Catholic Junior College
JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME	
CLASS	2T

PHYSICS
Paper 2: Structured Questions

9749/2
August 2023
2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

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

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

Answer **all** questions.

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

Suggested Solutions

FOR EXAMINER'S USE	
Q1	/ 10
Q2	/ 10
Q3	/ 8
Q4	/ 10
Q5	/ 14
Q6	/ 9
Q7	/ 19
PAPER 2	/ 80

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

[Turn over

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} mol^{-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	=	$u t + \frac{1}{2} a t^2$
	v^2	=	$u^2 + 2as$
work done on / by a gas	W	=	$p \Delta V$
hydrostatic pressure	p	=	$\rho g h$
gravitational potential	ϕ	=	$-\frac{Gm}{r}$
temperature	T / K	=	$T / {}^{\circ}C + 273.15$
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_0 \cos \omega t$
		=	$\pm \omega \sqrt{x_0^2 - x^2}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + ...$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + ...$
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	=	$\frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o n I$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

Answer **all** questions from this paper.

1 (a) A swimmer is swimming at a constant speed in a pool. Drag forces due to the water oppose the motion of the swimmer.

Explain why the swimmer travels at constant speed.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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

Solution:

The swimmer experiences a forward force from the water (thrust) which is equal and opposite to the drag force so that the net force is zero. 1

According to Newton's first law of motion, since there is no net force the swimmer will travel at a constant speed. 1

(b) The power output P of a swimmer used to overcome the drag forces travelling when at speed v is given by

$$P=\frac{1}{2}C_D\rho Av^3$$

where C_D is the drag coefficient, ρ is the density of water and A is the frontal area of the swimmer.

In an experiment to measure the C_D for freestyle, the data for a particular swimmer is collected. The data is shown in Table 1.1.

Table 1.1

quantity	magnitude	uncertainty
P/W	294	±2
ρ/kg m^{-3}	1000	±1
A/m^2	0.20	±0.01
v/m s^{-1}	1.4	±0.1

Determine the C_D of the swimmer, with its actual uncertainty. Give your answer to an appropriate number of significant figures.

			C_D = ……………… ± …………..	[4]
		Solution: $C_D = \dfrac{2P}{\rho A v^3} = \dfrac{2(294)}{1000(0.20)(1.4)^3}$ $C_D = 1.07$ $\dfrac{\Delta C_D}{C_D} = \dfrac{\Delta P}{P} + \dfrac{\Delta \rho}{\rho} + \dfrac{\Delta A}{A} + 3\dfrac{\Delta v}{v} = \dfrac{2}{294} + \dfrac{1}{1000} + \dfrac{0.01}{0.20} + 3\dfrac{0.1}{1.4}$ $\dfrac{\Delta C_D}{C_D} = 0.272$ $\Delta C_D = 0.272 \times 1.07 \approx 0.3$ $C_D = 1.1 \pm 0.3$		1 1 1 1
	(c)	**(i)**	Derive, from the definition of power, an expression of the drag force *F* experienced by the swimmer in terms of the velocity *v*.	[2]
			Solution: Since $P = \dfrac{W}{t} = \dfrac{Fs}{t} = Fv$ $F = \dfrac{P}{v} = \dfrac{\frac{1}{2}C_D \rho A v^3}{v}$ $F = \dfrac{1}{2}C_D \rho A v^2$	1 1
		(ii)	Hence or otherwise, calculate the work done by the swimmer to overcome the drag force when he swims a distance of 50 m at a constant speed of 1.4 m s^{-1}.	

			work done = ………………. J	[2]
			Solution: $W = Fs = \frac{1}{2}C_D\rho Av^2 s = \frac{1}{2}(1.07)(1000)(0.20)(1.4)^2(50)$	1
			W = 10500 J	1

2	**(a)**	Fig. 2.1 shows a mass initially travelling at right angles to the Earth's uniform gravitational field.	

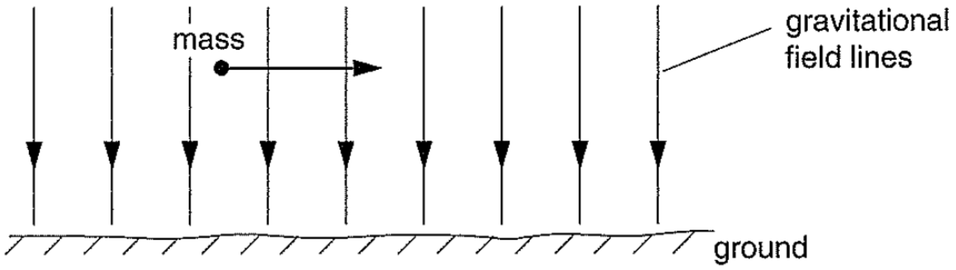


Fig. 2.1

Describe the subsequent motion of the mass.

……

…… [1]

Solution:
Mass will follow a parabolic path towards the ground | 1

(b) Fig. 2.2 shows an electron initially travelling parallel to a uniform electric field.

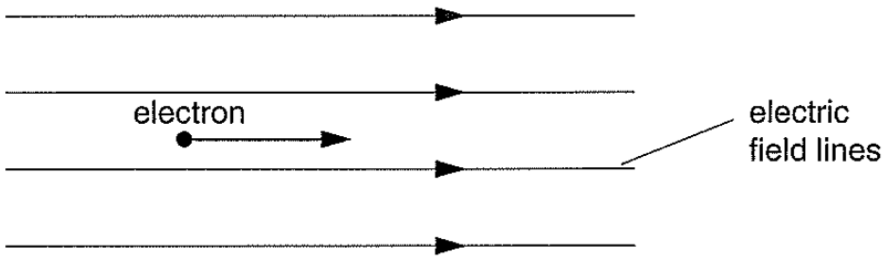
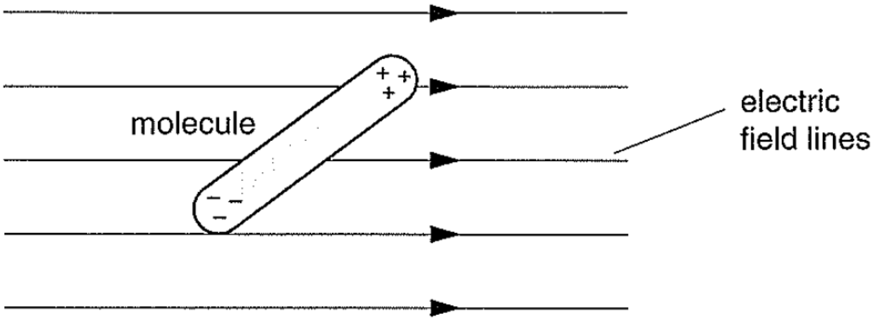


Fig. 2.2

Describe the subsequent motion of the electron.

		……………………………………………………………………………………………… ……………………………………………………………………………………………… ………………………………………………………………………………………………[2]
		Solution: Electron will slow down to a stop and then 1 accelerate to the left 1
	(c)	Fig. 2.3 shows a long molecule placed in a uniform electric field.  **Fig. 2.3** The ends of the molecule have equal but opposite charges. Describe and explain the initial motion of the molecule in the electric field.
		……………………………………………………………………………………………… ……………………………………………………………………………………………… ……………………………………………………………………………………………… ……………………………………………………………………………………………… [2]
		Solution: Forces acting on ends of the molecule are equal and opposite or they form a couple 1 This causes the molecule to rotate clockwise about its centre of mass 1
	(d)	Fig. 2.4 shows a sphere of weight 1.6×10^{-2} N with an electric charge of +2.0 μC. It is released from rest, in vacuum, between two parallel, vertical metal plates. The separation of the plates is 0.10 m. One plate has a potential of +80 V and the other plate has a potential of -80 V.

0.10 m

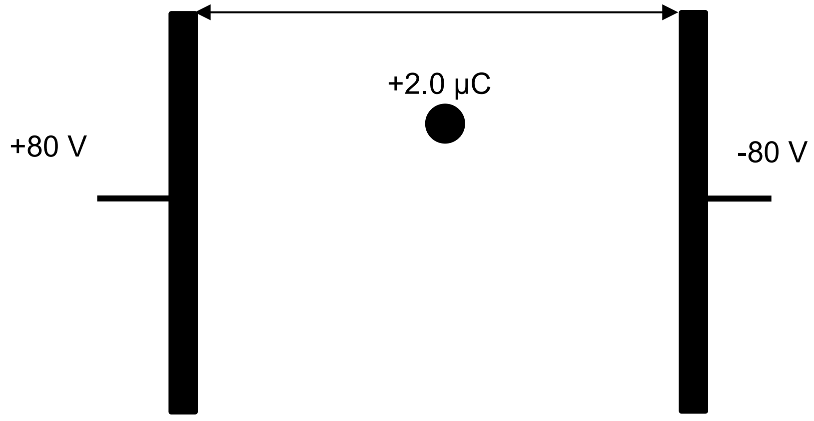


Fig. 2.4

(i) Determine the electric force experienced by the sphere.

force = ……………… N [2]

Solution:

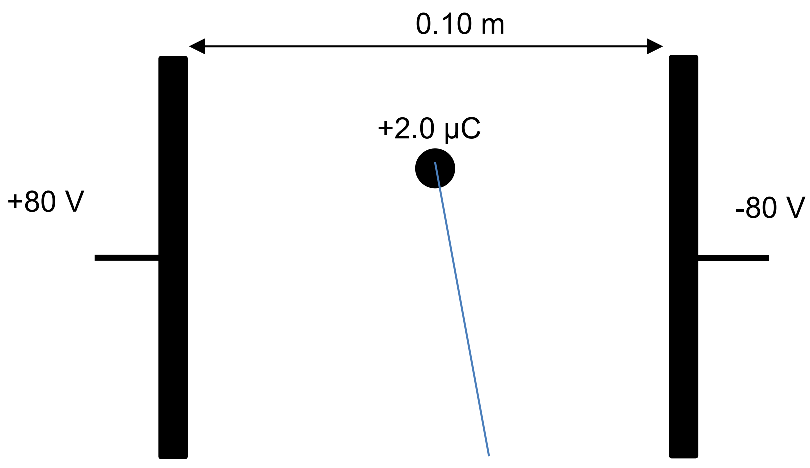
$F_E = qV/d$

$= 2 \times 10^{-6} \times 160 / 0.10$ 1

$= 3.2 \times 10^{-3}$ N 1

(ii) On Fig. 2.4, sketch the path taken by the sphere after it is released. [1]

Solution:



Straight line pointing downward slightly to right (less than 20 degrees from vertical) 1

(e) The variations with separation of the gravitational potential energy U_G and of the electric potential energy U_E between two protons are shown in Fig. 2.5.

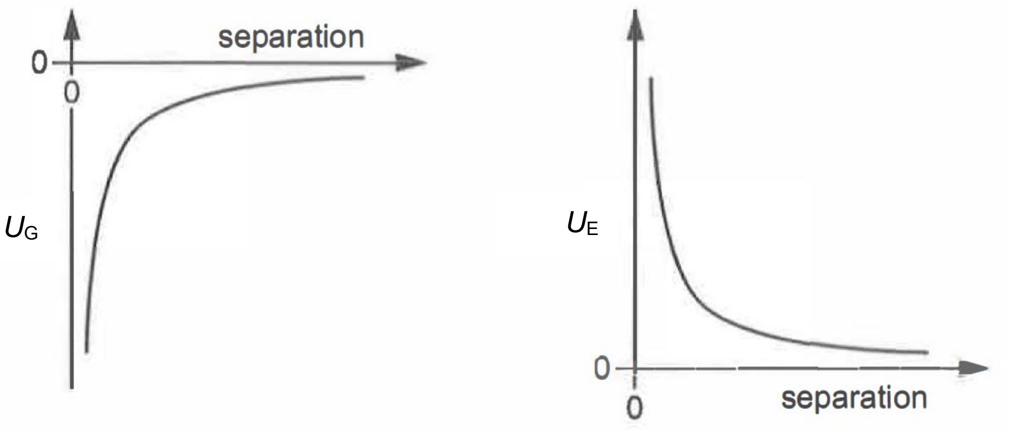


Fig. 2.5

Explain why the gravitational potential energy and the electric potential energy have opposite signs.

....

....

....

.... [2]

Solution:

The gravitational force acting between the protons are attractive whereas the electric force acting between the protons are repulsive, 1

so

the work done by an external agent to bring a proton from infinity to the point is negative. 1

the work done by an external agent to bring a proton from infinity to the point is positive.

3 A cantilever spar cable-stayed bridge is a unique yet functional variation of the traditional cable suspension bridge.

In one such model bridge, a bridge beam is supported by a cable. The cable connected at an angle of 30° to a non-uniform cantilever spar of length *L* slanted at an angle of 50° from the ground with a base at P, as shown in Fig. 3.1.

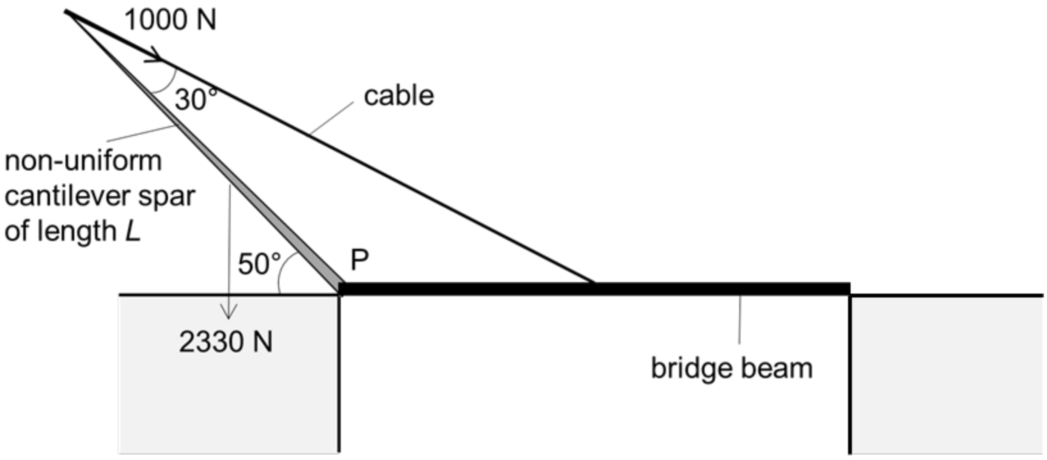


Fig 3.1 (not to scale)

The tension in the cable is 1000 N and the weight of the cantilever spar is 2330 N.

(a) By taking moments about P, show that the centre of mass of the cantilever spar is located at a distance of 0.33*L* from P.

[3]

Solution:

Taking moments about P:

Let d be the distance of the centre of mass from P

Moment due to the tension = Moment due to the weight 1

$T \times L\sin(30) = W \times d\cos(50)$ 1

$1000 \times 0.5L = 2330 \times 0.643d$ 1

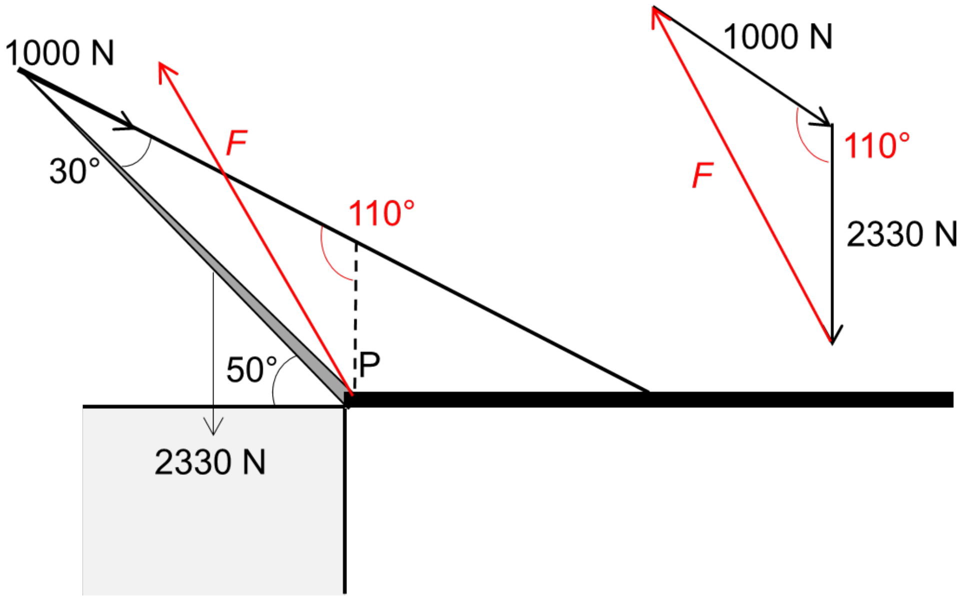
$d = 0.33L$ (shown)

(b) Calculate the magnitude of the force acting on the cantilever spar at P.

magnitude of force at P = ………………… N [3]

Solution:

Since the forces are in equilibrium, the three forces must form a closed vector triangle. 1



To solve for F, use the cosine rule:

$$F^2 = 1000^2 + 2330^2 - 2(1000)(2330)\cos 110$$ 1

$$F = 2830 \text{ N}$$ 1

(c) The traditional cable-stayed bridge design is shown in Fig 3.2

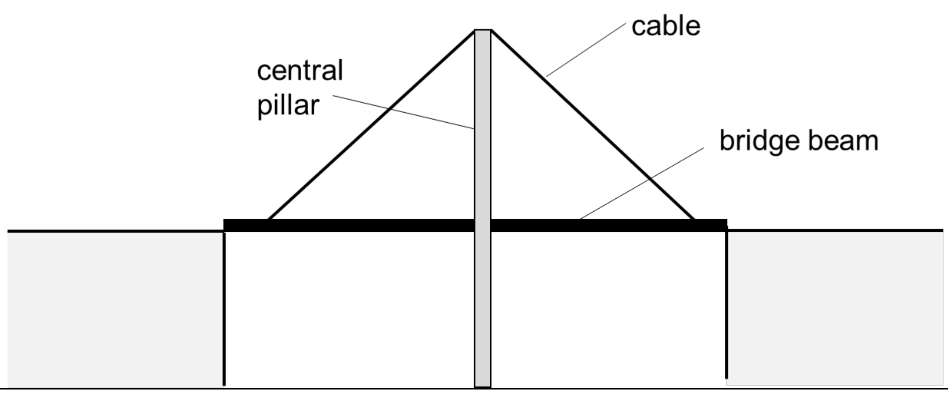


		Fig 3.2 Suggest, with a reason, one advantage a cantilever spar cable-stayed bridge may have over a traditional cable-stayed bridge design. ………………………………………………………………………………………… ………………………………………………………………………………………… ………………………………………………………………………………………… ……………………………………………………………………………………[2]	
		Solution: the cantilever spar requires fewer cables to support a bridge since there is no need to support spans on either side of the central pillar OR wider space of vessels to pass through under the bridge since there is no central pillar	1 1 1 1

4 (a) A battery of electromotive force (e.m.f.) 9.0 V and internal resistance *r* is connected to two resistors S and T, as shown in Fig. 4.1.

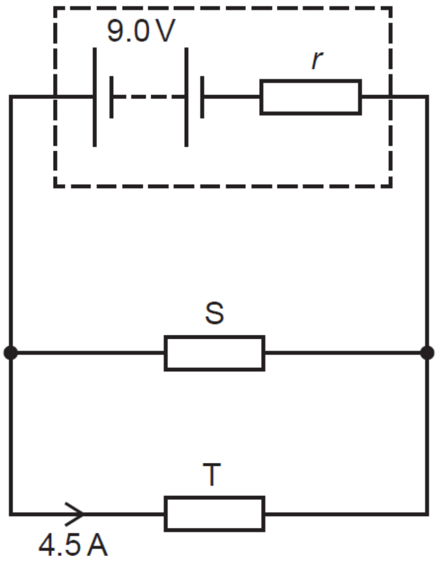


Fig 4.1

A total charge of 650 C moves through resistor S in a time interval of 540 s. During this time resistor S dissipates 4800 J of energy. The current in resistor T is 4.5 A. Assume that the e.m.f. of the battery remains constant.

Calculate:

(i) the current in resistor S

current = ...A [1]

Solution:

$I = \frac{Q}{t} = \frac{650}{540} = 1.2\text{ A}$ 1

(ii) the internal resistance *r* of the battery.

r = ... Ω [3]

Solution:

$V = \frac{W}{Q} = \frac{4800}{650} = 7.38\text{ V}$ or use $V = \frac{P}{I}$ and $P = \frac{W}{t}$ 1

			Find $I_{tot} = 1.2 + 4.5 = 5.7\ A$ Terminal p.d. $V = E - I_{tot}\, r$ $= 9 - 5.7\, r$ $7.38 = 9 - (1.2 + 4.5)\, r$ $r = 0.28\ \Omega$	1 1
	(b)	A sinusoidal alternating voltage has a root-mean-square (r.m.s.) potential difference (p.d.) of 4.2 V and a frequency of 50 Hz.		
		(i)	By reference to heating effect, explain what is meant by the root-mean-square (r.m.s.) value of an alternating current.	
			....[1]	
			Solution: the value of steady direct current that dissipates energy at the same rate as the alternating current in a given resistance.	1
		(ii)	The alternating voltage is applied across a resistor of resistance 760 Ω. Determine the maximum power dissipated by the resistor.	
			maximum power dissipated = ... mW	[2]
			Solution: From $V_{rms} = \dfrac{V_o}{\sqrt{2}}$ $V_o = 4.2\, x \sqrt{2} = 5.94 V$ $P_{\max} = \dfrac{V_o^2}{R} = \dfrac{5.94^2}{760}$ $= 46\, mW$	 1 1
		(iii)	On Fig. 4.2, sketch the variation with time t of the power P transferred in the resistor. Include on your graph a time equal to two periods of the alternating potential difference.	

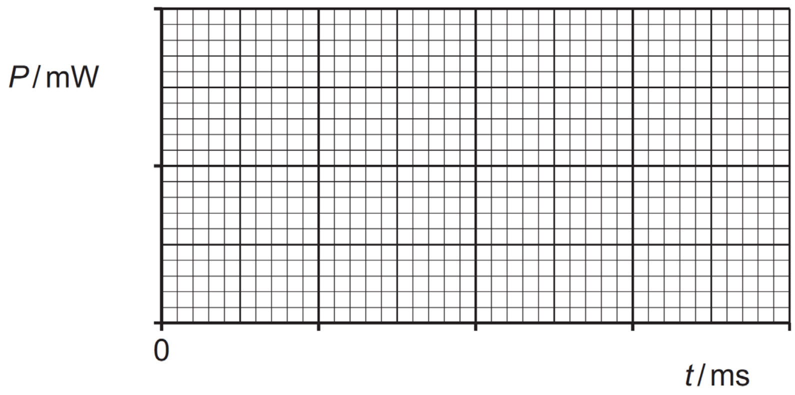
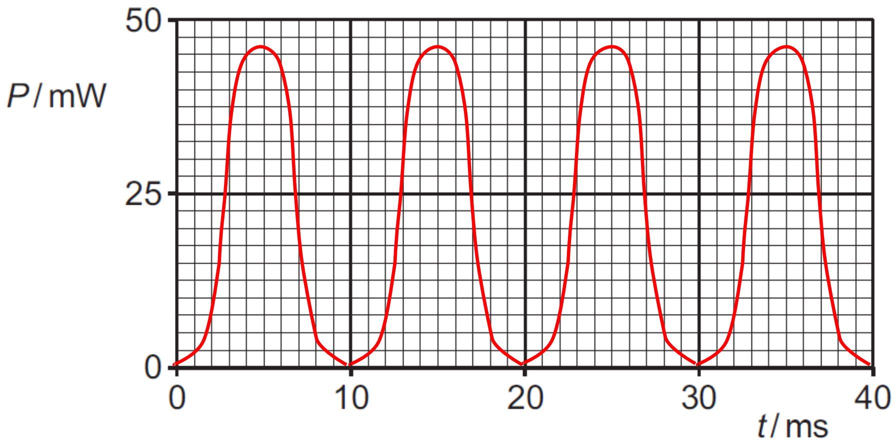


Fig. 4.2

[3]

Solution:



1
1
1

5	**(a)**	State Faraday's law of electromagnetic induction.	
		....[2]	
		Solution: The magnitude of the electromotive force (e.m.f.) induced in a conductor is directly proportional to the rate of change of magnetic flux linkage of the conductor.	1 1
	(b)	Two coils, P and S, are wound on an iron core, as shown in Fig. 5.1.	

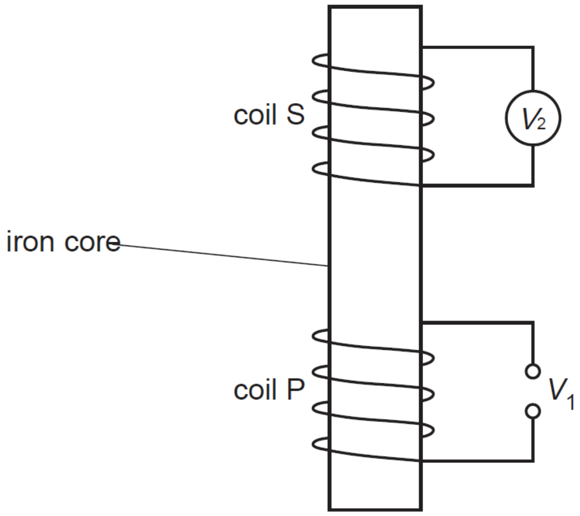


Fig. 5.1

Coil P is connected to a potential difference (p.d.) V_1 that gives rise to a magnetic field in the iron core.

Fig. 5.2 shows the variation with time t of the magnetic flux density B in the iron core.

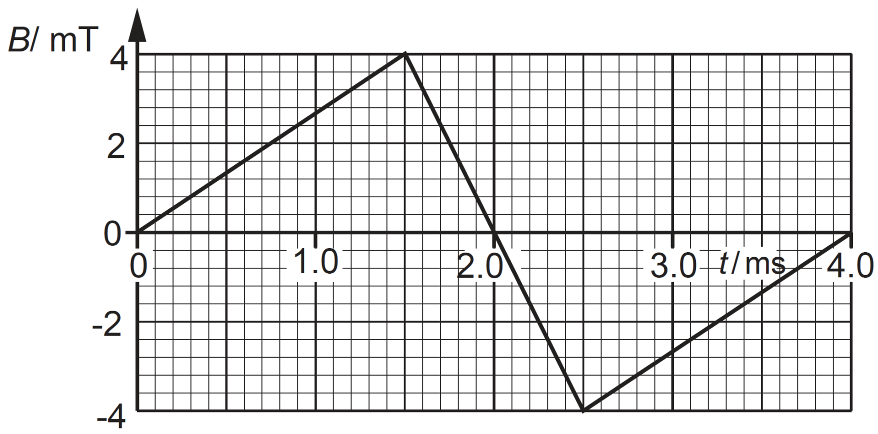


Fig. 5.2

Coil S contains 250 turns of wire. Each turn of wire has a diameter of 2.5 cm. A voltmeter measures the electromotive force (e.m.f.) V_2 that is induced across coil S.

Use data from Fig. 5.2 to determine the maximum electromotive force (e.m.f.) induced in coil S.

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

Solution:

Max gradient of the B-t graph

$$= \frac{dB}{dt} = \frac{(4-(-4))\,x10^{-3}}{(2.5-1.5)\,x10^{-3}} = 8 \text{ T s}^{-1}$$ 1

Maximum induced e.m.f. in coil S

$$= |E| = \frac{dNBA}{dt} = NA\frac{dB}{dt}$$

$$= N\,x\,\pi\,x\left(\frac{D}{2}\right)^2 x\frac{dB}{dt}_{\text{max}}$$ 1

$$= 250\,x\,\pi\,x\left(\frac{2.5x10^{-2}}{2}\right)^2 x\,8$$

= 0.982 V 1

(c) On Fig. 5.3, sketch the variation with t of V_2 between t = 0 and t = 4.0 ms.

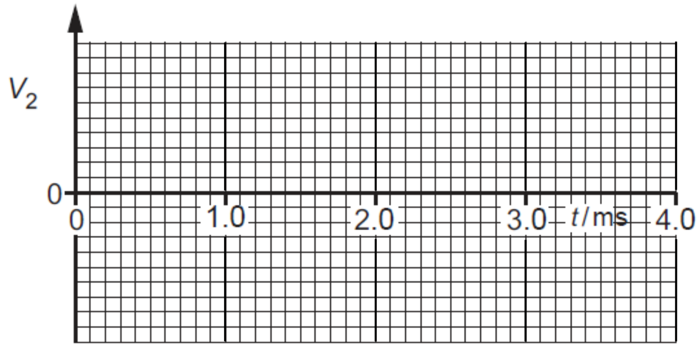


Fig. 5.3

[4]

Solution:

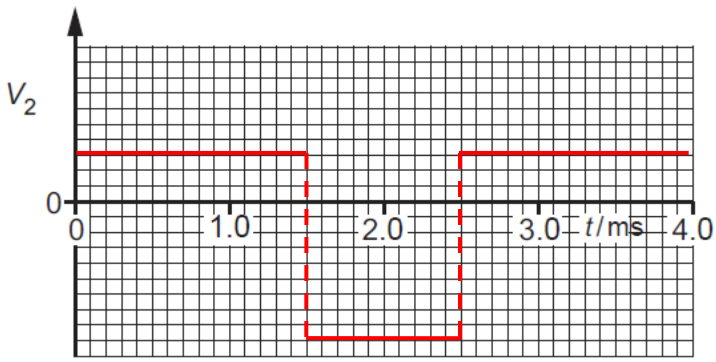
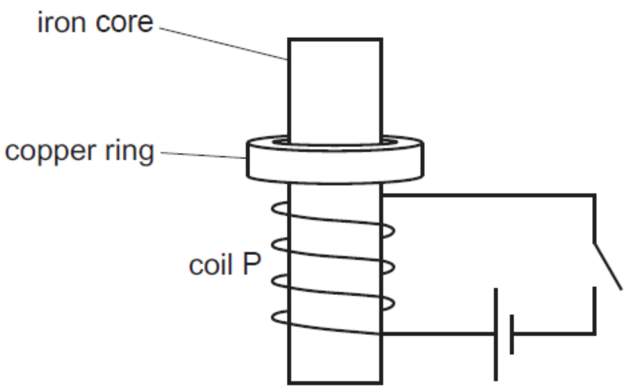


Fig. 5.3

V_2 stepped, all at non-zero values, between t = 0 and t = 0.40 s (horizontal line for all 3 segments) – *Marker: not time based* 1

V2 shown with same non-zero magnitude up to t = 0.15 s and after t = 0.25 s but with a different magnitude between these times (Marker: either a hill or valley) 1

		V_2 shown with a magnitude between t = 0.15 s and t = 0.25 s that is three times the magnitude before t = 0.15 s and after t = 0.25 s V_2 shown with same sign up to t = 0.15 s and after t = 0.25 s, and opposite sign in between		1 1
	(d)	Coil S in **(b)** is now replaced with a copper ring that rests loosely on top of coil P. The supply to coil P is replaced with a cell and a switch that is initially open, as shown in Fig. 5.4.  **Fig. 5.4**		
		(i)	The switch is now closed. As it is closed, the copper ring is observed to move vertically upwards on the iron core. Explain why this happens.	
			....[4]	
			Solution: Increasing/ changing current in coil P causes increasing/ changing magnetic flux density in coil iron core links the magnetic flux density/ field from coil P to the ring Increasing/changing (magnetic) flux linkage experienced by the ring causes induced e.m.f. in ring by Faraday's law and this causes a current in ring (closed circuit) (magnetic) field due to (induced) current in ring interacts with (coil's) field to oppose the change to cause an upwards force (on ring) according to Lenz's law.	1 1 1 1
		(ii)	Suggest, with a reason, what would be the effect on the ring of repeating the procedure in **(d)(i)** with the terminals of the cell reversed.	
			....	[1]

			Solution: Both magnetic fields reverse direction so ring still moves up or current (in ring) and (coil's) field both reverse so ring still moves up or when terminals are reverse, there will still be a changing flux experienced by the ring so ring still moves up.	1

6	**(a)**	State how a line emission spectrum may be explained on the basis of the existence of discrete electron energy levels in atoms.	
		…………………………………………………………………………………………… …………………………………………………………………………………………… …………………………………………………………………………………………… …………………………………………………………………………………………… ……………………………………………………………………………………………[3]	
		Solution: A line emission spectrum shows that only certain values of wavelengths (or frequencies) of photons are emitted when gas atoms de-excite. Photons emitted have energies equal to the differences between the pairs of electron energy levels involved in the de-excitation. The fact that only certain wavelengths are seen implies that only photons of certain energies are emitted, which in turn implies that electrons inside an atom can only possess certain discrete values of energies (called the electron energy levels).	1 1 1

(b) The lowest six discrete energy levels for a hydrogen atom are shown in Fig. 6.1. The diagram is drawn to scale and the ground state is at -13.6 eV.

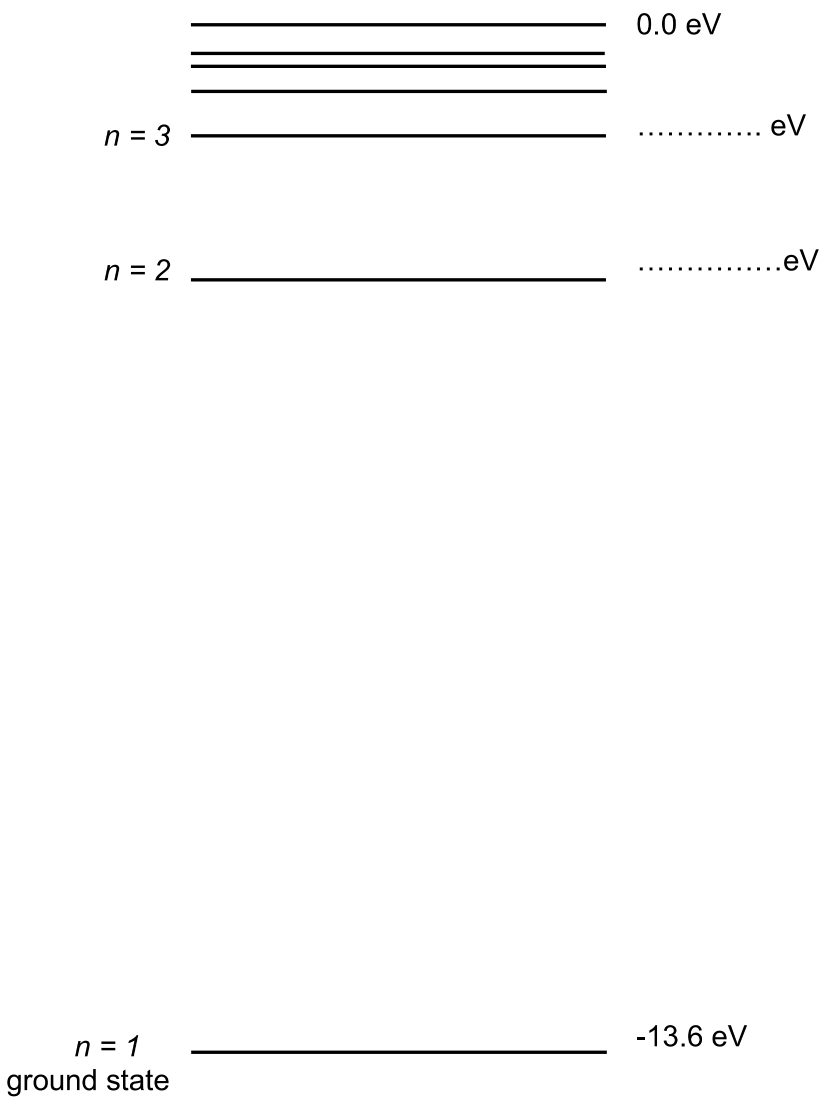


Fig. 6.1

(i) On Fig. 6.1, label the values for energy at energy levels n = 2 and n = 3. [1]

Solution:

Use ruler to measure

n = 2 is - 3.4 eV 1
n = 3 is -1.5 eV 1

		(ii)	Calculate the wavelength of the light emitted when an electron falls from n = 3 energy level to the n = 2 energy level.	
			wavelength = …………………….. m	[3]
			Solution: Energy of photon = (-1.5 – (-3.4)) eV $\frac{hc}{\lambda}$ = (-1.5 – (-3.4)) (1.6 x 10^{-19}) $\frac{6.63 x 10^{-34} x 3x10^{8}}{\lambda}$ = (-1.5 – (-3.4)) (1.6 x 10^{-19}) λ = 6.54 x 10^{-7} m (For info: visible region)	 1 1 1
		(iii)	Electromagnetic radiation is emitted when an electron falls to the ground state from any of the other energy levels. State the region of the electromagnetic spectrum in which the radiation lies.	
			electromagnetic radiation is …………………………	[1]
			Solution: From (b)(ii), energy of photons emitted when electrons fall to n = 2 state lie in the visible region. For greater difference in energy levels (eg. n = 2 to n = 1, photons emitted when electrons fall to n=1 state lie in the ultraviolet region.	 1
		(iv)	Describe one way by which an electron in gaseous hydrogen can be raised from a lower energy level to a higher energy level.	
			…………………………………………………………………………………… ……………………………………………………………………………………	[1]
			Solution: By thermal excitation by heating up the hydrogen gas. (electrons of high energy) OR By applying high voltage across the gas using a voltage discharge tube/ cathode ray tube OR Shine white light on the gas (use photons of all wavelengths)/ expose to sunlight	 1 1 1

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

Beginning in 1934, the Italian physicist Enrico Fermi began bombarding elements with neutrons instead of protons, theorizing that Chadwick's uncharged particles could pass into the nucleus without resistance. Like other scientists at the time, Fermi paid little attention to the possibility that matter might disappear during bombardment and result in the release of huge amounts of energy in accordance with Einstein's formula, $E = mc^2$, which stated that mass and energy were equivalent. Fermi and his colleagues bombarded sixty-three stable elements and produced thirty-seven new radioactive ones. They also found that carbon and hydrogen proved useful as moderators in slowing the bombarding neutrons and that slow neutrons produced the best results since neutrons moving more slowly remained in the vicinity of the nucleus longer and were therefore more likely to be captured.

One element Fermi bombarded with slow neutrons was uranium, the heaviest of the known elements. Scientists disagreed over what Fermi had produced in this transmutation. Some thought that the resulting substances were new "transuranic" elements, while others noted that the chemical properties of the substances resembled those of lighter elements. Fermi was himself uncertain. For the next several years, attempts to identify these substances dominated the research agenda in the international scientific community, with the answer coming out of Nazi Germany just before Christmas 1938.

The radiochemists Otto Hahn and Fritz Strassmann were bombarding elements with neutrons in their Berlin laboratory when they made an unexpected discovery. They found that while the nuclei of most elements changed somewhat during neutron bombardment, uranium nuclei changed greatly and broke into two roughly equal pieces. They split and became not the new transuranic elements that some thought Fermi had discovered but radioactive barium isotopes (barium has the atomic number 56) and fragments of the uranium itself. The substances Fermi had created in his experiments, that is, did more than resemble lighter elements; they were lighter elements. Importantly, the products of the Hahn-Strassmann experiment weighed less than that of the original uranium nucleus, and herein lay the primary significance of their findings. For it followed from Einstein's equation that the loss of mass resulting from the splitting process must have been converted into energy in the form of kinetic energy that could in turn be converted into heat.

Calculations made by Hahn's former colleague, Lise Meitner, a refugee from Nazism then staying in Sweden, and her nephew, Otto Frisch, led to the conclusion that so much energy had been released that a previously undiscovered kind of process was at work. Frisch, borrowing the term for cell division in biology - binary fission - named the process fission. For his part, Fermi had produced fission in 1934 but had not recognized it.

The large amount of energy released in a nuclear fission reaction, together with the emission of more than one neutron, has made it possible for neutron-induced fission to be used as a source of useful energy. When a neutron is captured by a Uranium-235 nucleus, it causes the nucleus to fission. On average, 2.5 neutrons are emitted in these fission reactions. This is illustrated in Fig. 7.1.

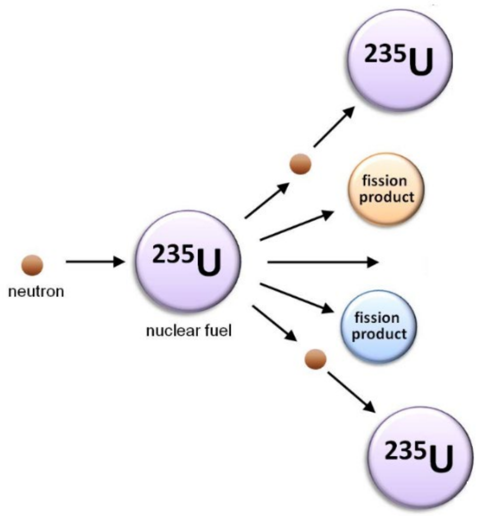


Fig. 7.1

When the conditions are suitable, a chain reaction can occur. If this chain reaction is not controlled, an explosion is likely to occur. However, if the chain reaction is controlled, as in a nuclear reactor, a source of continuous power may be created.

(a) **(i)** Explain what is meant by neutron-induced fission.

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

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

Solution:
splitting up of a (large) nucleus / nuclide after absorbing a neutron 1

(ii) Explain what is meant by chain reaction.

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

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

Solution:
(neutrons) one of the products prompt further fission or neutrons collide with further nuclei 1

(iii) Suggest why, in an uncontrolled chain reaction where all neutrons are captured by Uranium-235 nuclei, the majority of the energy is released during the final stages of the fission of a sample of the uranium.

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

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

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

Solution:
The number of neutrons emitted will be very large as the stages proceed 1
and hence leading to a very large number of reactions 1

(b) The induced fission reaction of Uranium-235 may be represented by a nuclear equation of the form

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{a}_{b}P + ^{c}_{d}Q + (2 \text{ or } 3)\,^{1}_{0}n + 198\text{MeV}$$

The fission products P and Q have approximately equal masses. However, when any two nuclei are fissioned, the fission products may not be the same. If a large sample of Uranium-235 is fissioned, many different fission products will be produced. The percentage amount of each fission product in the fissioned material is referred to as the percentage yield.

The variation with nucleon number of the percentage yield of different fission products is referred to as a 'fission yield curve' and is illustrated in Fig. 7.3.

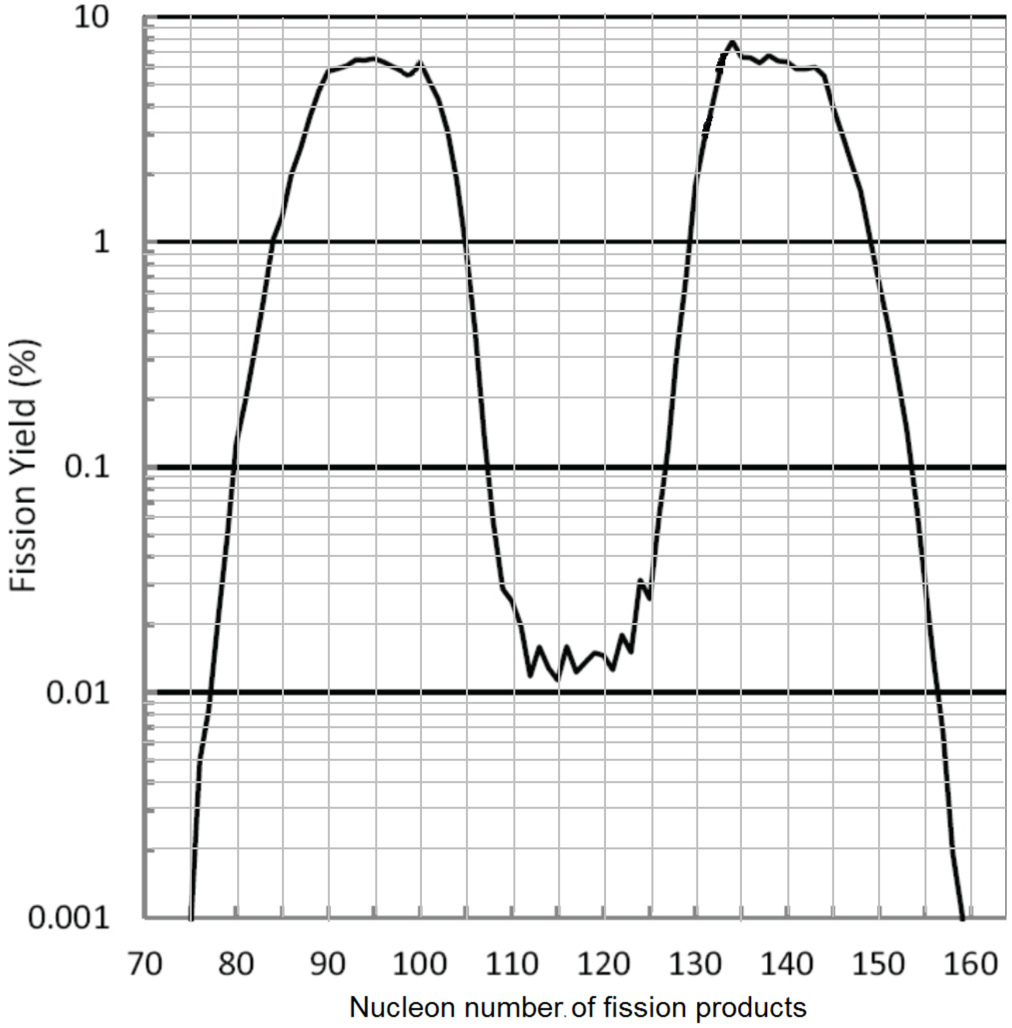


Fig. 7.3

(i) State the proton number of the other fission product for the fission of one uranium if one of the products is $^{89}_{36}Kr$.

proton number = ………………………… [1]

Solution:
92 – 36 = 56   1

(ii) Suggest why the percentage yield is shown on a logarithmic scale.

…………………………………………………………………………………………………

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

Solution:
The range of percentage yield varies over a wide range of magnitude and hence in order to show the variation of the values in a single graph, a logarithmic scale is used. 1

(iii) Show that the percentage yield of Molybdenum-99 ($^{99}_{42}\mathrm{Mo}$) is about 400 times more than those fission products having approximately equal masses.

[2]

Solution:
Percentage yield of having 99 = 6 % 1
Percentage yield of masses equal = 1.5 x 10^{-2} % 1
Both values to get 1 mark each
Therefore, the ratio = 6/(1.5 x 10^{-2})
= 400

(c) The energy released during one fission reaction of a uranium nuclei occurs partly as kinetic energy of the fission products (167 MeV) and of the neutrons (5 MeV).

(i) Suggest one other mechanism by which energy is released in the fission reaction.

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

Solution:
Gamma photon 1

(ii) In a nuclear power station, 25% of the energy of the fission products is converted into electrical energy.

Calculate, for the fission of a mass of 1.0 kg of Uranium-235,

1. the number of nuclei in 1.0 kg of Uranium-235,

number of nuclei = …………………… [2]

Solution:
1.00kg / 235 u = 1.00 kg / 235 x (1.66 x 10^{-27} kg) 1
=2.56 x 10^{24} 1

2. the electrical energy generated,

energy = ……………………J [3]

Solution:

Energy of fission products = $2.5634 \times 10^{24} \times 167 \times 10^{6} \times 1.6 \times 10^{-19}$ 1

Electrical energy = $0.25 \times 2.5634 \times 10^{24} \times 167 \times 10^{6} \times 1.6 \times 10^{-19}$ 1

= 1.71×10^{13} J 1

3. the average power output, in megawatts, of the power station if the uranium is fissioned in a time of 24 hours.

power = ……………………MW [2]

Solution:

Power = energy / time

= $1.7124 \times 10^{13} / (24 \times 60 \times 60)$ 1

= 1.98×10^{8} W 1

(d) The fission products are usually radioactive and give rise to a series of radioactive decay products. Each decay product has its own half-life. Two such fission products with their decay products and half-lives are shown below.

$$^{99}_{42}\text{Mo} \xrightarrow{\text{67 hours}} {}^{99}_{43}\text{Tc} \xrightarrow{2 \times 10^{5}\text{ years}} {}^{99}_{44}\text{Ru} \text{ (stable solid)}$$

$$^{140}_{54}\text{Xe} \xrightarrow{\text{16 seconds}} {}^{140}_{55}\text{Cs} \xrightarrow{\text{1.1 minutes}} {}^{140}_{56}\text{Ba} \xrightarrow{\text{13 days}} {}^{140}_{57}\text{La} \xrightarrow{\text{40 hours}} {}^{140}_{58}\text{Ce} \text{ (stable solid)}$$

Consider equal amounts of these two products.

Suggest why there are very different problems for the storage of this nuclear waste.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

		Solution: $^{99}_{42}Mo$ and its decay products have a very long half life. This means that the storage of $^{99}_{42}Mo$ will have to be in a lead container and put away for a very long time. (Max 2 marks for the next 3 points) On the other hand, $^{140}_{54}Xe$ has a very short half life and many decay products. For the same amount of these fission products, $^{140}_{54}Xe$ having many more fission products imply a greater safety concern for 2 reasons: 1. the total activity of $^{140}_{54}Xe$ and its daughter products is much higher than $^{99}_{42}Mo$. 2. with a short half-life, it means the decay constant is much greater, using $A=\lambda N$, the activity from $^{140}_{54}Xe$ is much higher. The much higher activity implies that $^{140}_{54}Xe$ is very hazardous immediately after it is produced, and must be handled with great care.	1 1 1 1