NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2 PRELIMINARY EXAM

Higher 2

CANDIDATE NAME	

SUBJECT CLASS		REGISTRATION NUMBER	

PHYSICS **9749/03**

Paper 3 Longer Structured Questions

Candidate answers on the Question Paper.

25 Aug 2023

2 hours

No Additional Materials are required.

READ THESE INSTRUCTION FIRST

Write your subject class, registration number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a 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.

Section A
Answers **all** questions.

Section B
Answer **one** question only.

You are advised to spend one and a half hours on Section A and half an hour on Section B.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

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

This document contains **28** printed pages and **0** blank pages.

Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(1/(36\pi)) \times 10^{-9}\,\mathrm{F\,m^{-1}}$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
unified atomic mass constant	$u = 1.66 \times 10^{-27}\,\mathrm{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on / by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -Gm/r$
temperature	$T/\mathrm{K} = T/{}^\circ\mathrm{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $= \pm \omega \sqrt{x_0^2 - x^2}$
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	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

[Turn over

Section A

1 A bungee jumper of mass 60 kg is attached to an elastic rope which starts to stretch after a short time of free fall. The gravitational potential energy of the bungee jumper is 0 J when she has fallen through 40 m to the lowest point.

(a)

	gravitational potential energy / kJ	elastic potential energy / kJ	kinetic energy / kJ
top		0	0
half-way		2.6	
bottom	0		

Fig. 1.1

Fill up the missing energies at the top, bottom and half-way positions in Fig 1.1. Drag forces can be considered negligible. [2]

	gravitational potential energy / kJ	elastic potential energy / kJ	kinetic energy / kJ
top	24 (23.5)	0	0
half-way	12 (11.8)	2.6	9.2 (9.17) (accept 9.4)
bottom	0	24 (23.5)	0

Fig. 1.1

Fill up the missing energies at the top, bottom and half-way positions in Fig 1.1. Drag forces can be considered negligible. [2]

GPE (using mgh) [B1], EPE and KE at half-way and bottom positions (using conservation of energy) [B1]

Comments:
Most students are able to answer this part.
Some students seemed to forget that the total energy is the same regardless of the position.

(b) Show that the unstretched length of the elastic rope is 10 m.

[2]

		Let the spring constant of the elastic rope be k and unstretched length be x At half-way position, $2.6 = \frac{1}{2}k(20 - x)^2$ At bottom position, $23.5 = \frac{1}{2}k(40 - x)^2$ [B1 for equations] $\frac{2.6}{23.5} = \frac{(20-x)^2}{(40-x)^2}$ [M1] $\sqrt{\frac{2.6}{23.5}} = \frac{20-x}{40-x}$ $x = 10\ m$ [A0] Comments: Many students are not able to form up the 2 equations.	
	(c)	Determine at what extension will the kinetic energy of the bungee jumper be the highest.	
		extension = ... m	[3]
		Initially, when the bungee jumper jumps, her weight is greater than the tension in the elastic rope. When the tension increases until it is equal to the weight, she stops accelerating and reaches her highest velocity and kinetic energy. $mg = ke$ where e is the extension when her speed is the highest [B1] $\frac{1}{2}kx^2 = \frac{1}{2}k(30)^2 = 23500$ $k = 52.2$ [C1] $e = \frac{60\times9.81}{52.2} = 11.3\ m$ [A1] Comments: Most students are unable to identify the location of max velocity as the location where there is no resultant force.	
			[Total: 7]

2	Fig. 2.1 shows a small conducting sphere suspended from a long insulating thread between two metal plates M and M' that are 0.0500 m apart. The plates are connected to a 5.0×10^3 V battery. The sphere has a radius of 0.0025 m and a mass of 1.0 g.

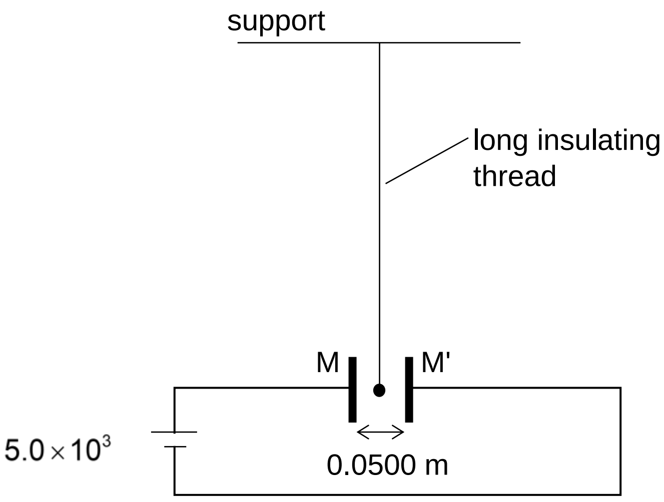


Fig. 2.1

The sphere is given an initial displacement such that the sphere touches M. It then moves rapidly to M', touches it, and returns rapidly to M again. This process repeats itself.

(a) State and explain why an initial displacement to touch one of the plates is necessary for the process to start.

…………………………………………………………………………………………

…………………………………………………………………………………………

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

When sphere is at the centre, the attractive force between sphere and M and Sphere and M' is equal and opposite.
There is translational equilibrium. The sphere does not have a resultant acceleration to move to M or M' [B1]

A displacement to M will result in sphere being positively charged, repelling M and attracted toward M' thus resulting in an acceleration towards M. This velocity will keep increasing as sphere move towards M. Constant electric Force/Field = constant acceleration [B1]

Comments:
Most students did not explain why without displacement, the oscillation cannot occur, and why with touching one of the plates, the oscillations occurs.

(b) When the sphere touches either plate, it acquires a potential that is equal to the potential difference between the plates.

The electrical potential on the surface of a charged conducting sphere can be determined by assuming that all its charges are accumulated at the centre of the sphere.

Show that the charge on the sphere when it touches M is $50\pi\varepsilon_o$.

[1]

		$V = \dfrac{Q}{4\pi\varepsilon_o r}$ $5.0\times10^3 = \dfrac{Q}{4\pi\varepsilon_o(0.0025)}$ $Q = 50\pi\varepsilon_o$ (proved) Comments: Most students are able to prove this part.	
	(c)	If the electric field between the plates is uniform, calculate the magnitude of the electrostatic force acting on the sphere.	
		force = N	[1]
		$F = QE = Q\dfrac{V}{d} = \left(50\pi\times8.85\times10^{-12}\right)\dfrac{5.0\times10^3}{0.0500} = 1.39\times10^{-4}$ N Comments: Most students are able to answer this part.	
	(d)	As a long thread is used, the motion of the sphere is nearly horizontal and is due to electrostatic force only. Determine the time taken for the sphere to move from M to M'.	
		time taken = s	[3]

$a = \frac{F}{m} = \frac{1.39 \times 10^{-4}}{0.0010} = 1.39 \times 10^{-1}\ \text{ms}^{-2}$

$s = ut + \frac{1}{2}at^2$

$0.0500 - 0.0050 = \frac{1}{2}(1.39 \times 10^{-1})t^2$

$t = 0.805\ \text{s}$

Comments:
Most students did not take into account the dimension of the moving sphere and its effect on the total displacement possible.

(e) When the battery is removed from Fig. 2.1, the plates remain equally but oppositely charged. The sphere is totally discharged and given an initial displacement to enable it to reach one of the plates. State and explain how the time taken to move from one plate to the other will change.

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

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

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

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

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

- The electric field or potential difference between the plates decreases with each impact. **OR** Charge on each plate reduces with each impact. **OR** The amount of charge deposited on the sphere decreases with each impact.
- The electrostatic force acting on the sphere decreases with each impact.
- The time taken increases.

Comments:
Many students did not realise what is happening and there is a transfer of electrons.
Some students talk about Gravitational force which is always equal to tension and does not affect the oscillations – student did not appreciate the reason why the string is long.

[Total: 10]

3 (a) A student wanted to light a lamp, but only had available a 12 V battery of negligible internal resistance. In order to reduce the battery voltage, he connected the circuit as shown in Fig. 3.1. The maximum value of the resistance of the rheostat XY was 1000 Ω.

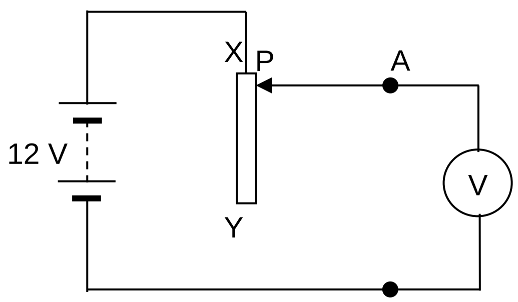


Fig. 3.1

He found that, when the sliding contact P of the rheostat was moved down from X to Y, the voltmeter reading dropped from 12 V to 11 V.

Calculate the resistance of the voltmeter.

resistance = ... Ω [2]

Let the voltmeter resistance be R_V.

When the sliding contact P was at Y, potential divider rule gives:

$$\left(\frac{R_V}{R_V + 1000}\right)(12\ \text{V}) = 11\ \text{V}$$

$$\Rightarrow R_V = 11\ \text{k}\Omega$$

OR

Current through XY $= 1/1000$ A.

$$R_V = \frac{11}{1/1000} = 11\ \text{k}\Omega$$

Comments:
Mostly well done except for sum miscalculation.

(b) He modified the above circuit into the one shown in Fig. 3.2 below, using the rheostat as a potentiometer, and was now able to adjust the rheostat to give a voltmeter reading of 3.0 V.

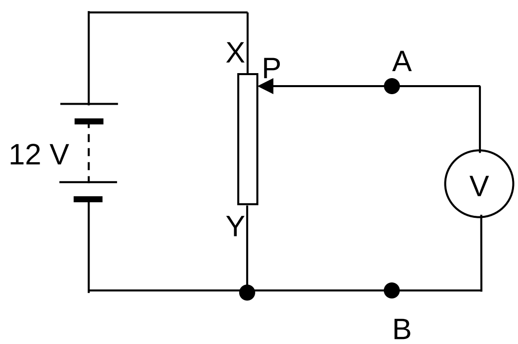


Fig. 3.2

(i) Calculate the current that flows through the voltmeter.

current = ... A [1]

$$I_V = 3\ \text{V}/11\ \text{k}\Omega$$
$$= 0.27\ \text{mA}$$

Comments:
Mostly well done except for sum miscalculation.

(ii) Assuming that the current in **(i)** is negligible compared with the current through the rheostat, determine how far down from X the sliding contact P would have been moved.

Express your answer as a fraction of the length of XY.

fraction of the length of XY = ... A [2]

Position of slider has to be such that $\frac{PY}{XY}=\frac{3\text{ V}}{12\text{ V}}=\frac{1}{4}$

Sliding contact would have been moved down 3/4 of its length from X.

Comments:
Mostly well done except for sum miscalculation.

(iii) The student then removed the voltmeter in Fig.3.2 and then connected a lamp rated at 0.60 W, 3.0 V in its place, but it was very dim.

By calculating the power delivered to the lamp, explain this observation.

....

....

....

.... [4]

resistance of lamp = V^2/P = $(3.0)^2/0.60$ = 15 Ω

effective resistance across AB, $R_{AB}=\frac{15\times 250}{15+250}=\underline{14.2\ \Omega}$

p.d. across AB, $V_{AB}=(12)\left(\frac{R_{AB}}{R_{AB}+750}\right)=\underline{0.222\text{ V}}$

power delivered to the lamp $=\frac{V_{AB}{}^2}{15\ \Omega}=\underline{0.0033\text{ W}}$

OR

current from power supply, $I=\frac{12}{(750+R_{AB})}=0.0157$ A,

current through lamp, $I_{lamp}=I\left(\frac{250}{250+15}\right)=0.0157\left(\frac{250}{250+15}\right)=\underline{0.0148\text{ A}}$,

power delivered to the lamp $=I_{lamp}V_{AB}$ or $I_{lamp}{}^2(15)=\underline{0.0033\text{ W}}$

This is only 0.55% of 0.6 W. Since <u>this is much lower than 0.6 W</u>, its brightness is very low.

Comments:

		Many students have difficult imagining the effect of the removal of the voltmeter and replacing with a lamp. Because the results that the lamp is very dim is given, students need to be very detailed in explaining.		
				[Total: 9]

4	**(a)**	**(i)**	Explain what is meant by the *diffraction* of a wave,	
			…………………………………………………………………………………………………	
			………………………………………………………………………………………………	[1]
			Diffraction is the spreading of waves after passing through a slit or around the edge of an obstacle. B1 Comments: Many students did not remember this definition.	
		(ii)	state an important condition for significant diffraction to occur.	
			………………………………………………………………………………………………	[1]
			For an observable pattern, the size of the obstacle should be of the same order in size as the wavelength of the light. B1 Comments: Many students did not remember this condition.	
	(b)	A diffraction grating with 300 lines per millimeter is being used in a typical light experiment. Different types of light are allowed to fall normally on a diffraction grating and the resultant pattern formed is to be studied. The first light source to be studied is a white light consisting of wavelengths between 400 nm and 700 nm		
		(i)	Find the maximum order of the complete spectrum that can be observed.	
			maximum order = ………………..	[2]
			$(1\times10^{-3}/300)\sin(90) > n\,(700\times10^{-9})$ $n < 4.76$ C1 Maximum order for each side of the grating is 4. A1	

[Turn over

Comments:
Many students did not remember that the 700nm wave is the limiting condition for the complete spectrum and use 400nm. It should be noted that bigger wavelength bends more.

(ii) Find the order of the complete spectrum before the first overlapping between two higher order spectra.

order = ………………… [3]

For 1st order red

$\theta = \sin^{-1} (700 \times 10^{-9})/ (3.333\times10^{-6}) = 0.2118$ rad

For 2nd order red

$\theta = \sin^{-1} 2(700 \times 10^{-9})/ (3.333\times10^{-6}) =0.4339$ rad

for 2nd order violet

$\theta = \sin^{-1} 2(400 \times 10^{-9})/ (3.333\times10^{-6})= 0.2426$ rad

for 3rd order violet

$\theta = \sin^{-1} 3(400 \times 10^{-9})/ (3.333\times10^{-6}) = 0.3686$ rad C1

Hence the 3rd order violet is overlapping in the 2nd spectrum. M1

There is only one pure spectrum. A1

Comments:
Not well answered.

(c) The next experiment is of light from a low pressure sodium lamp. Light from the lamp consists mostly of two wavelengths, 588.99 nm and 589.59 nm.

(i) Explain quantitatively the problem that would likely arise in observing the spectral lines?

……………………………………………………………………………………………

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

			Angle for 588.99nm, θ = $\sin^{-1}$ (588.99 x 10^{-9})/ (3.333x10^{-6})=0.177809 Angle for 589.59nm, θ = $\sin^{-1}$ (589.59 x 10^{-9})/ (3.333x10^{-6})=0.177992 C1 since the angle, between the two is very small, we might not be able to differentiate between the two lines. A1 Comments: Many students did not give a quantitative explanation despite being asked to do so.	
		(ii)	Suggest a refinement to the set up to help overcome this problem.	
			....	
			....	[1]
			To use a higher order for viewing, To change the grating to a finer one. B1 Comments: Not well answered.	
				[Total: 10]

[Turn over

5 **(a)** Define *magnetic flux density*.

....

.... [1]

(magnetic) force per unit length per unit current experienced by a (long straight) current-carrying conductor placed perpendicular to the (magnetic) field [B1]

Comments:
Many students did not remember this definition.

(b) Negatively-charged particles are moving with speed *v* through a vacuum in a parallel beam. The particles enter a region of uniform magnetic field of flux density 930 μT. Initially, the particles are travelling at right-angles to the magnetic field. The path of a single particle is shown in Fig. 5.1.

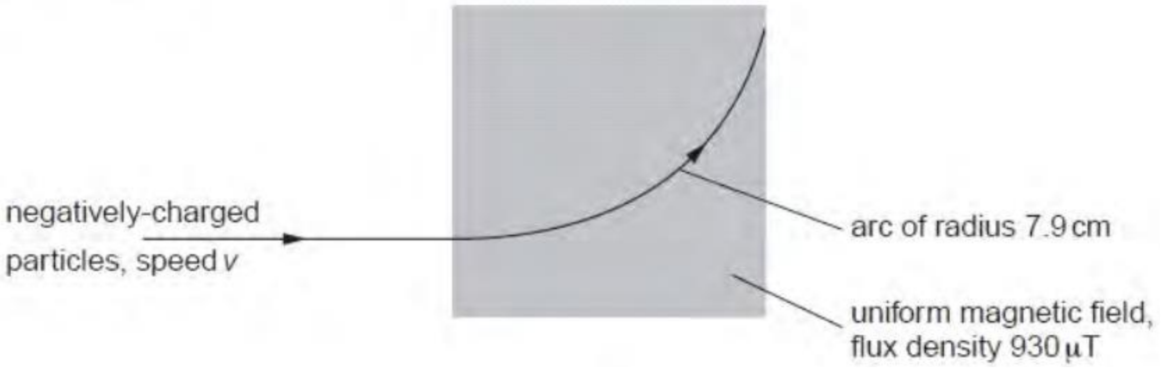


Fig. 5.1

The negatively-charged particles follow a curved path of radius 7.9 cm in the magnetic field.

A uniform electric field is then applied in the same region as the magnetic field. For an electric field strength of 12 kV m^{-1}, the particles pass through the region of the fields without deviation.

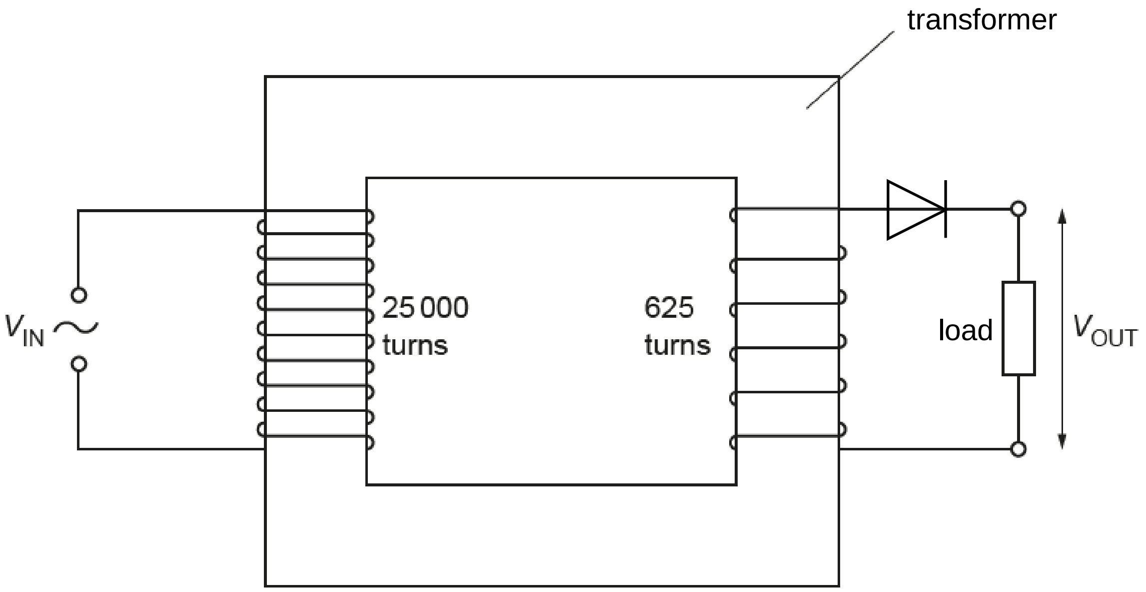
(i) On Fig. 5.1, mark with an arrow the direction of the electric field. [1]

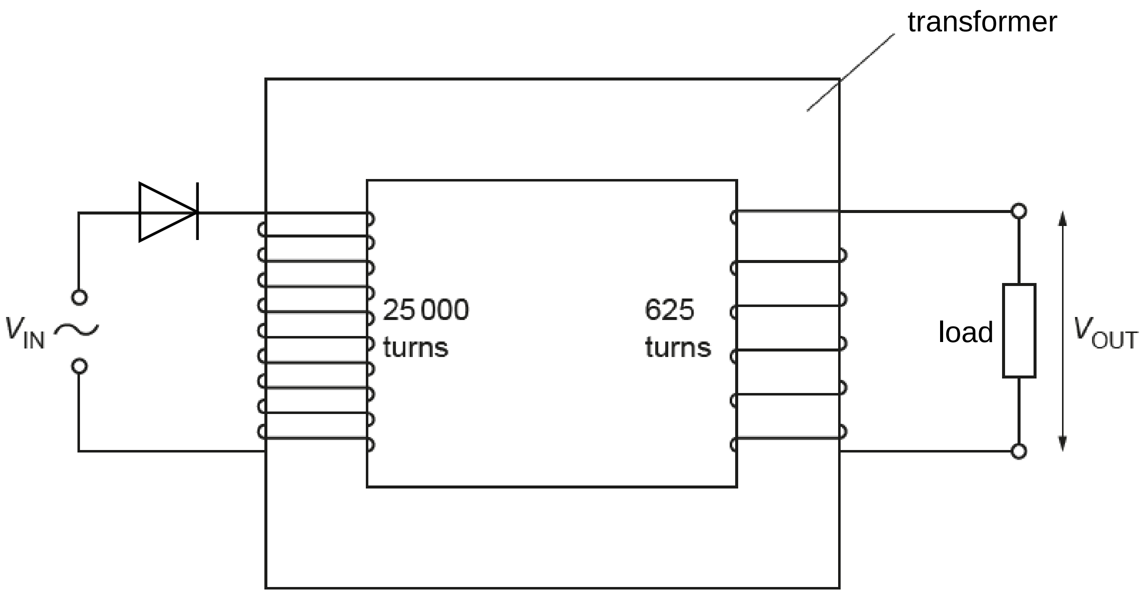
arrow pointing up the page [B1]

Comments:
Mostly well done.

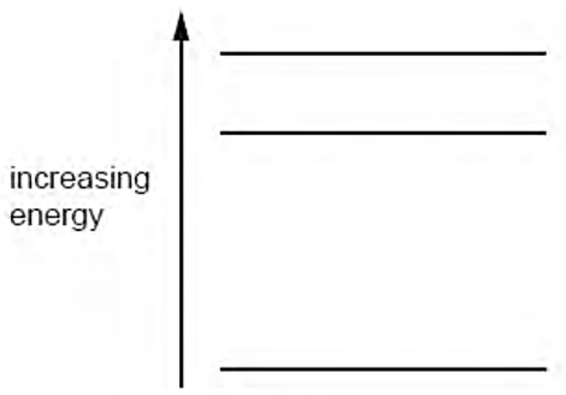
(ii) Calculate the speed *v*.

			v = ... m s^{-1}	[3]
			$Eq = Bqv$ [C1] $v = (12 \times 10^3) / (930 \times 10^{-6})$ [C1] $= 1.3 \times 10^7$ m s^{-1} [A1] Comments: Mostly well done.	
		(iii)	Calculate the $\frac{\text{charge}}{\text{mass}}$ ratio of the negatively-charged particles.	
			ratio = ... C kg^{-1}	[3]
			$Bqv = mv^2 / r$ $q/m = (1.3 \times 10^7) / (7.9 \times 10^{-2} \times 930 \times 10^{-6})$ $= 1.8 \times 10^{11}$ C kg^{-1} *Most students got this correct.*	
		[Total: 8]		

6	Fig. 6.1 shows a simple transformer consisting of a primary coil of 25000 turns and a secondary coil of 625 turns.  **Fig. 6.1** The primary coil is connected to an alternating voltage V_{IN} which is represented by the equation $V_{IN} = 220 \sin(120\pi t)$ The secondary coil is connected to a diode and a load in series. The voltage across the load is V_{OUT}.		
	(a)	Calculate the r.m.s. value for V_{OUT}. r.m.s. V_{OUT} = ... V	[3]
		$N_S / N_P = V_S / V_P$ $V_{S\text{-peak}}$ = (625 / 25000) × 220 OR $V_{S\text{-rms}}$ = (625 / 25000) × 220/√2 rms $V_{OUT} = V_{S\text{-peak}} / 2$ OR rms $V_{OUT} = V_{S\text{-rms}} / \sqrt{2}$ = 2.75 V (or 2.8 V) *Most students did not seem to realize that the output on the secondary coil is half rectified which means the rms value is half the peak value.*	

	(b)	An electrician mistakenly connected the diode to the primary circuit instead as shown in Fig. 6.2.  **Fig. 6.2** The load requires a direct current to flow in it to operate properly. However, due to the mistake, an alternating current flow in it instead and the load fails to operate properly.	
		Use Lenz's Law to explain why an alternating current instead of a direct current would flow in the load.	[3]
		(In 1 cycle,) Current in primary coil (in the same direction) increases and decreases leading to increase and decrease in magnetic flux linkage in secondary coil When magnetic flux linkage increases, current in secondary coil will flow in a direction by Lenz's law (to produce a magnetic flux) that opposes the increase in magnetic flux linkage When magnetic flux linkage decreases, current in secondary coil will flow in the opposite direction hence alternating *Several students thought the input was alternating which means the whole understanding of the situation is wrong. Others knew that it was half-rectified but thought that the alternating output was due to the sudden switching on and off of the current which is again a wrong understanding.* *It is key that responses should state that the magnetic flux increases and decreases. Then Lenz's law should be used to deduce that this will lead to currents of opposite directions.* *Many responses were generic. They quoted and used the laws correctly but did not use them in the context of the question and hence could not gain credit because such an*	

		explanation can be applied to any situation. Also, some correctly stated that the current is periodic or that it changed continuously, except they did not elaborate how it is periodic and exactly in what way it is changing. (e.g. a constantly increasing current is changing continuously). There were also a lot of confusing and vague descriptions of the direction of the current, e.g., the current in the secondary coil being opposite to that in the primary coil, the coils are not connected so what exactly is the relationship between the direction in the coils?	
			[Total: 6]

7	**(a)**	The emission spectrum of atomic hydrogen consists of a number of discrete wavelengths. Explain how this observation leads to an understanding that there are discrete electron energy levels in atoms. …………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………………… ……………………………………………………………………………………		[2]
		Discrete wavelength is associated with a discrete energy of the photon. Discrete energy of the photon imply discrete energy changes / difference which implies discrete energy levels *The key point is that discrete wavelengths imply discrete energies of the photons (not energy levels of the photons). This was not always stated explicitly. Formulas were used without further explanation, requiring the examiner to make inferences.* *Then because the energy of the photon is discrete, this must imply discrete energy changes for the electron hence implying discrete energy levels.* *Many responses made correct statements but lacked the requisite flow of logic, e.g., discrete wavelengths imply discrete energy levels. The focus of the question is to make logical inferences and not merely describe what is known about quantum energy levels.*		
	(b)	Three electron energy levels in atomic hydrogen are represented in Fig. 7.1.  **Fig. 7.1** The wavelengths of the spectral lines produced by electron transitions between these three energy levels are 486 nm, 656 nm and 1880 nm.		
		(i)	On Fig. 7.1, draw arrows to show the electron transitions between the energy levels that would give rise to these wavelengths. Label each arrow with the wavelength of the emitted photon.	[3]
			Three energy changes shown correctly Arrows 'pointing' in correct direction (decreasing energy) Wavelengths correctly identified *This part was well done.*	
		(ii)	Calculate the maximum change in energy of an electron when making transitions between these levels.	

			energy = ………………………………… J	[2]
			$\Delta E = hc / \lambda$ $= (6.63 \times 10^{-34})(3.00 \times 10^{8}) / (486 \times 10^{-9}) = 4.09 \times 10^{-19}$ J *This part was well done.*	
		(iii)	When an electron undergoes transition, there is a change in momentum of the hydrogen atom.	
			1. Explain the origin of the change in momentum of the hydrogen atom. ………………………………………………………………………………………… ………………………………………………………………………………………… …………………………………………………………………………………………	[2]
			Since photon has momentum, photon emission comes with a change in momentum Since total momentum conserved, equal and opposite change in momentum of hydrogen atom *The key point is to discuss the energy or momentum of the photon. Many responses simply state that the atom must lose or gain energy without further explanation. The source or origin of this change in energy should be explained.* *Also, students should not assume that the initial total momentum is zero. Unnecessary or erroneous assumptions can be penalized.*	
			2. For the electron transition in **(ii)**, calculate the change in momentum of the hydrogen atom. change in momentum = ………………………………… kg m s^{-1}	[1]
			(magnitude of) change in momentum = momentum of photon = h / λ $= (6.63 \times 10^{-34}) / (486 \times 10^{-9})$ $= 1.36 \times 10^{-27}$ kg m s^{-1} *This was generally well done, although some attempted to use $p^2/2m$ which leads nowhere.*	
				[Total: 10]

Section B

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

8 In a power station generator, a large rectangular coil is rotating at 50 revolutions per second in a magnetic field of magnetic flux density of 0.29 T. The coil as shown in Fig. 8.1 has 38 turns each 2.0 m long and 1.2 m wide.

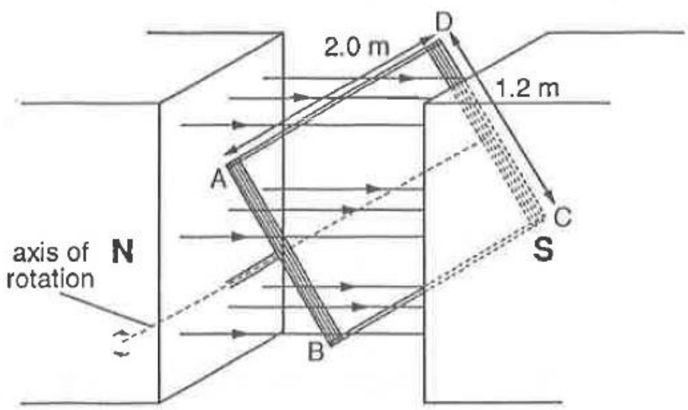


Fig. 8.1

The maximum output e.m.f. of the coil occurs when it moves near the plane of the magnetic field as shown in Fig. 8.2.

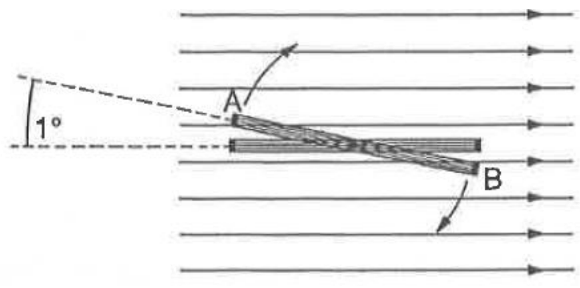


Fig. 8.2

(a) State Faraday's law of electromagnetic induction.

……

…… [1]

Faraday's Law states that the magnitude of the induced e.m.f ε in a conductor is directly proportional to the **rate of change of magnetic flux linkage** or to the **rate of cutting of magnetic flux**.

Many responses left out rate of cutting of magnetic flux

(b)	For the coil moving through an angle of 1.0° near the plane of the magnetic field, calculate			
	(i)	the time taken for it to rotate 1.0°		
			time = ………………..s	[1]
		period = 1/50 Time = 1/50/360 = 5.56×10^{-5} s *This was generally well done.*		
	(ii)	the flux cut by one turn of the coil in this time		
			flux cut = …………..Wb	[3]
		ϕ = BA cosθ = 0.29 x 2 x 1.2 x (cos 89° - cos 90°) = 0.0121 Wb *Many responses could not get the correct component of the magnetic flux density, often using cos 1° or did not note that there is a change of flux.*		
	(iii)	the e.m.f. generated by one turn of the coil in this time		
			e.m.f. = ………………V	[2]
		E = -dϕ/dt = 0.0121 / 5.56×10^{-5} = 218 V *Most could do this even with error carried forward.*		
	(iv)	the e.m.f. generated by all 38 turns of the coil in this time		

			e.m.f. = ………………V	[1]
			218 x 38 = 8.27 kV Most could do this even with error carried forward.	
	(c)	**(i)**	The value obtained in (b)(iv) is the peak value of the sinusoidal output of the coil. Calculate the r.m.s. value of the output of the coil.	
			r.m.s. value of the output = ……………V	[1]
			V_{rms} = 8269 / $\sqrt{2}$ = 5.85 kV Most could do this even with error carried forward.	
		(ii)	State the direction of the current induced inside AD as a result of this e.m.f. Explain how you deduced your answer.	
			………………………………………………………………………………………………	
			………………………………………………………………………………………………	
			………………………………………………………………………………………………	[2]
			By Lenz's Law, to counter the increase in flux, must produce a field opposite to original on the coil and thus by Right Hand Grip rule, Current is from A to D. OR Use Fleming's Right Hand Rule with appropriate description in directions of the 3 fingers. Current is from A to D. *Several responses did not describe the directions in using Fleming's Right Hand Rule.*	
	(d)	**(i)**	State *Lenz's* law.	
			………………………………………………………………………………………………	
			………………………………………………………………………………………………	[1]
			Lenz's Law states that the <u>direction</u> of the <u>induced e.m.f</u> is such that it <u>produces effects</u> that <u>**opposes the change that causes it**</u>. *Many responses talked about induced current, even though induced current may not always occur. Also many responses like to talk about the induced emf or current opposing the change rather than produce effects to oppose the change.*	
		(ii)	Explain the following two situations, using the laws of electromagnetic induction:	

1. A copper disc spins freely between the poles of an unconnected electromagnet as shown in Fig 8.3.

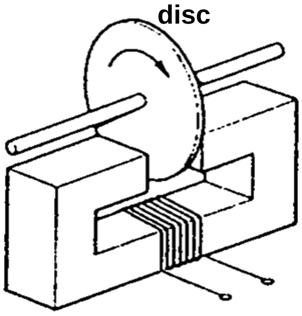


Fig 8.3

Describe and explain what will happen to the speed of rotation of the disc when a direct current is switched on in the electromagnet.

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

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

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

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

…………………………………………………………………………………………………… [4]

When the electromagnet is switched on, there is a magnetic field between the poles.

Thus the spinning disc <u>cuts through the magnetic flux</u> lines.

The cutting of flux lines results in an <u>induced emf</u>, by <u>Faraday's Law</u>.

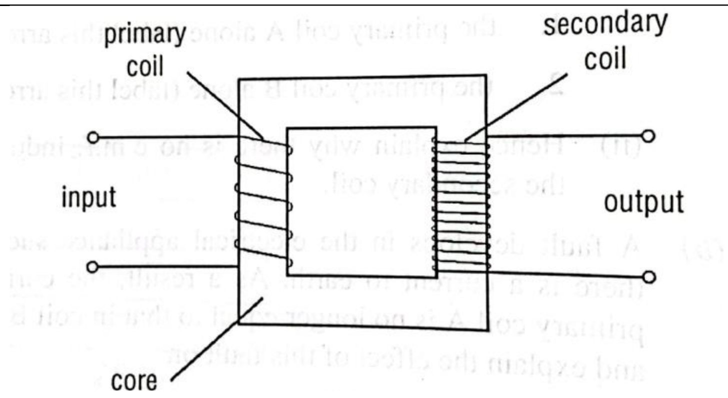
The disc is a closed circuit and thus <u>current flows in it</u>, which by <u>Lenz's Law</u>, acts in a direction that <u>opposes the change</u> that causes it in the first place.

The induced (eddy) currents in the spinning disc results in heat dissipation and energy loss, and hence this <u>slows down the rotation of the spinning disc</u>.

Many responses talked about change in magnetic flux. This is an inappropriate analysis of Faraday's disc.

Several responses also thought that the disc will eventually spin at a constant, albeit, lower rate, indicating their lack of understanding of the context.

2. A simple iron-cored transformer is shown below.



Suggest why the input voltage and the output e.m.f. have the same frequency.

....

....

....

.... [3]

Since magnetic flux density (B) is proportional to the current (I) flowing through the coil, B and I have the same frequency.

The B produced from the primary coil is linked to the secondary coil via the soft iron core. By Faraday's law, there will be an induced emf in the secondary coil given by dB/dt.

Hence, the induced emf will have the same frequency as the B in the primary coil, which is then has the same frequency as the I in the primary coil.

The crux of this question is to use laws of electromagnetic induction. Responses that do not use these laws will not get credit.

Many responses lack a logical flow. The first step is to establish that the flux density and hence the flux is proportional to the current hence the flux must change at the same frequency as the input voltage.

Next by Farday's law, the induced emf is dB/dt which means the secondary voltage has the same frequency with B.

Finally using the two previous statements, one can conclude theoutput voltage is at the same frequency as the input voltage.

Most responses make quick conclusions without establishing the link between the different quantities.

[Total: 20]

9 Some elements that are normally stable, such as lead (Pb), have isotopes which are radioactive. The nucleus $^{214}_{82}Pb$ is one such isotope of lead.

(a) State what is meant by isotopes.

……

……

…… [2]

Two or more forms of the same element, having the <u>same number of protons</u> but <u>different number of neutrons</u> in their nuclei.

This was well done. However, students should not include electrons in the definition.

(b) A nucleus of $^{214}_{82}Pb$ decays by β emission into $^{214}_{83}Bi$. This bismuth nuclide is itself radioactive with an unusual decay pattern. Sometimes it decays by α emission into tellurium (Tl) and sometimes by β emission into polonium (Po). Write the nuclear equations for these two decays of $^{214}_{83}Bi$.

α emission: …………………………………………………………………………………

β emission: ………………………………………………………………………………… [2]

$^{214}_{83}Bi \rightarrow {}^{210}_{81}Tl + {}^{4}_{2}He$

$^{214}_{83}Bi \rightarrow {}^{214}_{84}Po + {}^{0}_{-1}e$

Generally well done, although a small number of students were not clear which decay to represent.

(c) The two decay patterns of the $^{214}_{83}Bi$ each give rise to γ ray photons. Suggest why each of these photons have different energies.

……

……

…… [2]

The <u>total mass/binding energies of the products</u> of these two decay patterns are <u>different</u>.

Hence the <u>difference in total mass/binding energies before and after decay is different</u> for these two decay patterns and the energies released in the γ ray photons are different.

Some phrases are unclear or nonsensical, e.g. the mass defect of a decay, only nuclides can have a mass defect or the responses did not indicate clearly which mass or binding energy they are referring to.

(d) A stationary $^{214}_{82}Pb$ decays by β emission into $^{214}_{83}Bi$ as shown in Fig. 9.1.

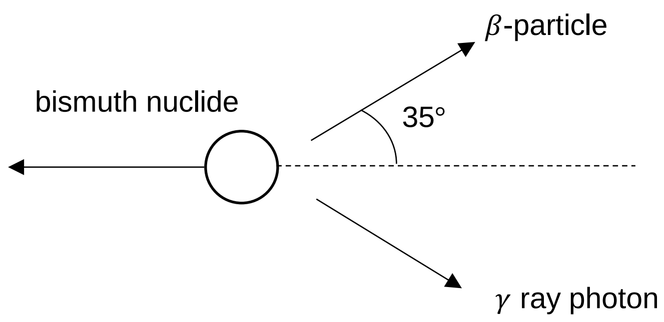


Fig. 9.1

The energy of the β-particle is 0.74 MeV and the energy of the bismuth nuclide is 5.5 eV.

(i) Determine the momentum of

1. the β-particle

momentum = ... kg m s^{-1} [1]

2. and the bismuth nuclide

momentum = ... kg m s^{-1} [1]

Momentum of β-particle $= \sqrt{2mE}$

$= \sqrt{2 \times 9.11 \times 10^{-31} \times 0.74 \times 10^{6} \times 1.60 \times 10^{-19}} = 4.645 \times 10^{-22}\ kg\ m\ s^{-1}$

Momentum of bismuth nuclide $= \sqrt{2mE}$

$= \sqrt{2 \times 214 \times 1.66 \times 10^{-27} \times 5.5 \times 1.60 \times 10^{-19}} = 7.907 \times 10^{-22}\ kg\ m\ s^{-1}$

Many responses used the wrong masses.

		(ii)	Hence, using the principle of conservation of linear momentum that the wavelength of the γ ray photon is 1.36 pm.	
				[4]
			Using conservation of linear momentum Horizontal component of momentum of γ ray photon $= 7.907 \times 10^{-22} - 4.645 \times 10^{-22} cos35°$ $= 4.102 \times 10^{-22}\ kg\ m\ s^{-1}$ Vertical component of momentum of γ ray photon $= 4.645 \times 10^{-22} sin35°$ $= 2.664 \times 10^{-22} kg\ m\ s^{-1}$ momentum of γ ray photon $= \sqrt{4.102^2 + 2.664^2} \times 10^{-22} = 4.891 \times 10^{-22} kg\ m\ s^{-1}$ wavelength of γ ray photon $= \frac{h}{p} = \frac{6.63\times10^{-34}}{4.891\times10^{-22}}$ $= 1.36 \times 10^{-12}\ m$ *There were good responses but many were unsure of the relationships regarding momentum.*	
	(e)	At time t = 0 s, a sample consists only of the isotope ${}^{214}_{82}Pb$.		

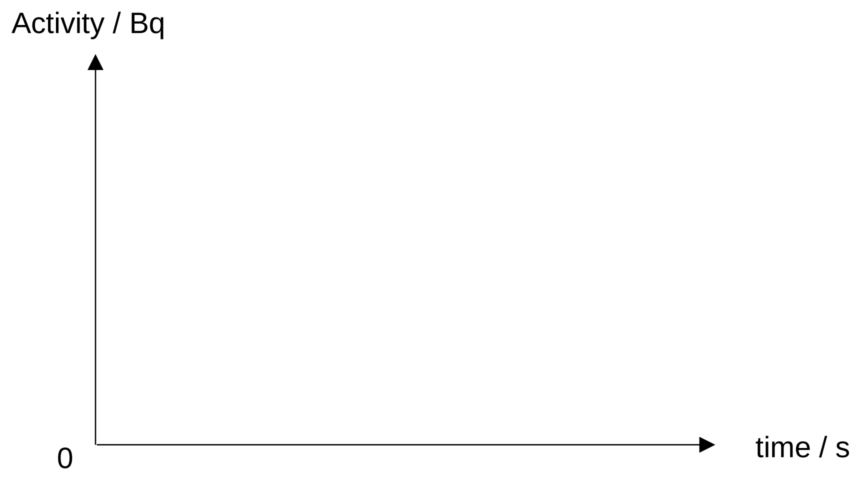


Fig. 9.2

		(i)	Without numerical values, sketch on Fig. 9.1 a graph of the activity of ${}^{214}_{82}Pb$ with time. Label this graph Pb.	[1]
		(ii)	Without numerical values, sketch on Fig. 9.1 a graph of the activity of ${}^{214}_{83}Bi$ with time. Label this graph Bi.	[2]

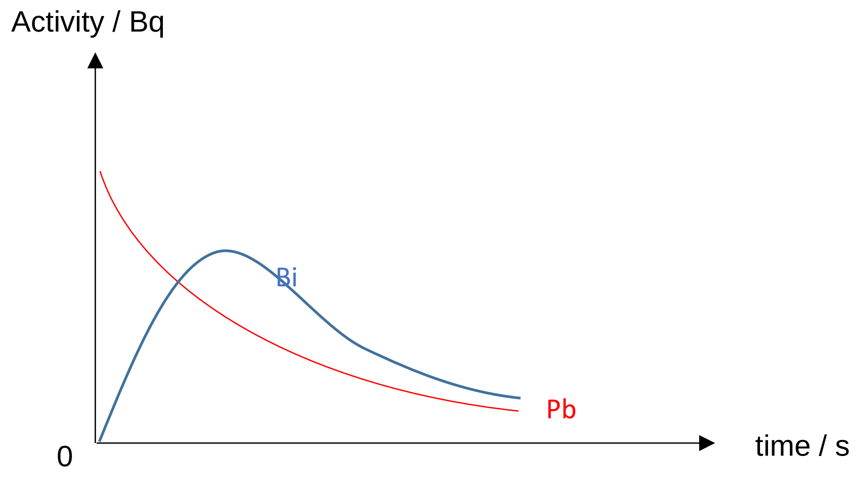


Fig. 9.2

Bi : Starts from zero, Turning point

Most were able to produce the graph for Pb, but responses for Bi often neglected to include the turning point. Many thought the amount of Bi would increase continuously without considering that Bi would undergo decay.

	(f)	A sample of ${}^{214}_{82}Pb$ has mass 3.5 μg at time t = 0 s. The half-life of ${}^{214}_{82}Pb$ is 27 minutes.		
		(i)	Show that the sample contains approximately 9.8×10^{15} atoms.	
				[1]
			1 mole of ${}^{214}_{82}Pb$ is 214 g.	

			Hence number of moles $= \frac{3.5\times10^{-6}}{214}$ Number of atoms $= \frac{3.5\times10^{-6}}{214} \times 6.02 \times 10^{23}$ $= 9.8 \times 10^{15}$ *Generally well done.*	
		(ii)	Show that its decay constant is 4.3×10^{-4} s^{-1}.	
				[1]
			$\lambda = \frac{\ln 2}{27\times60}$ $= 4.3 \times 10^{-4}\ s^{-1}$ *Generally well done.*	
		(iii)	Calculate its activity at time t = 0 s.	
			activity = ... Bq	[1]
			$A_0 = \lambda N = 4.3 \times 10^{-4} \times 9.8 \times 10^{15}$ $= 4.2 \times 10^{12}\ Bq$ *Generally well done.*	
		(iv)	Hence, calculate the time at which its activity has fallen to 8.8×10^{9} Bq.	
			time = ... min	[2]
			$A = A_0 e^{-\lambda t}$ $8.8 \times 10^{9} = 4.2 \times 10^{12} e^{-\frac{\ln 2}{27\times60}t}$ $t = 14400\ s = 240\ min$ *Generally well done.*	
				[Total: 20]