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

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

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}
		=	$\left(1/\left(36\pi\right)\right) \times 10^{-9}$ 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	=	$-\frac{GM}{r}$
temperature	T/K	=	T/°C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
mean translational kinetic energy of an ideal gas molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
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	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current / voltage	X	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_0 I}{2\pi d}$
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 B: Structured Questions

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

1	**(a)**	State Newton's law of gravitation.	
		………………………………………………………………………………………..................	[1]
		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
		Comments: Average done. There are several key terms which students tend to miss out. proportional – hence the need for constant of proportionality G product of masses – not product of objects (which does not make sense) square of the distance – not just the distance.	
	(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 $T^2 = \dfrac{4\pi^2 r^3}{GM}$ where *G* is the gravitational constant. Explain your working.	
			[2]
		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
		Comments: Average done. Some do not understand the meaning of "gravitational force provides for centripetal force". Some wrongly write that "centripetal force provides for gravitational force", or that "gravitational force is provided by centripetal force". Some students got the formula for gravitational force wrong.	

(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.

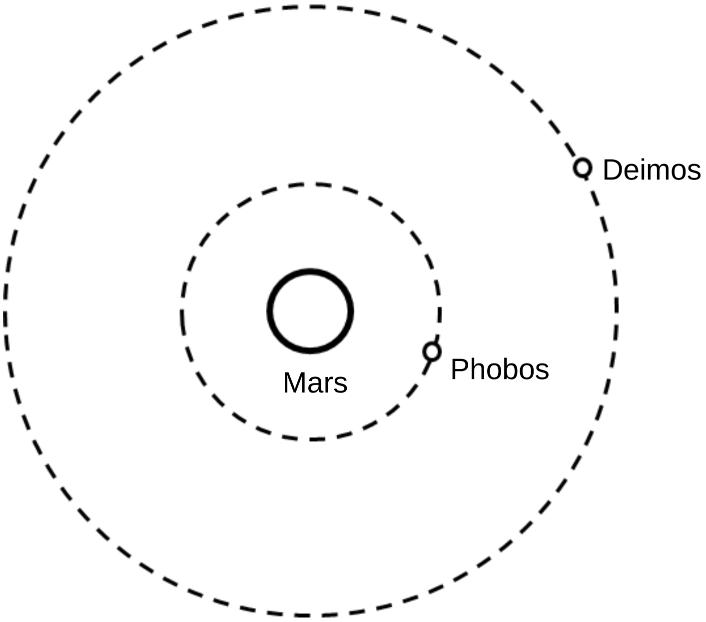


Fig. 1.1 (not to scale)

(i) Determine the orbital radius of Phobos.

orbital radius = …………………….. m [2]

For Deimos:

$$\left(30.3\times60\times60\right)^2=\frac{4\pi^2}{GM}(23500\times10^3)^3$$

$$1.19\times10^{10}=\frac{4\pi^2}{GM}\times1.30\times10^{22}$$

For Phobos:

$$\left(7.7\times3600\right)^2=\frac{4\pi^2}{GM}r^3$$

$$7.68\times10^8=\frac{4\pi^2}{GM}r^3$$

Alternatively:

$$T^2\propto r^3$$

$$\frac{T_P{}^2}{T_D{}^2}=\frac{r_P{}^3}{r_D{}^3}$$

Dividing the second equation by the first equation gives: C1

$$\frac{(7.7\times60\times60)^2}{(30.3\times60\times60)^2}=\frac{r^3}{(23500\times10^3)^3}$$ [C1]

$$\frac{7.68\times10^8}{1.19\times10^{10}}=\frac{r^3}{1.30\times10^{22}}$$

$r=9.43\times10^6$ m A1

			Comments: Poorly done. Students should recognise the proportional relationship between T^2 and r^3; using ratio to work this question would be the best method as this would minimise unnecessary careless mistakes. 1) Some tried to find the mass M, obtaining the wrong value as they did not do the necessary conversion to SI units (e.g. T, r). 2) Some dropped either the square of the period and/or the cube of the radius when they did their calculations.	
		(ii)	Hence, or otherwise, determine the orbital speed of Phobos.	
			orbital speed = ………………… m s^{-1}	[2]
			Thus the orbital speed of Phobos is: $v = \frac{2\pi r}{T} = \frac{2\pi \times 9.43 \times 10^6}{7.7 \times 3600}$ $= 2137 \approx 2100 \text{ m s}^{-1}$	C1 A1
			Comments: Poorly done. Common mistakes include: 1) Some used the wrongly formulae v = r / T or v = 2π / T in their calculations. 2) Not using SI unit for the substitutions or wrong conversions 3) Small handful wrongly used the escape velocity formula. 4) Some correctly used $v = \sqrt{\frac{GM}{r}}$ but substituted the wrong mass *M.* No e.c.f can be awarded if student used the wrong *M* which they have calculated in (i).	

(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]

Total energy of orbit = kinetic energy + gravitational potential energy.

$$\text{Total energy } = \frac{1}{2}mv^2 + \left(-\frac{GMm}{r}\right)$$

$$= \frac{1}{2}\left(9.6\times10^{15}\right)\left(2137\right)^2 - \frac{6.67\times10^{-11}\times6.4\times10^{23}\times9.6\times10^{15}}{9.43\times10^{6}}$$

$$= -2.15\times10^{22}\text{ J}$$

M1
A1

Note that it can be shown that (refer to lecture notes):

$$E_K = \frac{GMm}{2r},\ E_T = -\frac{GMm}{2r}$$

Hence the following alternatives are accepted:

$$\text{a. Total energy } = -\frac{GMm}{2r}$$

$$= -\frac{6.67\times10^{-11}\times6.4\times10^{23}\times9.6\times10^{15}}{(2)9.43\times10^{6}} = -2.2\times10^{22}\text{ J}$$

$$\text{b. Total energy } = -E_K = -\frac{1}{2}mv^2$$

$$= -\frac{1}{2}\left(9.6\times10^{15}\right)\left(2137\right)^2 = -2.2\times10^{22}\text{ J}$$

Comments:

Poorly done

1) Many students calculated potential energy instead of total energy.
2) Students also wrote the formulae wrongly, such as using r^2 instead of r
3) Others dropped the negative sign, wrongly thinking that total energy must be positive.
4) Careless mistakes made such as dropping the square in kinetic energy formula when they calculate

	(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]
		As the total energy decreases, the orbital radius decreases and the orbital speed increases. Thus the kinetic energy of Phobos will increase.	A1
		Comments: Poorly done. As this is a “state” question, explanation is not expected. However **no credit** can be given if students correctly indicate that kinetic energy increase but wrongly state that it is a result of conservation of energy; the concept of conservation of energy cannot be applied here as the total energy as decreased.	

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.

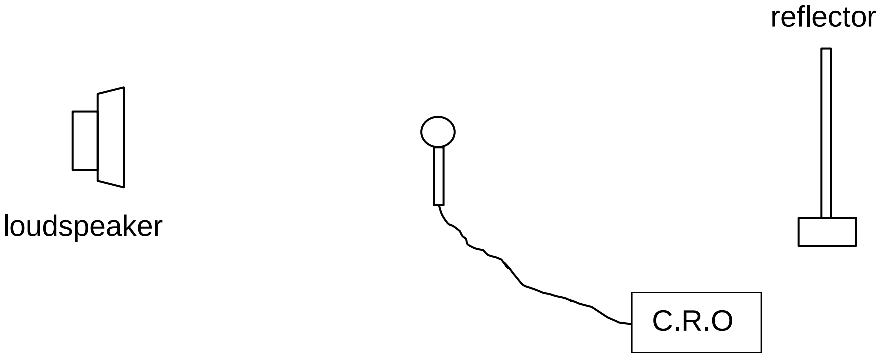


Fig. 2.1

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

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

Sound waves produced by the loudspeaker is reflected by the reflector and travel back towards the loudspeaker. [B1]

As the reflected waves have the same frequency, amplitude and speed as the incident waves, [B1]

they will overlap and interfere to produce a stationary wave. [B1]

Comments:

Not well done as only a handful of students managed to get the full credit.

1) It is important for the students to demonstrate in their answer that the sound waves and the reflected waves are travelling towards each other and will overlap. It is not sufficient to just say that the sounds waves are reflected.
2) Many students wrongly stated that the incident sound waves and the reflected sound waves are in phase. They do not need to be in phase, they just need to be coherent.
3) Many students did not state that the reflected waves have the same speed as the incident waves, Students who state that the reflected waves have the same frequency, amplitude and wavelength are given the credit.
4) Many students state that the waves collide/ superpose. The actual process is known as **interference**.
5) Some students wrongly state that the two waves interference constructively. It is actually a series of constructive and destructive interference.

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

.... [2]

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.

Comments:

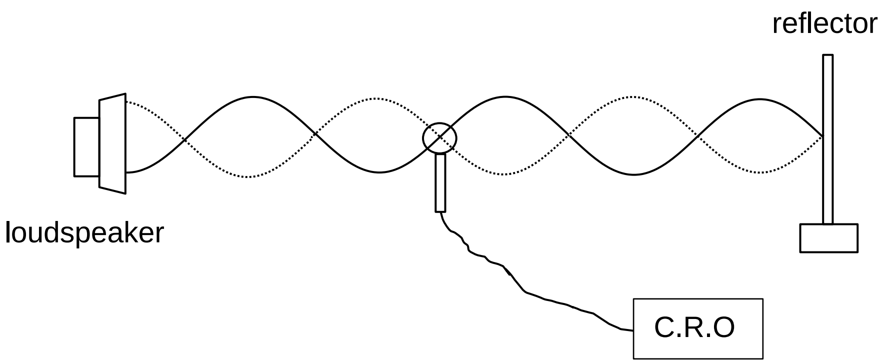
Poorly done as only a handful of students got the full credit.

1) Many students were able to state that the reflector was a closed end/surface but could not explain the reason why a closed end will result in a node being formed at the surface.
2) Many students incorrectly stated that the closed end absorbed all the energies of the wave and hence a node is formed.
3) A significant number of students are still mixing up the terms ‘node’ and ‘anti-node’.
4) Only a handful of students recognise that the reflected wave is out-of-phase with the incident wave.

(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]



B1:Correct positions antinode (loudspeaker) & nodes (reflector & microphone)
B1:2 lines (dotted and dark lines)

Comments:

1) Many students are still sketching their stationary waves with two solid lines. Students must remember that that the dotted line is to represent the waveform after half a period, which indicates that it is a stationary wave.
2) Confusion between nodes and antinodes resulted in many students not getting full credit.

	(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]
		$v = f(0.400)$ ---- (1) [C1] $v = (f + 480)(0.250)$ ---- (2) [C1] Solving $v = 320$ m s^{-1} [A1]	
		Comments: 1) Most common error is not recognising that the distance between two adjacent nodes is half a wavelength.	

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

.... [2]

The first law of thermodynamics states that the increase in internal energy of a system [B1]

is equal to the sum of the heat supplied to the system and the work done on the system. [B1]

Comments: Poorly attempted. It is clear that many students are not familiar with the definition of the law, or did not bother to memorise it.

Common mistakes include:

- Use “change in internal energy” or “total internal energy” instead of “increase in internal energy”
- Did not state “sum of”
- Use “gas”, “substance” or “object” instead of “system”

(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]

$Q = mc\Delta\theta = 3.6 \times 156 \times (86 - 60)$ C1

$= 1.5 \times 10^4$ J (or 1.46×10^4 J) A1

Comments: Very well attempted. Most students are able to calculate the heat supplied correctly. However there are a minority of students who wrongly added 273 or 273.15 to the difference of 26 K.

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

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

1.5×10^4 J (or 1.46×10^4 J) A1

Comments: Well attempted. Most students were able to see that the work done on system is zero, and hence the heat supplied is equal to the increase in internal energy. Note that no working is needed as it is a “state” question.

(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]

$$\left(\frac{3.6}{65}-\frac{3.6}{840}\right)$$

work done = $p\Delta V$ = 1.01 × 10^5 × $\left(\frac{3.6}{65}-\frac{3.6}{840}\right)$ C1

= 5160 J A1

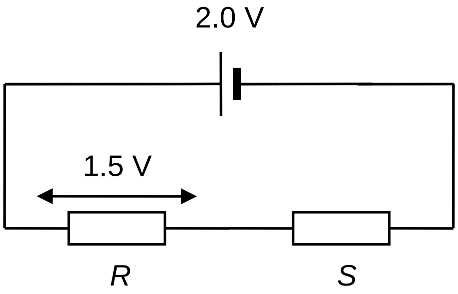
Comments: Poorly attempted. It should be noted that the question ask for work done against the atmosphere, which is equivalent to work done BY gas (against the atmosphere). Hence there should be no negative sign in the answer since it is an expansion.

Common mistakes include:

- Multiplying the pressure with the initial (or final) volume instead of the volume difference
- Multiplying pressure with the density difference instead of volume difference
- Finding mass by taking answer in b(i) divided by the specific latent heat of vaporization. Note that the mass (= 3.6 kg) is already given in the question!
- Finding volume difference using $\left(\frac{3.6}{65-840}\right)$ or $\left(\frac{3.6}{840-65}\right)$.

  Clearly this is not the same as $\left(\frac{3.6}{65}-\frac{3.6}{840}\right)$. A case of wrong mathematics.
- Including the negative sign in the answer (1 mark will be deducted).

		(ii)	determine the increase in internal energy.	
			increase in internal energy = ………………… J	[2]
			$\Delta U = q + w = 3.6 \times 1.32 \times 10^4 + (-5160)$	C1
			$= 4.2 \times 10^4$ J (or 4.24×10^4)	A1
			Comments: Poorly attempted. Many students do not seem to be aware that this is a simple application of the first law of thermodynamics. However, students need to find the heat supplied to the liquid first. Common mistakes include: • Using the answer in b(i) as the heat supplied. This is incorrect as the answer in b(i) is the heat supplied to raise the temperature of the liquid from 60 °C to 86 °C. It is NOT the heat supplied during the boiling process. • Adding the answer in b(i) to the heat supplied in the boiling process. Question asked for the “boiling process” only.	

4	**(a)**	Distinguish between electromotive force (e.m.f.) and potential difference (p.d.).		
		……………………………………………………………………………………........................ .		[1]
		The e.m.f. is the non-electrical (or other forms or chemical) energy converted to electrical energy per unit charge while the p.d. is the electrical energy converted to non-electrical (or other forms or chemical) energy per unit charge.		A1
		Comments: 1) Missed out the words “per unit charge”. The word “coulomb” not accepted. 2) Some gave the exact same definition for both e.m.f. and p.d.		
	(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]
			$EQ = 2.0 \times 4.0$	C1
			= 8.0 J	A1
			Comments: 1) Common mistake – student use 1.5 V instead and obtained wrong answer of 6.0 J. 2) Some gave answer as 8 J and was penalized for s.f.	

		(ii)	calculate the rate of heat generated in *R*,	
			rate of heat generated = ………………… W	[2]
			$\frac{VQ}{t} = \frac{1.5 \times 4.0}{25}$	C1
			= 0.24 W	A1
			Comments: 1) Some didn't recognize that rate of heat generated is power. Also not realizing that the given unit is W.	
		(iii)	show that the resistance of S is $\frac{R}{3}$.	
			………………………………………………………………………………………	[2]
			p.d. across *S* = 0.5 V and p.d. $\propto$ resistance (or current is constant for both resistors, or usage of potential divider method with clear working) so *S* = *R*/3	B1 B1 A0
			Comments: 1) Some students chose to calculate the resistance value for both resistors – accepted. Students should include the units for the resistance though not penalized, unless wrong unit given. 2) Some students chose to use the p.d across R of 1.5 V instead and the potential divider method, also accepted. But clear working must be shown.	

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

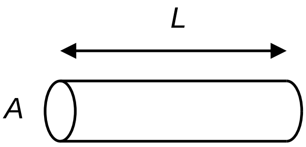
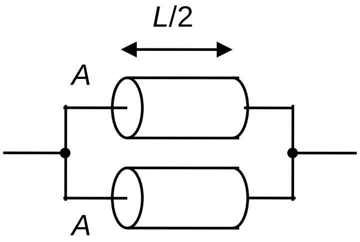


Fig. 4.2

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]

resistance of each half = $R/2$	C1
effective resistance = $R/4$	A1

Comments:

1) Some have difficulty with reciprocal, so they have answer like 4/R
2) Some did not do reciprocal and simply add up, so their answer is R

(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]

$\dfrac{R/4}{R/4+R/3}\times 2.0$	C1
= 0.86 V	A1

Comments:

1) Generally could do this question.

(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.

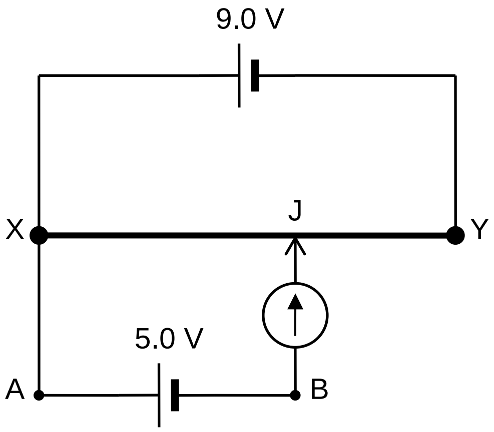


Fig. 4.4

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

length L_{XJ} = ………………… cm [2]

$$\frac{5.0}{9.0}\times 100$$ C1

= 55.6 cm A1

Comments:

1) Most could get the answer

(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]

same (terminal p.d. remains the same as no current flows through cell) A1

Comments:

1) Majority wrongly thought it would change

(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.

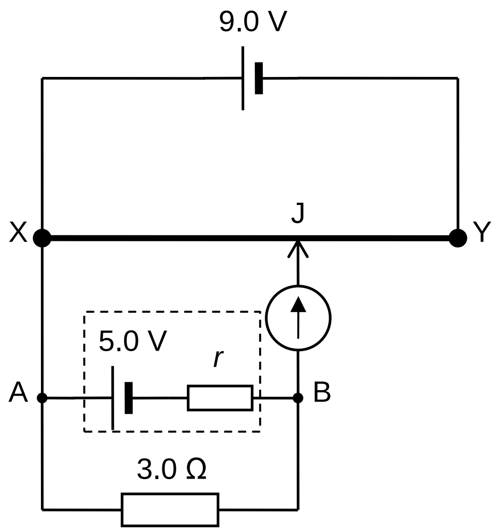


Fig. 4.5

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

Calculate r.

r = ………………… Ω [2]

$$\frac{39.7}{100}\times 9.0=\frac{3.0}{3.0+r}\times 5.0$$ C1

r = 1.2 Ω A1

Comments:

1) Majority can get the answer

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.

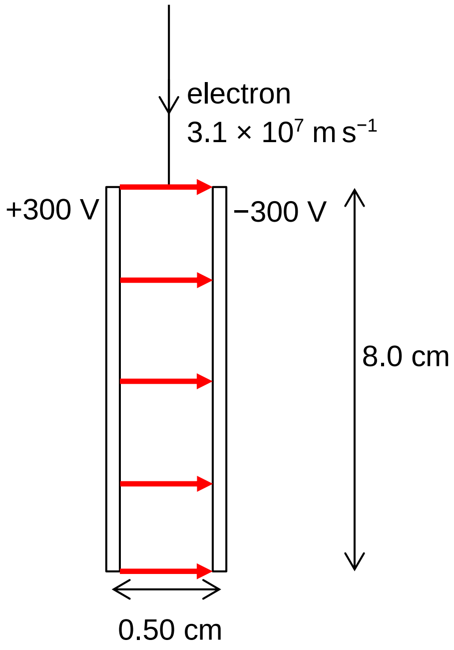


Fig. 5.1 (not to scale)

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

arrows pointing towards the right + equal spacing between the arrows. [B1] [1]

Comments:

1) Question stated to sketch 5 arrows, hence if more or less arrows are drawn, no marks awarded.
2) The 5 arrows should be spread out across the whole region of the E-Field. If the arrows are too far away from the edge, no marks awarded.
3) Please use a RULER to draw the lines neatly (with the E-field lines being perpendicular to the plates)
4) There are a few students who included a curve (presuming is the path of the electron) in the figure on top of the E-field line arrows, no marks are awarded as there were no labels so I will assume the curve is part of the arrows for E-field.

	(b)	Show that magnitude of the electric field strength between the plates is 1.2 × 10^5 V m^{-1}.	
			[1]
		$E = \frac{\Delta V}{d}$ $= \frac{300-(-300)}{\frac{0.50}{100}}$ [M1] $= 1.2 \times 10^5$ V m^{-1} [A0]	
		Comments: 1) Generally well done. 2) A minority of students are still incorrectly trying to use $E = \frac{Qq}{4\pi\varepsilon_o r^2}$ to solve for uniform field questions. Please note the difference!	

(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]

$$a=\frac{F}{m}=\frac{qE}{m}=\frac{1.6\times10^{-19}\times1.2\times10^{5}}{9.11\times10^{-31}}=2.11\times10^{16}\text{ m s}^{-2}\quad\text{[C1]}$$

Since this acceleration 2.11 × 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,

$$s_x=u_xt+\frac{1}{2}a_xt^2$$

$$\frac{0.25}{100}=0+\frac{1}{2}(2.11\times10^{16})t^2$$

$$t=4.87\times10^{-10}\text{ s}$$

$$v_x=u_x+a_xt$$

$$v_x=0+2.11\times10^{16}\times4.87\times10^{-10}\quad\text{[C1]}$$

$$=1.03\times10^{7}\text{ m s}^{-1}$$

Or using

$$v_x{}^2=u_x{}^2+2aS_x$$

$$v_x{}^2=0+2(2.11\times10^{16})(\frac{0.25}{100})\quad\text{[C1]}$$

$$v_x=1.03\times10^{7}\text{ m s}^{-1}$$

Consider the vertical motion,

$$v_y=u_y+a_yt$$

$v_y=u_y$ [a_yt is insignificant because $a_y=9.81$ m s^{-2} and t is very small]

$$=3.1\times10^{7}\text{ m s}^{-1}\quad\text{[C1]}$$

Hence, final speed $v=\sqrt{v_y{}^2+v_x{}^2}$

$$v=\sqrt{\left(3.1\times10^{7}\right)^2+\left(1.03\times10^{7}\right)^2}$$

$$=3.27\times10^{7}\text{ m s}^{-1}\quad\text{[A1]}$$

Method 2: Using conservation of energy
Loss in EPE = gain in KE [C1]

$$q\Delta V=\frac{1}{2}mv_f{}^2-\frac{1}{2}mv_i{}^2=\frac{1}{2}m(v_f{}^2-v_i{}^2)$$

$$(-1.6\times10^{-19})(0-300)=\frac{1}{2}(9.11\times10^{-31})(v_f{}^2-(3.1\times10^{7})^2)\quad\text{[C1]}$$

$$v_f=3.27\times10^{7}\text{ m s}^{-1}\quad\text{[A1]}$$

Loss in GPE (electron only moves 1.5 cm downwards before touching the left plate)

$$mgh = 9.11 \times 10^{-31}(9.81)(\frac{1.5}{100})$$

$$= 1.34 \times 10^{-31} \text{ J}$$

Loss in EPE

$$q\Delta V = (-1.6 \times 10^{-19})(0 - 300)$$

$$= 4.8 \times 10^{-17} \text{ J}$$

Calculations shown [M1]

loss in GPE is significantly less than the loss in EPE, hence the effects of gravitational fields is not considered. [B1]

Comments:

1) *Direction*:
   - Many students are mixed up with horizontal and vertical direction! The subscripts in the working is incorrect. Subscripts were ignored when marking, bod was given.

2) *Explanation*:
   - To explain why G-field is not considered, credit is given only when students compare the force or acceleration values in G-field with force or acceleration values in E-field.
   - Simply stating G-field strength less than E-field strength gains no credit as it is just rehashing the question asked.
   - Common incorrect answer was stating that the mass is small. This is incorrect as the same small mass experiences effects in an E-field but not G-field so mass is not the determining factor here when comparing.

3) *Calculation using Kinematics eqn*:
   - Use of incorrect value of s_x, which resulted in wrong values of time and v_x.
   - To note that electron started at the mid-point between the plates, hence s_x = 0.25 cm.
   - Wrong calculation of v_x due to substituting wrong value of u_x.
     $u_x = 0$ and $u_y = 3.1 \times 10^7$ m s^{-1}
   - Final velocity has both horizontal and vertical component. A good number of students did not realise this.

4) *Calculation using COE*:
   - Students got mixed up with which energy is gained and which energy is lost.
   - Initial KE was not included in working
   - Initial and final EPE was incorrect, mainly due to the oversight that electron started at the mid-point between the plates, hence $V_{initial} = V_{midpt} = 0$ V.
   -

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

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

The electron moves in a parabolic path because it has a constant vertical (downwards) velocity [B1]
while experiencing a perpendicular constant acceleration (horizontal or leftwards). [B1]

Comments:

1) Many students were able to identify that the electron follows a parabolic path, however, they were either not able to bring out the conditions or did not read the question properly which stated to describe the motion using acceleration and velocity.
2) To be awarded full credit, answers should mention “constant” and give direction of both velocity and acceleration.
3) Many students are mixed up with horizontal and vertical direction!
4) If student simply stated constant acceleration towards +ve plate, no marks awarded as this description does not clearly represent a horizontal leftward motion.
5) The underlined words were extracted from the learning outcome of the syllabus: describe and explain motion due to a uniform velocity in one direction and a uniform acceleration in a perpendicular direction.

(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]

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]

Comments:

1) Very well done.
2) Note that if there are any wrong physics mentioned in the answer, no marks are given (e.g. circular motion, curve upwards, etc)

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.

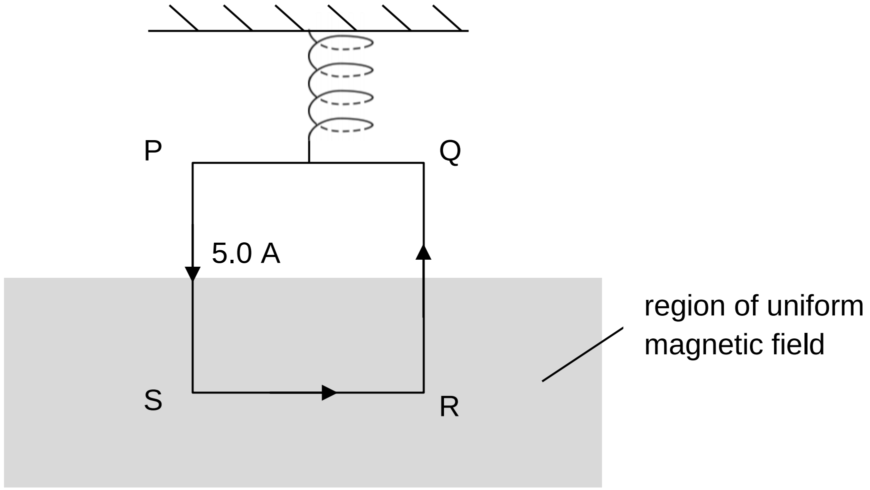


Fig. 6.1

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]

Since the spring is compressed when the current is passing through coil, <u>magnetic force on the wire is upwards</u>. [M1]

<u>By Fleming's Left Hand Rule,</u>

the direction of the magnetic field is into the paper. [A1]

Comments:

1) Generally well done.
2) A small number of students did not indicate the direction of force or wrong apply Newton 3rd Law and stated for is acting downwards on coil→ zero marks
3) A small number of students used right hand grip rule to explain and was given zero.

	(b)	Calculate the spring constant of the spring.	
		spring constant = ………………… N m^{-1}	[2]
		$F = BIL$ $kx = BIL$ $k(0.0080) = (3.0)(5.0)(0.40)$ [C1] $k = 750\ \text{N m}^{-1}$ [A1]	
		Comments: 1) A considerable number of students recalled the formula for force on a spring wrongly and quoted F= ½ kx or F= kx^2 or F=1/2 kx^2 and were given zero mark 2) Others who got it wrong did not correctly convert the values of L and x into meters.	

(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.

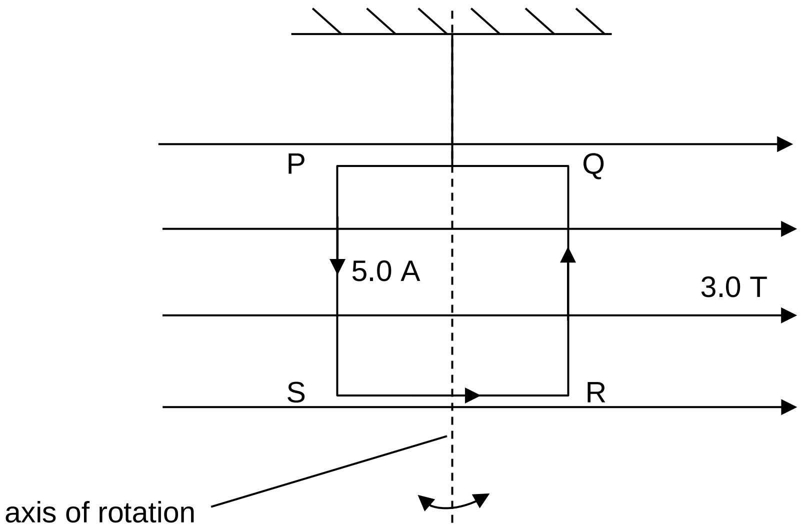


Fig. 6.2

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

maximum torque = ... N m

minimum torque = ... N m [3]

Max Torque $= F \times L_{SR}$

$= BIL^2$

$= (3.0)(5.0)(0.40)^2$ [M1]

$= 2.40$ N m [A1]

Min Torque = 0 N m [A1]

Comments:

1) Generally well done.
2) A small number simply took the force x ½ distance (ie 0.20 m) of SR without realizing that they should be finding torque of a couple.

		(ii)	Using Fig. 6.2, explain why the coil will oscillate about the axis.	
			………………………………………………………………………………..............	[3]
			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.	
			Comments: 1) Not well done. 2) A small number of students applied Faraday and Lenz's Law for their explanation and was given zero marks. 3) Most students believe that a turning moment constitute to oscillation which is not true. 4) Phrases that **would not be awarded any mark** include: - Force on PS is upwards and force on QR is downward. [First B1] - Coil **oscillate**, **spins** instead of coil turning or rotating or there is a torque on coil due to the forces on PS and QR. [Second B1]	

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

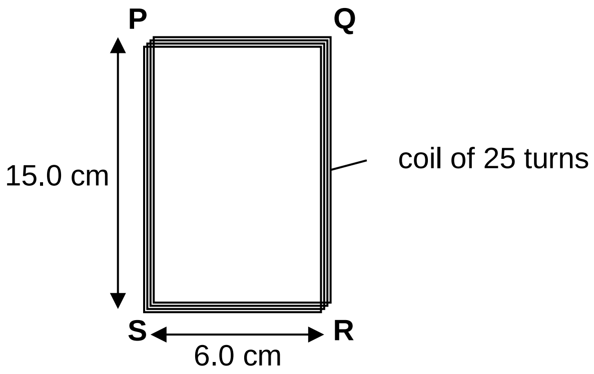


Fig. 7.1 (not to scale)

(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]

$\Phi = NBA$

$\Phi = 25\times0.025\times0.150\times0.060$ [C1]

$= 5.63 \times 10^{-3}$ Wb [A1] (also accept negative answer)

Comments:

1) Most errors were due to unit conversion errors, one common one being $\frac{15\times6}{100}$ to find the area in m^2 which is incorrect.

(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.

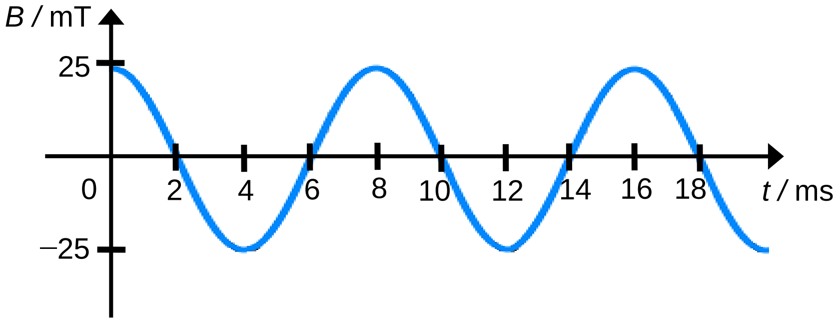


Fig. 7.2

(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]

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 of magnetic flux linkage, a (sinusoidal) e.m.f. is induced or generated in the coil. [B1]

Comments:

1) In this case because "Use Faraday's Law" is a condition of a question, vague references to Faraday's Law is insufficient.
2) For example, one common error is to fail to specify that emf is directly proportional to the rate of change of magnetic flux linkage.
3) Note: the coil is NOT rotating.
4) Explanation should be in English words and not mathematical equations.
5) Faraday's Law is not "the magnitude of induced emf" but simply "the emf" because the emf can have positive and negative direction values.

(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]

$E = NAB_0 \frac{2\pi}{T} \sin\left(\frac{2\pi}{T} t\right)$

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]

Comments:

1) A common error is to forget that the maximum induced emf is simply the coefficient of the sine term. The maximum value of $NBA\omega \sin(\omega t)$ is simply $NBA\omega$
2) If a time is substituted into the equation, the calculator must be in radians mode for the result to be correct.

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

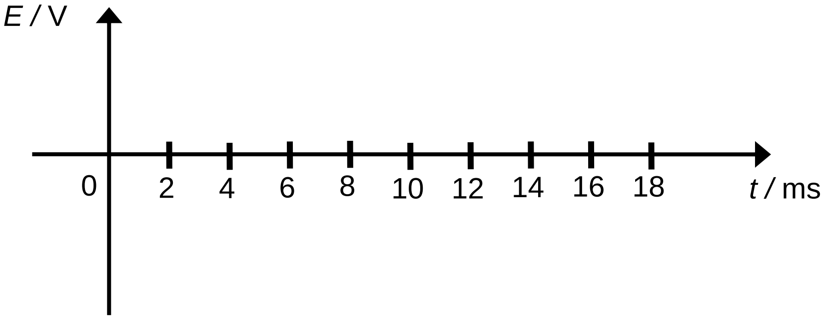


Fig. 7.3

[2]

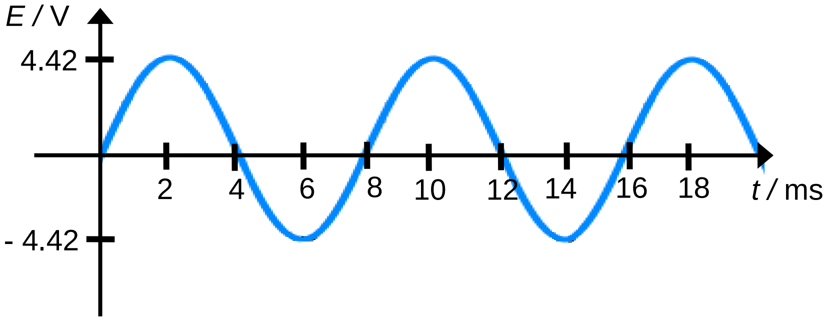


Fig. 7.3

Current shape: positive sine graph [M1]

Correct values indicated: E_{max} = 4.42 V (allow ecf) and T = 8.0 ms [A1]

Comments:

1) Common errors were to forget that the emf is the negative differential of the flux linkage, so the graph is a sine curve and not a negative sine curve.
2) Note that the frequency of the curve does not change after differentiation. Curves showing double the period are incorrect.
3) The period is 8 ms not 6 ms.

(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]

The induced current flows in PQRS or clockwise direction (do not accept PQ, QR, RS, SP) [A1] so as to produce a magnetic flux into the paper to oppose the decrease or change in magnetic flux linkage. [M1]

Comments:

1) Question does not require definition of Lenz's Law. Incorrect to mention "induced e.m.f. flows". It is the induced current that flows.
2) Induced current cannot oppose the decrease/change in magnetic flux linkage. Some students did not clearly state what the opposing effect is.
3) Direction of the magnetic flux is either not stated or wrongly stated.
4) Not accepted: "towards the page" as unclear whether into or out of the page and "PQ, QR, RS, SP" as current flow has to be continuous.

(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]

Root-mean-square voltage of input,

$$V_{rms} = \frac{V_0}{\sqrt{2}}$$

$$V_{rms} = \frac{4.42}{\sqrt{2}} = V_P \text{ [C1]}$$

$$\frac{N_S}{N_P} = \frac{V_S}{V_P}$$

No. of turns in sec coil,

$$N_S = \frac{V_S}{V_P} N_P = \frac{240}{\frac{4.42}{\sqrt{2}}} \times 15 = \frac{240\sqrt{2}}{4.42} \times 15 \text{ [C1]}$$

$$N_S = 1150 \text{ [A1]}$$

Comments:

1) Some students did not use V_{rms} for V_{primary} or wrongly remembered the relationship between V_{rms} and V_0 from b(ii).

		(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]
			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]	
			Comments: 1) The ratings given are rms values. 2) Efficiency of 81% is for power. Some students wrongly apply 81% on voltage only. 3) Some students were confused between power output and power input.	

8	**(a)**	State a phenomenon that provides evidence for the		
		(i)	particulate nature of electromagnetic radiation.	
			…………………………………………………………………………………..	[1]
			Photoelectric effect	B1
			Comments: 1) Well done. 2) If the photoelectric effect is not clearly referenced, the mark is not awarded. E.g. Just writing: “Threshold frequency.”	
		(ii)	wave nature of electromagnetic radiation.	
			…………………………………………………………………………………..	[1]
			Diffraction or interference	B1
			Comments: 1) Well done. 2) Some students mistakenly cited “electron diffraction” or passing the beam through graphite, which only works for electrons.	
	(b)	Distinguish between the appearance of the emission and absorption line spectra for the visible line spectrum.		
		……………………………………………………………………………………….		[2]
		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
		Comments: 1) Poorly done, due to missing key words. Discrete – each colored line in the emission spectrum comprises a single frequency of light. Continuous – the white light, upon passing through the prism, is spread sequentially by wavelength. Spectrum – The presence of different wavelengths White light – indicates the full spectrum of visible light had been used		

(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.

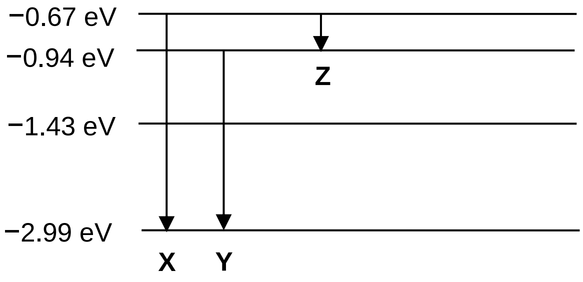


Fig. 8.1

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

wavelength = ………………… m [2]

$$\lambda = \frac{hc}{\Delta E} = \frac{\left(6.63\times10^{-34}\right)\times\left(3.0\times10^{8}\right)}{\left(-0.94-\left(-2.99\right)\right)\times\left(1.6\times10^{-19}\right)}$$ C1

$$= 6.06\times10^{-7}\ \text{m}$$ A1

Comments:

1) Well done
2) Mistakes include
    a. forgetting to include elementary charge in calculation
    b. wrong calculations

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

……………………………………………………………………………………… [1]

Visible light (or red/orange light) B1

Comments:

1) ECF based on previous answer

(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.

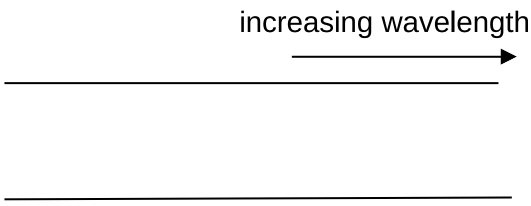
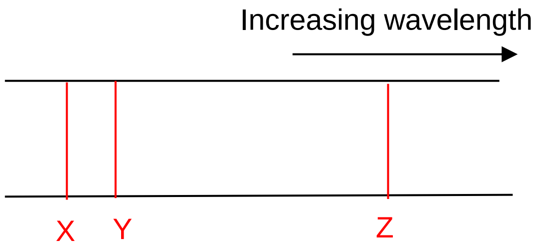


Fig. 8.2

[2]



B1 for correct labelled lines
B1 for correct gap spacing

Comments:

1) Well done.
2) If time permitted, the student could consider re-using the calculation in the preceding question to calculate the wavelengths of transition Y and Z, for a firm answer.

(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]

6 possible transitions. B1

Comments:

1) Well done
2) Students are advised to sketch out the possible transitions.

9	**(a)**	State what is meant by *nuclear binding energy*.	
		…………………………………………………………………………………………....................	[1]
		Nuclear binding energy is the minimum energy required to completely separate all the nucleons of a nucleus (to infinity).	B1
		Comments: Most students did not remember the correct definition 1) A majority thought it was energy to binding the nucleons into nucleus 2) Key words like “minimum” and “completely” are commonly missing	

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

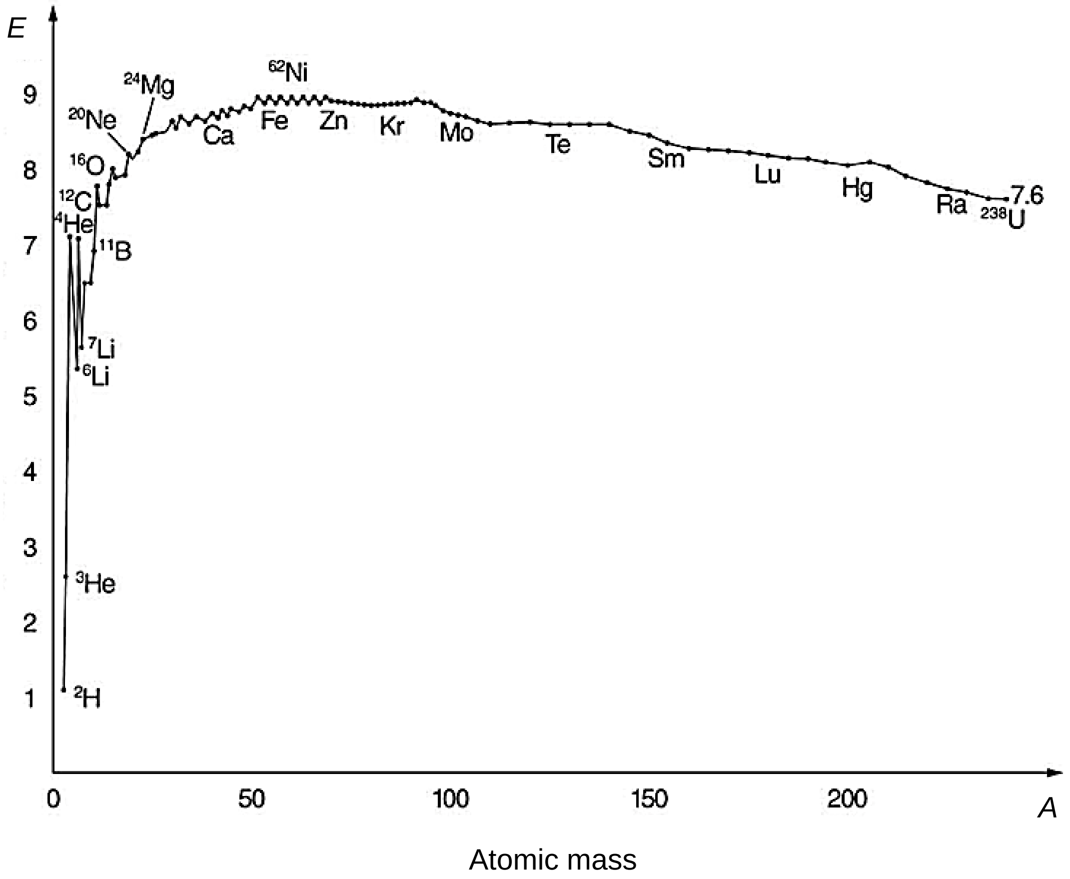


Fig. 9.1

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]

The nucleus of $^{1}_{1}H$ is a single proton and so no energy is needed to separate it. B1

Comments:

1) Most wrote about $^{1}_{1}H$ being a single proton and therefore cannot be separated anymore, but stopped short of linking it properly to the concept of binding energy (which is not about separating the nucleons itself, but rather, the energy required to separate)

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

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

.... [2]

From the graph, the product $^{3}_{2}\mathrm{He}$ has a higher binding energy per nucleon than the reactant $^{2}_{1}\mathrm{H}$ (and $^{1}_{1}\mathrm{H}$ has no binding energy). B1

This means that the total binding energy of the products is higher than the total binding energy of the reactants (and mass defect has increased in the reaction). B1

Since mass defect has increased, it means that mass has been converted into energy during the reaction, thus energy is released.

Comments:
1) As Fig 9.1 is about binding energy *per nucleon*, and not binding energy itself, first mark is not awarded if the student commented that "binding energy of $^{3}_{2}\mathrm{He}$ is higher".
2) The second mark is awarded only if there is clear indication that student has considered the *sum* of binding energies of *all* reactants (i.e. BE of $^{2}_{1}\mathrm{H}$ + BE of $^{1}_{1}\mathrm{H}$) when comparing with the binding energy of $^{3}_{2}\mathrm{He}$.

(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, $^{2}_{1}\mathrm{H}$	1.12
helium-3, $^{3}_{2}\mathrm{He}$	2.90

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

energy released = ... MeV [2]

energy released = total binding energy of products – total binding energy of the reactants.

energy released = 2.90 x 3 – 1.12 x 2 C1

= 6.46 MeV A1

Comments:
1) Many students did not multiply the nucleon number to the binding energy per nucleon value to obtain the binding energy for calculating energy release.

(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:

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

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

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

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

energy = ………………… J [2]

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} C1

= 1.94 x 10^{-13} J A1

energy change = + 1.94 x 10^{-13} J

Comments:
1) A common mistake is not converting the rest mass values to kg.
2) Since question is asking about energy associated, and not energy release, negative answer is not accepted.

		(ii)	Explain whether the reaction in **(d)** can occur spontaneously.	
			……………………………………………………………………………….......	[2]
			The energy change in the reaction is positive, meaning that the total mass of the products is higher than the total mass of the reactants / energy is absorbed in the reaction. Thus, the reaction is not spontaneous 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
			Comments: 1) The most common wrong answer was to justify the reaction can/ cannot occur spontaneously based on the size of the amount of energy as calculated in (d) (for example "reaction is spontaneous because the energy in (d) is very small")	

End of Section B