EUNOIA JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATIONS 2021
General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME							
CIVICS GROUP	2	0	-			REGISTRATION NUMBER	

PHYSICS

9749/02

Paper 2 Structured Questions

15 September 2021

2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and registration number on all the work you hand in.
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 paper clips, highlighters, glue or correction fluid.

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

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

For Examiner's Use	
1	
2	
3	
4	
5	
6	
7	
8	
9	
Total	

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

Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
hydrostatic pressure,	$p = \rho gh$
gravitational potential,	$\phi = -\frac{Gm}{r}$
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,	$V = \frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage,	$x = x_o \sin \omega t$
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,	$x = x_o \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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

1 Two groups of students performed similar experiments to measure the acceleration due to gravity g. Their results are shown in Fig. 1.1.

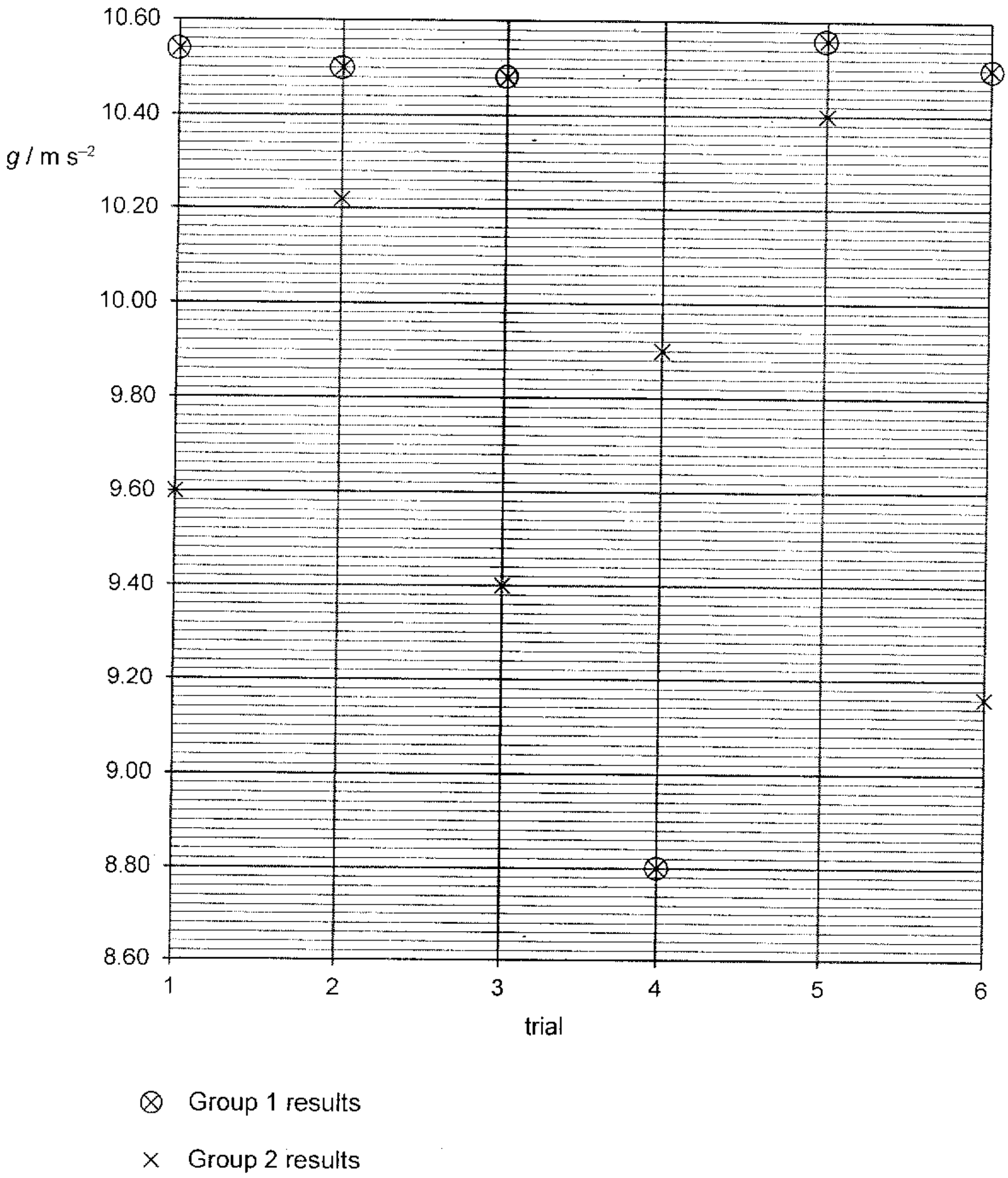

Fig. 1.1

The accepted value for g is 9.81 m s^{-2}.

Use Fig. 1.1 to answer the following questions. You should make calculations with clear working in support of your answer.

State and explain which group of results has

(a) larger *systematic* errors,

....

....

.... [2]

(b) larger *random* errors.

....

....

.... [2]

[Total: 4]

2 (a) State Newton's second law of motion.

....

....

.... [2]

(b) A soccer ball of mass 0.20 kg is kicked from point A of a sloping ground as shown in Fig. 2.1.

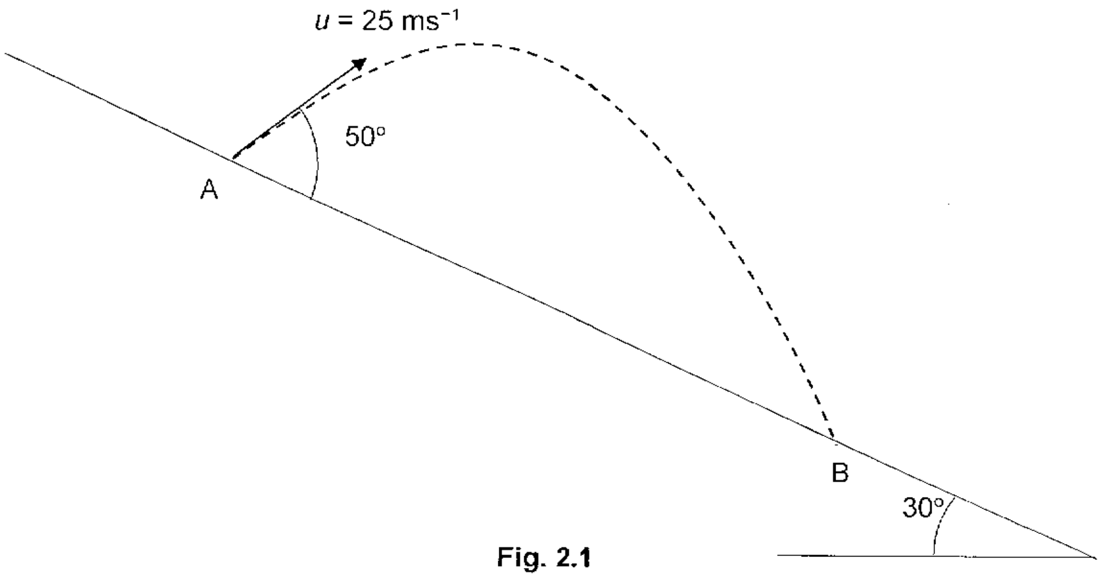

Fig. 2.1

(i) Calculate the time of travel between A and B.

time = ... s [3]

(ii) The ball hits the slope at B as illustrated in Fig. 2.2.

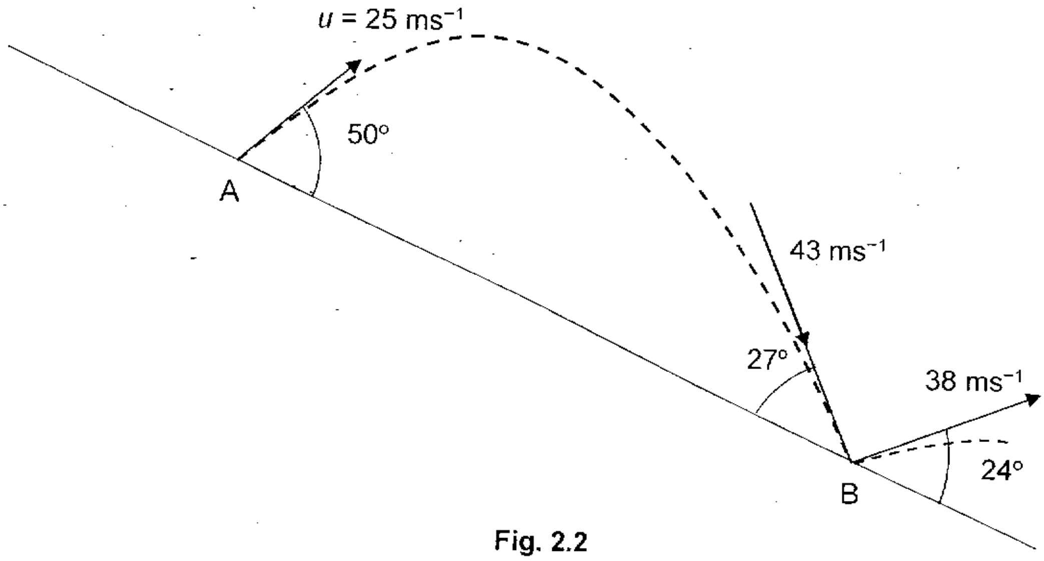

Fig. 2.2

Calculate the change in velocity of the ball at B due to the impact.

change in velocity = ... $m\ s^{-1}$ [2]

(iii) Calculate the resultant force on the ball at B, given the duration of impact is 0.050 s.

resultant force = ... N [1]

[Total: 8]

3 Fig 3.1 shows a man pushing a wheelbarrow with a total weight of 100 N. At the instant shown, the wheelbarrow is stationary. The dimensions of the wheelbarrow, the contact force R exerted by the ground on the wheelbarrow, and the combined weight W of the wheelbarrow and the load it carries are shown in Fig. 3.2. The force H exerted by the person on the wheelbarrow is not given in the diagram.

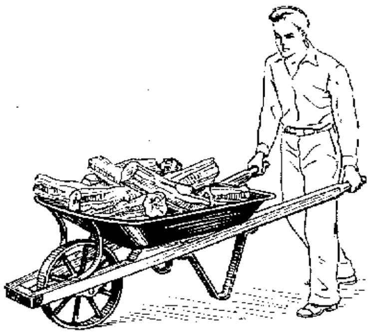

Fig. 3.1

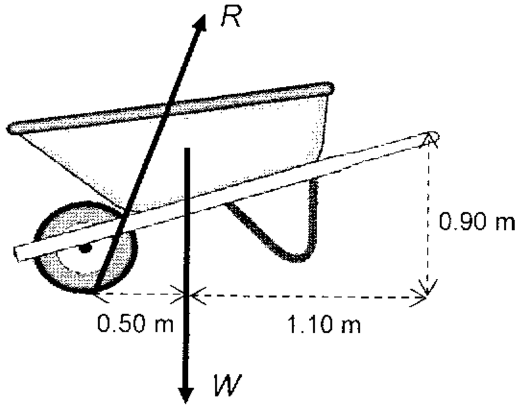

Fig. 3.2

(a) Given that the force R exerted by the ground on the wheelbarrow acts 73° above the horizontal, determine the magnitude of R.

R = ... N [2]

(b) Hence, determine the magnitude and direction of H.

magnitude of H = ... N

direction of H = ... [3]

[Total: 5]

4 **(a)** A force F is acting on a body of mass m that causes it to move with a velocity v. Given that the body started from rest, show that the kinetic energy E_k of the body is given by

$$E_k = \frac{1}{2}mv^2$$

[3]

(b) Fig. 4.1 below shows a vertical semi-circular path which has a radius of 2.0 m centred at **O**. A point object of mass 3.0 kg is released from rest at **P**. The path exerts a constant frictional force on the object and it reaches point **Q** where it comes to rest momentarily. The angular displacement between **P** and **Q** with respect to **O** is 145°.

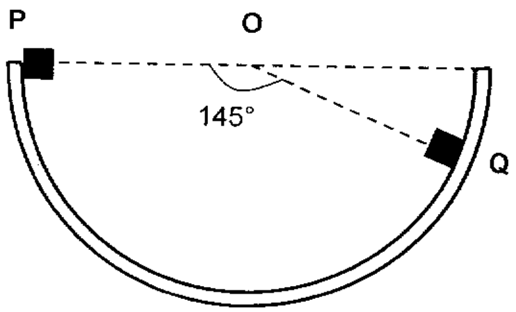

Fig. 4.1

(i) Calculate the frictional force exerted by the track on the object.

frictional force = ... N [3]

(ii) Calculate the kinetic energy of the object at the lowest point on the track.

kinetic energy = ... J [2]

[Total: 8]

5 **(a)** An ideal gas initially at 300 K undergoes expansion at a constant pressure of 2.5 kPa. The volume of the gas increases from 1.0 m^3 to 3.0 m^3 and 12.5 kJ is transferred to the gas by heat.

Determine the change in the internal energy of the gas.

change in internal energy = ... J [2]

(b) By reference to the first law of thermodynamics, state and explain the change, if any, in the internal energy of:

(i) a lump of solid lead as it melts at constant temperature

....

....

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.... [3]

(ii) some gas in a toy balloon when the balloon bursts.

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....

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.... [3]

[Total: 8]

6 **(a)** Fig. 6.1 shows an electron in an electric field, in a vacuum, at an instant when the electron is stationary.

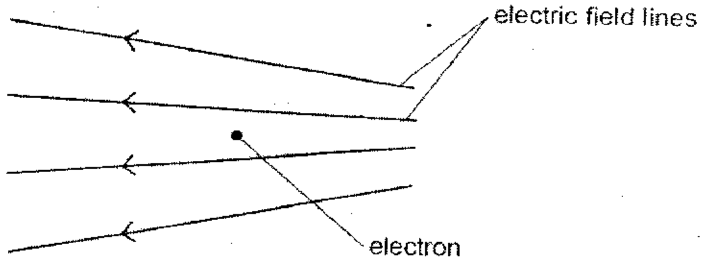

Fig. 6.1

(i) On Fig. 6.1, draw an arrow to show the direction of the electric force acting on the stationary electron. [1]

(ii) The electric field causes the electron to move from its initial position.

Describe and explain the acceleration of the electron due to the field, as the electron moves through the field.

....

....

.... [2]

(iii) A stationary proton is now placed in the same electric field at the same initial position that was occupied by the electron.

Compare the initial electric force acting on the proton with the initial electric force that acted on the electron.

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.... [2]

(b) Two point charges A and B are separated by a distance of 12.0 cm in a vacuum, as illustrated in Fig. 6.2.

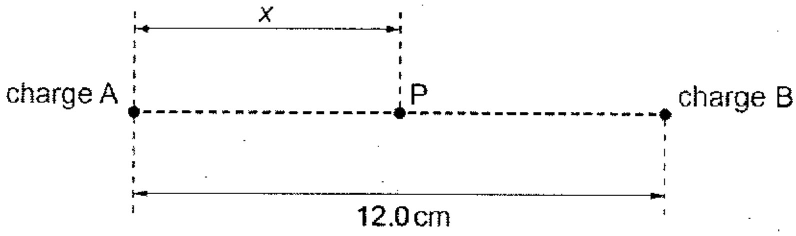

Fig. 6.2

The charge of A is $+2.0 \times 10^{-9}$ C.

A point P lies on the line joining charges A and B. Its distance from charge A is x.

The variation with distance x of the electric potential V at point P is shown in Fig. 6.3.

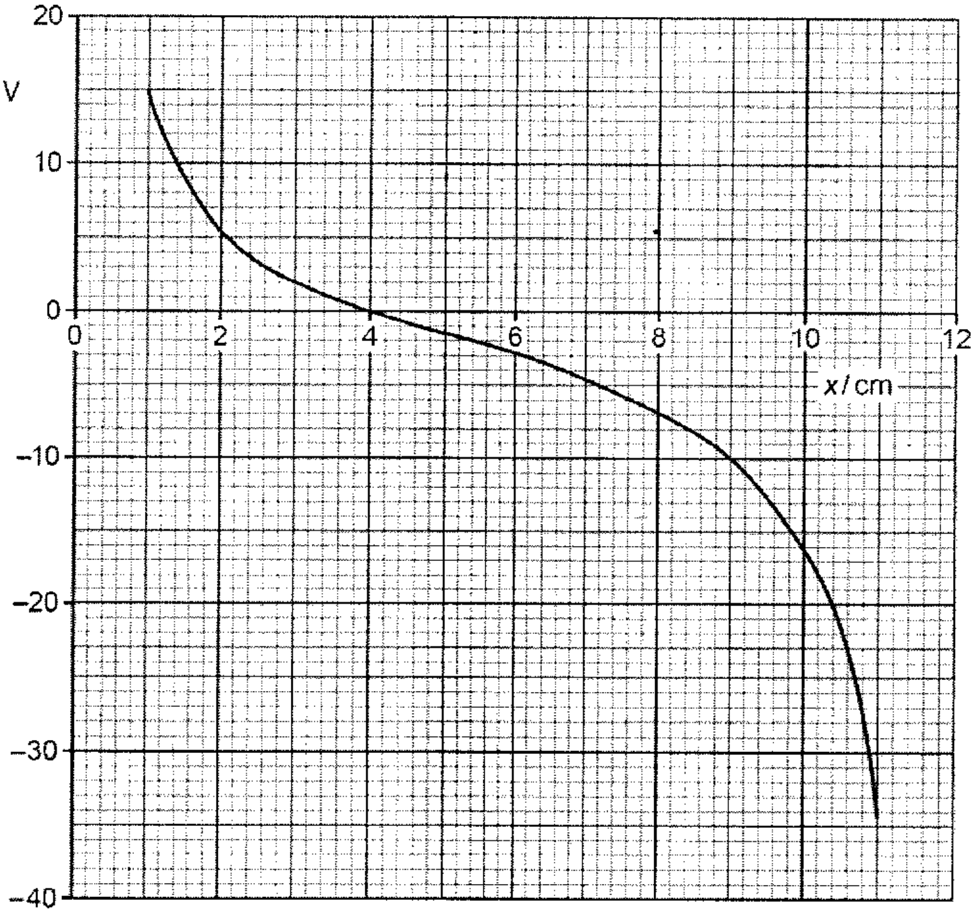

Fig. 6.3

(i) A proton moves along the line joining point charges A and B in Fig. 6.2.

The proton moves from the position where x = 9.0 cm and just reaches the position where x = 3.0 cm.

Calculate the speed v of the proton at the position where x = 9.0 cm.

v = ... m s^{-1} [3]

(ii) State and explain the value of x where the proton experiences the smallest electric force.

....

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.... [2]

[Total: 10]

7 Fig. 7.1 shows an iron-cored transformer that is 90% efficient. The primary coil of the transformer has 2700 turns and is connected to a 240 V r.m.s. supply. The secondary coil has 450 turns and is connected, through an ideal diode to resistors X and Y.

Resistor X dissipates energy at a mean rate of 90 W and the resistance of Y is twice of X's.

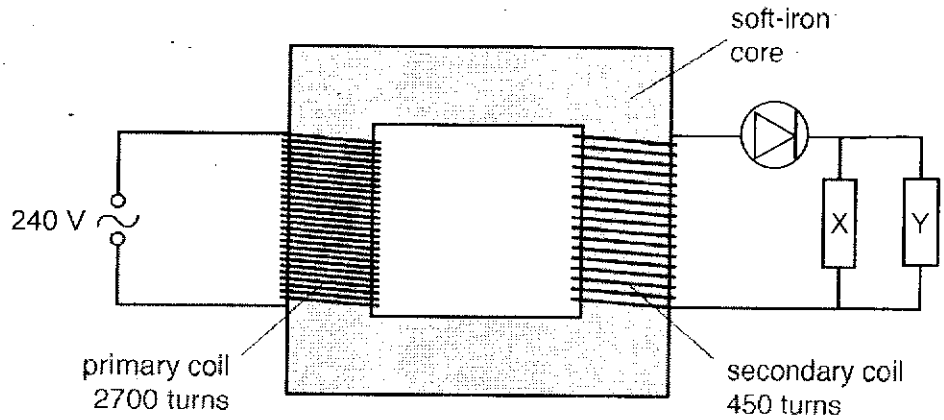

Fig. 7.1

(a) Calculate

(i) the peak voltage across the secondary coil,

peak voltage = ... V [2]

(ii) the r.m.s. voltage across X,

r.m.s. voltage = ... V [1]

(iii) the r.m.s. current in the primary coil.

r.m.s. current = ... A [3]

(b) On Fig 7.2, show the variation with time t of the power P dissipated in resistor X for two periods of the alternating voltage supply. The alternating voltage supply has period T.

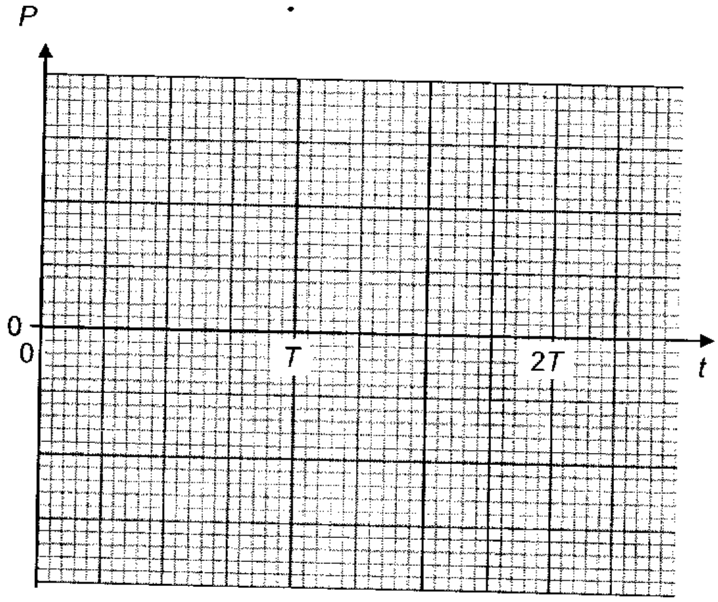

Fig. 7.2

[2]

[Total: 8]

8 (a) White light passes through a cloud of cool low-pressure gas, as illustrated in Fig. 8.1.

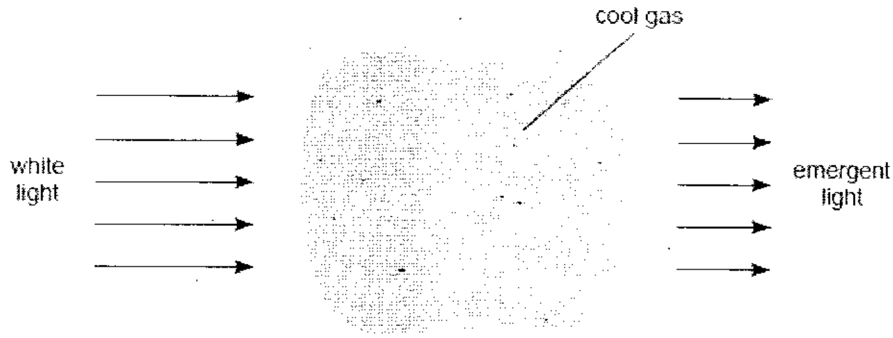

Fig. 8.1

For light that has passed through the gas, its continuous spectrum is seen to contain a number of darker lines.

Use the concept of discrete electron energy levels to explain the existence of these darker lines.

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.... [3]

(b) Electrons in a beam are travelling at high speed in a vacuum. The electrons are incident on a metal target, causing X-ray radiation to be emitted.

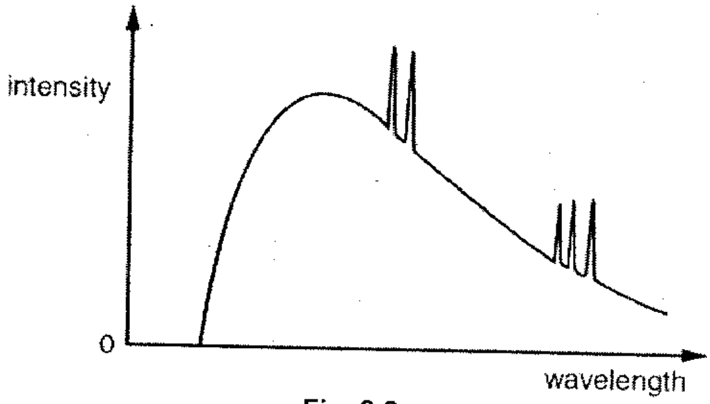

Fig. 8.2

The variation with wavelength of the intensity of the emitted X-ray radiation is shown in Fig. 8.2.

Explain why:

(i) there is a continuous distribution of wavelengths.

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....

....

.... [3]

(ii) at certain wavelengths, there are narrow peaks of increased intensity.

....

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....

....

.... [3]

[Total: 9]

9 Nuclear magnetic resonance (NMR) is a phenomenon which soon after its discovery in 1946 became a powerful research tool in a variety of fields from physics to chemistry and biochemistry. It is also an important medical imaging technique.

When atoms are placed in a magnetic field, atomic energy levels split into several closely spaced levels. Nuclei, such as the hydrogen nuclei, also exhibit these magnetic properties. This is useful for medical imaging. The hydrogen nucleus consists only of a single proton. A physical property of nuclei is known as the spin angular momentum. It can take on only two values when placed in a magnetic field: we call these "spin up" (parallel to the field) and "spin down" (antiparallel to the field), as illustrated in Fig. 9.1.

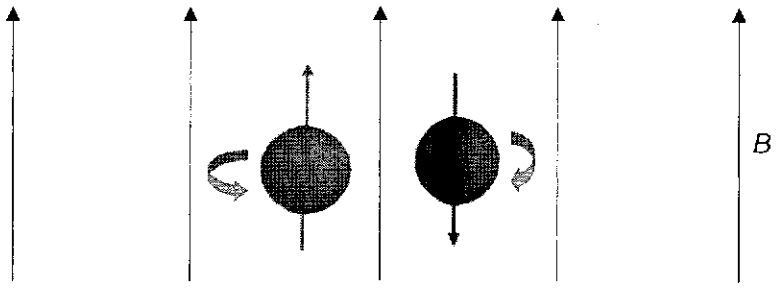

Fig. 9.1

When a magnetic field is present, the energy of the nucleus splits into two levels as shown in Fig. 9.2, with the spin up (parallel to field) having the lower energy.

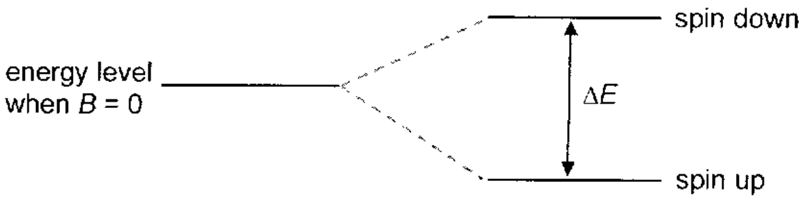

Fig. 9.2

The difference in energy ΔE between these two levels is proportional to the magnetic flux density B applied at the nucleus:

$$\Delta E = kB$$

where k is a proportionality constant that is different for different nuclides.

In a standard nuclear magnetic resonance (NMR) setup, the sample to be examined is placed in a static magnetic field. A radiofrequency (RF) pulse of electromagnetic radiation (that is, photons) is applied to the sample. If the energy of this photon matches the energy difference between the two energy levels ΔE in Fig. 9.2, then the photons of the RF beam will be absorbed, exciting many of the nuclei from the lower state to the upper state. For a free unbounded hydrogen nucleus, the frequency is 42.58 MHz for a magnetic flux density of B = 1.00 T.

For producing medically useful NMR images - now commonly called MRI, or magnetic resonance imaging - the element most used is hydrogen since it is the commonest element in the human body and gives the strongest NMR signals.

The experimental apparatus is shown in Fig. 9.3. The large magnetic field coils set up the static magnetic field, and the RF coils produce the RF pulse of electromagnetic waves (photons) that cause the nuclei to jump from the lower state to the upper one. Another coil detects the emitted radiation when the nuclei jump back down to the lower state.

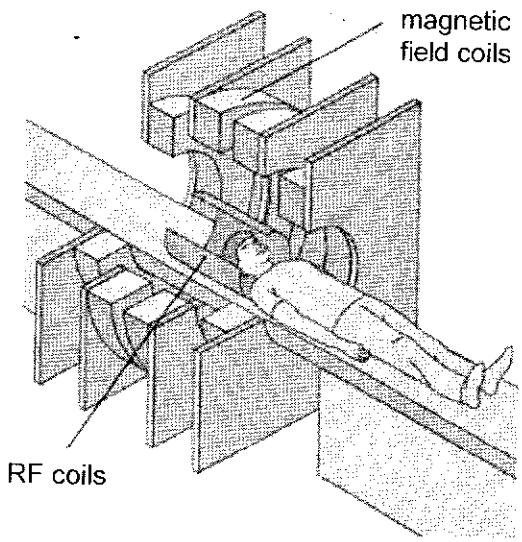

Fig. 9.3

The formation of a two-dimensional or three-dimensional image can be done using techniques similar to those for computed tomography. The simplest thing to measure for creating an image is the intensity of absorbed and or re-emitted radiation from many different points of the body, and this would be a measure of the density of Hydrogen atoms at each point.

One technique to know which part of the body an emitted photon comes from is to give the static magnetic field a gradient; that is, instead of applying a uniform magnetic field, the field is made to vary with position across the width of the sample (or patient) as shown in Fig. 9.4.

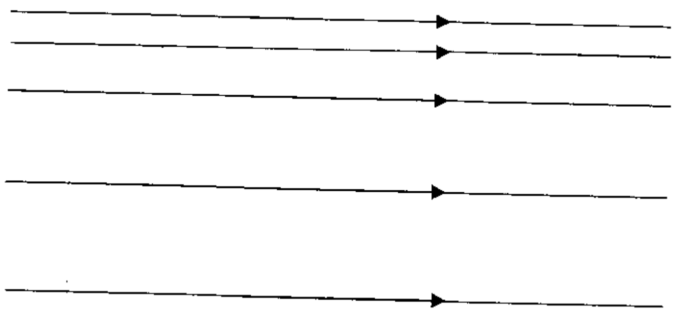

Fig. 9.4

NMR imaging is considered to be non-invasive. Since molecular bonds are in the order of 1 eV, the RF photons can cause little cellular disruption. This should be compared to X-rays, whose energies can cause significant damage. The static magnetic fields, though often as high as 1.0 to 1.5 T, are believed to be harmless except for people who wear heart pacemakers.

(a) Calculate the proportionality constant k for a free unbounded hydrogen nucleus in a magnetic flux density of B = 1.00 T.

k = ... J T^{-1} [3]

(b) The variation of some values of B/T with RF frequency/ Hz for a free unbound hydrogen nucleus is shown in Fig. 9.4.

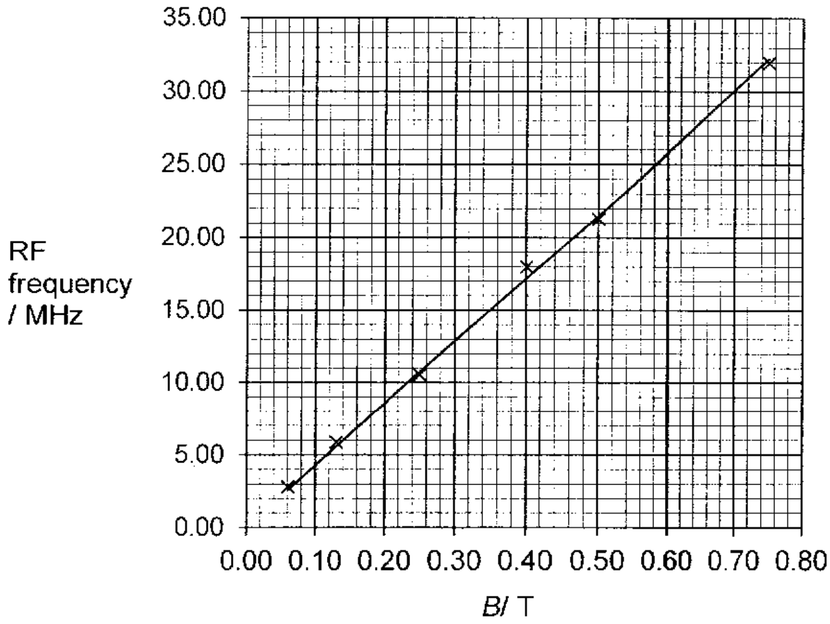

Fig. 9.4

(i) State and explain, using the features of the graph, whether RF frequency is proportional to B.

....

.... [2]

(ii) Suggest how the proportionality constant *k* for a free unbounded hydrogen nucleus can also be found using the gradient of the trend line in Fig 9.4.

.... [1]

(iii) Describe which feature of the graph shows that the presence of random errors.

....

.... [1]

(c) Explain how a gradient magnetic field allows us to know the part of the body that is absorbing or emitting photons.

....

....

.... [2]

(d) Starting by estimating the wavelength of X-rays and using information from the passage, explain quantitatively why X-rays can cause significant damage to the human body.

....

.... [3]

(e) A rigid copper wire carrying a current is balanced on a pivot. The wire is placed within the non-uniform horizontal magnetic field as illustrated in Fig. 9.5a and Fig. 9.5b. The wire is balanced horizontally by means of a small weight W. Section RS of the wire has length 0.85 cm. The perpendicular distance of RS from the pivot is 5.6 cm.

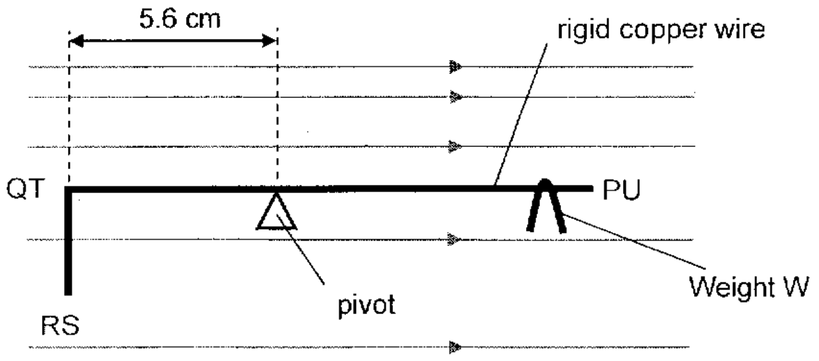

Fig. 9.5a (Side View)

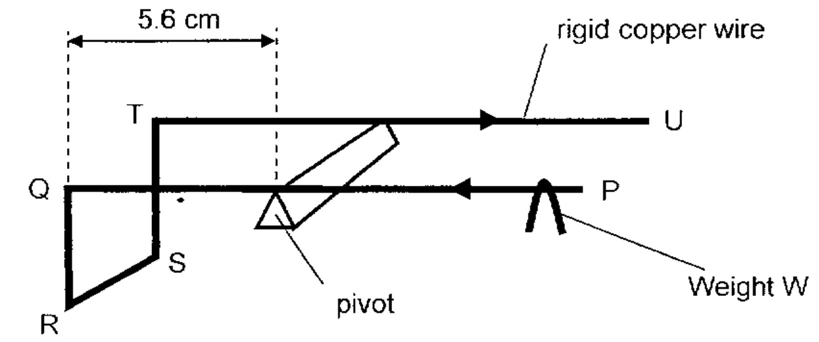

Fig. 9.5b (3D View)

(i) Explain why the following sections of the wire do not affect the equilibrium of the wire.

1. QR and TS

....

....

.... [2]

2. QP and TU

....

.... [1]

(ii) When the current in the wire is changed by 1.2 A, W is moved a distance of 2.6 cm along the wire in order to restore equilibrium.

The mass of W is 2.5×10^{-3} kg.

Determine the magnetic flux density B of the field where RS is.

B = ... T [3]

(f) Fig. 9.6 shows the front view of the non-uniform horizontal magnetic field, with the field directed out of the plane of the paper and magnetic flux density increasing in the vertical direction.

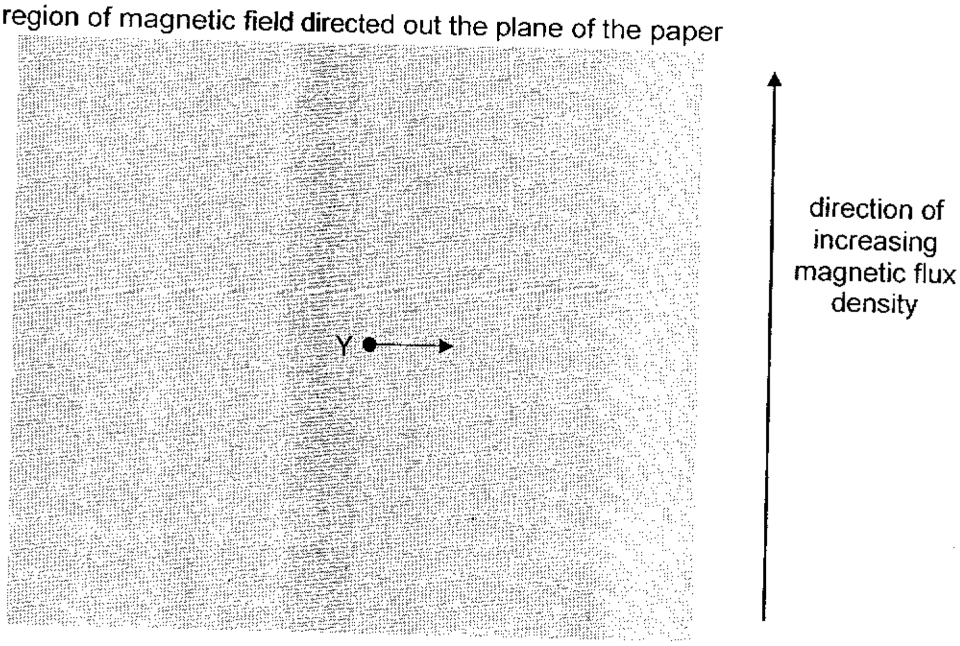

Fig. 9.6 (Front View)

An electron is travelling to the right at point Y. Assuming that the electron undergoes at least one cycle in the field, sketch a possible path of the electron in Fig 9.6. Show the direction of motion clearly.

[2]

[Total: 20]

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EUNOIA JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATIONS 2021
General Certificate of Education Advanced Level
Higher 2

PHYSICS

MARK SCHEME

9749/02

September 2021

Question			Solution	Marks
1	(a)		Calculations if g_1 = 8.80 m s^{-2} rejected as anomalous: $<g_1> -9.81 = 10.52 - 9.81 = 0.71$ $<g_2> -9.81 = 9.78 - 9.81 = -0.03$ Since $<g_1>$ is further away from the accepted g value, results for group 1 have larger systematic errors.	M1 A1
	(b)		Range of $g_1 = 10.56 - 10.48 = 0.08$ Range of $g_2 = 10.40 - 9.16 = 1.24$ Since values for g_2 has a larger range compared to values for g_1, results for group 2 have larger random errors.	M1 A1
			Calculations if all data used: $<g_1> -9.81 = 10.23 - 9.81 = 0.42$ $<g_2> -9.81 = 9.78 - 9.81 = -0.03$ Since $<g_1>$ is further away from the accepted g value, results for group 1 have larger systematic errors.	max 3 marks (anomaly not accounted)
			Range of $g_1 = 10.56 - 8.80 = 1.76$ Range of $g_2 = 10.40 - 9.16 = 1.24$ Since values for g_1 has a larger range compared to values for g_2, results for group 1 have larger random errors.	

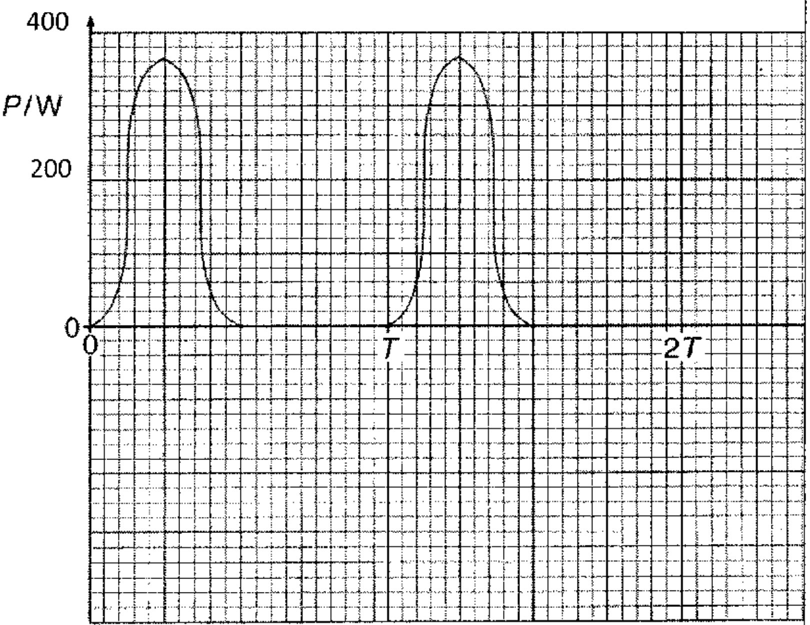
Question			Solution	Marks
2	(a)		The rate of change of momentum of a body is proportional to the resultant force acting on it,	B1
			and takes place in the direction of the resultant force.	B1
	(b)	(i)	$s_X = u_Xt + \frac{1}{2} a_Xt^2 = (25 \cos 20°)\, t$ ($a_X = 0$) $s_Y = u_Yt + \frac{1}{2} a_Yt^2 = (25 \sin 20°)\, t + \frac{1}{2}(-9.81)t^2$	M1
			$\tan 30° = -S_Y / S_X$	M1
			time = 4.5 s	A1
		(ii)	change of velocity $= \sqrt{[(43^2 + 38^2 - 2(43)(38)\cos(24° + 27°))]}$	M1
			$= 35 \text{ m s}^{-1}$	A1
		(iii)	Resultant force = rate of change of momentum $= m\,\Delta v / \Delta t$ $= (0.20)(35) / (0.050)$ $= 140$ N	A1

Question				Solution	Marks
3	(a)			Taking moments about the handle, By principle of moments Sum of anticlockwise moments = sum of clockwise moments $W(1.10) + R\cos 73°\,(0.90) = R\sin 73°\,(1.10 + 0.50)$ $R = \frac{100(1.10)}{1.60\sin 73° - 0.90\cos 73°} = 86.82$ $R = 87\text{ N}$	M1 A1
	(b)			Since net force = 0, Horizontal component $H_x = R\cos 73° = 25.38\text{ N}$ Vertical component $H_y = 100 - R\sin 73° = 16.97\text{ N}$ $\tan\theta = \frac{H_y}{H_x} = \frac{16.97}{25.38}$ $\theta = 34°$ $H = \sqrt{H_x^2 + H_y^2} = 30.53\ N$ $H = 31$ N at an angle of 34° above the horizontal (towards the left)	M1 M1 A1

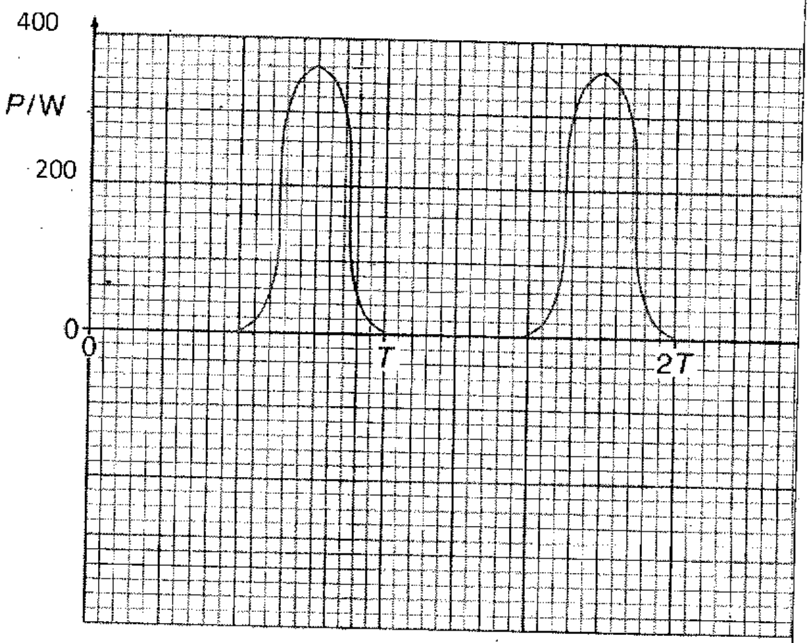
Question			Solution	Marks
4	(a)		Consider the body moving with initial velocity u with a constant acceleration a through a displacement s on a horizontal frictionless surface due to F.	B1
			From the kinematics equation $v^2 = u^2 + 2as$ $$s = \frac{v^2 - u^2}{2a}$$	
			Work done by $F = Fs$	B1
			Since **Gain in** kinetic energy = Work done by F $$\Delta E_K = Fs = mas$$ $$\Delta E_K = ma\frac{v^2 - u^2}{2a}$$ $$\Delta E_K = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$$ Given that the object started from rest, its change in kinetic energy is its final kinetic energy **OR** its initial kinetic energy is zero. $$E_K = \frac{1}{2}mv^2$$	B1
	(b)	(i)	$$\Delta E_P = mgR\cos(145° - 90°)$$	C1
			Loss in E_P = work done against friction (spelled in full)	B1
			$$mgR(\cos 55°) = F\left(\frac{145}{180} \times \pi R\right)$$	
			$$F = 6.67\text{ N}$$	A1
		(ii)	Work done against friction from P to the lowest point of the track $=F\left(\frac{\pi R}{2}\right)$	
			Increase in E_K = Decrease in E_P – Work done against friction	C1
			$$E_K = mgR - F\left(\frac{\pi R}{2}\right)$$ $$E_K = (3.0)(9.81)(2.0) - (6.67)\left(\frac{\pi \times 2.0}{2}\right)$$	
			$$E_K = 37.9\text{ J}$$	A1

Question			Solution	Marks
5	(a)		$W_{on} = P \Delta V$ $= -2.5 \times 10^3 \times (3.0 - 1.0)$ = - 5000 J (Since gas is expanding, work is done by the gas) $\Delta U = Q_{to} + W_{on}$ $= 12500 - 2.5 \times 10^3 \times (3.0 - 1.0)$ = 7500 J	C1 A1
	(b)	(i)	(little/no volume change so) little/no external work done thermal energy supplied to provide latent heat internal energy increases	B1 M1 A1
		(ii)	no thermal energy enters or leaves the gas (rapid) increase in volume, gas does work against the atmosphere internal energy decreases	B1 M1 A1

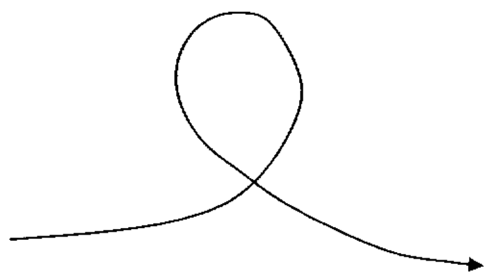
Question			Solution	Marks
6	(a)	(i)	Arrow points to the right	B1
		(ii)	(electric) field strength increases **or** (electric) force increases acceleration increases	B1 B1
		(iii)	force (on proton) has same the magnitude (of force on electron) force (on proton) is in opposite direction (to force on electron)	B1 B1
	(b)	(i)	Loss in KE = Gain in Electric PE $\frac{1}{2}mv^2 = qV$ $\frac{1}{2} \times 1.66 \times 10^{-27} \times v^2 = 1.60 \times 10^{-19} \times 1200$ $v = 4.8 \times 10^5$ m s^{-1}	C1 C1 A1
		(ii)	x = 5 cm. (4.5 cm to 5.5 cm) Smallest potential gradient. Potential gradient is proportional to field strength Force is proportional to field strength	B1 B1

Question			Solution	Marks
7	(a)	(i)	$N_S / N_P = V_S / V_P$ $\frac{450}{2700} = \frac{V_s}{240}$ $V_s = 40V$ Peak voltage = 40 x √2 = 56.5 = 57 V	M1 A1
		(ii)	r.m.s voltage across the load = 57 / 2 = 28 V (or 29 V)	M0 A1
		(iii)	$P = \frac{V^2}{R} \rightarrow P \propto \frac{1}{R}$ $\frac{P_Y}{P_X} = \frac{R_Y}{R_X} \rightarrow \frac{P_Y}{90} = \frac{1}{2}$ $P_Y = 45W$ $(0.90)P_{primary} = (P_{sec\,ondary})$ $(0.90)IV = 90 + 45$ $(0.90)(240)I = 90 + 45$ $I = 0.63\ A$	C1 C1 A1
	(b)		Half-wave rectified (see below for diagram) Peak power 360 W (unit to be written) Either: 	B1 B1

OR:



Question			Solution	Marks
8	(a)		• photon gives energy to electron (in an inner shell) **or** electron (in an inner shell) absorbs a photon • electron moves (from lower) to higher energy level	B1
			• energy (of photon) is equal to difference in energy levels	B1
			• electron de-excites giving off photon (of same energy) • photons emitted in all directions	B1
	(b)	(i)	X-ray photon produced when electron is decelerated larger acceleration results in larger photon energy continuous range of accelerations so continuous spectrum of wavelengths/ frequencies	B1 B1 B1
		(ii)	electron in (inner shell of) target atom is excited (on collision) electron de-excites causing emission of a photon discrete energy levels so discrete photon wavelengths	B1 B1 B1

Question			Solution	Marks
	(a)		$E = hf$ $hf = kB$ $(6.63\times10^{-34})(42.58\times10^{6}) = k(1.0)$ $k = 2.82\times10^{-26}$ J T^{-1}	 C1 C1 A1
	(b)	(i)	Straight line that cuts through origin So RF proportional to B	M1 A1
		(ii)	K = gradient × Planck's Constant	
		(iii)	Scattering of points about the best fit line	B1
	(c)		Varying flux density B Photon absorbed (or emitted) only when energy = kB OR Photon absorbed (or emitted) proportional to B Only specific areas will absorb (or emit)	B1 B1 (B1)
	(d)		Wavelength of X-ray = 10^{-10} m Energy of X-ray = $\frac{hc}{\lambda} = \frac{(6.63\times10^{-34})(3.0\times10^{8})}{10^{-10}(1.6\times10^{-19})} = 1.2\times10^{4}eV$ X-ray energy is larger than molecular bonds, in the order of 1 eV.	B1 M1 A1
	(e)	(i)	1. forces act through the same line **or** forces are horizontal forces are equal (in magnitude) and opposite (in direction)	B1 B1
			2. They are parallel to the field	B1
		(ii)	$mg \times (\Delta)L = B \times (\Delta)I \times L \times x$ $2.5 \times 10^{-3} \times 9.81 \times 2.6 \times 10^{-2} = B \times 1.2 \times 0.85 \times 10^{-2} \times 5.6 \times 10^{-2}$ $B = 1.1$ T	C1 C1 A1
	(f)		Spiral with radius decreasing towards the top of the field Anticlockwise direction 	M1 A1