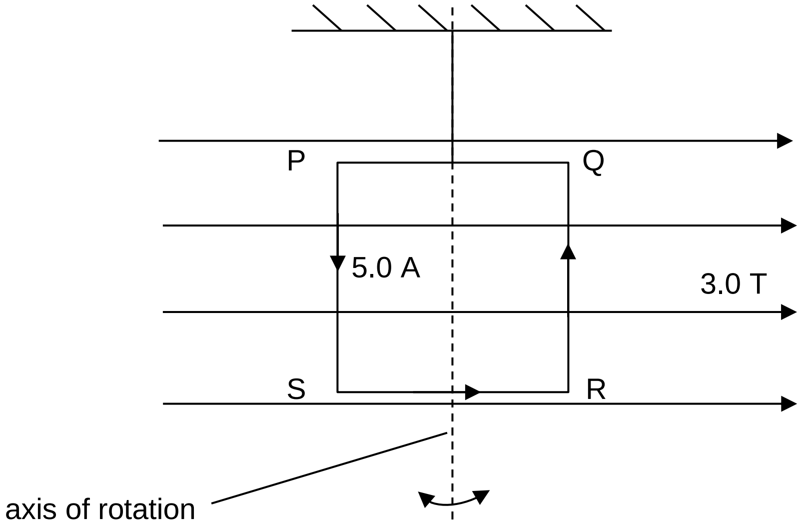

Fig. 6.2

(i) Determine the maximum and minimum torque acting on the coil.

maximum torque = ……………… N m

minimum torque = ……………… N m [3]

(ii) Using Fig. 6.2, explain why the coil will oscillate about the axis.

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

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

7 Fig. 7.1 shows a rectangular coil PQRS. The coil has 25 turns with dimensions of 15.0 cm by 6.0 cm.

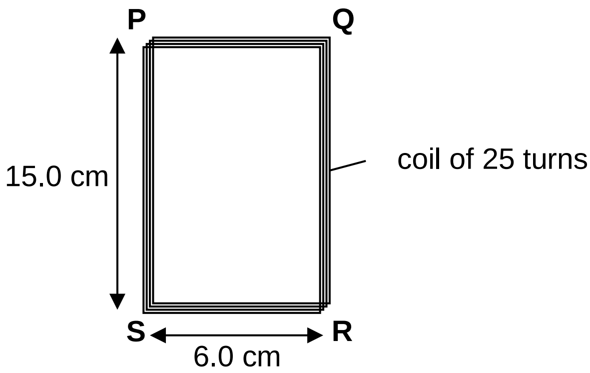

Fig. 7.1 (not to scale)

(a) Initially, a uniform magnetic field of flux density 25 mT is at right angles to the plane of the coil and directed into the page.

Calculate the magnetic flux linkage of the coil at this instance.

magnetic flux linkage =…………….......Wb [2]

(b) The uniform magnetic field is now replaced by a sinusoidal magnetic field with flux density *B* as shown in Fig. 7.2. Consider the direction of *B* is into the page when it is positive value.

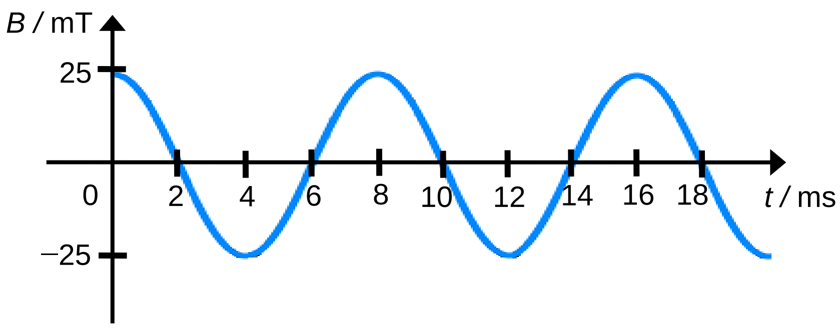

Fig. 7.2

(i) Use Faraday's law to explain why the variation in magnetic flux density passing through the coil as shown in Fig. 7.2 leads to a generation of sinusoidal e.m.f.

……………………………………………………………………………………………..

……………………………………………………………………………………………..

……………………………………………………………………………………………..

……………………………………………………………………………………………..

…………………………………………………………………………………… [2]

(ii) The induced e.m.f. E of the coil is represented by the equation

$$E = NAB_o \frac{2\pi}{T} \sin\left(\frac{2\pi}{T} t\right)$$

where N is the number of turns in the coil, A is the area of coil, B_0 is the maximum magnetic flux density and T is the period of the change in magnetic flux density.

Determine the maximum magnitude of the induced e.m.f. of the coil.

maximum induced e.m.f. = ……………… V [2]

(iii) On Fig. 7.3, sketch a graph to show the variation with time of the e.m.f. induced in the coil.

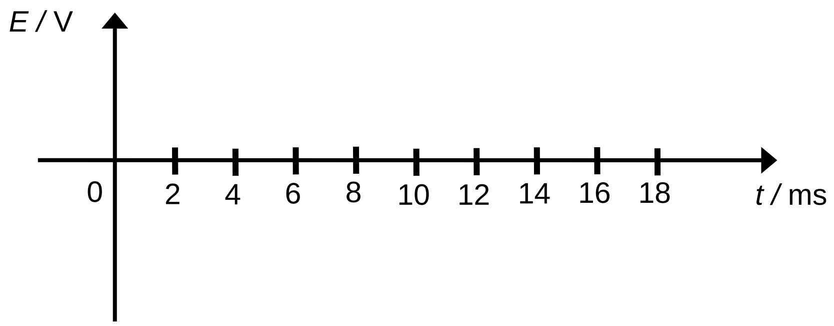

Fig. 7.3

[2]

(iv) Use Lenz's law to determine the direction of the induced current passing through the coil PQRS when magnetic flux density B is decreasing from $t = 0$ to $t = 2.0$ ms.

……………………………………………………………………………………………..

……………………………………………………………………………………………..

……………………………………………………………………………………………..

……………………………………………………………………………………………..

……………………………………………………………………………………………..

……………………………………………………………………………………… [2]

(c) **(i)** The alternating current generated by the same rectangular coil is then passed through an ideal transformer. The primary coil of the transformer has 15 turns.

Calculate the number of turns in the secondary coil if the value of r.m.s. voltage at the secondary coil is 240 V.

number of turns =……………...... [3]

(ii) A practical transformer has an input e.m.f. of 12 V while the secondary coil draws a current of 0.25 A with a voltage of 240 V.

If the efficiency of the transformer is 81%, determine the r.m.s. current in the primary coil.

r.m.s. current =……………...... A [2]

8 **(a)** State a phenomenon that provides evidence for the

(i) particulate nature of electromagnetic radiation.

………………………………………………………………………….. [1]

(ii) wave nature of electromagnetic radiation.

………………………………………………………………………….. [1]

(b) Distinguish between the appearance of the emission and absorption line spectra for the visible line spectrum.

………………………………………………………………………………………….

………………………………………………………………………………………….

………………………………………………………………………………………….

………………………………………………………………………………… [2]

(c) Fig. 8.1 shows some of the electron energy levels in an isolated atom of lithium. The atom was excited to the energy level of −0.67 eV and below shows three possible transitions that leads to radiation emissions X, Y, and Z.

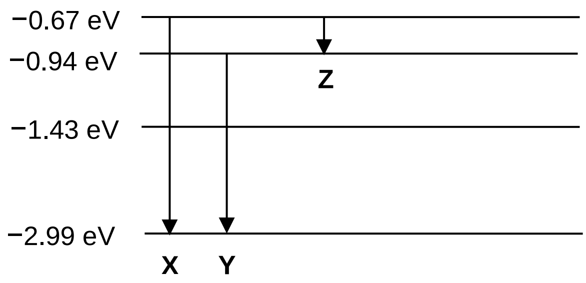

Fig. 8.1

(i) Calculate the wavelength of the radiation emission Y.

wavelength = ………………… m [2]

(ii) Hence state the region of the electromagnetic spectrum in which the radiation emission Y lies.

………………………………………………………………………….. [1]

(iii) On Fig. 8.2, sketch the appearance of the spectrum which the three transitions X, Y and Z would produce, with clear labels of X, Y and Z.

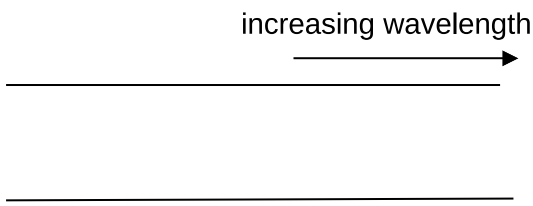

Fig. 8.2

[2]

(iv) Given the above energy levels in Fig. 8.1, state the total number of possible transitions that result in an emission of photon.

total no of possible transitions = ………………… [1]

9 **(a)** State what is meant by *nuclear binding energy*.

....

....

.... [1]

(b) The variation with nucleon number *A* of binding energy per nucleon *E* is shown in Fig. 9.1.

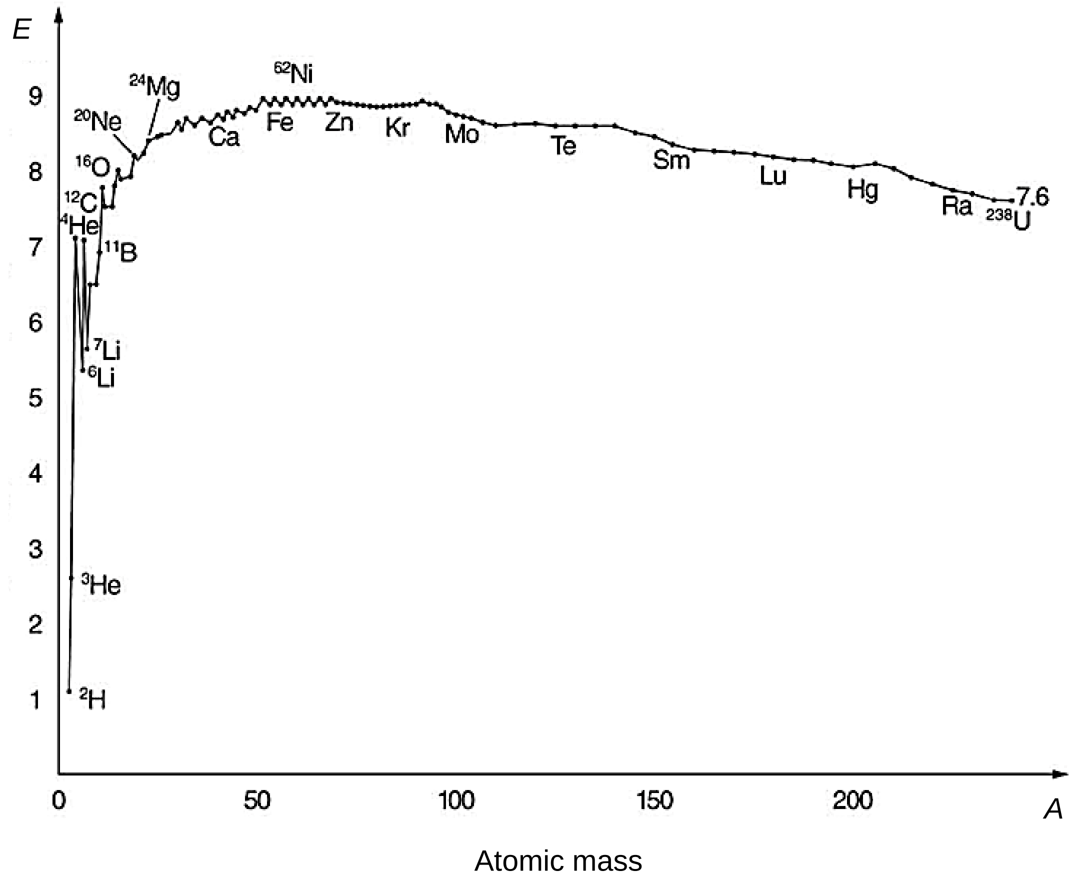

Fig. 9.1

A common nuclear reaction is:

$$^{1}_{1}H + ^{2}_{1}H \rightarrow ^{3}_{2}He$$

(i) Explain why the binding energy of $^{1}_{1}H$ is zero.

....

....

.... [1]

(ii) Explain, with reference to Fig. 9.1, why energy is released in the reaction

$${}^{1}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{2}He$$

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

……………………………………………………………………………………… [2]

(c) The binding energy per nucleon of the respective nuclei in the reaction in **(b)(ii)** are as follows:

nucleus	**binding energy per nucleon / MeV**
deuterium, ${}^{2}_{1}H$	1.12
helium-3, ${}^{3}_{2}He$	2.90

Calculate the energy released for the reaction in part **(b)(ii)**.

energy released = ………………… MeV [2]

(d) In 1919, Ernest Rutherford and his students created the first man-made nucleus. They bombarded nitrogen atoms with high-speed alpha particles in the reaction below:

$$^{14}_{7}\text{N} + {}^{4}_{2}\text{He} \rightarrow {}^{17}_{8}\text{O} + {}^{1}_{1}\text{H}$$

(i) The nuclear masses of the respective nuclei in the reaction in part **(d)** are as follows:

nucleus	**rest mass / u**
nitrogen-14, $^{14}_{7}\text{N}$	14.00307
helium-4, $^{4}_{2}\text{He}$	4.00260
oxygen-17, $^{17}_{8}\text{O}$	16.99914
hydrogen, $^{1}_{1}\text{H}$	1.00783

Calculate the energy associated with the change in mass for the reaction.

energy = ………………… J [2]

(ii) Explain whether the reaction in **(d)** can occur spontaneously.

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

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

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

End of Section B

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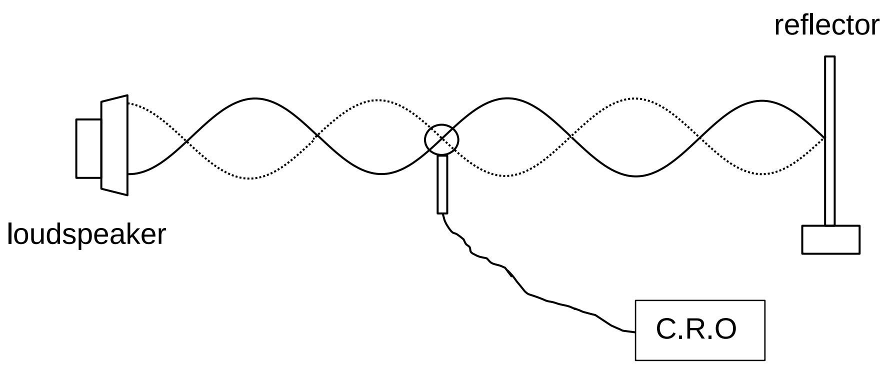
H2 Physics solutions:

1	**(a)**		Two point masses attract each other with a force that is proportional to the product of their masses and inversely proportional to the square of the distance between them.	B1
	(b)		Gravitational force provides centripetal force $\dfrac{GMm}{r^2} = mr\omega^2$ $\dfrac{GM}{r^2} = r\left(\dfrac{2\pi}{T}\right)^2$ $T^2 = \dfrac{4\pi^2}{GM}r^3$	B1 B1
	(c)	**(i)**	For Deimos: $(30.3\times 60\times 60)^2 = \dfrac{4\pi^2}{GM}(23500\times 10^3)^3$ $1.19\times 10^{10} = \dfrac{4\pi^2}{GM}\times 1.30\times 10^{22}$ For Phobos: $(7.7\times 3600)^2 = \dfrac{4\pi^2}{GM}r^3$ $7.68\times 10^8 = \dfrac{4\pi^2}{GM}r^3$ Alternatively: $T^2 \propto r^3$ $\dfrac{T_P^{\,2}}{T_D^{\,2}} = \dfrac{r_P^{\,3}}{r_D^{\,3}}$ Dividing the second equation by the first equation gives: $\dfrac{7.68\times 10^8}{1.19\times 10^{10}} = \dfrac{r^3}{1.30\times 10^{22}}$ $r = 9.43\times 10^6$ m	C1 A1
	(c)	**(ii)**	Thus the orbital speed of Phobos is: $v = \dfrac{2\pi r}{T} = \dfrac{2\pi\times 9.43\times 10^6}{7.7\times 3600}$ $= 2137 \approx 2100$ m s^{-1}	C1 A1
	(d)		Total energy of orbit = kinetic energy + gravitational potential energy. Total energy $= \dfrac{1}{2}mv^2 + \left(-\dfrac{GMm}{r}\right)$ $= \dfrac{1}{2}(9.6\times 10^{15})(2137)^2 - \dfrac{6.67\times 10^{-11}\times 6.4\times 10^{23}\times 9.6\times 10^{15}}{9.43\times 10^6}$ $= -2.15\times 10^{22}$ J	M1 A1
	(e)		As the total energy decreases, the orbital radius decreases and the orbital speed increases. Thus the kinetic energy of Phobos will increase.	A1

2	(a)	Sound waves produced by the loudspeaker is reflected by the reflector and travel back towards the loudspeaker. As the reflected waves have the same frequency, amplitude and speed as the incident waves, they will overlap and interfere to produce a stationary wave.	[B1] [B1] [B1]
	(b)	At the reflector, the reflected will be anti-phase [B1] with the incident wave, hence, destructive interference [B1] occur and a node is formed. Or Since the reflector is a fixed end [B1], the air particle cannot oscillate [B1], hence, a node is formed.	
	(c)	 B1:Correct positions antinode (loudspeaker) & nodes (reflector & microphone) B1:2 lines (dotted and dark lines)	
	(d)	$v = f(0.400)$ ---- (1) [C1] $v = (f + 480)(0.250)$ ---- (2) [C1] Solving $v = 320 \text{ m s}^{-1}$ [A1]	

3	(a)	The first law of thermodynamics states that the <u>increase</u> in internal energy of a system [B1] is equal to the sum of the heat supplied <u>to</u> the system and the work done <u>on</u> the system. [B1]		
	(b)	(i)	$Q = mc\Delta\theta = 3.6 \times 156 \times (86 - 60)$	C1
			$= 1.5 \times 10^4$ J (or 1.46×10^4 J)	A1
		(ii)	1.5×10^4 J (or 1.46×10^4 J)	A1
	(c)	(i)	$\left(\frac{3.6}{65} - \frac{3.6}{840}\right)$ work done $= p\Delta V = 1.01 \times 10^5 \times \left(\frac{3.6}{65} - \frac{3.6}{840}\right)$	C1 C1
			= 5160 J	A1
		(ii)	$\Delta U = q + w = 3.6 \times 1.32 \times 10^4 + (-5160)$	C1
			$= 4.2 \times 10^4$ J (or 4.24×10^4)	A1

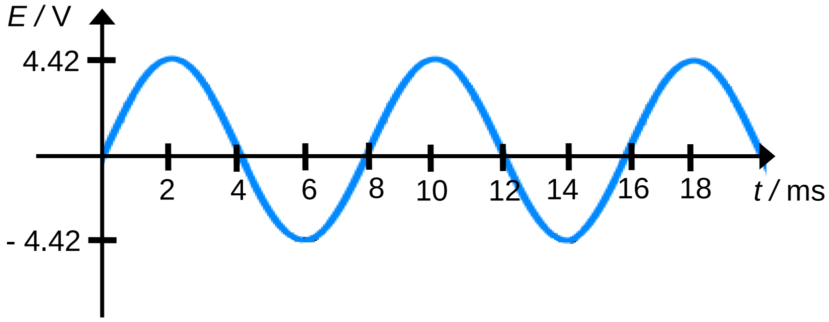
4	(a)	The e.m.f. is the non-electrical energy converted to electric energy per unit charge while the p.d. is the electrical energy converted to non-electrical energy per unit charge.		A1
	(b)	(i)	$EQ = 2.0 \times 4.0$	C1
			= 8.0 J	A1
		(ii)	$\frac{VQ}{t} = \frac{1.5 \times 4.0}{25}$	C1
			= 0.24 W	A1
		(iii)	p.d. across S = 0.5 V and p.d. $\propto$ resistance, so $S = R/3$	M1 A1 A0
		(iv)	resistance of each half = $R/2$	C1
			effective resistance = $R/4$	A1
		(v)	$\frac{R/4}{R/4 + R/3} \times 2.0$	C1
			= 0.86 V	A1
	(c)	(i)	$\frac{5.0}{9.0} \times 100$	C1
			= 55.6 cm	A1
		(ii)	same (terminal p.d. remains the same as no current flows through cell)	A1
		(iii)	$\frac{39.7}{100} \times 9.0 = \frac{3.0}{3.0 + r} \times 5.0$	C1
			$r = 1.2\ \Omega$	A1

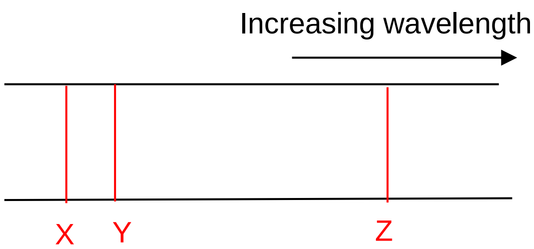
5	**(a)**	arrows pointing towards the right + equal spacing between the arrows. [B1]
	(b)	$E = \dfrac{\Delta V}{d}$ $= \dfrac{300-(-300)}{\frac{0.50}{100}}$ [M1] $= 1.2 \times 10^5 \text{ V m}^{-1}$ [A0]
	(c)	$a = \dfrac{F}{m} = \dfrac{qE}{m} = \dfrac{1.6\times10^{-19}\times1.2\times10^{5}}{9.11\times10^{-31}} = 2.11\times10^{16} \text{ m s}^{-2}$ [C1] Since this acceleration 2.11 x 10^{16} is very much larger than gravitational acceleration of (9.81 m s^{-2}), the effects of gravitational field is not considered. [B1] Method 1: Using kinematics: Consider the horizontal motion, $s_x = u_x t + \frac{1}{2}a_x t^2$ $\dfrac{0.25}{100} = 0 + \dfrac{1}{2}(2.11\times10^{16})t^2$ $t = 4.87\times10^{-10}$ s $v_x = u_x + a_x t$ $v_x = 0 + 2.11\times10^{16}\times4.87\times10^{-10}$ [C1] $= 1.03\times10^{7} \text{ m s}^{-1}$ Or using $v_x^{\ 2} = u_x^{\ 2} + 2aS_x$ $v_x^{\ 2} = 0 + 2(2.11\times10^{16})(\dfrac{0.25}{100})$ [C1] $v_x = 1.03\times10^{7} \text{ m s}^{-1}$ Consider the vertical motion, $v_y = u_y + a_y t$ $v_y = u_y$ [$a_y t$ is insignificant because $a_y = 9.81$ m s^{-2} and t is very small] $= 3.1\times10^{7} \text{ m s}^{-1}$ [C1] Hence, final speed $v = \sqrt{v_y^{\ 2} + v_x^{\ 2}}$ $v = \sqrt{(3.1\times10^{7})^2 + (1.03\times10^{7})^2}$ $= 3.27\times10^{7} \text{ m s}^{-1}$ [A1]

		Method 2: Using conservation of energy Loss in EPE = gain in KE [C1] $q\Delta V = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = \frac{1}{2}m(v_f^2 - v_i^2)$ $(-1.6\times10^{-19})(0-300) = \frac{1}{2}(9.11\times10^{-31})(v_f^2 - (3.1\times10^7)^2)$ [C1] $v_f = 3.27\times10^7$ m s^{-1} [A1] Loss in GPE (electron only moves 1.5 cm downwards before touching the left plate) $mgh = 9.11\times10^{-31}(9.81)(\frac{1.5}{100})$ $= 1.34\times10^{-31}$ J Loss in EPE $q\Delta V = (-1.6\times10^{-19})(0-300)$ $= 4.8\times10^{-17}$ J Calculations shown [M1] loss in GPE is significantly less than the loss in EPE, hence the effects of gravitational fields is not considered. [B1]
	(d)	The electron moves in a parabolic path because it has a constant vertical (downwards) velocity [B1] while experiencing a perpendicular constant acceleration (horizontally leftwards). [B1]
	(e)	Any of the following: The proton moves in a parabolic path but in the opposite direction (or rightwards) compared to that of electron. [B1] the proton may hit the plate (on the right) at a lower position or even missed hitting the plate. [B1] final speed of proton is lower than that of electron [B1] less curved path [B1]

6	(a)	Since the spring is compressed when the current is passing through coil, magnetic force on the wire is upwards. By Fleming's Left Hand Rule, the direction of the magnetic field is into the paper.		 [M1] [A1]
	(b)	$F = BIL$ $kx = BIL$ $k(0.0080) = (3.0)(5.0)(0.40)$ [C1] $k = 750\ \text{N m}^{-1}$ [A1]		
	(c)	(i)	Max Torque $= F \times L_{SR}$ $= BIL^2$ $= (3.0)(5.0)(0.40)^2$ [M1] $= 2.40\ \text{N m}$ [A1] Min Torque = 0 N m [A1]	
	(c)	(ii)	Based on Fig. 6.2, by Fleming's left hand rule, at t = 0 s, rod PS will experience an out of paper magnetic force while rod QR will experience a magnetic force into the paper. [B1] Hence, the forces will cause a torque on the coil is anti-clockwise (from top view) and hence will cause the coil to rotate in the anti-clockwise direction. [B1] After the coil has rotated 90°/ passed the mid-point, rod PS experience an into the paper force, while QR experience an out of paper force, the torque acting the coil will act in the opposite direction, [B1] causing the coil to rotate back in the clockwise direction. Hence the coil will oscillate about the pivot.	

7	(a)	$\Phi = NBA$ $\Phi = 25 \times 0.025 \times 0.150 \times 0.060$ [C1] $= 5.63 \times 10^{-3}$ Wb [A1] (also accept negative answer)	
	(b)	(i)	As magnetic flux density is proportional to the magnetic flux linkage, the magnetic flux linkage through the coil is also varying sinusoidally or constantly changing. [B1] Hence, since there is a rate of change of magnetic flux linkage and induced emf is directly proportional to the rate of change, a (sinusoidal) e.m.f. is induced or generated in the coil. [B1]

	b	(ii)	$E = NAB_0 \frac{2\pi}{T} \sin\left(\frac{2\pi}{T} t\right)$ Since the maximum magnitude of induced e.m.f. is when $\sin\left(\frac{2\pi}{T} t\right) = 1$, $E_{max} = NAB_0 \frac{2\pi}{T} = 25 \times 0.150 \times 0.060 \times 0.025 \times \frac{2\pi}{0.008}$ [C1] = 4.42 V [A1]
	b	(iii)	 **Fig. 7.3** Current shape: positive sine graph [M1] Correct values indicated: E_{max} = 4.42 V (allow ecf) and T = 8.0 ms [A1]
	b	(iv)	The induced current flows in <u>PQRS or clockwise</u> direction (do not accept PQ, QR, RS, SP) [A1] so as to produce <u>a magnetic flux into the paper to oppose the decrease or change in magnetic flux linkage</u>. [M1]
	(c)	(i)	Root-mean-square voltage of input, $V_{rms} = \frac{V_0}{\sqrt{2}}$ $V_{rms} = \frac{4.42}{\sqrt{2}} = V_P$ [C1] $\frac{N_S}{N_P} = \frac{V_S}{V_P}$ No. of turns in sec coil, $N_S = \frac{V_S}{V_P} N_P = \frac{240}{\frac{4.42}{\sqrt{2}}} \times 15 = \frac{240\sqrt{2}}{4.42} \times 15$ [C1] $N_S = 1150$ [A1]
	(c)	(ii)	For efficiency, $\frac{\text{Power output}}{\text{Power input}} \times 100\%$ $= \frac{\text{Power in secondary coil}}{\text{Power in primary coil}} \times 100\%$ $= \frac{0.25 \times 240}{12I} \times 100\% = 81\%$ [C1] Therefore, $I = 6.17\text{A}$ [A1]

8	**(a)**	**(i)**	Photoelectric effect	B1
		(ii)	Diffraction or interference	B1
	(b)	**(i)**	Emission line spectrum consists of discrete coloured lines on a dark background. whereas an absorption line spectrum consists of dark lines against a continuous spectrum of the white light.	B1 B1
	(c)	**(i)**	$\lambda = \dfrac{hc}{\Delta E} = \dfrac{(6.63\times10^{-34})\times(3.0\times10^{8})}{(-0.94-(-2.99))\times(1.6\times10^{-19})}$ $= 6.06\times10^{-7}$ m	C1 A1
		(ii)	Visible light (or red/orange light)	B1
		(iii)	 B1 for correct labelled lines B1 for correct gap spacing	
		(iv)	6 possible transitions.	B1

9	(a)	Nuclear binding energy is the minimum energy required to completely separate all the nucleons of a nucleus (to infinity).		B1
	(b)	(i)	The nucleus of ^1_1H is a single proton and so <u>no energy is needed to separate</u> it.	B1
		(ii)	From the graph, the product ^3_2He <u>has a higher binding energy per nucleon</u> than the reactant ^2_1H (and ^1_1H has no binding energy). This means that the <u>total binding energy of the products is higher than the total binding energy of the reactants</u> (and mass defect has increased in the reaction). Since mass defect has increased, it means that mass has been converted into energy during the reaction, thus energy is released.	B1 B1
	(c)	energy released = total binding energy of products – total binding energy of the reactants. energy released = 2.90 x 3 – 1.12 x 2 = 6.46 MeV		C1 A1
	(d)	(i)	mass difference = 16.99914 + 1.00783 – (14.00307 + 4.00260) = 0.0013 u Since the total mass has increased, energy is absorbed in the reaction. energy absorbed = 0.0013 x 1.66 x 10^{-27} x (3 x 10^{8})^2 = 1.94 x 10^{-13} J energy change = + 1.94 x 10^{-13} J	C1 A1
		(ii)	The energy change in the reaction is positive, meaning that the <u>total mass of the products is higher than the total mass of the reactants</u> / <u>energy is absorbed in the reaction</u>. Thus, <u>the reaction is not spontaneous</u> because energy has to be provided in the form of the kinetic energy of the alpha particle. Without this, the reaction cannot occur.	M1 A1