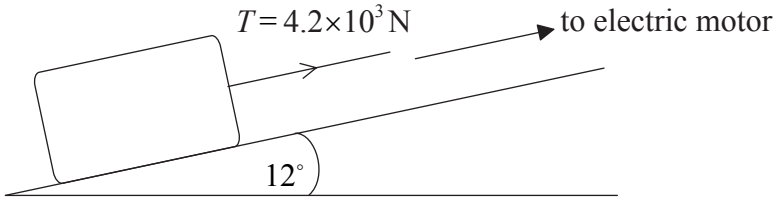
SECTION A: (Short Answer questions - 60 marks or 30 % of total for paper)

Answer all 14 questions in the spaces provided.

Question 1

A stone block is pulled at a constant speed up an incline by a cable attached to an electric motor.



The incline makes an angle of 12° with the horizontal. The weight of the block is 1.5 x 10^4 N and the tension T in the cable is 4.2 x 10^3 N.

Calculate the magnitude of the friction force acting on the block.

[3 marks]

Constant speed means net force = 0	**0.5 mark**
T = Weight component down slope + friction force	**0.5 mark**
4.2 x 10^3 = mgsinθ + friction = 1.5 x 10^4 sin 12 + friction	**1 mark**
Friction force = 4.2 x 10^3 – 3.12 x 10^3 = 1.08 x 10^3 N	**1 mark**

Question was poorly answered – very few students know anything about inclined planes

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Question 2

A car wheel is held in place by four nuts. Each nut was put on by a machine that tightened it with a torque of 3.00×10^2 Nm.

The photograph below shows the 30.0 cm long horizontal lever that is used to remove the nuts from the wheel.

Assuming that it also takes 3.00×10^2 Nm to undo the nut, show (by calculation) that if a person of mass 90.0 kg stands on the end of the lever without bouncing, the weight of the person is **not** enough to turn the wheel nut.

[3 marks]

Weight of person $F_W = mg = 90 \times 9.8 = 882$ N	**1 mark**
Applied torque = F x r = $882 \times 0.30 = 2.65 \times 10^2$ Nm	**1 mark**
Since applied torque < 3.00×10^2 Nm it is not possible to turn wheel nut	**1 mark**

Question was well answered –most students achieved full marks

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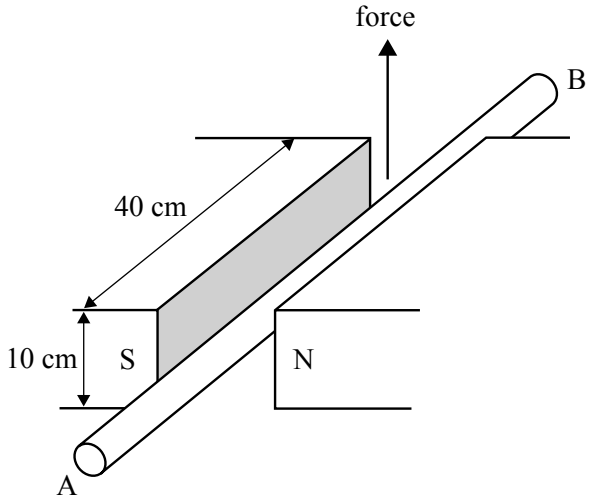
Question 3

The diagram below shows a magnet with pole pieces that are each 40 cm x 10 cm.

The uniform magnetic field strength between the poles is 1.95 x 10^{-3} T, and zero outside the poles. A conducting wire, AB, carrying a current of 3.85 A, is placed between the poles as shown.

The force on the wire is upwards.



a) In which direction, **A** to **B** or **B** to **A**, is the current flowing in the wire?

[1 mark]

Using RH rule, current must flow from A to B	**1 mark**

b) What is the magnitude of the force acting on the wire?

[2 marks]

Magnetic force acting F = ILB	**0.5 mark**
F = ILB = 3.85 x 0.40 x 1.95 x 10^{-3}	**1 mark**
Force F = 3.00 x 10^{-3} N	**0. 5 mark**

Part a) many students had B to A – could have used LH rule!

Part b) was well done

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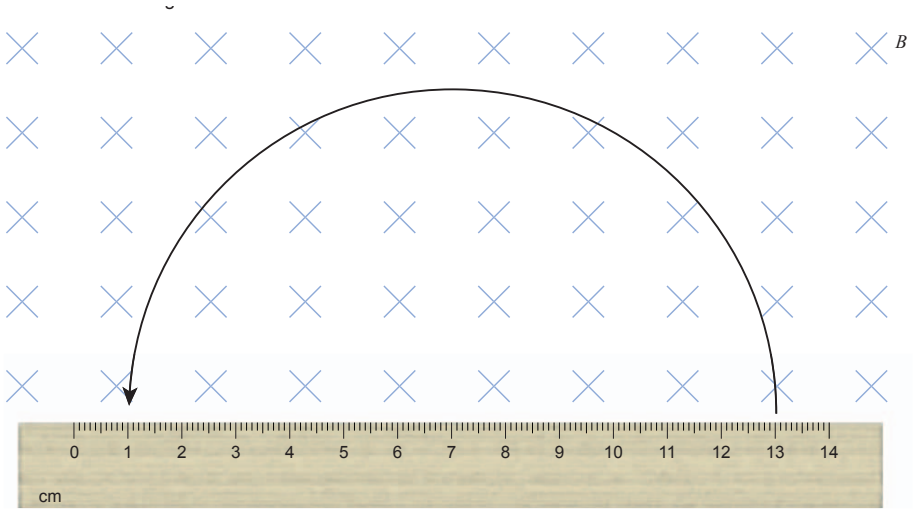
Question 4

The diagram below shows the path of a charged particle that has entered a magnetic field of magnitude B = 0.14 T, which is directed into the page. The initial velocity of the particle was 4.25×10^5 ms^{-1}, perpendicular to the magnetic field. The particle has a charge of magnitude 3.2×10^{-19} C.



Using the above diagram determine:

a) the sign of the charge of the particle. _____

[1 mark]

Using RH rule, the particle must carry a positive charge	**1 mark**

b) the mass of the charged particle.

[2 marks]

Radius of path = 6 cm = 0.06 m	**0.5 mark**
r = mv/qB	
m = qBr/v = $3.2 \times 10^{-19} \times 0.14 \times 0.06 / 4.25 \times 10^5$	**1 mark**
Mass of particle = 6.32×10^{-27} kg	**0.5 mark**

Generally well done – some students used the diameter or read the scale incorrectly

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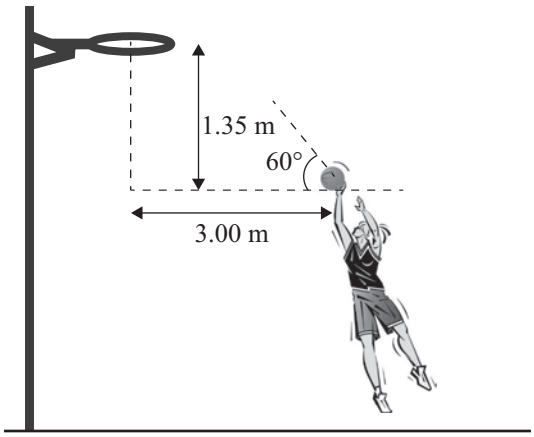
Question 5

Natasha is shooting at goal in a game of basketball. She stands 3.0 m from the hoop. She throws a ball with an initial velocity of 6.5 ms^{-1} at an angle of 60° above the horizontal. The hoop is 1.35 m above the bottom of the ball when it is released.



With appropriate calculations, determine whether or not the ball will go through the hoop. Begin your answer by calculating the horizontal and vertical components of the ball's initial velocity.

[5 marks]

$V_V = v\sin\theta = 6.5\sin60 = 5.63\ ms^{-1}$ $V_H = v\cos\theta = 6.5\cos60 = 3.25\ ms^{-1}$	1 mark
$R = V_H \times t$ so $t = 3.00 / 3.25 = 0.923$ seconds	1 mark
Vertical displacement $h = ut + ½ at^2 = 5.63 \times 0.923 - 4.9 \times 0.923^2$ $= 1.02$ m	2 marks
For the ball to pass through the hoop, the vertical displacement must be 1.35 m	
Since h < 1.35 m, the ball will not go through the hoop	1 mark

Well done by those who understood the strategy Many errors made with finding time

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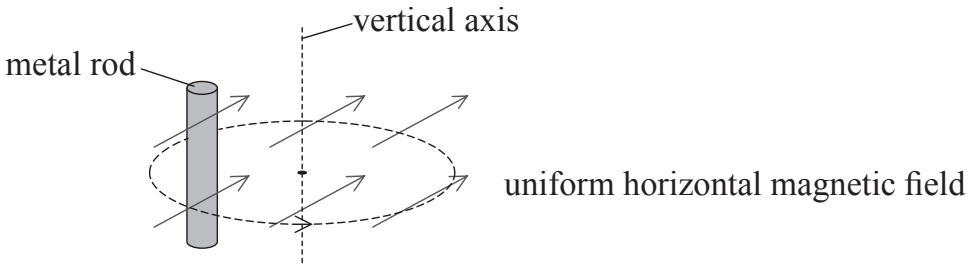
Question 6

A vertical metal rod of length 0.25 m moves in a horizontal circle about a vertical axis in a uniform horizontal magnetic field.



The metal rod completes one circle of radius 0.066 m in 0.020 seconds in the magnetic field of strength 61 mT

a) Determine the maximum EMF induced between the ends of the metal rod.

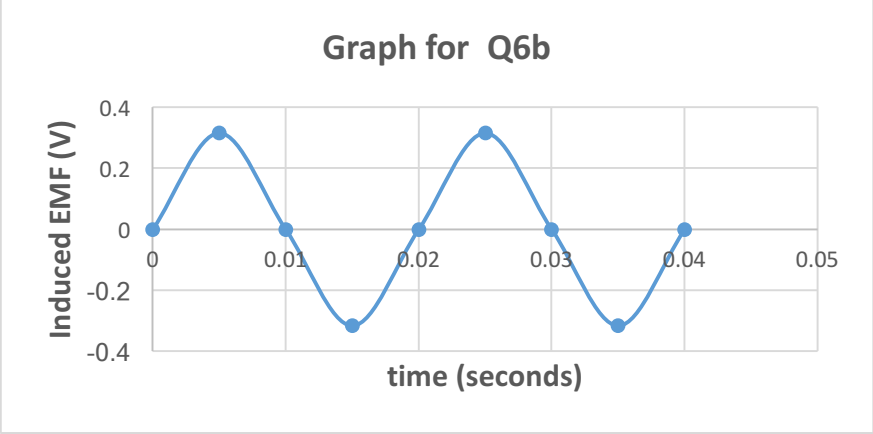
[3 marks]

Velocity of metal rod $v = 2\pi r / T = 2 \times 3.142 \times 0.066 / 0.020 = 20.74\ ms^{-1}$	1 mark
Induced EMF = $vLB = 20.74 \times 0.25 \times 61 \times 10^{-3}$	1 mark
EMF = 0.316 V	1 mark

Many incorrect equations used – it is not a generator question

b) Using the axes, sketch a graph to show the variation with time of the induced EMF in the metal rod.

[2 marks]



The metal rod cuts the magnetic flux at varying angles so the graph will be a curve since the rate of change of flux is not constant. Think of the graph for the output of an AC generator	
The rod will move parallel to the B-field (hence EMF = 0) and then cut the flux at 90° (EMF = maximum = 0.316 V as calculated in part a)	1 mark
The EMF must alternate as the rod rotates a full 360°. A full rotation takes 0.02 seconds so the period of the AC output must also be 0.02 seconds.	1 mark

Question 7

This question is about special relativity, simultaneity and and length contraction.

One of the postulates of special relativity may be stated as"

"*The laws of physics are the same for all observers in inertial frames of reference*"

a) What is meant by an inertial frame of reference?

Any frame of reference which is at rest or moving at a constant velocity	**1 mark**

A basic fact not known by many students at all

[1 mark]

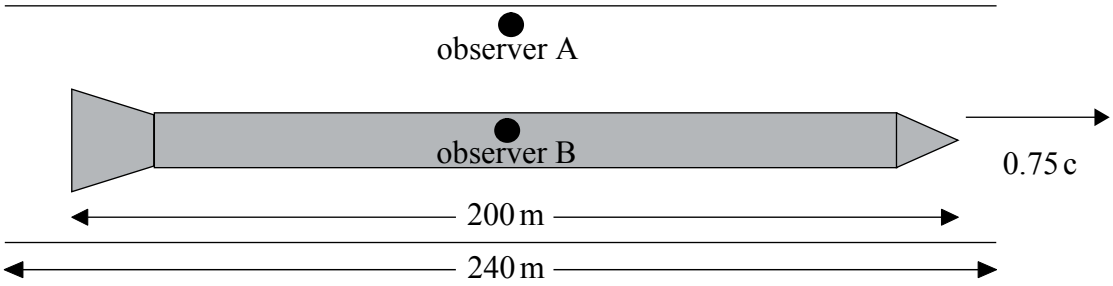
b) State the other postulate of special relativity.

[1 mark]

The speed of light is always measured by an observer as 3.00 x 10^8 ms^{-1} regardless of their frame of reference	**1 mark**

A spaceship is travelling to the right at a speed of 0.75 c, through a tunnel which is open at both ends. Observer **A** is standing at the centre of one side of the tunnel. Observer **A**, for whom the tunnel is at rest, measures the length of the tunnel to be 240 m and the length of the spaceship to be 200 m.

The diagram below shows this situation from the perspective of observer **A**.



Observer **B**, for whom the spaceship is stationary, is standing at the centre of the spaceship.

c) Calculate the length of the tunnel according to observer **B**.

[2 marks]

Length contraction will occur $L = L_o (1- v^2/c^2)^{0.5}$	**1 mark**
$L = 240 (1 – 0.75^2)^{0.5} = 159$ m	**1 mark**

Generally well answered though using L = 240 m was a common error

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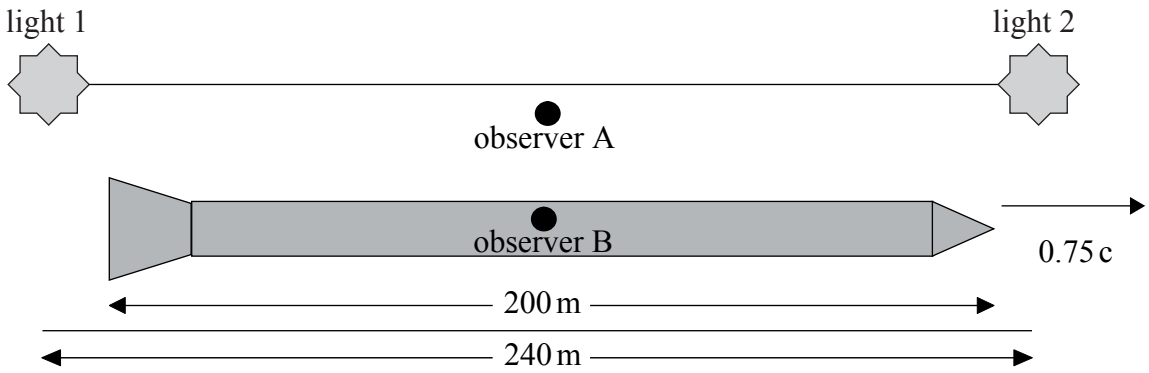
Two sources of light are located at each end of the tunnel. The diagram below shows this situation from the perspective of observer **A**.



According to observer **A**, at the instant when observer **B** passes observer **A**, the two sources of light emit a flash. Observer **A** sees the two flashes simultaneously.

d) Discuss whether or not observer **B** sees the two flashes simultaneously. Briefly explain the reasons for your answer.

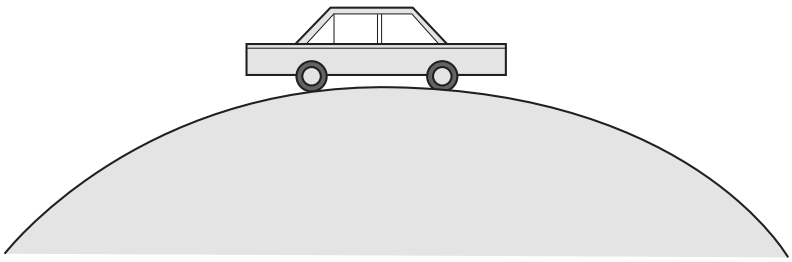
B will see the flash of light from light 2 before light 1 – the events are not simultaneous for observer B	**1 mark**
B is moving towards the flash from light 2 and away from the flash from light 1	**1 mark**

Very well answered – the concept of simultaneity is well understood

[2 marks]

Question 8

A car is driving over a hill with a radius of 195 m at a speed of 110 kmh^{-1}. Determine the **magnitude** and **direction** of the reaction force exerted on a 68.5 kg passenger by the seat of the car.



[3 marks]

Velocity of car = 110/3.6 = 30.55 ms^{-1}	**0.5 mark**
Net force towards centre F_C = mg – R, so R = mg – mv^2/r **R = (68.5 x 9.8) – (68.5 x 30.55^2/195) = 3.43 x 10^2 N**	**1 mark** **1 mark**
Reaction force = 3.43 x 10^2 N in upwards direction	**0.5 mark**

Generally well answered though adding W and F_C was a common mistake

Question 9

The following tables show information about the properties of quarks and leptons.

Use the information presented in the tables to answer the following questions.

Properties of Quarks

Type of quark	Charge	Baryon number
up u	$+\frac{2}{3}e$	$+\frac{1}{3}$
down d	$-\frac{1}{3}e$	$+\frac{1}{3}$
$\overline{\text{u}}$	$-\frac{2}{3}e$	$-\frac{1}{3}$
$\overline{\text{d}}$	$+\frac{1}{3}e$	$-\frac{1}{3}$

Lepton Numbers

Particle	Lepton number L		
	L_e	L_μ	L_τ
e^-	1		
e^+	−1		
υ_e	1		
$\overline{\upsilon}_e$	−1		
μ^-		1	
μ^+		−1	
υ_μ		1	
$\overline{\upsilon}_\mu$		−1	
τ^-			1
τ^+			−1
υ_τ			1
$\overline{\upsilon}_\tau$			−1

a) Pions are sub-atomic particles made up of two quarks. Which of the following best describes pions? Circle your answer. **[1 mark]**

A. Leptons

B. Mesons **[1 mark]**

C. Baryons

b) There are 3 types of pions:

π^+ particles which have a charge of +1 and consist of an up quark and an anti-down quark

π^- particles which have a charge of -1

π^o particles which have zero charge

State the quark composition of each of the following: **[2 marks]**

π^-	π^o
down, anti-up **(1 mark)**	**down, anti-down or up, anti-up** **(1 mark)**

c) π^+ particles have a mean (average) lifetime of 2.6×10^{-8} seconds in their own frame of reference. In an experiment in a particle accelerator, π^+ particles are accelerated to a velocity of 0.9 c.

Calculate the mean lifetime of these π^+ particles relative to a stationary observer.

[2 marks]

Time dilation will be observed: $t = t_o / (1 - v^2/c^2)^{0.5}$	**1 mark**
$t = 2.6 \times 10^{-8} / (1 - 0.9^2)^{0.5} = 5.96 \times 10^{-8}$ seconds	**1 mark**

The following table gives some information about particles known as kaons (symbol ***K***).

Particle	Overall charge	Quark Composition
K^-	-1	anti-up, strange
K^+	+1	up, anti-strange
K^o	0	down, anti-strange

d) Deduce the charge of a "strange" quark.

[1 mark]

Strange quark has a charge of -1/3 e	**1 mark**

e) Muons are leptons which can decay via the weak force into electrons and neutrinos. One such decay may be represented by the following equation.

$$\mu^+ \rightarrow e^+ + \nu_e + \overline{\nu}_\mu$$

Verify that this decay process conserves **both** charge and lepton number.

[2 marks]

Charge: LHS +1 RHS +1 + 0 + 0 LHS +1 = RHS +1 **Charge has been conserved**	**1 mark**
Lepton number: LHS = -1 RHS = (-1) + (+1) + (-1) = -1 **Lepton number has been conserved**	**1 mark**

This whole question was very well answered by almost all students

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Question 10

A satellite orbits 4.22 x 10^7 m above the Earth's centre. At a certain point in its orbit around the Earth, the satellite and the Moon line up as shown in the diagram below. Show (with relevant calculations) that in this position the influence of the Moon on the satellite is negligible, compared with the influence of the Earth.

[4 marks]

Gravitational field due to Earth $g_E = GM_E/ r^2 = 6.67 \times 10^{-11} \times 5.97 \times 10^{24} / (4.22 \times 10^7)^2 = 0.224$ ms^{-2} towards Earth	**1 mark**
Distance between satellite and moon = $3.84 \times 10^8 - 4.22 \times 10^7 = 3.418 \times 10^8$ m	**1 mark**
Gravitational field due to Moon $g_M = GM_M / r^2 = 6.67 \times 10^{-11} \times 7.35 \times 10^{22} / (3.418 \times 10^8)^2 = 4.20 \times 10^{-5}$ ms^{-2} towards Moon	**1 mark**
Since g_E is much greater than g_M, the influence of the Moon on the satellite is negligible	**1 mark**

This question could be answered by assuming a mass for the satellite and then calculating the strength of the gravitational force exerted by the Earth and the Moon. Comparing the size of the forces will give the same overall conclusion.
Well done by those students who used the appropriate strategy

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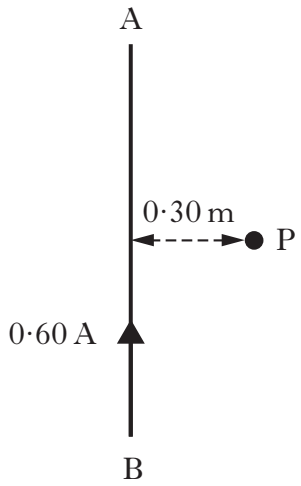
Question 11

A long straight conductor carries a current of 0.60 A from **B** to **A**, as shown in the diagram below.

There is an uncertainty of ± 0.05 A in the current measurement and ± 0.05 m in the distance measurement.



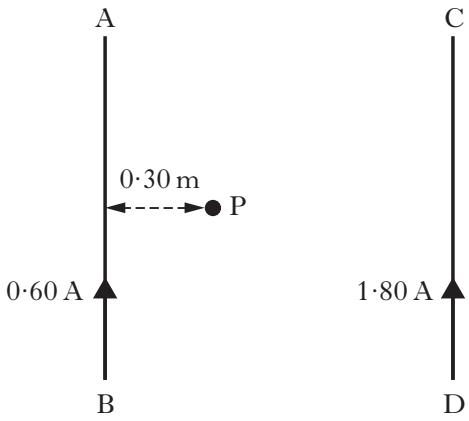
a) Calculate the strength of the magnetic field at point P, a distance of 0.30 m from the conductor. Include an estimate in the **relative error** for the value the magnetic field strength.

[2 marks]

Magnetic field B = ($\mu/2\pi$) I/r = 2.0 x 10^{-7} x 0.60 / 0.30 = 4.00 x 10^{-7} T	**1 mark**
% error in current = 0.05 x 100 / 0.60 = 8.33 % **% error in distance = 0.05 x 100/ 0.30 = 16.67 %**	**0.5 mark** **0.5 mark**
Total relative error = 8.33 + 16.67 = 25.0%	

This question was very poorly done as most students didn't identify correct equation to use.
Some students found the size of B but didn't work out the error. A major area of weakness

A second conductor CD, carrying a current of 1.80 A, is placed parallel to AB as shown in the diagram below.



b) At this separation the resultant magnetic field strength at point P is measured and found to be zero. Explain why the resultant magnetic field strength at point P is zero.

[2 marks]

Using RH rule, direction of magnetic field due to AB at P is into the page **Using RH rule, direction of magnetic field due to CD at P is out of the page**	**1 mark**
Since the two magnetic fields are acting in the opposite directions they can cancel out and produce a magnetic field which is zero	**1 mark**

Very few students could explain why the two magnetic fields will cancel out

c) Calculate the distance of conductor CD to conductor AB.

[2 marks]

Field due to AB = 4.00 x 10^{-7} T into page **Hence field due to CD = 4.00 x 10^{-7} T out of page**	
B = ($\mu/2\pi$) I/r = 2.0 x 10^{-7} x 1.80 / d = 4.00 x 10^{-7} T where d = distance from CD **d = 0.90 m** **Total distance from AB to CD = 0.30 + 0.90 = 1.20 m**	**1 mark** **1 mark**

Poorly done but consistent with the lack of understanding of the previous parts of the question.

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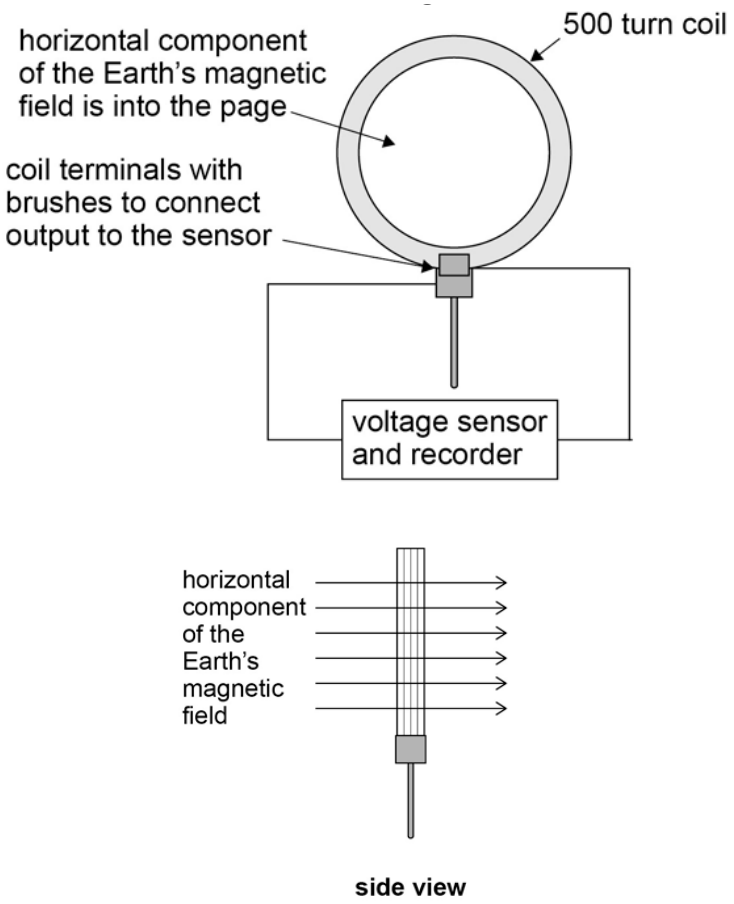
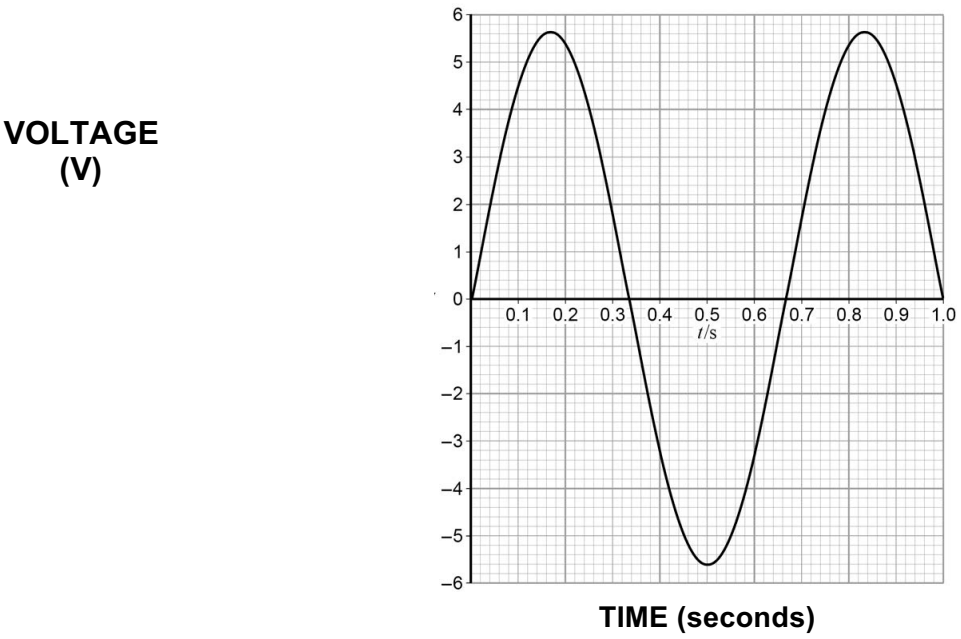
Question 12

An "Earth Inductor" consists of a 500 turn coil. It is set up to measure the horizontal component of the Earth's magnetic field. When the coil is rotated an induced EMF is produced.



The mean radius of the turns on the coil is 35 cm. The graph below shows how the voltage generated in the coil (V) varies with time when the coil is rotated at 1.5 revolutions per second.



a) What is the **peak voltage** generated in the coil?

[1 mark]

Peak voltage (as read from graph) = 5.5 V	**1 mark**

What is the **root mean square** (RMS) voltage generated in the coil?

[1 mark]

RMS voltage = $1/\sqrt{2}$ x 5.5 = 3.89 V	**1 mark**

b) Determine the strength of the horizontal component of the Earth's magnetic field.

[3 marks]

Area of coil A = πr^2 = 3.142 x 0.35^2 = 0.385 m^2	**1 mark**
Induced EMF = 2πNfBA **5.5 = 2 x 3.142 x 500 x 1.5 x 0.385 x B**	**1 mark**
B = 5.5 / (2 x 3.142 x 500 x 1.5 x 0.385) = 3.03 x 10^{-3} T	**1 mark**

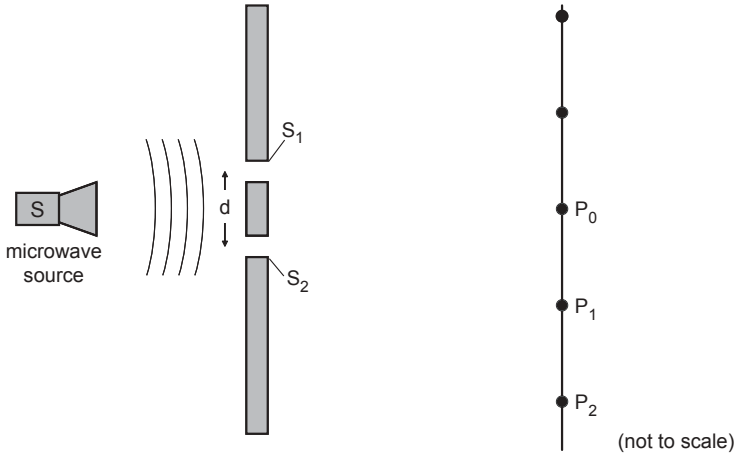
Most students started with the wrong formula and/or did not include all relevant numerical data in their working

Question 13

A group of students have set up an experiment similar to that of English physicist Thomas Young. The students' experiment uses microwaves of wavelength λ = 2.8 cm instead of visible light.

The beam of microwaves passes through two narrow slits S_1 and S_2 as shown in the diagram below. The students measure the intensity of the resulting beam at points along the line shown

and determine the positions of maximum intensity. These are shown as filled circles and marked as P_o, P_1, P_2 etc.



Explain what observations made in Young's Experiment or in the students' experiment tell us about the nature of light.

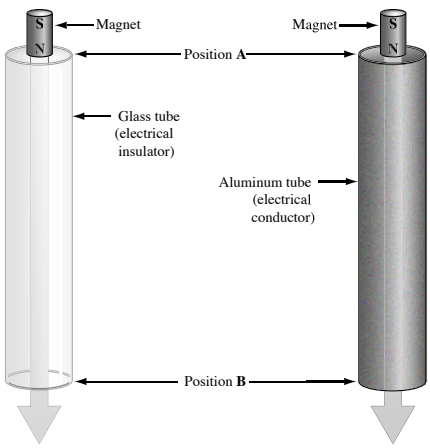
[3 marks]

The variation in the intensity is the result of the interference between the microwaves passing through S_1 and those passing through S_2	**1 mark**
The points where maximum intensity is observed occur when the two waves are "in phase" and constructive interference occurs	**1 mark**
The observations support the idea that light has wave-like properties	**1 mark**

Very poorly answered – only a few students made the link between the observations and the evidence for a "wave theory" of light. The question is NOT related to the dual nature of light.

Question 14

Two hollow tubes, one made of glass and the other made of aluminium, are positioned vertically. A student holds identical cylindrical magnets against the outsides of the tubes and observes that neither tubes attracts a magnet. Based on her observations, the student predicts that each magnet will fall through its respective tube with an acceleration of 9.80 ms^{-2}. The student and her lab partner then drop the magnets into the tubes from rest at position A, as shown below.



The students make the following observations:

- The magnets do not touch the sides of the tube as they fall.
- The time for the magnet to fall through the aluminium tube is much greater than the time for the identical magnet to fall through the glass tube.

	Glass Tube	Aluminium Tube
Mass of magnet (kg)	0.150	0.150
Tube length (m)	0.95	0.95
Time for magnet to fall from position A to position B	0.44	0.76

Explain the difference in the time taken for the magnets to fall through the respective tubes.

[3 marks]

As the magnet falls there is a change in magnetic flux in the vicinity of the aluminium tube and so an EMF will be induced in the metal tube because it is a conductor. This will not happen with the glass tube.	**1 mark**
According to Lenz's Law, the current which is induced in the aluminium tube will flow in a direction which opposes the change which created it.	**1 mark**
Initially a N pole will be created at the top of the tube which will repel the approaching N pole of the magnet. When the magnet leaves the tube a N pole will be created at the bottom of the tube which will attract the magnet upwards. Since both magnetic forces act in an upwards direction and hence, against gravity, the net force acting downwards on the falling magnet is smaller – this means that the time taken to fall through the aluminium tube will be longer	**1 mark**

Very inconsistent responses – the word "explain" requires a detailed discussion of what happens and why it happens. Overall understanding of Lenz's Law is poor.

END of SECTION A

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SECTION B: (Problem Solving – worth 100 marks or 50 % of total for paper)

Answer all **EIGHT** (8) questions in the spaces provided.

Question 15

An exoplanet is a planet that revolves around a star that is not our sun. As one such exoplanet revolves around a distant star, it causes the star to oscillate, or wobble, in its path as the star and the exoplanet orbit their common centre of mass.

In the following calculations, assume that the centre of the exoplanet's orbit coincides with the star's centre of mass, and that the orbit is circular.

Some details of the star and exoplanet are shown below:

Mass of star $M_S = 2.15 \times 10^{30}$ kg

Mass of exoplanet $M_P = 1.95 \times 10^{27}$ kg

Distance between centre of star and centre of exoplanet = 7.50×10^{9} m

a) Verify that the magnitude of the gravitational force acting on the exoplanet is 4.97×10^{27} N.

[2 marks]

$F = Gm_1m_2 / r^2$ $= 6.67 \times 10^{-11} \times 2.15 \times 10^{30} \times 1.95 \times 10^{27} / (7.50 \times 10^{9})^2$	1 mark
$F = 4.97 \times 10^{27}$ N	1 mark

Very well done – most students scored full marks

b) Calculate the exoplanet's orbital velocity. Show **all** workings.

[3 marks]

$v^2 = GM/r$	1 mark
$v^2 = 6.67 \times 10^{-11} \times 2.15 \times 10^{30} / 7.50 \times 10^{9} = 1.91 \times 10^{10}$	1 mark
Orbital velocity = 1.38×10^{5} ms^{-1}	1 mark

Generally well done though a common error was to use the mass of the exoplanet instead of the mass of the central star

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c) Calculate the exoplanet's orbital period, and express your answer in hours. Show **all** workings.

[4 marks]

Since $v = 2\pi r / T$, $T = 2\pi r / v$	1 mark
$T = 2 \times 3.142 \times 7.50 \times 10^9 / 1.38 \times 10^5 = 3.42 \times 10^5$ seconds	1 mark
Convert period T into hours = $3.42 \times 10^5 / (60 \times 60) = 94.9$ hours	1 mark
Orbital period = 94.9 hours	1 mark

Could use the Kepler formula: $R^3 = GM/4\pi^2 \times T^2$ but there are more steps/unit conversions required. Also need to use the mass of the star and not the mass of the exoplanet

d) Calculate the magnitude of the gravitational field strength **due to the star** at the location of the exoplanet.

[2 marks]

Gravitational acceleration = centripetal acceleration = $a_c = v^2/r$	1 mark
$g = (1.38 \times 10^5)^2 / 7.50 \times 10^9 = 2.54\ ms^{-2}$ Could also use $g = GM/r^2 = 2.55\ ms^{-2}$	1 mark

Well done – most students found the correct answer.

e) What other information is required to determine the acceleration due to gravity on the **surface** of the exoplanet?

Need to know the radius of the exoplanet since $g = GM/r^2$	1 mark

Well done – most students identified the correct answer.

[1 mark]

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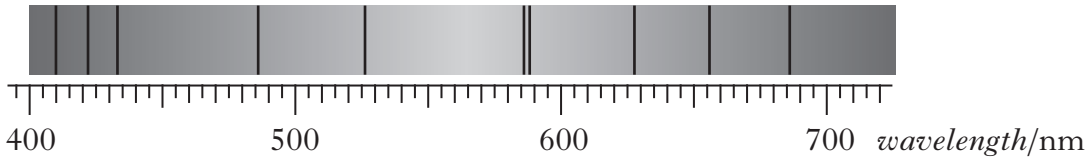
Question 16

Light from the Sun is used to produce a visible spectrum. A student views this spectrum and observes a number of dark lines as shown.



a) Explain how these dark lines in the spectrum of sunlight are produced.

[3 marks]

Photons of visible light are emitted by the very hot gases at the centre of the Sun.	**0.5 mark**
Gases in the cooler outer layers of the Sun's atmosphere absorb some of these photons. **Electrons within the energy levels of the atoms absorb photons with an energy equal to the difference between two energy levels and undergo a transition to a higher energy level.**	**0.5 mark** **1 mark**
When sunlight is examined through a spectroscope specific wavelengths of light are missing and appear as "black lines" in an otherwise continuous spectrum.	**1 mark**

Very poorly answered – understanding of how line absorption spectra are formed is limited for most students.

b) Estimate the energy of the photon with the **third longest** wavelength shown in the diagram. Give your answer in eV.

[3 marks]

Estimated wavelength = 626 nm	**1 mark**
Photon energy $E = hf = hc/\lambda = 6.63 \times 10^{-34} \times 3 \times 10^{8} / 626 \times 10^{-9}$ **$= 3.18 \times 10^{-19}$ J**	**1 mark**
Convert to eV $E = 3.18 \times 10^{-19} / 1.6 \times 10^{-19} = 1.99$ eV	**1 mark**

Well done though a number of students didn't convert their answer into electron volts as required.

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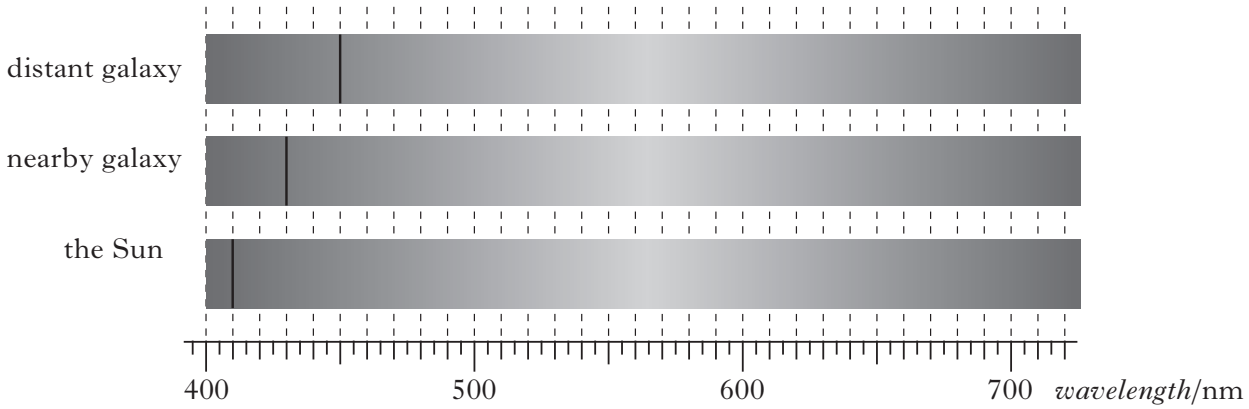
One of the absorption lines in the spectrum is due to hydrogen. The position of this hydrogen line in the visible spectrum is shown for a distant galaxy, a nearby galaxy and the Sun.



c) Explain why the position of the line is different in each of the spectra.

[3 marks]

The spectral lines show "red shift"	**1 mark**
The galaxies are moving away from the Earth and so there is an apparent increase in the wavelength of the light observed.	**1 mark**
The galaxies are moving at different speeds and so the amount of red shift varies from galaxy to galaxy	**1 mark**

Most students failed to see the point of the question – the diagrams all show the absorption lines for hydrogen gas. The difference in position of the lines is a result of red shift .

d) Explain how the spectra shown above support the theory of the expanding Universe.

[3 marks]

The speed of a galaxy determines the amount of red shift observed	**1 mark**
The distant galaxy shows a greater red shift in its spectrum and is therefore moving at a greater speed than the nearby galaxy	**1 mark**
Distant galaxies move away from the Earth at a faster rate -> the Universe must be expanding	**1 mark**

Generally well answered by those students who understood the point of part b)

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Further analysis of the spectrum of hydrogen shows that the wavelength of a line, as measured in the laboratory, is 656 nm. The same line in the spectrum of light from a distant galaxy is measured to be 790 nm.

e) Show that the recessional speed of the galaxy is 6.13×10^7 ms^{-1}.

You may use the additional information:

$$v_{galaxy} = (\Delta\lambda / \lambda)\, c$$

Change in wavelength $\Delta\lambda$ = 790 – 656 = 134 nm	**1 mark**
Recession velocity of galaxy = $(134 \times 10^{-9} / 656 \times 10^{-9}) \times 3 \times 10^8$ = 6.13×10^7 ms^{-1}	**1 mark**

Well answered by most students

[2 marks]

f) The galaxy is 3.1×10^6 light years from Earth. Determine, using your answer to e), a value for the Hubble constant H_o. Express your answer in units of ms^{-1} ly^{-1}

You may use the additional information:

$$v_{galaxy} = H_o\, d$$

[3 marks]

H_o = v / d	**1 mark**
= 6.13×10^7 ms^{-1} / 3.1×10^6 ly	**1 mark**
= 19.7 ms^{-1} ly^{-1}	**1 mark**

Basically well answered by most students except those who tried to change the units for some reason and hence made a straightforward question much more difficult

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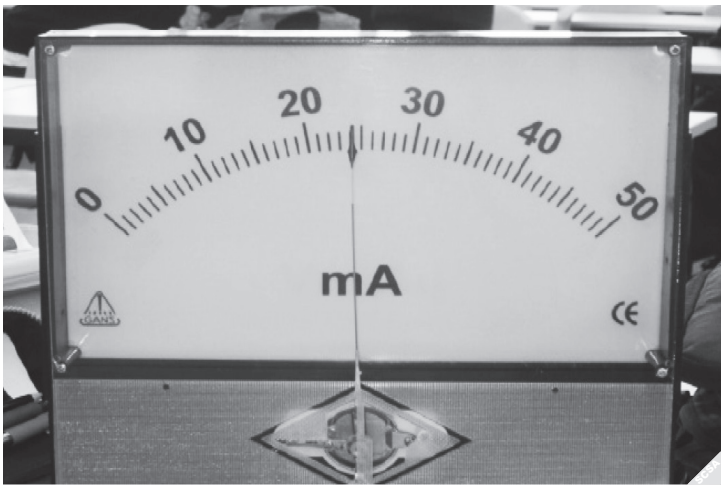
Question 17

An ammeter is a device that is used to determine the magnitude of an electric current. The unknown current is passed through a coil of wire in a magnetic field. The turning effect of the current carrying coil is balanced by a spring and a corresponding value is read from the meter.



a) Use the photograph of the ammeter scale to determine each of the following:

The value of the current passing through the ammeter in mA.	The absolute uncertainty involved in reading the scale (use the ± notation)	The relative uncertainty in the current measurement.

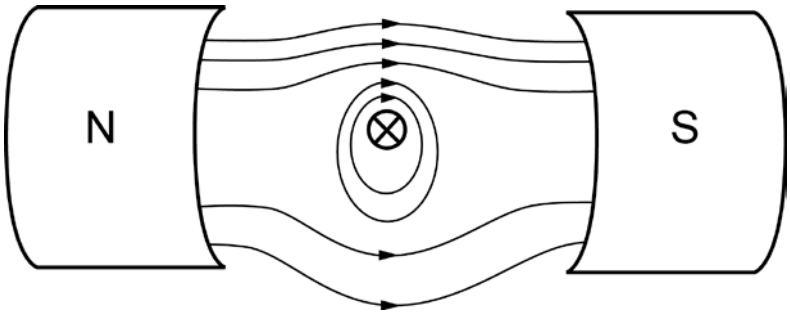
Reading on scale = 24.0 mA	**1 mark**
Absolute uncertainty = ½ SSD = ± 0.5 mA	**1 mark**
Relative error = (0.5 / 24) x 100 = 2.1 %	**1 mark**

No follow through errors were applied to this question. Students need to review the idea of absolute error and relative error very carefully.

[3 marks]

b) A simplified diagram representing one current - carrying wire of the ammeter's coil between two magnets, is shown below. Draw at least **five** field (flux) lines to show the resultant magnetic field between the magnets.

[3 marks]



Shows 5 field lines	1 mark
Arrows show N to S	1 mark
Correct interaction between fields is shown	1 mark

Very poorly done – only a few students achieved full marks. The diagram is self-explanatory!

c) The actual ammeter shown has 300 turns of wire that form a square coil with sides of 3.20×10^{-2} m. Determine the magnitude of the current in the coil if a torque of 2.65×10^{-2} Nm is produced in the magnetic field of strength 42.5 mT.

[4 marks]

Torque = 2 (F x r) = 2 (NILB) x r	1 mark
$2.65 \times 10^{-2} = 2 \times 1.60 \times 10^{-2} \times 300 \times 42.5 \times 10^{-3} \times 3.20 \times 10^{-3} \times I$	1 mark
Current $I = 2.65 \times 10^{-2} / (2 \times 1.60 \times 10^{-2} \times 300 \times 42.5 \times 10^{-3} \times 3.20 \times 10^{-3})$	1 mark
Current I = 2.03 A	1 mark

This question created a range of difficulties – the fact that there are 2 torques and there are 300 turns were common omissions from the working of many students.

d) When the ammeter is disconnected, the spring rotates the coil so that the marker needle returns to zero. This causes a change in magnetic flux of 2.18×10^{-5} Wb to occur in the coil in 0.112 seconds. Determine the average potential difference (voltage) induced in the coil during this time.

[2 marks]

Induced EMF = $- N\Delta\phi / \Delta t$	
EMF = $300 \times 2.18 \times 10^{-5} / 0.112$	1 mark
Average EMF induced = 5.84×10^{-2} V	1 mark

Very well answered – note the change to the mark allocation for this question

Question 18

a) Ultraviolet light of wavelength 210 nm is shone onto the surface of mercury metal. The work function for mercury is 4.50 eV. Determine the maximum kinetic energy and hence the maximum velocity of the photoelectrons emitted.

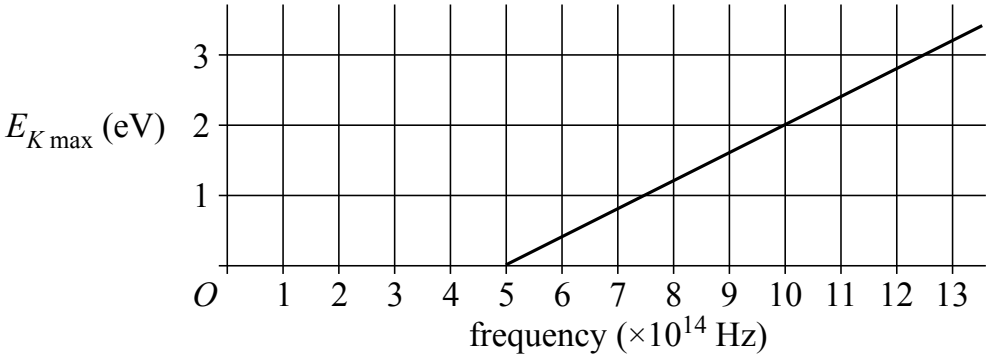
[4 marks]

Photon energy $E = hf = hc / \lambda = 6.63 \times 10^{-34} \times 3 \times 10^{8} / 210 \times 10^{-9}$ $= 9.47 \times 10^{-19}$ J = 5.92 eV	1 mark
Maximum KE = $hf - hf_o = 5.92 - 4.50 = 1.42$ eV $= 2.27 \times 10^{-19}$ J	1 mark
$\frac{1}{2} mv^2 = 2.27 \times 10^{-19} = \frac{1}{2} \times 9.11 \times 10^{-31} v^2$	1 mark
$v^2 = 2 \times 2.27 \times 10^{-19} / 9.11 \times 10^{-31} = 4.99 \times 10^{11}$ so $v = 7.06 \times 10^{5}$ ms^{-1}	1 mark

Most students were able to determine the maximum KE of the photoelectrons.
Several students did not notice that the question also asked for the maximum velocity of the electrons
Note the change to the mark allocation for the question –it is worth a maximum of 4 marks

Students conduct three different experiments to investigate the photoelectric effect.

For experiment 1, light of various frequencies is shone on the surface of metal A. The following graph of maximum kinetic energy (KE_{MAX}) of the photoelectrons against frequency was plotted using the data from experiment 1.



b) Determine the photoelectric work function (W) for metal A.

[2 marks]

From graph, threshold frequency $f_o = 5 \times 10^{14}$ Hz	**1 mark**
Work function W $= hf_o = 6.63 \times 10^{-34} \times 5 \times 10^{14} = 3.32 \times 10^{-19}$ J	**1 mark**

Well answered by most students

c) Use the **graph** to calculate the value of Planck's constant for experiment 1.

[3 marks]

Planck's constant = gradient of graph = rise / run	**1 mark**
h = (2 x 1.6 x 10^{-19}) / (10 x 10^{14} – 5 x 10^{14})	**1 mark**
h = 6.41 x 10^{-34}Js	**1 mark**

Most students knew how to approach the question. The working must clearly specify that the value for "h" will be the gradient of the line.

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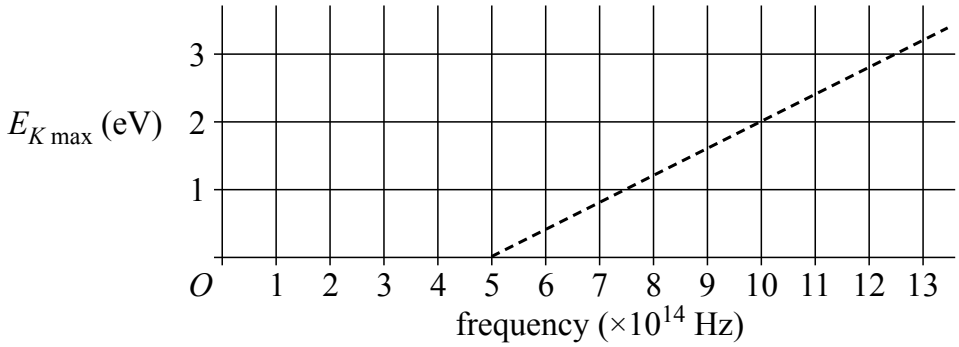
In experiment 2, the intensity of the light for each frequency is doubled and again shone on metal A.

The dotted line shows the results of experiment 1.

d) On the graph below, draw a solid line to sketch the graph of maximum KE against frequency for experiment 2.

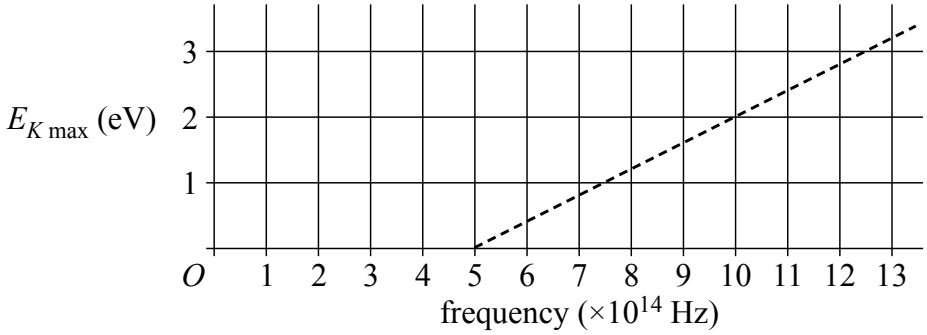


[2 marks]

The intensity does not affect the KE of the photoelectrons	**1 mark**
New graph must be superimposed over the original dotted line	**1 mark**

In experiment 3, the metal A is replaced with metal B that has a work function 50% larger than that of metal A. The original intensity of light is used. A dotted line shows the results of experiment 1.

e) On the graph below, draw a solid line to sketch the graph of maximum KE versus frequency for experiment 3.



[2 marks]

New threshold frequency should be 7.5 x 10^{14} Hz	**1 mark**
New graph must be parallel to (same gradient) as the original dotted line	**1 mark**

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Question 19

A wind turbine generates electricity at a rate of 200 kW at a voltage of 690 V.

The turbine is connected to a transformer which increases the voltage to 33 x 10^3 V before connecting it to the electricity grid.

a) Why is the electricity transmitted in the grid system at such a high voltage?

Using a high voltage to transmit the power will reduce the size of the current flowing in the transmission wires (P = VI)	**1 mark**
Using a smaller current will reduce the amount of energy wasted as heat due to the resistance of the power lines ($P_{LOSS} = I^2R$)	**1 mark**

Some confusion over this concept – the resistance of the grid system is a fixed value. By simply saying " to reduce energy losses" does not answer the question

[2 marks]

b) The transformer connected to the wind turbine has a primary coil of 75 turns. How many turns does the secondary coil have? Express your answer to the nearest whole number.

[2 marks]

Transformer relationship $N_S / N_P = V_S / V_P$	**1 mark**
$N_S = 33 \times 10^3 \times 75 / 690 = 3587$ turns	**1 mark**

Very well done – most students answered correctly

c) What current flows in the transmission lines which connect the transformer to the grid system?

[3 marks]

Since P = VI I = P / V	**1 mark**
Current = 200 x 10^3 / 33 x 10^3	**1 mark**
Current = 6.06 A	**1 mark**

Very well done – most students answered correctly

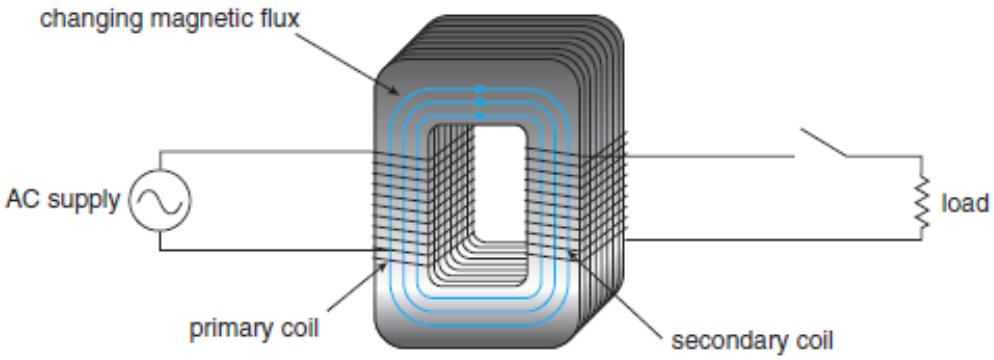
d) If the transmission lines have a resistance of 0.08 ohm per kilometre, how much power is **lost** in the first 40 km of the transmission lines?

[3 marks]

Total resistance = 40 x 0.08 = 3.20 ohms	**1 mark**
$P_{LOSS} = I^2 R = 6.06^2 \times 3.20$	**1 mark**
$P_{LOSS} = 1.18 \times 10^2$ W	**1 mark**

Well answered – some students did not include the 40 km in their working

The diagram below shows the construction of a typical transformer.



e) One of the major reasons for transformers to have an efficiency less than 100 % is the formation of Eddy currents within the soft iron core of the transformer.

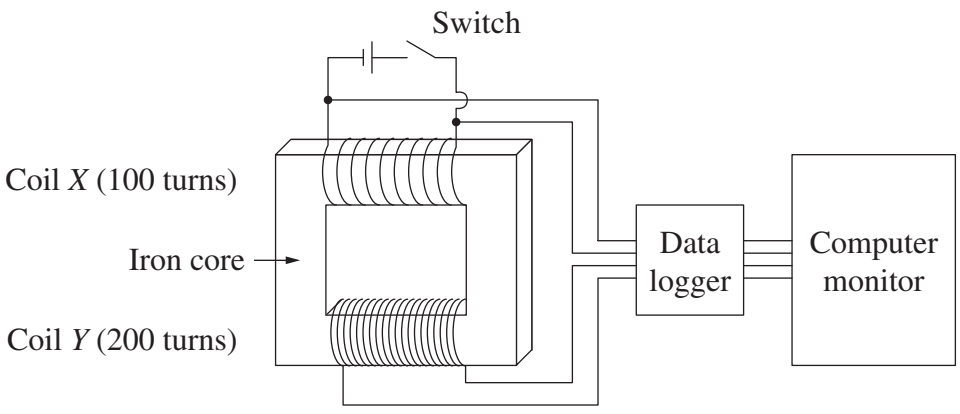
Why do energy currents form, and why are they undesirable?

Eddy currents are formed in the soft iron core of a transformer	**1 mark**
The changing magnetic flux associated with the AC input to the primary coil will induce an EMF in the iron core and induced currents will circulate within the iron core	**1 mark**
Eddy currents will generate heat ($P = I^2 R$) within the transformer core and hence reduce the overall efficiency of the transformer.	**1 mark**

Very poorly answered – only a few students know what an Eddy current is, or why they are created within the core of the transformer. This needs to be revised thoroughly.

[3 marks]

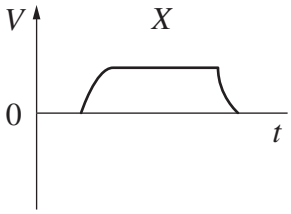
A group of students decide to investigate the principle of a transformer in more detail. They set up the following experiment in which a step-up transformer is connected to a **DC** voltage source.

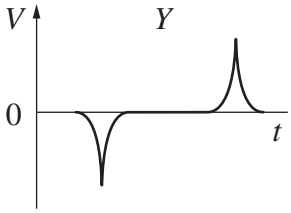


A student closes the switch for a short time, then opens it. The data logger records values of voltage for both coils for the duration of the investigation. The data logger software displays the results as a pair of voltage – time graphs on a computer monitor.

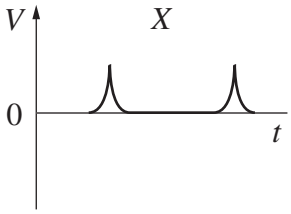
The graphs are shown below.

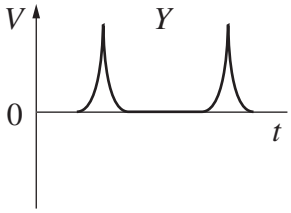
(A)



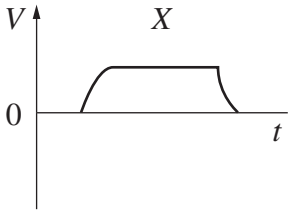


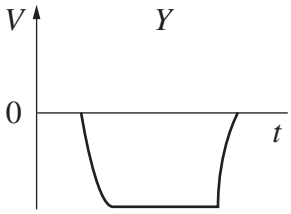
(B)



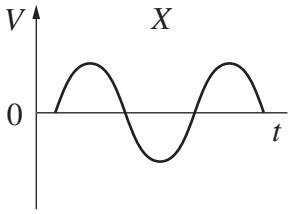


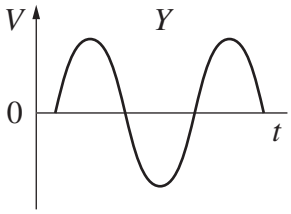
(C)





(D)





f) Which pair of graphs (A, B, C or D) will correctly represent the voltage for each coil?

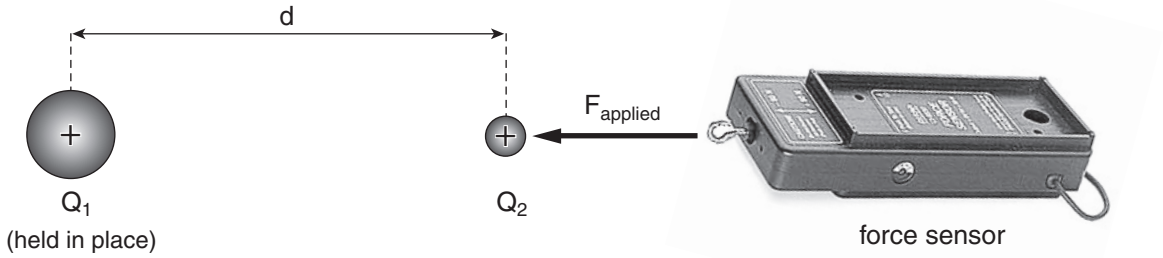
Correct pair of graphs = A	**1 mark**
Primary voltage will initially increase, then remain constant and then decrease back to zero when the switch is opened	**1 mark**
An EMF will be induced in the secondary coil only when there is a change in magnetic flux ($\Delta\phi$) when the switch is opened or closed. Since the input to the primary is DC, there will be no change in flux when the switch is held down and so there will be no EMF produced in the secondary coil. The direction of the induced EMF must reverse when the switch is opened.	**1 mark**

Most answers showed little understanding of how DC inputs produce a change in magnetic flux. The graphs only make sense if you understand how a transformer really works.

[3 marks]

Question 20

A charge Q_2 is pushed toward a fixed charge Q_1. A sensor is used to measure the repulsive force being experienced by Q_2.

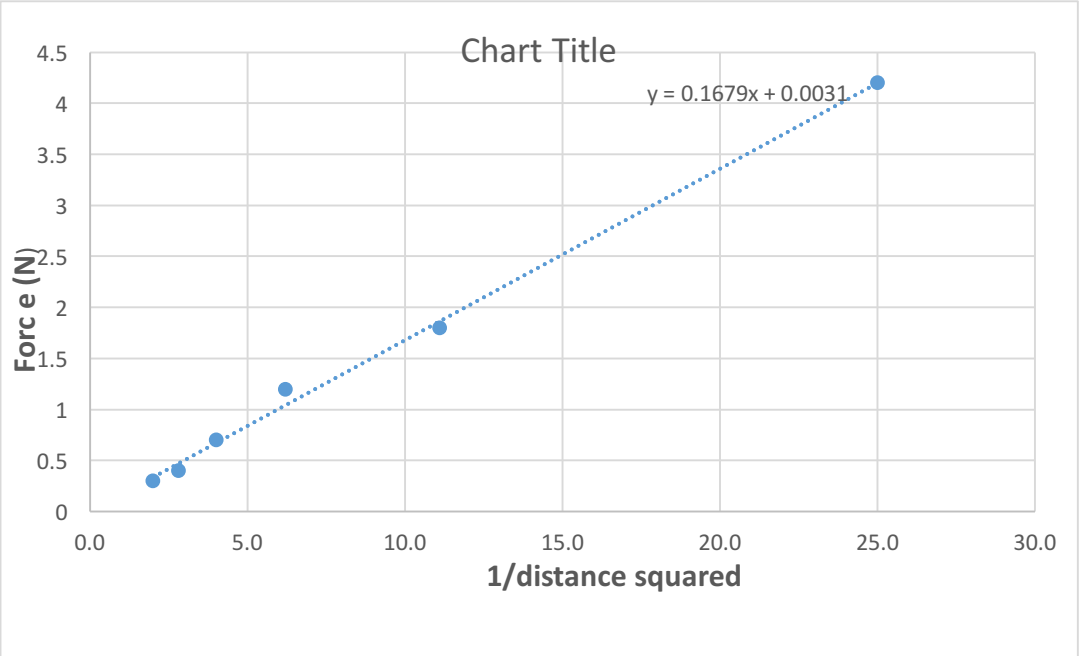


The distance between the charges and the readings on the force sensor are recorded for several different positions. In order to produce a linear plot of the data, the original measurements are adjusted as shown in the table below.

Adjusted Data

FORCE (N)	$\frac{1}{distance^2}\ \left(m^{-2}\right)$
4.2	25.0
1.8	11.1
1.2	6.2
0.7	4.0
0.4	2.8
0.3	2.0

a) Construct a linear plot of the adjusted data and determine the gradient of the best fit line. Include the appropriate units. **Use the graph grid on the next page**.



Working for gradient.

[6 marks]

Accuracy of data plot	**2 marks**
Line of best fit shown	**1 mark**
Gradient = rise/ run = (4.2 – 0.3) / (25.0 – 2.0)	**2 marks**
Gradient = 0.168 N m^2	**1 mark**

Generally well answered though expressing the units for the gradient still remains an issue

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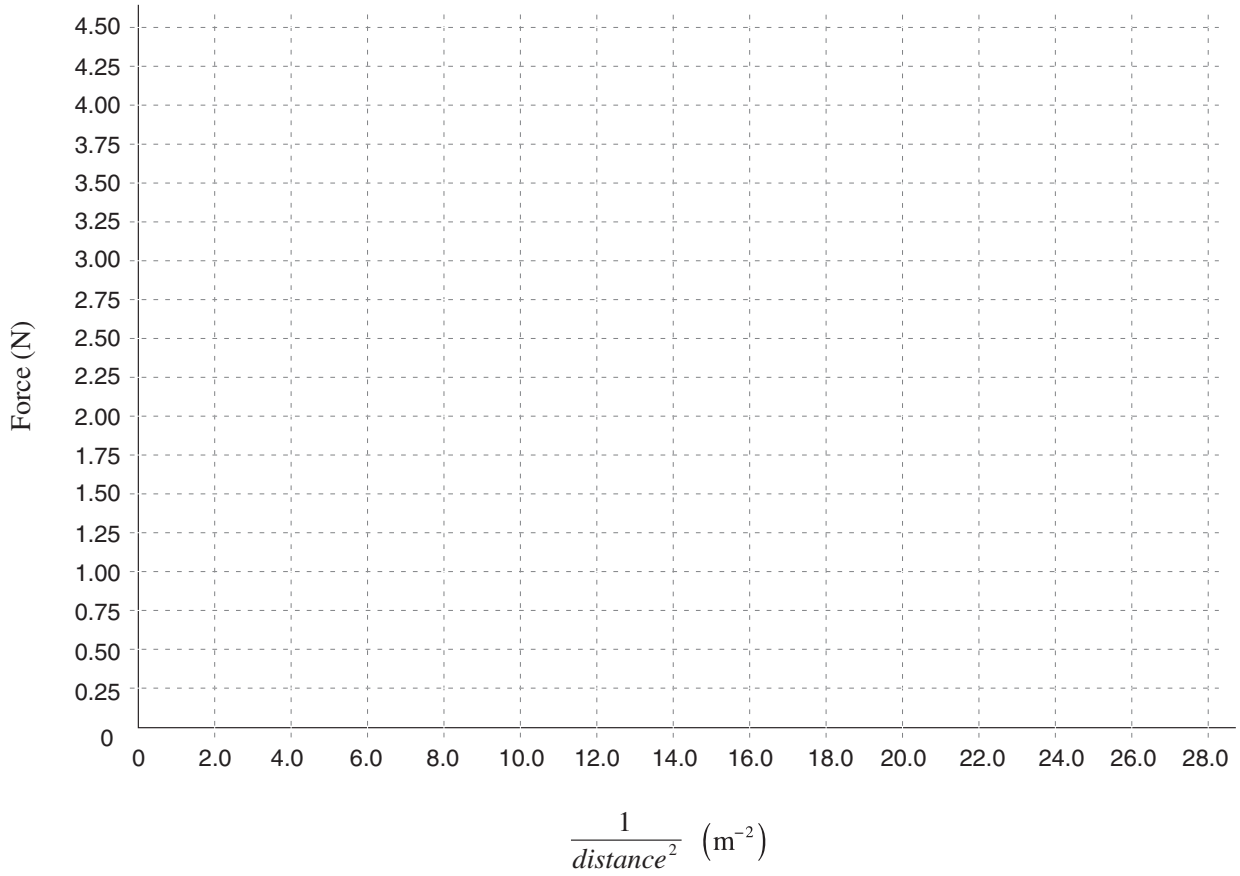
Linear Plot of the Data



b) Given that Q_2 has a charge that is three times larger than Q_1, use the gradient from part a) to calculate the magnitude of charge Q_1.

[4 marks]

Electrostatic force $F = \frac{1}{4\pi\varepsilon} Q_1Q_2 / r^2 = 9 \times 10^9 Q_1Q_2 / r^2$	**1 mark**
Since $Q_2 = 3 Q_1$ $F = 9 \times 10^9 Q_1 3Q_1 / r^2 = 9 \times 10^9 \times 3 Q_1^2 / r^2$	**1 mark**
Gradient of linear graph = $9 \times 10^9 \times 3 Q_1^2 = 0.168$	**1 mark**
$Q_1^2 = 0.168 / 27 \times 10^9 = 6.22 \times 10^{-12}$ so $Q_1 = 2.49 \times 10^{-6}$ C	**1 mark**

Very few students made the link to Coulomb's law and how the gradient is related to the formula. This was intended to be a challenge level question but relatively few students scored marks for their answers.

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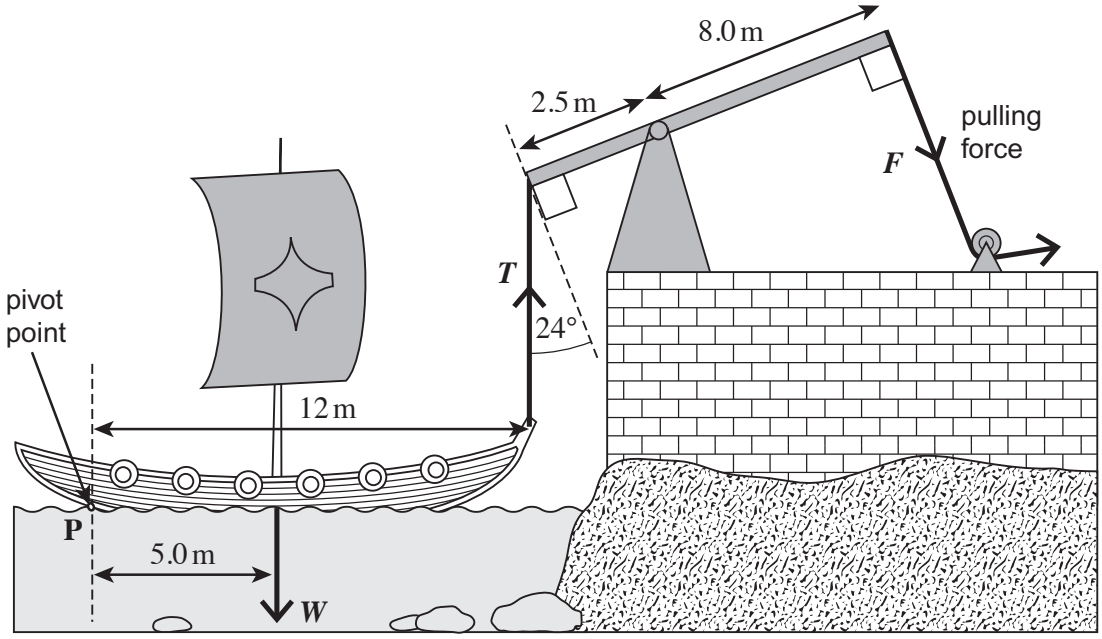
Question 21

It is said that Archimedes used huge levers to sink Roman ships invading the city of Syracuse. A possible system is shown in the following diagram where a rope is hooked on to the front of the ship and the lever is pulled by several men. The mass of the ship is 3.47 tonne.



a) Calculate the minimum vertical force **T**, required to start to raise the front of the ship. Assume that the ship pivots about point **P**

[3 marks]

Taking moments about P ΣCW = ΣACW	**1 mark**
W x 5.0 = T x 12 **3.47 x 10^3 x 9.8 x 5.0 = T x 12** **T = 3.47 x 10^3 x 9.8 x 5.0 / 12 = 1.42 x 10^4 N**	**1 mark**
Minimum force required = 1.42 x 10^4 N	**1 mark**

This question can only be answered by using moments. Note that both W and T act at 90° to the distance so angles are not required in the moment expression. Generally well answered

b) Calculate the minimum force **F**, that must be exerted to start to raise the front of the ship.

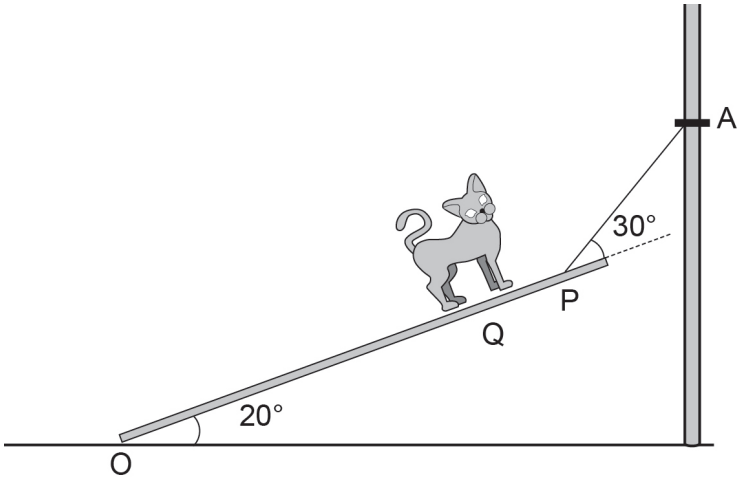
[3 marks]

Taking moments about X ΣCW = ΣACW	**1 mark**
F x 8 = (T x sin 66) x 2.5 **F = 1.42 x 10^4 x sin 66 x 2.5 / 8** **F = 4.03 x 10^3 N**	**1 mark**
Minimum force required = 4.03 x 10^3 N	**1 mark**

Again, this question can only be answered using moments but the ACW moment involves an angle of 66° [90 – 24]

A 3.00 m long plank with a mass of 10.0 kg is held by a cable at point P, 0.200 m away from the upper end of the plank. The angle between plank and ground is 20.0° and the angle between the plank and the cable is 30.0°.

The ship's cat has a mass of 2.00 kg moves up the plank to Point Q, 2.40 m from the bottom, point O.



c) Assuming that Point O is the pivot, calculate the tension force in the cable. Show **all** workings.

[4 marks]

Taking moments about O ΣCW = ΣACW	**1 mark**
(98 x sin 70 x 1.50) + (1.96 x sin 70 x 2.40) = (T x sin 30 x 2.80)	**1 mark**
138.1 + 47.3 = 1.40 T	**1 mark**
T = 142.52 /1.40 = 130 N	**1 mark**

A challenging question – all three moments require the use of an angle. Questions of this complexity need to be handled better. Again, forces up = forces down will not work as there are unknown reaction forces acting at point O.

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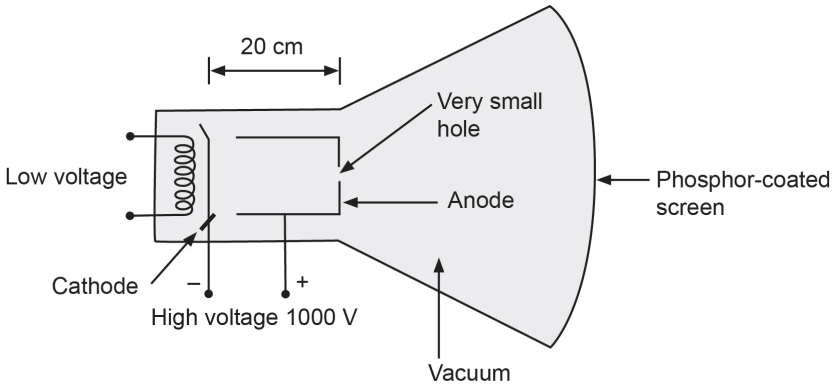
Question 22

Cathode ray tube (CRT) television screens worked by firing a stream of electrons through a vacuum at a phosphor coated screen. The electrons left the cathode and were accelerated by a uniform electric field towards the anode. Some passed through the very small hole at a high velocity. These electrons then travelled at a constant speed toward the screen.

These moving electrons excited the electrons within phosphor atoms on the screen. Each phosphor-electron then emitted green, red or blue light as that phosphor electron decayed back to its ground state.



a) Calculate the magnitude and direction of the electric field between the cathode and anode.

[2 marks]

Electric field strength E = V/d	**0.5 mark**
E = 1000 / 0.20 = 5.00 x 10^{3} Vm^{-1}	**1 mark**
Direction is towards the anode (to right on the diagram)	**0.5 mark**

Well answered by nearly all students

b) Calculate the force exerted on each electron as it left the cathode.

[2 marks]

Force exerted on the electron F = Eq	**1 mark**
F = 5.00 x 10^{3} x 1.6 x 10^{-19} = 8.00 x 10^{-16} N	**1 mark**

Well answered.

c) Calculate the kinetic energy of each electron just prior to it colliding with the phosphor atom on the screen. **[3 marks]**

Work done to move the electron from cathode to anode is W = Vq **W = 1000 x 1.6 x 10^{-19} = 1.6 x 10^{-16} J** **(or W = F x d = Eq x d = 1.6 x 10^{-16} J**	**1 mark** **1 mark**
Gain in KE of electron = Work done = 1.6 x 10^{-16} J	**1 mark**

A lot of answers failed to make the link that the gain in KE equals the work done by the electric field.

d) These electrons collided with the phosphor screen to produce red light of wavelength 700 nm. Calculate the **difference**, in joules, between energy levels of the phosphor atoms associated with this emission.

[3 marks]

Energy of photon emitted E = hf = hc/λ	**1 mark**
E = 6.63 x 10^{-34} x 3 x 10^{8} / 700 x 10^{-9} = 2.84 x 10^{-19} J	**1 mark**
The energy of the photon = difference between the energies of the levels involved ΔE = 2.84 x 10^{-19} J	**1 mark**

Nearly every student failed to actually answer the asked question. Having calculated the energy of the photon emitted, it is necessary to state/explain that this amount of energy is equal to the difference in energy of the two levels involved in the transition (Bohr Theory)

END of SECTION B

SEE NEXT PAGE

SECTION C: (Comprehension and Interpretation – 40 marks or 20 % of total for the paper).

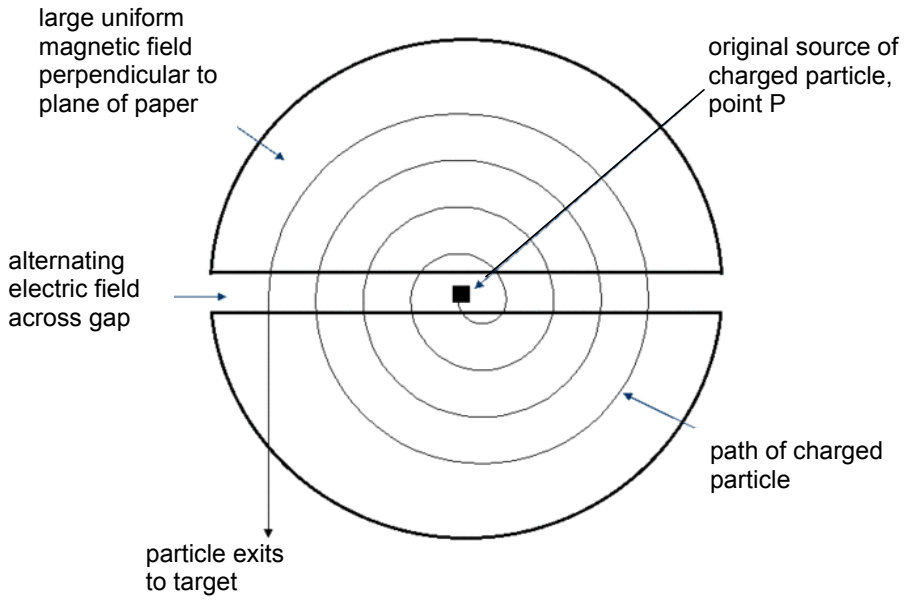
Answer both questions in the spaces provided.

Question 23

A cyclotron is a device used to accelerate charged particles to very high energies. The particles are then used to bombard other particles to investigate the nature of matter. Through experiments involving cyclotrons much of our current understanding of particle physics has been developed.

Sir Charles Gairdner Hospital in Nedlands uses a medical cyclotron to accelerate protons and deuterons to very high energies to produce short-lived radioisotopes for diagnostic purposes.

The structure of a cyclotron can be represented by the following schematic diagram.



How a cyclotron works

A cyclotron consists of two hollow D-shaped semicircular metal electrodes (called 'dees'), an ion source, an electromagnet and an alternating power supply.

The dees are mounted inside a vacuum chamber that fits between the two flat pole pieces of an electromagnet. The dees are connected to a high frequency alternating voltage supply that provides an alternating electric field across the gap between the dees.

When charged particles are injected at the centre of the dees (point P), they are accelerated by the electric field and then move into a semicircular path inside the hollow space of the dee under the influence of the uniform magnetic field that acts perpendicular to the path of the charged particles. Once inside the dee they are shielded from the electric field and thus do not gain any further energy.

Because the dees are connected to an alternating voltage supply, the charged particles are accelerated by the electric field each time they cross the gap, increasing their energy by a small amount qV. Therefore their speed increases and they move into larger and larger path radii. If the charged particles do not arrive at the gap when the polarity is correct, they will fall out of synchronisation and the beam will be lost. So for the satisfactory operation of the cyclotron, the frequency of the alternating voltage must be equal to the orbital or cyclotron frequency of the charged particles. This condition is valid only when the speed of the charged particles is much less than the speed of light. At higher particle speeds (above about 10% of the speed of light) the frequency of the circulating particle decreases steadily due to relativistic effects. Thus the particle goes out of step with the frequency of the oscillator and its energy stops increasing.

In the normal operation of the cyclotron, when the charged particles reach the outside perimeters of the dees, they are deflected by the electric field of an ejector plate and strike the outside target.

The following table shows some important data about common charged particles.

Charged particle data

Type of charged particle	Mass of charged particle (kg)	Charge of the particle (coulombs)	$\frac{q}{m}$
electron	9.11×10^{-31}	1.60×10^{-19}	
proton	1.67×10^{-27}	1.60×10^{-19}	
deuteron	3.34×10^{-27}	1.60×10^{-19}	

a) What provides the centripetal force that acts on the charged particle?

F_c is the net force acting towards the centre of the circular path	**1 mark**
The magnetic force acting on the charged particle F = qvB acts as right angles to the path of the charged particle and provides the required centripetal force	**1 mark**

[2 marks]

"the magnetic field" is not an acceptable answer –you need to explain how the magnetic force acting on the charged particle can result in circular motion.

b) Complete the last column of the data table, giving the ratio to three (3) significant figures.

[3 marks]

Electron 1.76 x 10^{11}	**1 mark**
Proton 9.58 x 10^{7}	**1 mark**
Deuteron 4.79 x 10^{7}	**1 mark**
Deduct 1 mark where ratio not expressed to 3 SF	

Very straightforward question – no problems.

c) The operation of the cyclotron is based on the principle that the frequency of revolution is independent of the speed of the charged particles and the radius of the circular path. Use the formula on the Data and Constants Sheet to show that the frequency f is given by the following equation

$$f = \frac{qB}{2\pi m}$$

[3 marks]

$F_C = F_M$ so $mv^2/r = qvB$, hence $v = qBr / m$	**1 mark**
$v = 2\pi r / T$ or $v = 2\pi r f$ (since $f = 1/T$)	**1 mark**
$2\pi r f = qBr /m$ since the radius r will cancel out $f = (qB / 2\pi m)$	**1 mark**

A full mark answer requires a complete derivation and not simply a re-arrangement of a formula. Unless all of the above working is shown then no marks are awarded.

d) Suppose a cyclotron with a dee radius of 53.0 cm is tuned to accelerate protons at an oscillator frequency of 12.0 MHz. Calculate the strength of the magnetic field needed to accelerate deuterons with the same frequency.

[3 marks]

Original magnetic field $B = 2\pi m \times f / q$ $B = 2 \times 3.142 \times 12 \times 10^{6} \times 1.67 \times 10^{-27} / 1.6 \times 10^{-19}$ $B = 0.787$ T	**1 mark**
Frequency is proportional to B and inversely proportional to m	
Since the mass of a deuteron = 2 x mass of a proton, the frequency will be halved unless the strength of the magnetic field is also doubled	**1 mark**
Hence, strength of magnetic field = 2 x 0.787 =1.57 T	**1 mark**

A hard question but a good number of students scored full marks

e) A conventional cyclotron begins to fail beyond a proton energy of 50 MeV. With the aid of a calculation, explain why this is so.

[3 marks]

KE of 50 MeV proton = $50 \times 10^6 \times 1.6 \times 10^{-19} = 8.00 \times 10^{-12}$ J	1 mark
KE = ½ mv^2 and so $v^2 = (2 \times 8.00 \times 10^{-12}) / 1.67 \times 10^{-27} = 9.58 \times 10^{15}$ Velocity of proton = 9.79×10^7 ms^{-1}	1 mark
As a % of "c" the velocity = 32.6 % of 'c" The article states that the velocity of the particle needs to be < 10 % of c or the cyclotron will fail.	1 mark

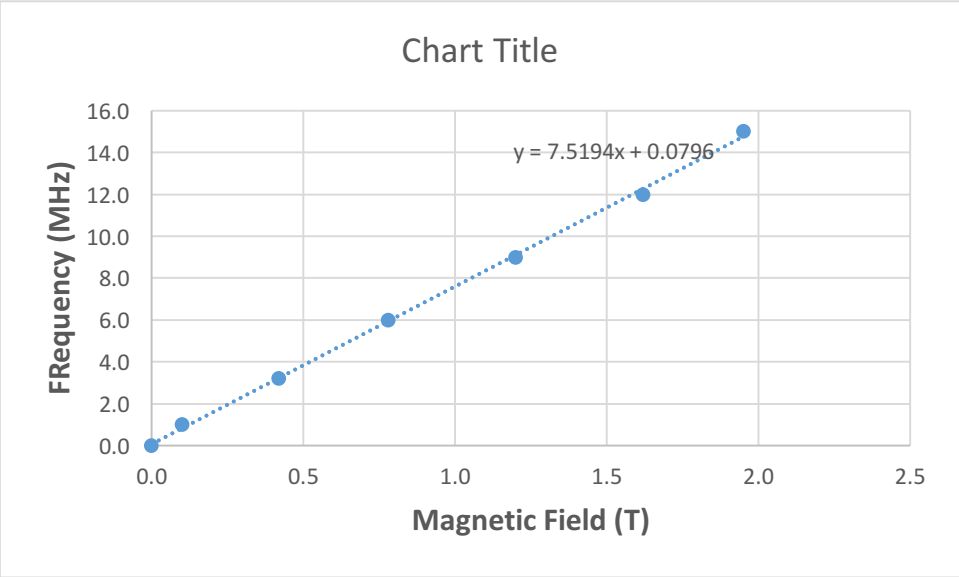
Not very well answered at all – need to use a crucial piece of information from the article to understand the significance of the speed calculated from the energy

An unknown particle was tested and gave the following values of high voltage oscillator frequency and the corresponding magnetic field.

Frequency of high voltage oscillator (x 10^6 Hz)	Magnetic Field B (tesla)
1.0 ± 0.1	0.10 ± 0.05
3.2 ± 0.1	0.42 ± 0.05
6.0 ± 0.1	0.78 ± 0.05
9.0 ± 0.1	1.20 ± 0.05
12.0 ± 0.1	1.62 ± 0.05
15.0 ± 0.1	1.95 ± 0.05

f) Using the graph paper provided, plot a straight line graph with the frequency on the y-axis and the magnetic field strength on the x-axis. **Show the error bars**.

[4 marks]



Axes correctly labelled + suitable scale	**1 mark**
Data plotted accurately	**1 mark**
Line of best fit shown	**1 mark**
Error bars are correctly shown for both quantities	**1 mark**

Graphing skills are sound but most students did not correctly show the size of the error bars for the B values and f values.

g) Calculate the gradient of this graph. Write the answer to 2 significant figures and include the appropriate units. **[3 marks]**

Gradient = Rise / Run = 6 x 10^6 / 0.78 = 7.7 x 10^6	**1 mark**
From computer graph, gradient = 7.5 x 10^6 Acceptable range is 7.4 x 10^6 to 8.0 x 10^6	**1 mark**
Units are Hz T^{-1}	**1 mark**

Generally, well answered but the units for the gradient still remain an issue. Some students forgot to include the scale factor (x 10^6 Hz) in the calculation of the gradient

h) Use the **gradient** to find the ratio of charge on the particle to the mass of the particle.

[3 marks]

Since $f = \frac{qB}{2\pi m}$ gradient of the linear graph = $\frac{q}{2\pi m}$	**1 mark**
q /m = gradient x 2π = 7.7 x 10^6 x 2 x 3.142 = 4.84 x 10^7	**1 mark**
q / m for the particle is 4.84 x 10^7 C kg^{-1}	**1 mark**

Interpreting a gradient to find other information is still a major problem for many students

i) Circle the identity of the unknown particle and briefly justify your decision.

✶Electron ✶ Proton ✶ Deuteron ✶ Neutron

[3 marks]

Unknown particle is a deuteron	**1 mark**
From earlier table q/m = 4.79×10^{7} Ckg^{-1}	**1 mark**
Value from previous question is closest to this value	**1 mark**

To get the mark for "Deuteron" there needs to be some justification to support that decision. The problems with part h) made it impossible for most students to score marks for this question. **No marks were awarded for the (correct) guess of "deuteron"**

Question 24

Extreme Ultra-Violet Astronomy

On June 7, 1992, NASA's Extreme Ultra-violet Explorer (EUVE) satellite was placed in orbit 550 km above the earth. Soaring over the atmosphere, which prevents extreme UV radiation from reaching earthbound telescopes, EUVE has detected a wide variety of astronomical objects. Among them are white dwarfs, coronally active stars and planetary objects in our solar system, all radiating in this high frequency band.

EUVE has even seen 10 sources of extreme UV (EUV) radiation beyond the Milky Way galaxy. This observation was all the more satisfying because of the long standing prediction that interstellar gas would absorb all EUV radiation coming from nearby stars, let alone that from intergalactic objects.

During the 1960's and early 1970's, astronomers believed that UV radiation – having wavelengths between 10 nm and 100 nm – would be completely absorbed by the interstellar medium. Thus, such light, if emanating from any star other than the sun, could not reach the earth's vicinity. If the interstellar medium (thought mainly to be hydrogen and helium) were uniformly distributed throughout the galaxy, EUV astronomy would indeed be impossible.

There are four telescopes on EUVE (see the diagram below). Three of these, the "sky survey" telescopes, point in the same direction and explore the EUV sky in four wavelength bands. The direction in which the survey telescopes look out is perpendicular to the axis of rotation of the EUVE satellite. As the satellite spins, the telescopes scan a strip of the sky; the strip changes daily as the earth travels in its orbit around the sun. The entire sky is mapped in six months. The fourth, "deep survey" telescope is aligned parallel to the axis of rotation of EUVE. The prolonged exposure allows more sensitivity than does the main survey and reveals fainter sources.

a) What is a typical frequency and photon energy for EUV?

[2 marks]

Typical wavelength = 60 nm	
Typical frequency = $3 \times 10^{8} / 60 \times 10^{-9} = 5 \times 10^{15}$ Hz	**1 mark**
Typical photon energy $E = hf = 6.63 \times 10^{-34} \times 5 \times 10^{15} = 3 \times 10^{-18}$ J	**1 mark**

Any wavelength in the specified range will do. Note that the question asked for both the frequency and energy of the photon. Question was well done.

b) Why isn't EUV detected by telescopes based on the Earth's surface?

[2 marks]

A large proportion of the EUV radiation is absorbed by the gases (helium and hydrogen) located between the star and the Earth	**1 mark**
Very little EUV radiation will actually reach the Earth's surface and will not be detected by telescopes on the surface	**1 mark**

Information needed for full marks is taken directly from the article

SEE NEXT PAGE

c) Look at the photograph of the EUVE satellite. What is the likely purpose of the solar array panels?

[1 marks]

The solar array will provide electrical energy to power the communication systems, computers etc. on the satellite	**1 mark**

An obvious answer that few students thought of! "For energy" is too vague.

d) What is the gravitational field strength at the altitude at which the EUVE satellite orbits the Earth?

[3 marks]

Orbital radius of EUVE satellite = $550 \times 10^3 + 6.38 \times 10^6 = 6.93 \times 10^6$ m	**1 mark**
$g = GM_E / r^2 = 6.67 \times 10^{-11} \times 5.97 \times 10^{24} / (6.93 \times 10^6)^2$	**1 mark**
$g = 8.29$ ms^{-2}	**1 mark**

Very well answered by most students

e) Does the EUVE satellite experience a force as it orbits the Earth? Explain.

Yes, the satellite is still within the Earth's gravitational field	**1 mark**
The gravitational force exerted by the Earth provides the centripetal force needed to keep the satellite in a stable orbit around the Earth.	**1 mark**

Well answered

[2 marks]

f) Analysis of the EUV radiation from a distant galaxy indicates that the galaxy is approximately 2.70 x 10^5 light years from Earth. How far from the Earth is the galaxy in kilometres?

[3 marks]

Convert light years to metres: 3 x 10^8 x 365 x 24 x 60 x 60 = 9.46 x 10^{15} m	**1 mark**
Distance to galaxy: 9.46 x 10^{15} x 2.70 x 10^5 = 2.55 x 10^{21} m	**1 mark**
Convert to kilometres: Distance = 2.55 x 10^{18} km	**1 mark**

A lot of students wanted to make this question a lot harder than it needs to be – the real point is to find out whether you understand the meaning of a "light year". Also, the question requires an answer in kilometres.

UNITS and SIGNIFICANT FIGURES

Wrong units or no units given with an answer – 1 mark is deducted each time it happens
Final answer not expressed to 3 significant figures – 1 mark is deducted each time it happens
For multi-step questions, "Error Carried Down" (ECD) applies unless additional mistakes are made and/or unit errors are made

END of QUESTIONS