GCE A LEVEL

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Part of WJEC

WJEC Eduqas GCE A LEVEL in PHYSICS

ACCREDITED BY OFQUAL

SPECIMEN ASSESSMENT MATERIALS

Teaching from 2015

wjec cbac

This Ofqual regulated qualification is not available for candidates in maintained schools and colleges in Wales.

Contents

Candidate Name	Centre Number					Candidate Number				

A LEVEL PHYSICS

COMPONENT 1

Newtonian Physics

SPECIMEN PAPER

2 hours 15 minutes

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1.**	10	
	2.	10	
	3.	10	
	4.	10	
	5.	20	
	6.	20	
Section B	**7.**	20	
	Total	100	

ADDITIONAL MATERIALS

In addition to this examination paper, you will require a calculator and a **Data Booklet**.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen.
Answer **all** questions.
Write your name, centre number and candidate number in the spaces at the top of this page.
Write your answers in the spaces provided in this booklet.

INFORMATION FOR CANDIDATES

This paper is in 2 sections, **A** and **B**.
Section **A**: 80 marks. Answer **all** questions. You are advised to spend about 1 hour 35 minutes on this section.
Section **B**: 20 marks; Comprehension. You are advised to spend about 40 minutes on this section.

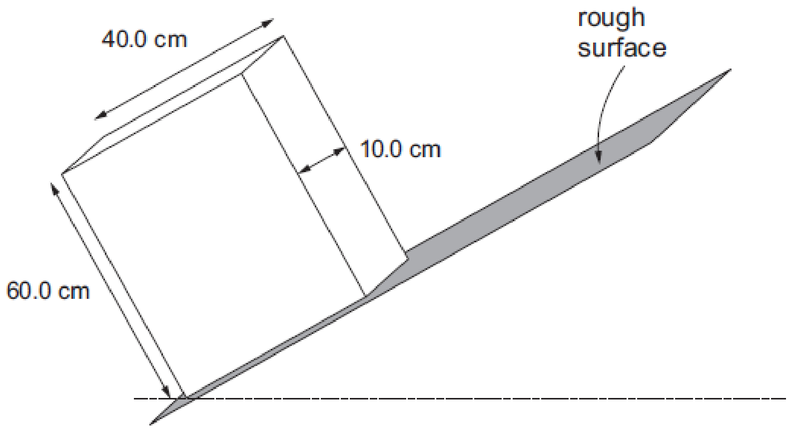
The number of marks is given in brackets at the end of each question or part-question.
The assessment of the quality of extended response (QER) will take place in questions 5*(d)* and 7*(c)*.

No certificate will be awarded to a candidate detected in any unfair practice during the examination.

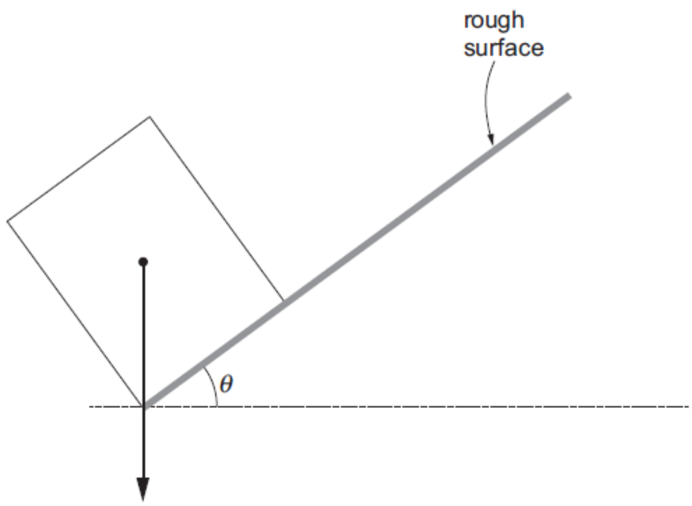
SECTION A

*Answer **all** questions.*

1. *(a)* A solid block of uniform density with sides 60.0 cm, 40.0 cm and 10.0 cm rests on a sloping rough surface.



The following diagram shows the block viewed from the side **at the point of toppling.** An arrow is shown passing through the centre of gravity of the block.



(i) Explain what is meant by *centre of gravity*. [1]

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(ii) Explain how you would measure the angle θ in practice. [2]

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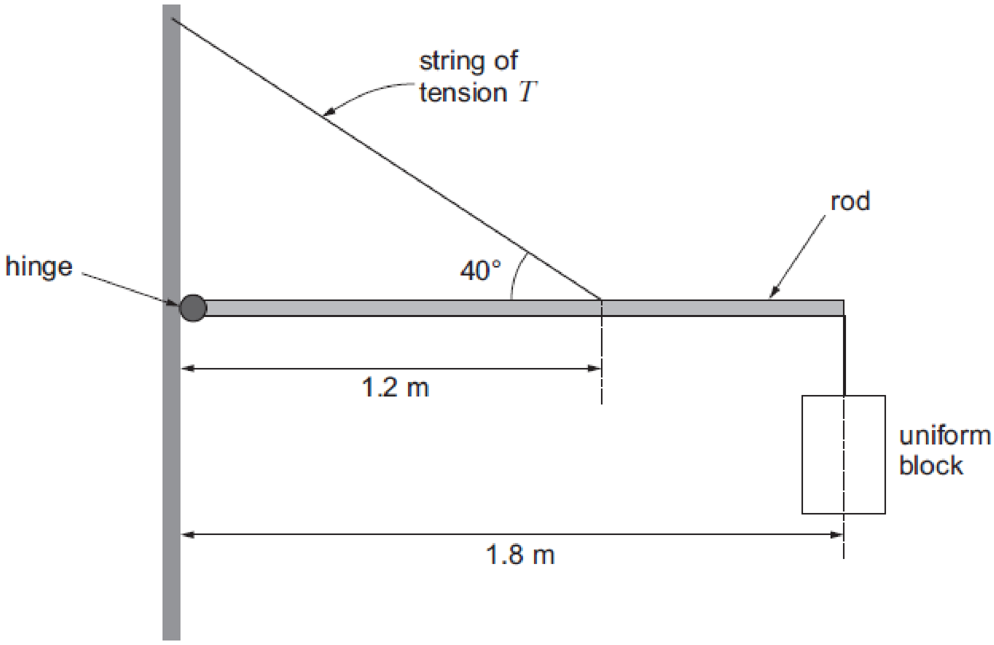
(b) The block (in part *(a)*) is now attached to a rod of **negligible weight** which is supported by a string and a frictionless hinge as shown in the diagram below.



(i) Calculate the tension in the string. The density of the material of the block is 400 kg m^{-3}. [5]

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(ii) Hence calculate the horizontal component of the force that the rod exerts on the hinge. [2]

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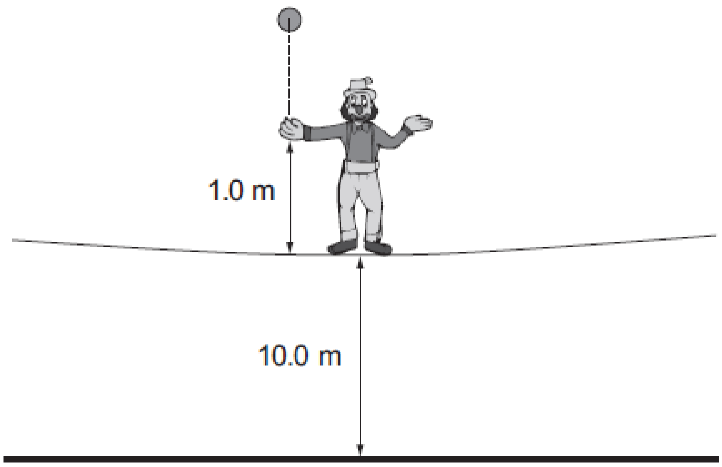
2. *(a)* A circus performer standing on a tightrope 10.0 m above the ground throws a ball vertically upwards at a speed of 6.0 m s^{-1}. The ball leaves his hand 1.0 m above the tightrope as shown. *The diagram is not to scale.* Ignore air resistance for part (a) only.



(i) Calculate the maximum height **above the ground** that the ball reaches. [3]

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(ii) The performer fails to catch the ball as it drops. Calculate the **total** time the ball is in the air. [4]

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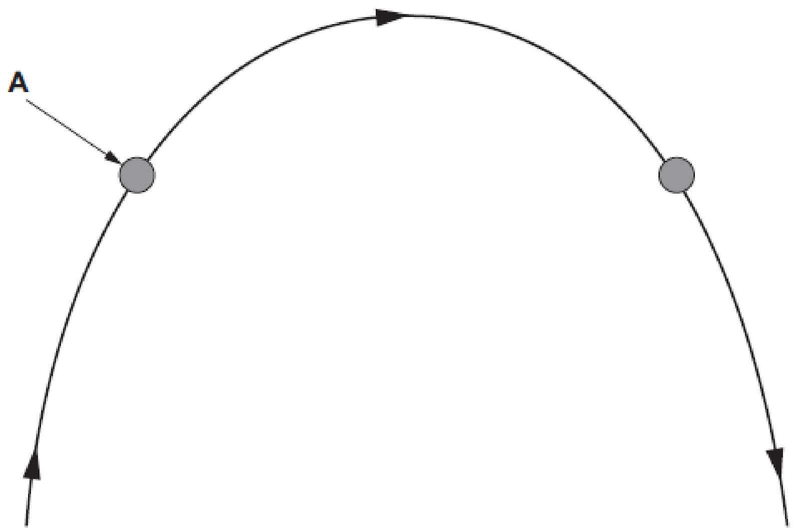
(b) Another ball is thrown **into the air** and follows the path shown. The ball is shown at a point labelled **A**.



Sketch a diagram to show the forces acting on the ball when it is at **A**. Justify your answer. [3]

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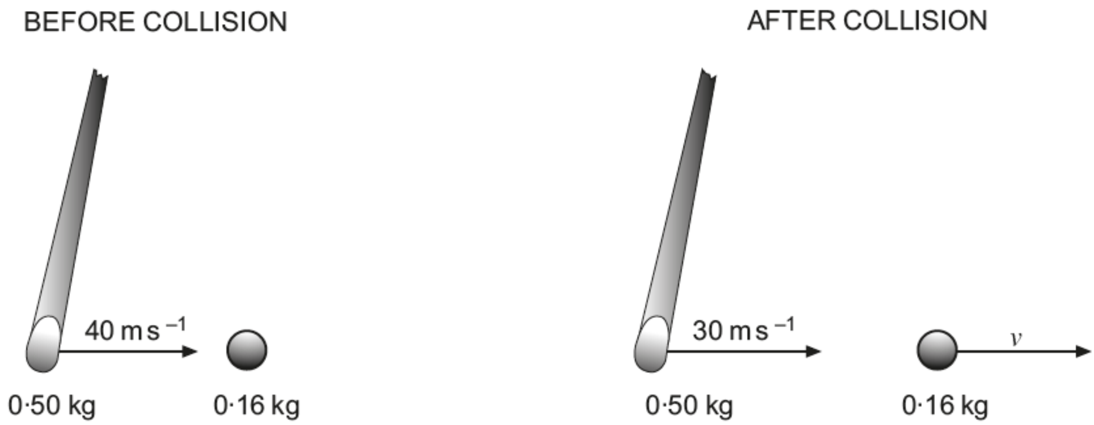
3. A hockey player swings her stick so that the head of the stick (mass 0.50 kg) strikes a stationary ball (mass 0.16 kg). The velocity of the stick drops from 40 m s^{-1} to 30 m s^{-1} during the collision. Assume that all velocities are horizontal, as shown in the diagram.



(a) (i) Apply the *Principle of Conservation of Momentum* to find a value for the velocity of the ball after the collision. [2]

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(ii) Momentum is not strictly conserved in this collision between the ball and the hockey stick. Justify this statement. [2]

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(b) The ball and club-head are in contact for 1.5×10^{-3} s. Naming the law of physics that you use, calculate the mean force exerted by the club-head on the ball. [3]

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(c) (i) Show that approximately 100 J of kinetic energy is lost in this collision. [1]

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(ii) Estimate the temperature rise of the hockey ball. [2]

(Specific heat capacity of ball = 850 $J\,kg^{-1}\,{}^{o}C^{-1}$)

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4. *(a)* Define *work*. [1]

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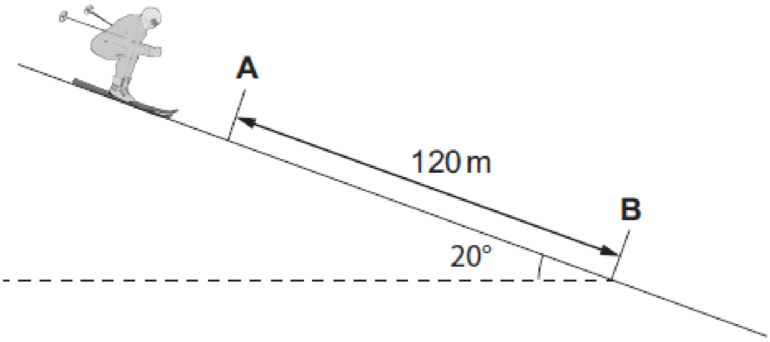

A skier of mass 70 kg descends a slope inclined at 20° to the horizontal as shown. The skier passes point **A** at a speed of 6 m s^{-1} and a second point **B** at a speed of 21 m s^{-1}. The distance between **A** and **B** is 120 m.

Calculate, for the descent from **A** to **B**:

(i) the gravitational potential energy lost by the skier; [2]

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(ii) the kinetic energy gained by the skier. [3]

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(c) Calculate the mean resistive force experienced by the skier between **A** and **B**. [4]

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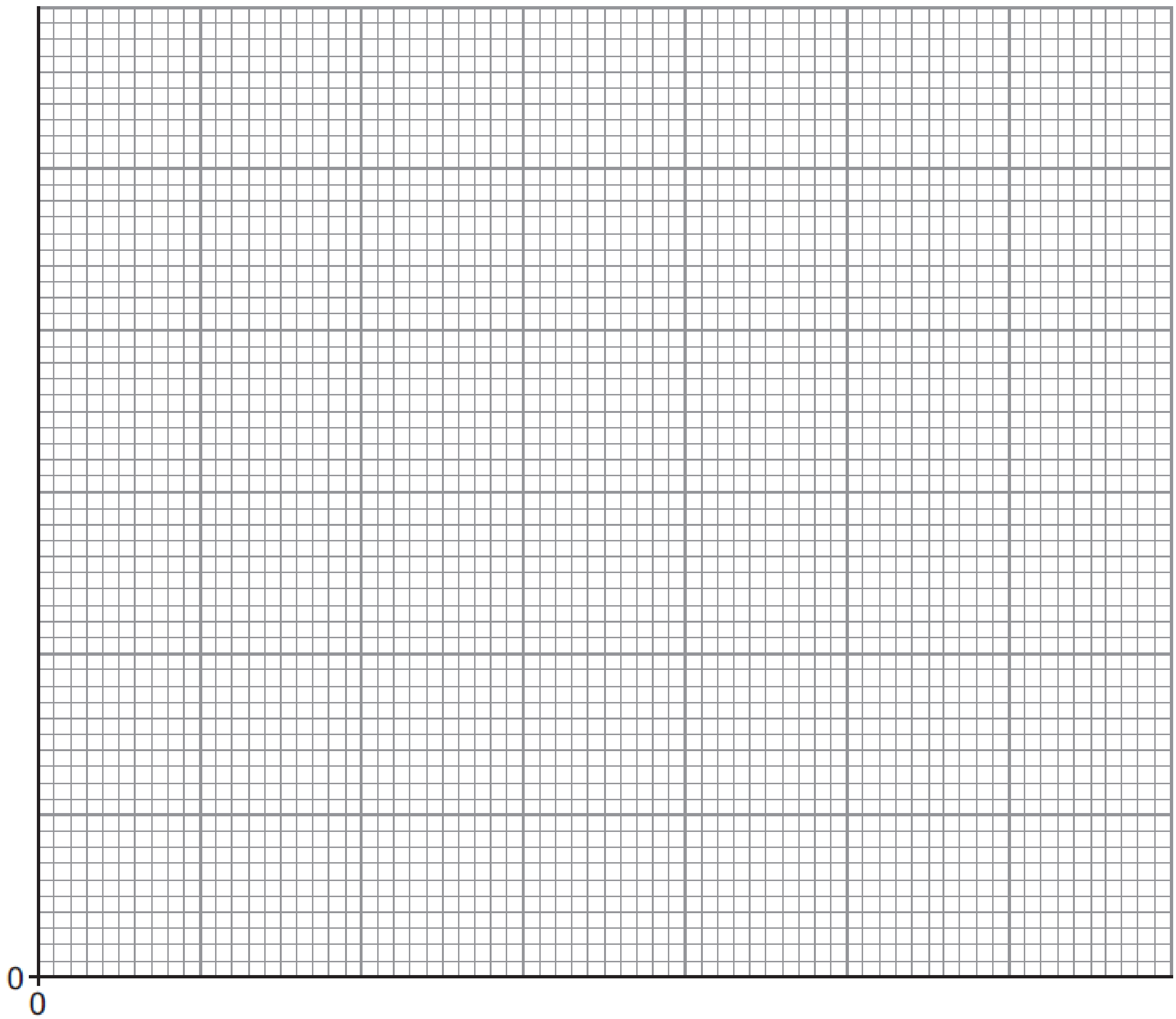
5. A container made of an insulating material contains 1.13 kg of water. The water is heated by a 3.0 kW electric immersion heater. A student records the water temperature at 20 second intervals. There is an uncertainty of ± 2 °C in the temperature measurements. The uncertainty in the time is negligible.

Time (s)	Water temperature (°C) (± 2 °C)
20	32
40	45
60	58
80	70
100	83
120	96

(a) Plot a graph of the water temperature (y-axis) against time in seconds (x-axis). Draw a line of maximum gradient and a line of minimum gradient through the data.
Plot error bars for the water temperature. [4]



(b) (i) State the main hazard involved in this experiment. [1]

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(ii) State a precaution to ensure the accuracy of the water temperature. [1]

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(c) (i) Calculate the maximum and minimum gradients for your graph. [2]

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(ii) Calculate the mean gradient with its **percentage** uncertainty. [3]

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(iii) Hence use the mean gradient to calculate the specific heat capacity of the water and its absolute uncertainty. [3]

P = power supplied to the water (3.0 kW)
m = mass of the water (1.13 kg)

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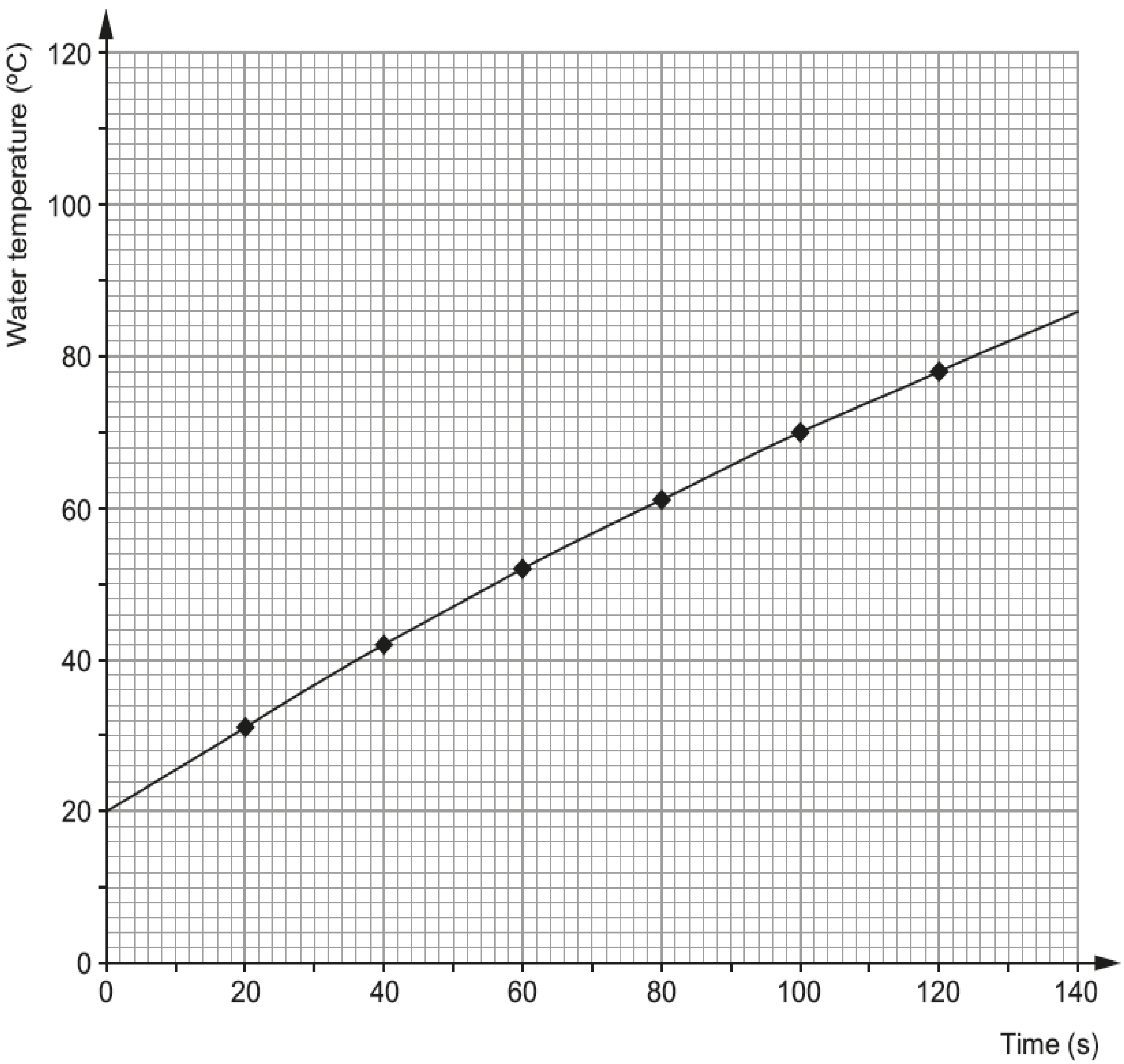
(d) Another student repeats the experiment with exactly the same mass of water and with exactly the same power of electric immersion heater but with a different container. The results of the second student are shown in the table below along with the better results of the first student.

Time (s)	First student Water temperature (°C) (± 2 °C)	Second student Water temperature (°C) (± 2 °C)
20	32	31
40	45	42
60	58	52
80	70	61
100	83	70
120	96	78

These are the second student's data when plotted in a graph.



Without further calculation and by comparing the results of both students suggest valid conclusions for the second student's experiment. Evaluate the second student's results critically. [6 QER]

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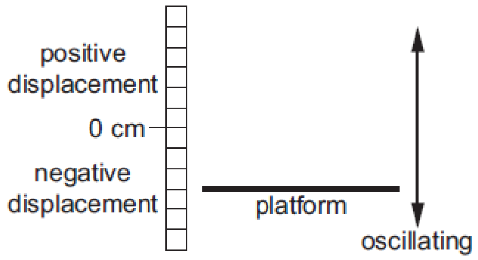
6. A horizontal platform oscillates vertically with simple harmonic motion around a central position with a period 0.40 s and amplitude 5.0 cm.



(a) Define *simple harmonic motion*. [2]

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(b) Determine the frequency of oscillation. [2]

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(c) Show that the angular frequency, ω, of oscillation is 15.7 rad s^{-1}. [1]

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(d) Calculate:

(i) the maximum velocity of the platform; [2]

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(ii) the maximum acceleration of the platform; [2]

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(iii) the acceleration of the platform when it is 0.020 m above the centre of oscillation. [3]

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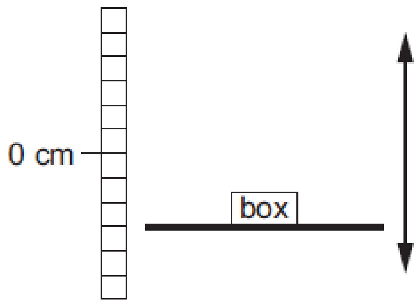
(e) (i)



A small box is carefully placed on the platform when it is at its lowest point. As the platform rises the box is seen to leave the platform when x = 4.0 cm. Explain this observation and justify your answer with a calculation. [5]

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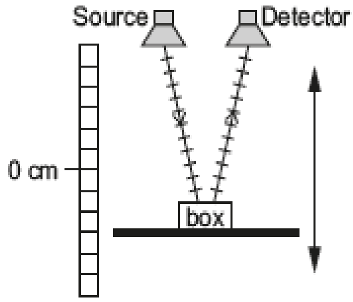
(ii) The velocity of the box is measured by having a microwave source and detector above it.



The microwaves that are reflected from the box are detected by the detector. Explain how the wavelength shift of the reflected microwaves can lead to a measurement of the platform's speed. [3]

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SECTION B

7. Read through the following article carefully.

DEPLETED URANIUM (DU) WEAPONRY: TECHNICAL AND POLITICAL ASPECTS

[Edited excerpts of a Panel discussion in the United Nations on October 26, 1999 sponsored by the NGO Committee on Disarmament, in cooperation with the UN Department for Disarmament Affairs.]

ROGER SMITH: We have a distinguished panel this afternoon to speak on the subject of “Depleted Uranium (DU) Weaponry: Technical and Political Aspects.” This is an issue that is emerging. It is not prominent on the UN’s agenda, but it relates to a form of weaponry which is now in active use. It was used both in the Gulf War and in the Bosnia and Kosovo operations of NATO.

DAMACIO LOPEZ: When the Depleted Uranium (DU) penetrator strikes the target it will have what appears to be an explosion. There are no explosives in the DU missile. It is the mass and speed and the energy from the radioactivity that gives the impression of an explosion. The projectile is referred to as a kinetic energy penetrator. It burns through like molten metal, and as it burns it is giving off smoke. The particles in that smoke are very tiny, somewhere between 1 and 5 micrometers in size. 30% to 70% of the depleted uranium goes up as smoke into the air, and is taken by winds.

COLONEL ERIC DAXON: Science does not support the contention that DU is a weapon of mass destruction. Science does not support the contention that the use of DU will result in an environmental catastrophe.
The explosion is not due to the radioactivity of the DU. When the penetrator first hits you see something that looks like a sparkler. That is the nature of the DU. It self-ignites when exposed to high temperatures and high pressures. A tungsten penetrator becomes blunt. A DU penetrator will become sharper as it is penetrating armor, and that is the primary reason that we are using it, along with its density. The self-sharpening effect gives it a significant tactical advantage.

DR. NAOMI HARLEY: Many workers have been exposed to high air concentrations of uranium during the extraction process. Uranium-235 is extracted by gaseous diffusion from natural uranium (that originally contained the isotopes, U-238 and U-235). The residual uranium, after extraction of the U-235, is called depleted uranium. Depleted uranium is about half as radioactive as the original natural uranium.
There is a lot of history of these workers with exposure to uranium. There are a tremendous number of people that have been followed for years to detect any health effects. There have been industrial exposures that have been quite enormous, from accidents, etc. Nobody has seen a significant health effect to date.

HARI SHARMA: Previous speakers have already described the radioactive properties of DU and, of course, it emits energetic alpha particles. Radioactivity should be treated with the care and respect it deserves. If you disperse it in the environment, one way or the other it will harm people. I learned during the course of my professional career that people should not disperse radioactive materials in the environment. And that is why I am here to spread this message.
How do we analyze for DU? We can determine the isotopic ratio of U-238 to U-235. It is a fixed ratio (137.8) in uranium from natural sources. If the isotopic ratios in the urine specimens of Gulf War veterans are significantly higher, then DU is present.
I thought the task could be performed easily because eight years had gone by, and the uranium that was inhaled or ingested by the veterans would not be present in their urine specimens. The biological half-life of uranium in the human body is very short. It is twelve hours. Within a week it is completely flushed out of the human system, provided uranium compounds are of soluble type.
As a matter of fact, I found that there was evidence of the presence of depleted uranium in the urine samples. This is a reality. The question then arises, where is it coming from?

We stress that we are dealing here not just with uranium dioxide, but with uranium dioxide produced at very high temperature. It is a ceramic compound, highly insoluble like silica. Its initial excretion rate may be complex but not necessarily enhanced.

STEVEN FETTER: Uranium is everywhere. There are 2-8 $\times$ 10^3 kg/km^2 in the top metre of natural soil. Compare this with <1 $\times$ 10^3 kg/km^2 for DU in battlefield areas.
We conclude that the risks of exposure to DU are very small, except for people in the following categories:

- People who were in vehicles struck by DU projectile, or
- People who entered struck vehicles subsequently to clean up the vehicles, or scavengers
- People who have continuous contact of bare skin with bare DU

Steps should still be taken to minimize exposure. For example, contaminated vehicles should be isolated from the public, soldiers should be trained to avoid any unnecessary contact with contaminated vehicles. The public should also be educated so that they do not pick up pieces of DU and fashion them into bracelets.

DAN FAHEY: In my report, I have reports from the Pentagon's own interviews with veterans showing people climbed on and entered multiple contaminated vehicles. The dust was being stirred up, and some of the very people the Pentagon interviewed are having health problems. Was it related to DU? That is another question. But because we have no base line data, no testing was done after the Gulf War, we simply don't know how much DU veterans were exposed to.

Answer the following questions in your own words. Direct quotes from the original article will not be awarded marks.

(a) Explain why a small particle "goes up as smoke into the air and is taken by winds" whereas a larger particle might not. You will need to refer to the forces acting on the particle and its cross-sectional area in your answer. [5]

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(b) Damacio Lopez and Colonel Eric Daxon seem to disagree about the energies involved in the initial explosion of the depleted uranium (DU) missile. Explain how these two experts disagree. [2]

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(c) Depleted uranium (DU) is a by-product that is obtained after the isotope U-235 has been removed from naturally occurring uranium. Discuss whether or not U-235 should continue to be produced and whether or not DU should be used in weapons. [6 QER]

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(d) Assuming a uniform surface concentration of 0.5×10^3 kg/km^2 and an activity of 12.3 MBq per kg of DU, calculate the activity of 1 cm^2 of the surface. How does your answer compare with normal background radiation activity? [3]

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(e) It is claimed that ingesting or inhaling insoluble uranium dioxide might lead to a ratio of U-238 to U-235 higher than 137.8 in urine samples and the ratio could remain high for a long time in the samples. Explain whether or not this claim is correct. [4]

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Candidate Name	Centre Number					Candidate Number				

A LEVEL PHYSICS

COMPONENT 2

Electricity and the Universe

SPECIMEN PAPER

2 hours

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	10	
2.	12	
3.	10	
4.	15	
5.	10	
6.	10	
7.	10	
8.	8	
9.	15	
Total	100	

ADDITIONAL MATERIALS

In addition to this examination paper,
you will require a calculator and a **Data Booklet**.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen.
Answer **all** questions.
Write your name, centre number and candidate number in the spaces at the top of this page.
Write your answers in the spaces provided in this booklet.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part-question.
The assessment of the quality of extended response (QER) will take place in question 2*(a)*(i).

No certificate will be awarded to a candidate detected in any unfair practice during the examination.

*Answer **all** questions.*

1. The current I in a metal conductor of cross-sectional area A is given by:

$$I = nAve$$

(a) State the meanings of n and v. [2]

n : ....

v : ....

(b) (i) A copper wire is 2.0 m long and has a cross-sectional area of 2.0×10^{-6} m^2. Determine the **total** number of free electrons in this wire given that an atom of copper has a mass of 1.05×10^{-25} kg and each atom contributes, on average, 1.5 free electrons.
[Density of copper = 8 920 kg m^{-3}.] [2]

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(ii) Calculate the mean drift velocity of the electrons in the wire when there is a current of 1.2 A. [3]

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(c) The table shows some properties of 3 different wires. Only two of the wires are made from the same material. Determine which wire is made from a different material to the others. [3]

Material	A (m^2)	v ($m\,s^{-1}$)	I (A)
A	1.0×10^{-6}	4.2×10^{-6}	0.04
B	1.5×10^{-6}	1.1×10^{-5}	0.22
C	2.0×10^{-6}	3.6×10^{-5}	0.68

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2. (*a*) (i) An experiment is carried out to determine the resistivity of a metal using variable lengths of the metal in the form of a wire. Explain how the experiment should be carried out and how an accurate value of the resistivity could be obtained from the results. [6 QER]

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(ii) A platinum wire has a cross-sectional area of $3.46 \times 10^{-9}\,\text{m}^2$, length 2.30 m and resistance 73.5 Ω. Calculate the resistivity of platinum. [2]

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(*b*) The experiment is repeated using a **thinner** wire made from the **same metal**. All other aspects of the experimental set-up are unchanged. Comment, with justification, on what would happen to the:

- resistance per metre;
- gradient of the graph;
- value of the resistivity of the metal in the wire. [4]

(No calculations are required.)

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3. *(a)* An equation which can be applied to a cell of emf E and internal resistance r is:

$$V = E - Ir$$

(i) What does V represent? [1]

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(ii) What does Ir represent? [1]

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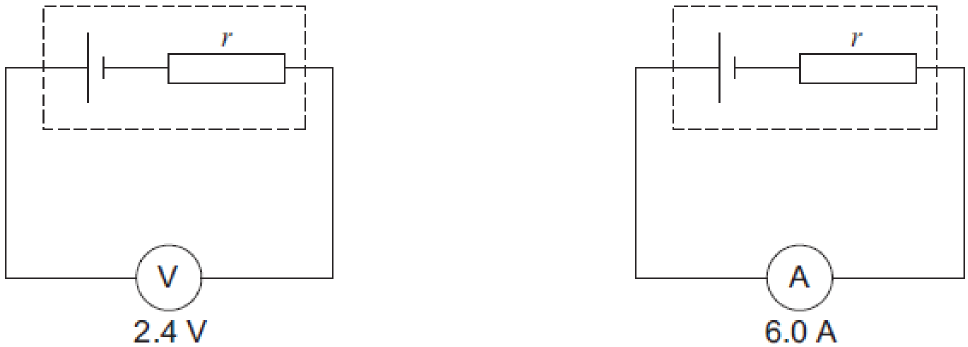
(b) A voltmeter connected across the terminals of a cell reads 2.4 V. An ammeter (whose resistance is zero) reads 6.0 A when connected briefly across the cell.



(i) Write down the emf of the cell. [1]

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(ii) Calculate the internal resistance of the cell. [1]

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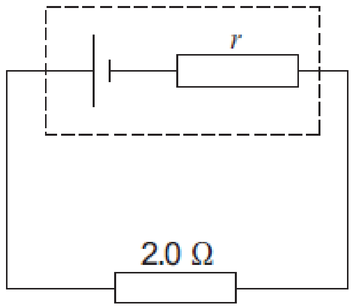
(c) Calculate the current through a 2.0 Ω resistor when it is connected across the cell. [2]



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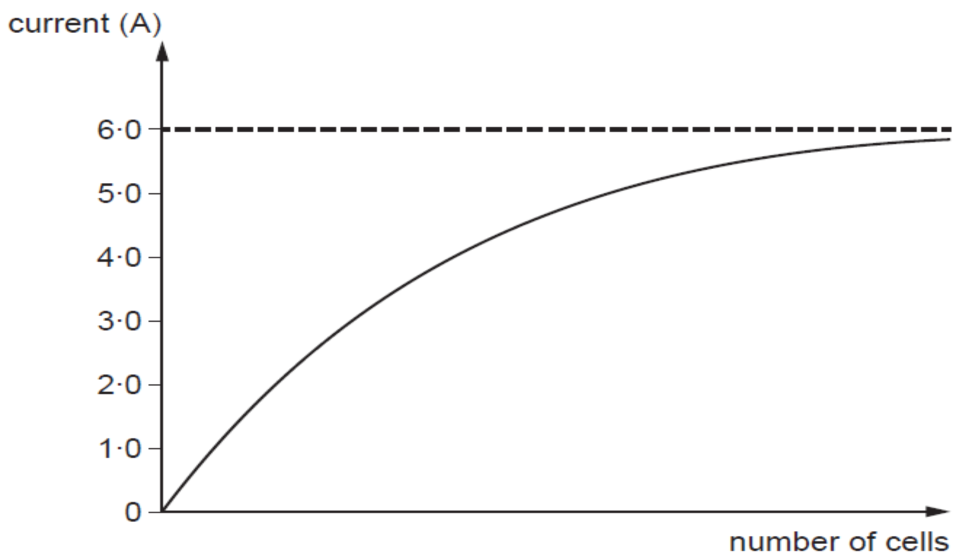
(d) The number of cells in series with the 2.0 Ω resistor is increased and the following graph is obtained. Explain, without further calculation why this variation is to be expected. [4]



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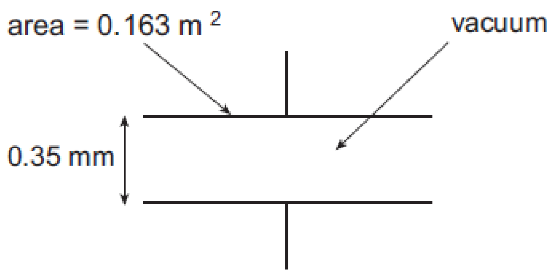
4. *(a)* Calculate the capacitance of the capacitor shown. [2]



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(b) The capacitor is charged so that there is a pd of 1.2 kV across the plates.

Calculate:

(i) the charge stored; [1]

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(ii) the energy stored in the capacitor. [1]

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(c) The capacitor is discharged through a 670 kΩ resistor. Calculate the time the capacitor takes to lose half its charge. [3]

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(d) Explain briefly whether or not the time the capacitor takes to lose half its energy is longer or shorter than your answer to *(c).* [1]

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(e) (i) You are to carry out an experiment to confirm that the charge held on the capacitor in part *(c)* decreases exponentially. Draw a circuit diagram of the apparatus you would use. State what data you would collect and how you would collect it (remembering that the time in part (*c)* was measured in ms). [4]

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(ii) Explain what graph you would plot to confirm that the charge on the capacitor decreases exponentially ($Q = Q_0 e^{-\frac{t}{RC}}$) and explain how you would know if your graph was in good agreement with this theory. [3]

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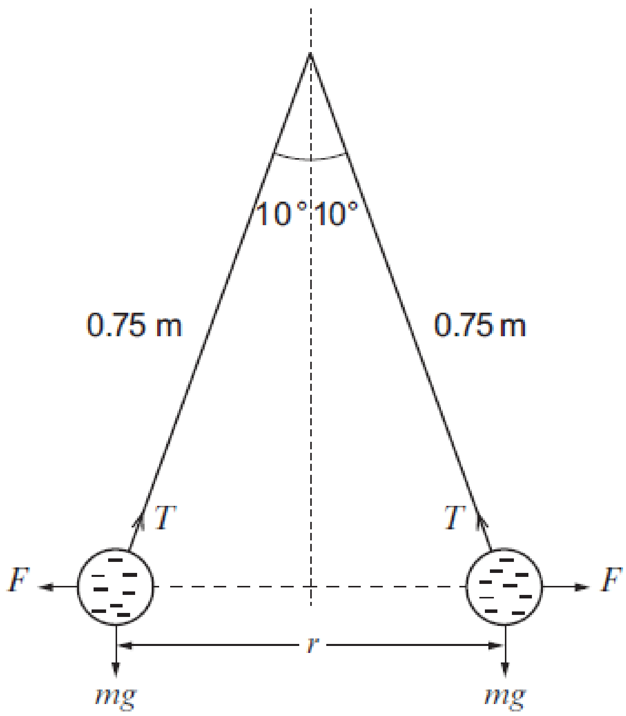
5. Two spherical balloons each of mass 5×10^{-3} kg carry equal numbers of excess electrons distributed uniformly over their surfaces.

When both balloons are hung from the same point by light strings of lengths 0.75 m, each string makes an angle $\theta = 10°$ with the vertical.



The weight, mg of each balloon, the electrostatic forces, F, acting on each balloon and the tensions, T, in the strings are shown in the diagram.

(a) Use the information in the diagram to show that the separation, r, of the centres of the balloons is approximately 0.26 m. [2]

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(b) A student suggests that the set-up may be used to determine the excess charge on each balloon and calculates a value of 2.5×10^{-7} C. Justify whether or not this answer is consistent with the data. [4]

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(c) In practice this experiment requires 3 measurements – a length, a mass and an angle. The uncertainty of the final charge value is approximately 10%. Justify how this uncertainty can be reduced by improving the accuracy of one of these readings especially. [4]

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(d) The separation of the balloons is increased while the charge remains constant and the balloons are then released. Describe briefly the resulting oscillations of the balloons and explain why you would expect this motion. [3]

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6. Information about the Earth, Jupiter and the Sun is given in the table:

	Radius (m)	Mass (kg)	Distance from the Sun (m)	Period of orbit (s)
Earth	6.37×10^6	5.97×10^{24}	1.50×10^{11}	3.16×10^7
Jupiter	6.99×10^7	1.90×10^{27}	7.79×10^{11}	3.74×10^8
Sun	6.96×10^8	1.99×10^{30}	–	-

(a) Determine the following at the position of the Earth:

(i) the gravitational field strength of the Sun; [2]

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(ii) the gravitational potential due to the Sun. [2]

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(b) Determine whether or not these data are in good agreement with Kepler's 3rd law ($r^3 \alpha T^2$). [3]

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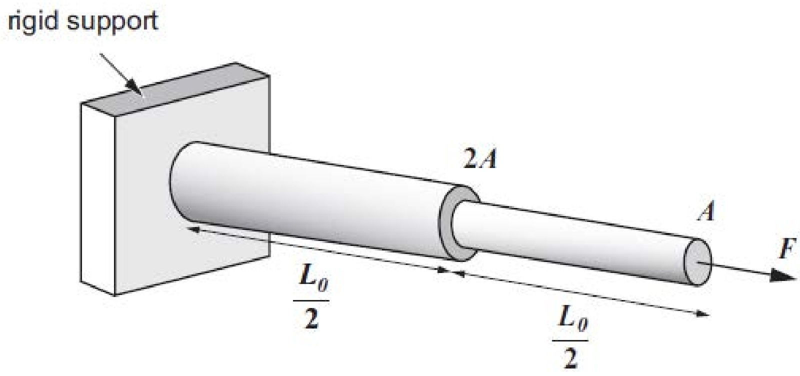
7. The bar in the figure below is made from a single piece of material. It consists of two segments of equal length $\frac{L_0}{2}$ and cross-sectional area A **and** $2A$. *The diagram is not drawn to scale.*



(a) Show that the **total** extension, Δx, of the bar under the action of an applied force, F, as shown in the diagram, can be given by:

$$\Delta x = \frac{3FL_0}{4AE}$$

where E represents the Young modulus of the material in the bar. [3]

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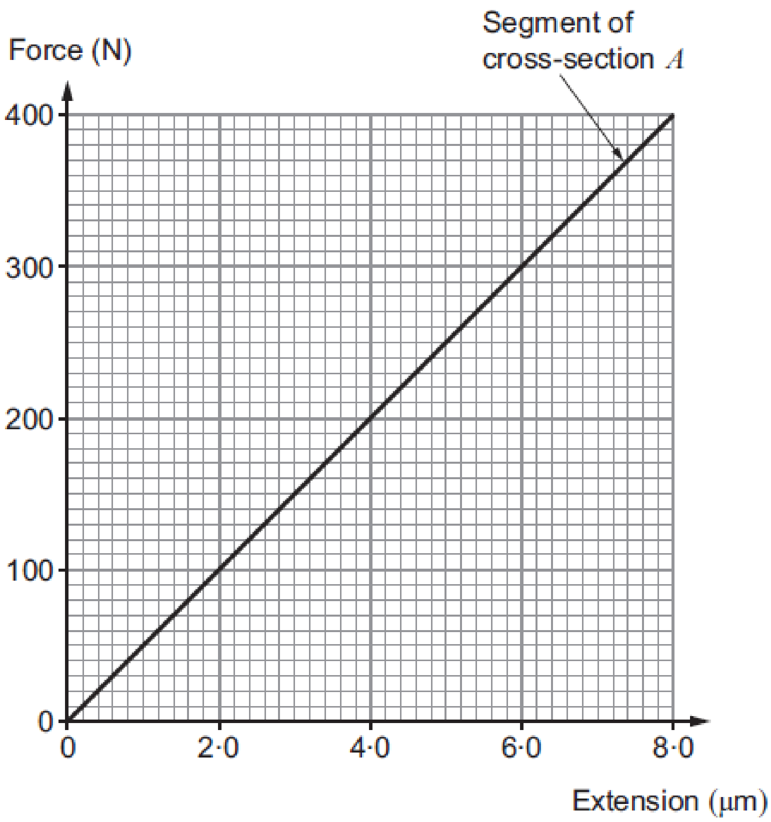
(b)



(i) The graph shows the variation of extension with applied force for the segment of cross-section A. Draw (on the same grid) the expected force-extension graph for the segment of cross-section $2A$. [1]

(ii) Determine the Young modulus of the metal in the bar given that L_0 = 4.0 m and $A = 5 \times 10^{-4}\ m^2$. [3]

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(iii) A mass of 20 kg is hung vertically from the segment of cross-section A. When released the mass performs simple harmonic motion with a very small amplitude. By calculating the gradient of the above graph (or otherwise), determine the period of oscillation of the mass. [3]

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8. *(a)* State what is meant by a black body. [1]

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(b) A table of astronomical data includes the following about the star *Alpha Centauri A*:
Radius = 8.54×10^8 m, Temperature = 5 790 K, Luminosity = 5.83×10^{26} W.

(i) Justify whether the data above are consistent with the star radiating as a black body. Show your working clearly and give your conclusion. [3]

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(ii) Calculate the wavelength of the star's peak spectral intensity, and sketch the spectrum on the axes provided. [4]

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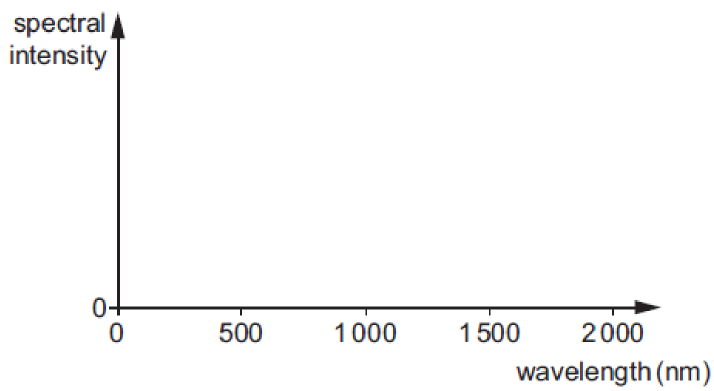

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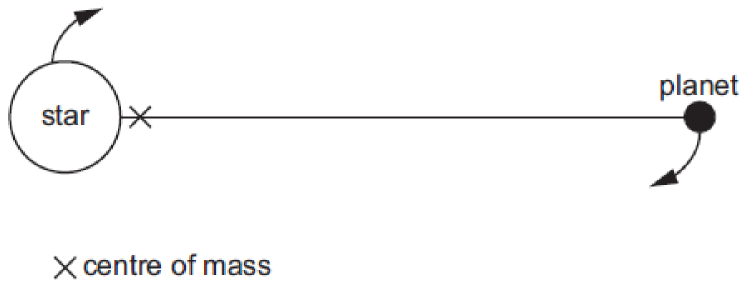
9. *(a)* A star of mass 2×10^{30} kg has a companion planet. The star and planet orbit a common centre of mass with an orbital period of 1 090 days. The star's orbital speed is 45.5 m s^{-1}. *The diagram is not drawn to scale*.



(i) Determine the radius of the star's orbit. [3]

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(ii) Estimate the distance from the planet to the star, specifying clearly any assumptions made. [3]

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(iii) Hence determine the mass of the planet. [2]

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(b) Edwin Hubble's original data from 1929 is shown in Figure 1.

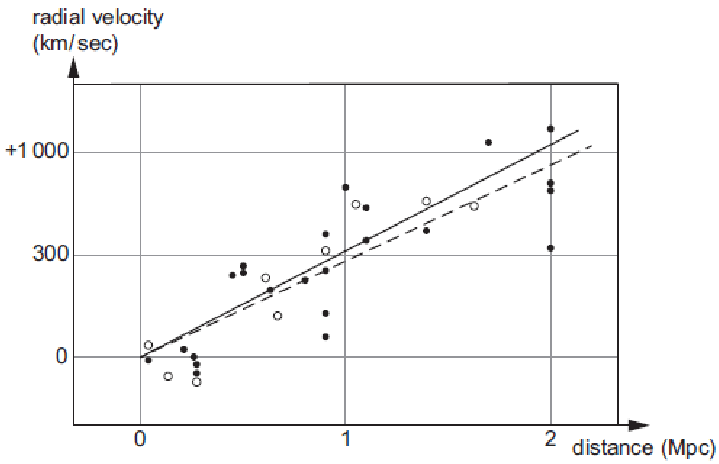

Figure 1

Figure 2 is an improved graph of radial velocity against distance based on more recent measurements.

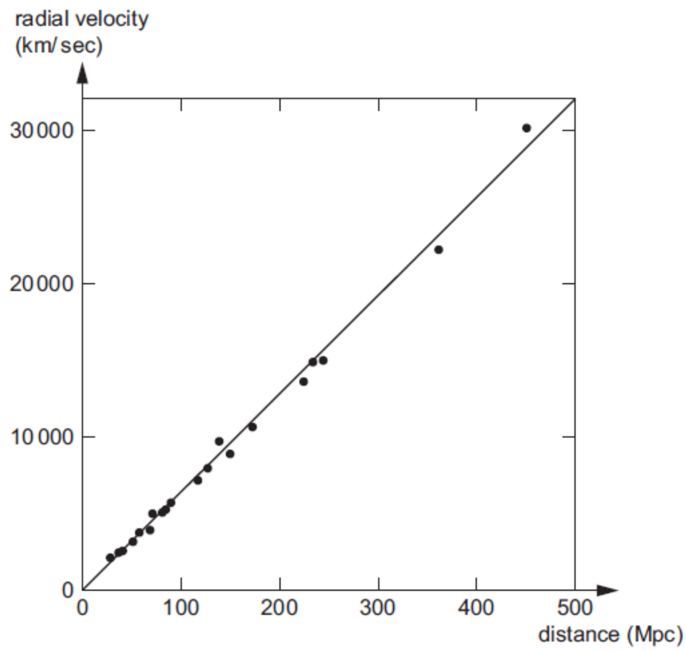

Figure 2

(i) The scientific community had less confidence in Hubble's law in 1929 than it currently has. Use Figure 1 and Figure 2 to justify this statement. [3]

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(ii) Use Figure 2 to calculate Hubble's constant in the unit km s^{-1} Mpc^{-1}. [2]

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(iii) Calculate the age of the universe in years given that a Mpc is 3.09×10^{22} m. [2]

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Candidate Name	Centre Number					Candidate Number				

A LEVEL PHYSICS

COMPONENT 3

Light, Nuclei and Options

SPECIMEN PAPER

2 hours 15 minutes

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1.**	20	
	2.	20	
	3.	10	
	4.	14	
	5.	6	
	6.	10	
	7.	10	
	8.	10	
Section B	**Option**	20	
	Total	120	

ADDITIONAL MATERIALS

In addition to this examination paper, you will require a calculator and a **Data Booklet**.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen.
Answer **all** questions.
Write your name, centre number and candidate number in the spaces at the top of this page.
Write your answers in the spaces provided in this booklet.

INFORMATION FOR CANDIDATES

This paper is in 2 sections, **A** and **B**.
Section **A**: 100 marks. Answer **all** questions. You are advised to spend about 1 hour 50 minutes on this section.
Section **B**: 20 marks; Options. Answer **one option only.** You are advised to spend about 25 minutes on this section.

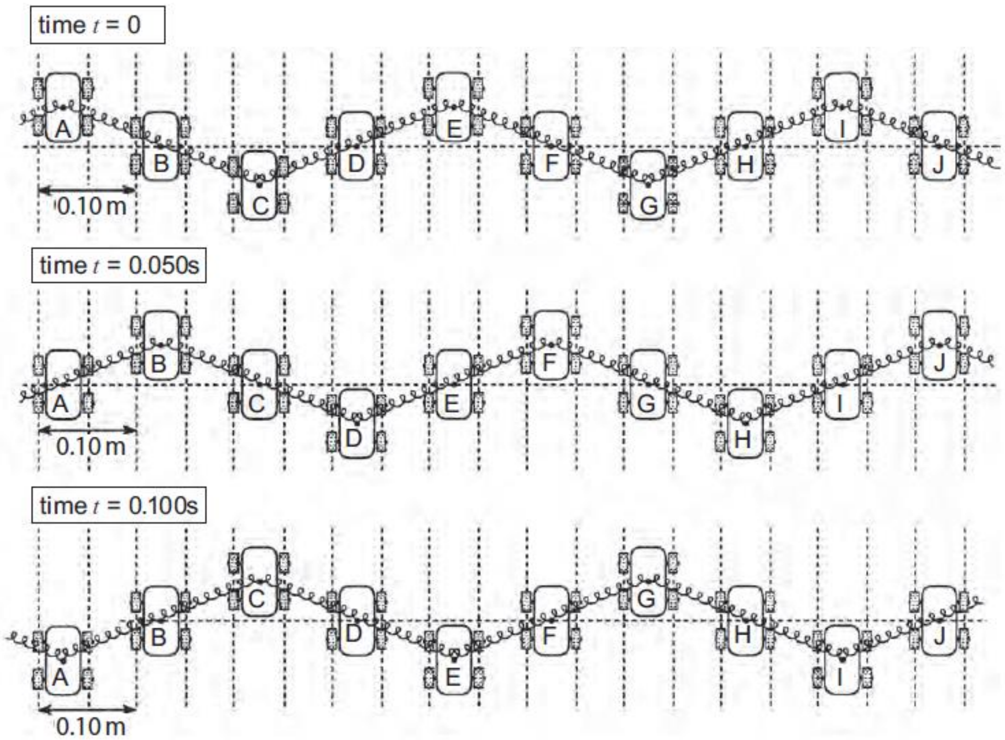
The number of marks is given in brackets at the end of each question or part-question.

No certificate will be awarded to a candidate detected in any unfair practice during the examination.

SECTION A

*Answer **all** questions.*

1. *(a)* Here are three 'snapshots' (three diagrams at different times) of a transverse wave travelling from left to right along a line of toy cars joined by springs.



(i) For this wave determine the value of each of the quantities in the equation $v = f\lambda$ giving your reasoning. [3]

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(ii) Which cars are oscillating in phase with car **B**? [1]

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(iii) Explain why the wave is described as transverse. [2]

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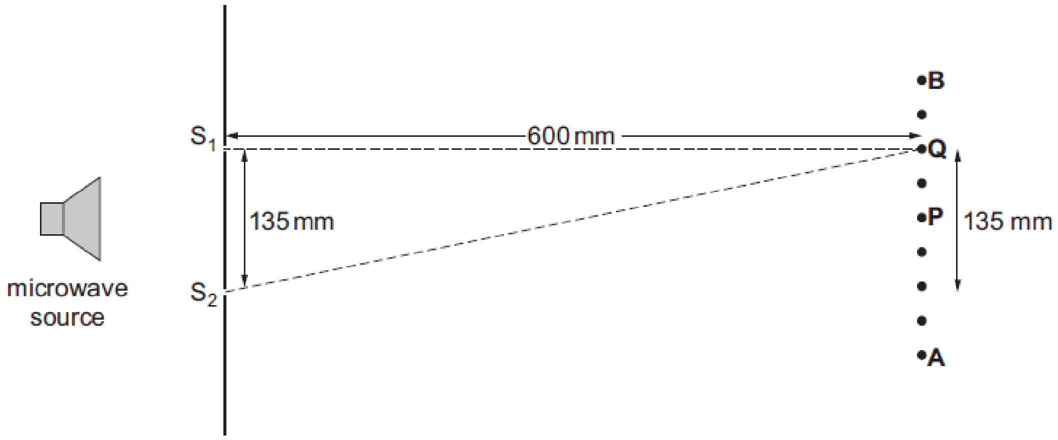
(iv) A longitudinal wave can be sent along a line of toy cars linked by springs if the cars are arranged differently. Sketch the arrangement, showing at least 3 cars. [1]

(b) A microwave source is placed to the left of two narrow slits, S_1 and S_2, so that these slits act as in phase sources.



A microwave sensor moved along the line **AB** detects maxima at the points shown as dots. One of these points, **Q**, is directly in front of S_1.

(i) Use the right angled triangle S_1S_2Q to determine the path difference $S_2Q - S_1Q$, and **hence** determine the wavelength of the microwaves, giving your reasoning. Note that point **P** is equidistant from S_1 and S_2. [4]

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(ii) Check your answer to *(a)*(i) using the two source interference (Young's fringes) formula, showing your working clearly. [2]

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(c) (i) Giving a labelled diagram, derive the diffraction grating equation:

$$n\lambda = d\sin\theta$$

[3]

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(ii) A student uses a diffraction grating to measure the wavelength of light from a laser. The separation between the centres of adjacent slits in the grating is 1 500 nm. The student records beams emerging from the grating at 24° ± 1° and at 57° ± 1° either side of the normal (as well as at 0°). The laser is believed to emit light of wavelength 635 nm. Justify whether the student's readings support this. [4]

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2. *(a)* (i) Light is shone on to a caesium surface ejecting electrons of maximum kinetic energy 1.7×10^{-19} J from the surface. Calculate the frequency of light used. (Work function = 3.0×10^{-19} J.) [2]

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(ii) Light of frequency 5.9×10^{14} Hz is now shone on to the caesium surface at the same time as the original frequency. Justifying your answer in terms of photons, state the effect (if any) of this extra light on:

(I) the number of electrons emitted per second; [2]

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(II) the maximum kinetic energy of the emitted electrons. [1]

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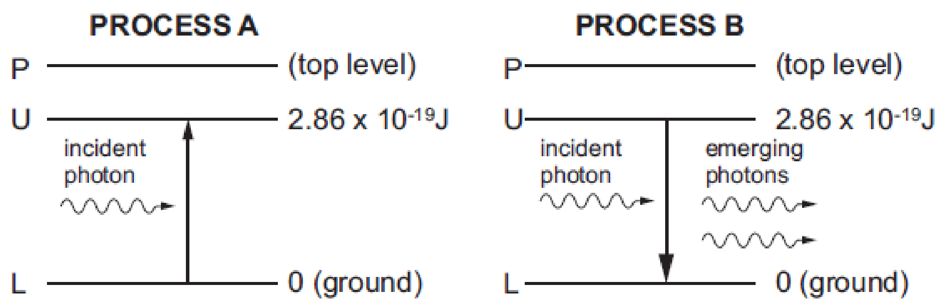
(b) A ruby laser is classed as a 3-level system. The amplifying medium is ruby, which is a crystal containing chromium ions. The diagrams show two processes which could occur when a photon of a certain wavelength is incident on a chromium ion.



(i) Calculate the wavelength of the incident photon. [2]

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(ii) Process **A** is absorption. State what happens to the energy of the incident photon in this process. [1]

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(iii) Process **B**, is *stimulated emission*. State two things, other than wavelength and frequency, that are the same for both the emerging photons**.** [1]

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(iv) Referring to energy levels as labelled on the diagrams, explain what is meant by a *population inversion*. [1]

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(v) Explain in terms of the processes **A** and **B** why the laser would not work unless there was a population inversion. [2]

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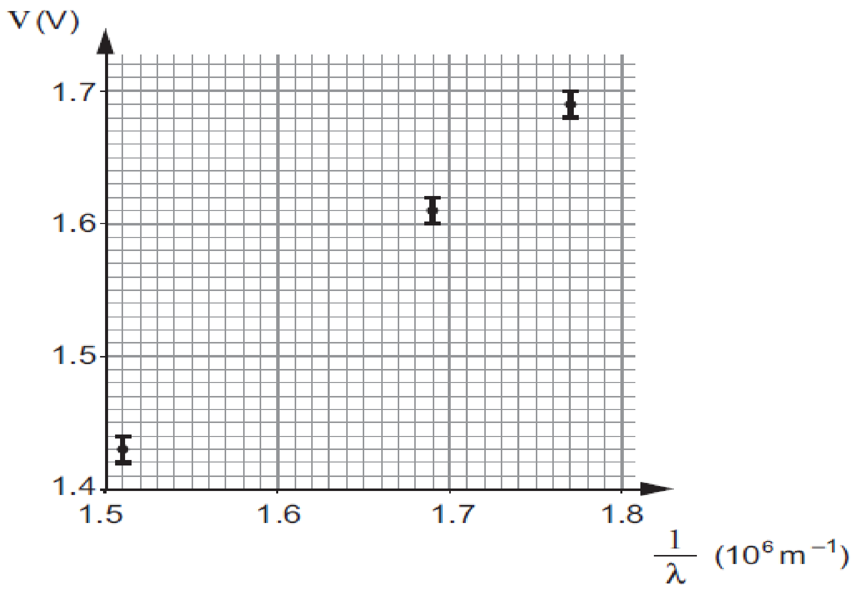
(c) The minimum potential difference, V, applied to a light emitting diode (LED) for it to be seen to emit light is related to the wavelength, λ, of the light by the approximate equation:

$$eV = \frac{hc}{\lambda}$$



V is measured for three LEDs, and a graph of V against λ is plotted using values of λ supplied by the makers of the diodes.

(i) Calculate the maximum and minimum gradients of the graph. [2]

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(ii) Hence calculate a value for the Planck constant, as well as its **percentage** uncertainty. [3]

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(iii) Discuss whether or not the graph confirms the equation. [3]

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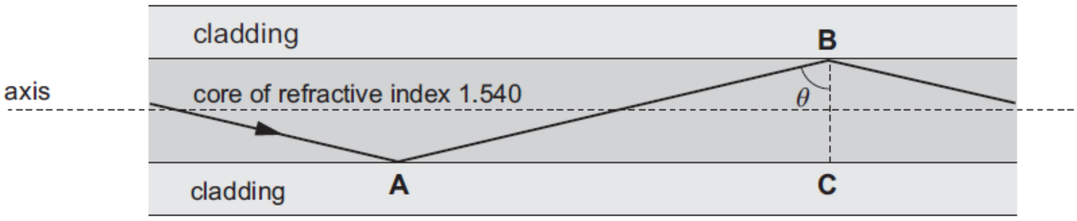
3. The diagram shows a path which light can take along a 'thick' optical fibre.



(a) The smallest angle θ at which total internal reflection can take place is 77°. Calculate the refractive index of the cladding. [2]

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(b) (i) Calculate the time it takes light to travel along 350 m of the fibre, if it travels in a straight line parallel to the axis of the fibre. [2]

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(ii) Show that the **extra** time it takes for light to travel 350 m along the fibre via the zigzag path for θ = 77° is approximately 50 ns. [Consider triangle ABC.] [3]

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(c) The difference in refractive index between the cladding and core is decreased. Explain carefully how this will affect the maximum frequency of data transmission along the optical fibre. [3]

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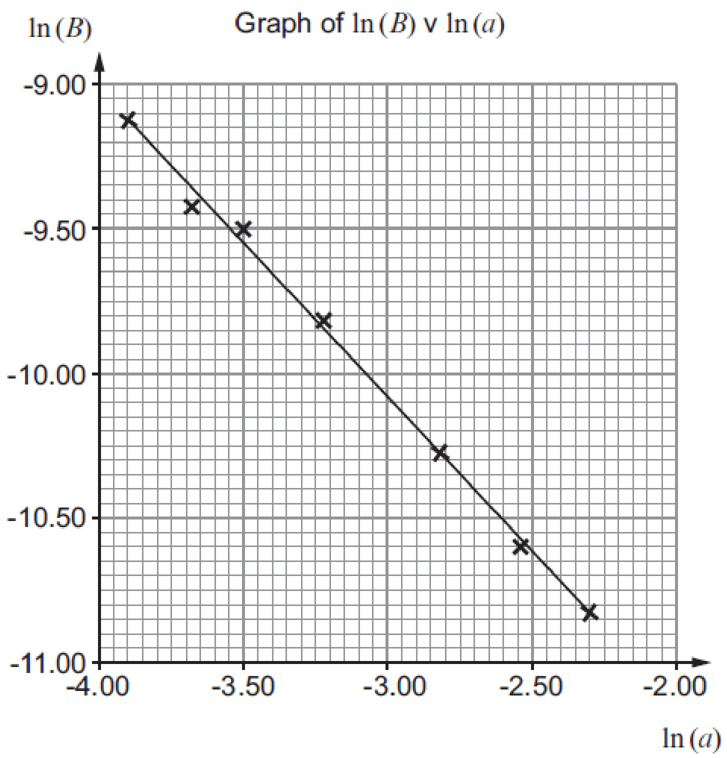
4. *(a)* A Hall probe was used to measure the magnetic field (B-field) due to a long wire carrying current. The experiment was carried out in order to confirm the relationship:

$$B = \frac{\mu_0 I}{2\pi a}$$

A student obtained the following data and plotted the following graph.

Distance a (m)	B-field (μT)	$\ln(a)$	$\ln(B)$
0.020	110	-3.91	-9.12
0.025	85	-3.69	-9.37
0.030	75	-3.51	-9.50
0.040	55	-3.22	-9.81
0.060	35	-2.81	-10.26
0.080	25	-2.53	-10.60
0.100	20	-2.30	-10.82



(i) Explain briefly how the student used the Hall probe to obtain the data. [2]

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(ii) Calculate the gradient of the line of best fit shown in the graph. [2]

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(iii) Does the graph confirm the relationship:

$B = \frac{\mu_o I}{2\pi a}$ (i.e. $\ln B = \ln \frac{\mu_0 I}{2\pi} - \ln a$)

Explain your reasoning. [3]

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(iv) A second student carries out the same experiment with a badly calibrated Hall probe that gives B-field readings that are consistently 40% too large. Explain how this would affect the graph shown on page 51. [3]

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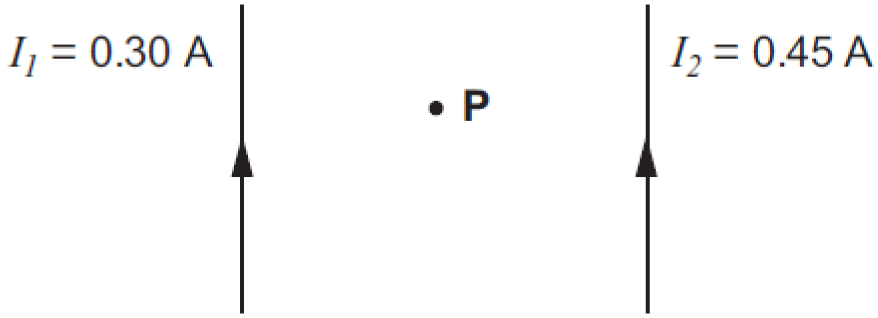
(b) Two long, straight wires carry currents as shown.



Point **P** is halfway between the two current carrying wires. Determine the direction of the B-field at **P** and explain in clear and logical steps how you obtained your answer. [4]

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5. *(a)* State *Faraday's law of electromagnetic induction*. [2]

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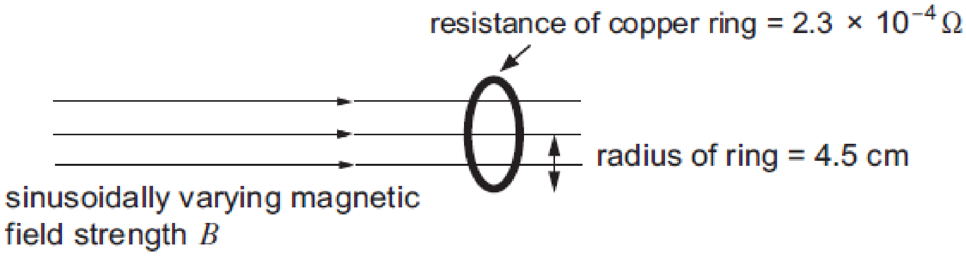
(b) A circular copper heating ring works by being placed in a sinusoidally varying magnetic field. A large sinusoidal current is then induced in the ring and the ring becomes hot (see below).



The maximum rate at which the magnetic field strength changes is 72 T s^{-1}. Show that the maximum current flowing in the ring is approximately 2 000 A. [4]

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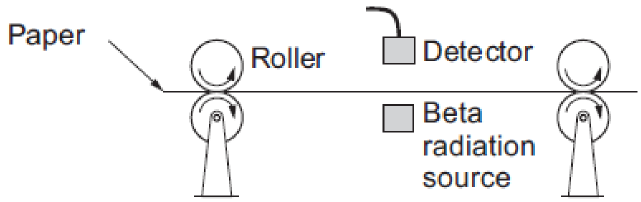
6. The thickness of paper is measured using a beta radiation source and detector (see below).



(a) When the paper is marketed as being "Hi-tech beta radiation" paper, sales figures of the paper decrease rapidly. A scientist claims that this is a reflection of the ignorance of society. Explain briefly whether the scientist is justified in making this statement. [2]

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(b) The beta radiation source most commonly used is strontium-90 which decays as shown. Place the correct numbers on the dotted lines. [1]

$${}^{90}_{38}\mathrm{Sr} \longrightarrow {}^{\cdots\cdots}_{\cdots\cdots}\mathrm{Y} \quad + \quad {}^{\cdots\cdots}_{\cdots\cdots}\beta$$

(c) The half-life of strontium-90 is 28.8 years. Show that its decay constant is $7.6 \times 10^{-10}\ \mathrm{s}^{-1}$. [2]

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(d) If the initial activity of the strontium-90 source is 140 GBq, calculate its activity after 10 years. [2]

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(e) The beta particles produced have a kinetic energy of 0.55 MeV. Explain why using your A level Physics knowledge will not provide an accurate value of their kinetic energies. Your explanation should be reinforced by a calculation. [3]

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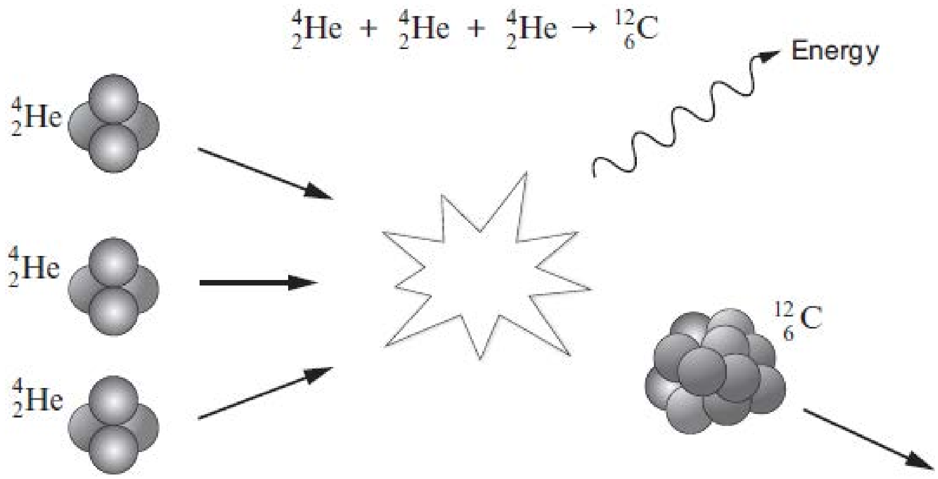
7. The following fusion reaction can occur inside stars with core temperatures of around 100 million kelvin.



(a) (i) Calculate the energy released in the above reaction from the following data. [3]

mass of $^{4}_{2}\text{He}$ = 4.0026 u

mass of $^{12}_{6}\text{C}$ = 12.0000 u

1 u = 931 MeV

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(ii) Scientists claim that this reaction is extremely important for life in the universe. Explain whether or not this claim is true. [2]

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(b) The isotope $^{62}_{28}\mathrm{Ni}$ has a binding energy per nucleon of 8.795 MeV/nucleon and this is the highest known binding energy per nucleon.

Calculate the mass of a $^{62}_{28}\mathrm{Ni}$ nucleus in unified atomic mass units (u) and give your answer to 5 significant figures. [5]

mass of proton = 1.00728 u

mass of neutron = 1.00866 u

1 u = 931 MeV

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8. *(a)* (i) State three differences (other than mass) in the properties of down quarks and electrons. [3]

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(ii) The Δ^- (delta minus) particle has the quark make-up ddd. Deduce its charge. [1]

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(b) The Δ^- particle decays in a very short time into a neutron and a pion (π meson):

$$\Delta^- \rightarrow n + \pi^-$$

The meson formation suggests a strong interaction. State two other features of the decay which point to it being a strong interaction. [2]

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(c) The neutron and the pion formed in the decay are themselves unstable. The neutron decays thus:

$$n \rightarrow p + x + y$$

in which p is a proton and x is a charged (first generation) lepton.

(i) Using appropriate conservation laws, identify x and y. [3]

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(ii) State, giving a reason, which force is responsible for this decay. [1]

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SECTION B: OPTIONAL TOPICS

Option A - **Alternating Currents** ☐

Option B - **Medical Physics** ☐

Option C - **The Physics of Sports** ☐

Option D - **Energy and the Environment** ☐

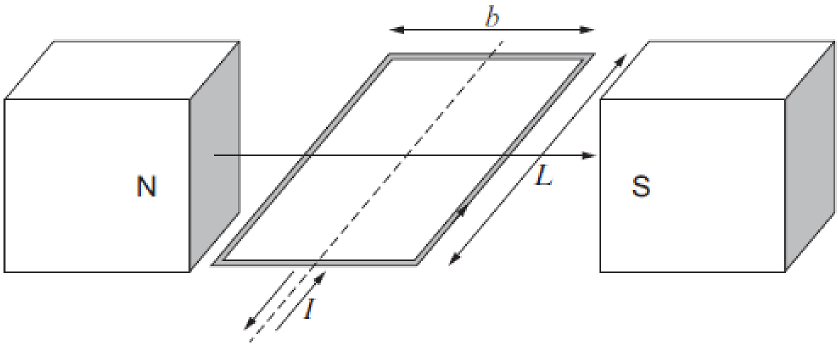
Answer the question on **one topic only.**

Place a tick (✓) in one of the boxes above, to show which topic you are answering.

You are advised to spend about 25 minutes on this section.

Option A **– Alternating Currents**

9.



(a) (i) The coil shown in the diagram is rotated. Explain why a sinusoidal emf is induced in the coil. [2]

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(ii) The coil has 55 turns and is rotated at a frequency of 50 Hz in a uniform B-field of strength 0.114 T. If L = 3.2 cm and b = 2.5 cm, calculate the peak emf induced in the coil. [3]

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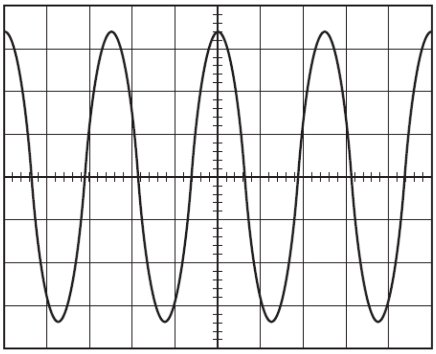
(b) Calculate the peak pd and the period of the signal shown on the oscilloscope. The time base of the oscilloscope is set to 50 μs per division and the gain set to 20 mV per division. [3]



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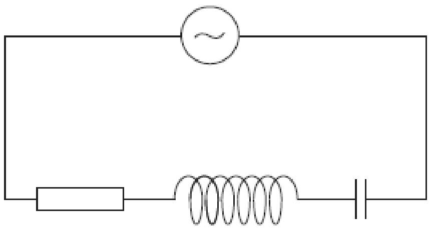
(c)



(i) The resonance frequency of the above circuit is 1 000 Hz. Explain why the rms current is just below 0.45 A. [2]

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(ii) Calculate V_L, the rms pd across the inductor. [2]

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(iii) State the value of V_C, the rms pd across the capacitor. [1]

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(iv) Calculate the Q factor of the circuit. [1]

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(v) Justify what changes you would make to the above circuit to make the resonance curve sharper whilst keeping the resonant frequency constant. [3]

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(d) Sketch a phasor diagram showing the pds across the inductor, capacitor and resistor when the frequency is doubled to 2 000 Hz. [3]

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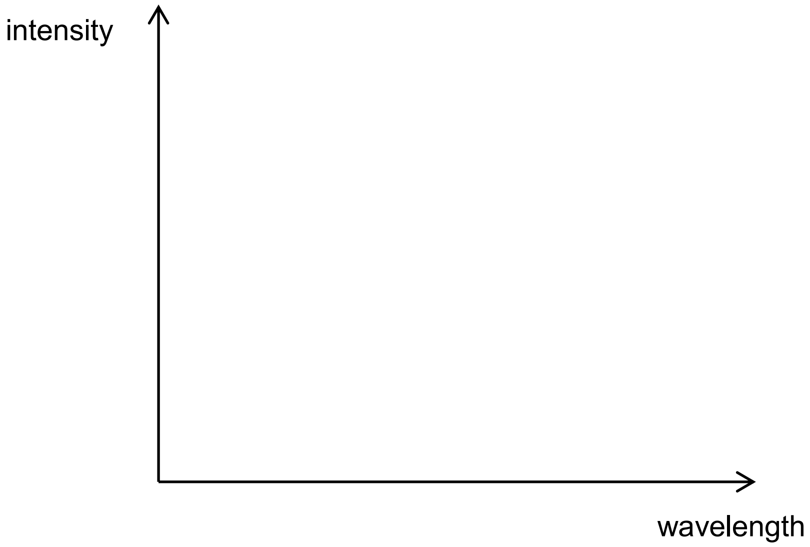
Option B **– Medical Physics**

10. *(a)* An X-ray machine is set to give out X-rays of minimum wavelength, $\lambda_{min} = 15 \times 10^{-12}$ m.

(i) Sketch a graph of intensity against wavelength for the resulting X-ray spectrum. Label the main features of the spectrum. [2]



(ii) Calculate the accelerating voltage used in the tube and explain the role of conservation of energy in your calculation. [3]

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(b) Describe how a CT scan differs from a conventional X-ray and justify why CT scans are **not** offered for the regular checking of healthy patients. [2]

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(c) An MRI scanner has a magnetic field that varies uniformly from 1.0 T to 1.5 T along its length. Calculate the wavelength of radio waves required to scan a slice halfway along its length. [3]

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(d) When using ultrasound to carry out B-scans a single transducer can be used to send and receive pulses of ultrasound.

(i) Describe how the ultrasound pulses are produced. [2]

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(ii) Use the data to explain the importance of coupling gel in ultrasound scans (a calculation should reinforce your argument). [4]

Medium	Density ($kg\,m^{-3}$)	Velocity of ultrasound ($m\,s^{-1}$)
Air	1.300	340
Skin	1 075	1 590

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(e) A patient is irradiated with a uniform beam of gamma rays of intensity 0.21 mW cm^{-2}.

(i) Calculate the intensity of gamma rays 0.4 cm and 9.8 cm below the outer layer of skin given that the mean attenuation coefficient of tissue is 2.2×10^{-2} cm^{-1}. [2]

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(ii) The tissue 0.4 cm below the skin has a cancer weighting factor of 0.08 and the tissue 9.8 cm below the skin has a weighting factor of 0.12. Justify which tissue is more likely to develop cancer from the gamma rays. [2]

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Option C – **The Physics of Sports**

11. *(a)* A golfer prepares to take a shot. Explain clearly how the golfer achieves a stable position in order to take the shot. [2]

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(b) The forces acting on the golfer's foot can be visualised by the following simplified diagram. Calculate the tension, T, in the Achilles tendon. [2]

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(c) The distance between the tee and the hole on a golf course is 148 m in length. A golfer is not sure whether to use a No.6 iron or a No.7 iron.

Determine which club the golfer should use given the following data about the clubs.

Club	Angle of projection	Initial speed of ball ($m\,s^{-1}$)
No.6 iron	30°	45
No.7 iron	34°	40

Show your workings clearly. Ignore the effects of air resistance and assume that no spin is applied to the ball. [5]

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(d) (i) In reality a golfer strikes the ball with large amounts of backspin. Explain how applying backspin will affect the mean distance travelled by the ball. Justify your answers by referring to the forces acting on the ball during the flight and how the ball lands. The effects of the air should be considered for this part.

[4]

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(ii) When the ball is first struck the ball is spinning at a rate of 50 revolutions per second. Given that the density of the ball is 1.13 g cm^{-3} and its diameter is 4.27 cm, calculate the rotational kinetic energy of the ball.
(Moment of inertia of the ball is given by the equation $I = \frac{2}{5}mr^2$.) [4]

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(iii) Calculate the torque applied to the ball when the golfer takes the shot if the club is in contact with the ball for a time of 0.5 ms. [3]

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Option D – **Energy and the Environment**

12\. *(a)* (i) State *Archimedes' principle*. [1]

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(ii) An iceberg floating in the sea and an ice sheet on land each melt releasing equal volumes of water into the sea. Explain which of these processes will have the greater effect on sea level. [2]

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(b) (i) Solar radiation of mean intensity 340 W m^{-2} falls on 2.6×10^{14} m^2 of the Earth's surface where it is absorbed. Calculate the rate of absorption of this solar energy by the Earth. [2]

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(ii) State the power that must be radiated from the Earth's surface in order for the Earth to maintain a steady equilibrium temperature. [1]

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(iii) Assume the Earth radiates this power uniformly from its entire surface. Calculate the radius of the Earth. [Each square metre of the Earth radiates power at 170 W.] [2]

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(c) A new nuclear reactor has been proposed based on the reaction of lithium-7 and a proton to produce two α-particles.

$$^{1}_{1}\text{p} + ^{7}_{3}\text{Li} \rightarrow ^{8}_{4}\text{Be} \rightarrow ^{4}_{2}\text{He} + ^{4}_{2}\text{He} + 17.1\ \text{MeV}$$

Although this is not a new nuclear reaction (it was the original splitting the atom experiment in 1932), there have been some theoretical developments that suggest this might be a useful reaction.

The above reaction is produced by ionising hydrogen and accelerating the resulting protons in a vacuum to an energy of around 300 keV. Unfortunately, in the past, only one in 30 million protons accelerated to the correct voltage have produced this nuclear reaction.

(i) The above reaction is produced by accelerating ionised hydrogen with 300 kV. Explain two possible benefits of the system compared with fission reactors. [4]

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(ii) Calculate the energy required to accelerate 30 million protons to an energy of 300 keV and explain why the above reaction does not seem profitable. [3]

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(iii) There is around 10^{16} kg of $^{7}_{3}\text{Li}$ in the world's oceans and the mass of $^{7}_{3}\text{Li}$ can be taken as 7 u. Calculate the number of $^{7}_{3}\text{Li}$ atoms in the world's oceans. [2]

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(iv) Scientists claim that there are sufficient ${}^{7}_{3}\mathrm{Li}$ atoms in the oceans to meet the world's energy needs for approximately 5 billion years.

Justify this claim. [Assume that each ${}^{7}_{3}\mathrm{Li}$ atom can, ideally, provide an energy of 17.1 MeV.] [3]

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WJEC Eduqas
A Level in PHYSICS

Data Booklet

A clean copy of this booklet should be issued to candidates for their use during each A level Physics examination.

Centres are asked to issue this booklet to candidates at the start of the A level Physics course to enable them to become familiar with its contents and layout.

Values and Conversions

Avogadro constant	N_A = 6·02 × 10^{23} mol^{-1}
Fundamental electronic charge	e = 1·60 × 10^{-19} C
Mass of an electron	m_e = 9·11 × 10^{-31} kg
Molar gas constant	R = 8·31 J mol^{-1} K^{-1}
Acceleration due to gravity at sea level	g = 9·81 m s^{-2}
Gravitational field strength at sea level	g = 9·81 N kg^{-1}
Universal constant of gravitation	G = 6·67 × 10^{-11} N m^2 kg^{-2}
Planck constant	h = 6·63 × 10^{-34} J s
Boltzmann constant	k = 1·38 × 10^{-23} J K^{-1}
Speed of light in vacuo	c = 3·00 × 10^8 m s^{-1}
Permittivity of free space	ε_0 = 8·85 × 10^{-12} F m^{-1}
Permeability of free space	μ_0 = 4π × 10^{-7} H m^{-1}
Stefan constant	σ = 5·67 × 10^{-8} W m^{-2} K^{-4}
Wien constant	W = 2·90 × 10^{-3} m K
Hubble constant	H_0 = 2.30 × 10^{-18} s^{-1}

T/K = θ/°C + 273·15

1 u = 1·66 × 10^{-27} kg

$$\frac{1}{4\pi\varepsilon_0} \approx 9\text{x}10^9$$

$\rho = \frac{m}{V}$	$T = \frac{1}{f}$
$v = u + at$	$v = -A\omega\sin(\omega t + \varepsilon)$
$x = \frac{1}{2}(u + v)t$	$T = 2\pi\sqrt{\frac{m}{k}}$
$x = ut + \frac{1}{2}at^2$	$T = 2\pi\sqrt{\frac{l}{g}}$
$v^2 = u^2 + 2ax$	$pV = nRT$ and $pV = NkT$
$\sum F = ma$	$p = \frac{1}{3}\rho\overline{c^2} = \frac{1}{3}\frac{N}{V}m\overline{c^2}$
$p = mv$	$M / \text{kg} = \frac{M_r}{1000}$
$W = Fx\cos\theta$	$n = \frac{\text{total mass}}{\text{molar mass}}$
$\Delta E = mg\Delta h$	$E = \frac{3}{2}RT$
$E = \frac{1}{2}kx^2$	$E = \frac{3}{2}kT$
$E = \frac{1}{2}mv^2$	$k = \frac{R}{N_A}$
$Fx = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$	$U = \frac{3}{2}nRT$
$P = \frac{W}{t} = \frac{\Delta E}{t}$	$W = p\Delta V$
efficiency = $\frac{\text{useful energy transfer}}{\text{total energy input}}$ × 100%	$\Delta U = Q - W$
$\omega = \frac{\theta}{t}$	$Q = mc\Delta\theta$
$v = \omega r$	$I = \frac{\Delta Q}{\Delta t}$
$a = \omega^2 r$	$I = nAve$
$a = \frac{v^2}{r}$	$R = \frac{V}{I}$
$F = \frac{mv^2}{r}$	$P = IV = I^2R = \frac{V^2}{R}$
$F = m\omega^2 r$	$R = \frac{\rho l}{A}$
$a = -\omega^2 x$	$V = E - Ir$
$x = A\cos(\omega t + \varepsilon)$	$\frac{V}{V_{\text{total}}}\left[or\ \frac{V_{\text{OUT}}}{V_{\text{IN}}}\right] = \frac{R}{R_{\text{total}}}$
$T = \frac{2\pi}{\omega}$	$C = \frac{Q}{V}$

$C = \frac{\varepsilon_o A}{d}$	$P = A\sigma T^4$
$E = \frac{V}{d}$	$\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$
$U = \frac{1}{2}QV$	$v = H_0 D$
$Q = Q_0\left(1 - e^{-\frac{t}{RC}}\right)$	$\rho_c = \frac{3{H_0}^2}{8\pi G}$
$Q = Q_0 e^{-\frac{t}{RC}}$	$r_1 = \frac{M_2}{M_1 + M_2} d$
$F = kx$	$T = 2\pi\sqrt{\frac{d^3}{G(M_1 + M_2)}}$
$\sigma = \frac{F}{A}$	$c = f\lambda$
$\varepsilon = \frac{\Delta l}{l}$	$\lambda = \frac{a\Delta y}{D}$
$E = \frac{\sigma}{\varepsilon}$	$d\sin\theta = n\lambda$
$W = \frac{1}{2}Fx$	$n = \frac{c}{v}$
$\Delta U_P = mg\Delta h$	$n_1 v_1 = n_2 v_2$
$F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{r^2}$	$n_1 \sin\theta_1 = n_2 \sin\theta_2$
$F = G\frac{M_1 M_2}{r^2}$	$n_1 \sin\theta_C = n_2$
$E = \frac{1}{4\pi\varepsilon_o}\frac{Q}{r^2}$	$E_{k\,\max} = hf - \phi$
$g = \frac{GM}{r^2}$	$p = \frac{h}{\lambda}$
$V_E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$	$A = -\lambda N$
$PE = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{r}$	$N = N_o e^{-\lambda t}$
$V_g = -\frac{GM}{r}$	$A = A_o e^{-\lambda t}$
$PE = -\frac{GM_1 M_2}{r}$	$N = \frac{N_o}{2^x}$
$W = q\Delta V_E$	$A = \frac{A_o}{2^x}$

$W = m\Delta V_g$	$\lambda = \frac{\ln 2}{T_{\frac{1}{2}}}$
$\lambda_{\max} = WT^{-1}$	$E = mc^2$

	leptons		quarks	
particle (symbol)	electron (e^-)	electron neutrino (ν_e)	up (u)	down (d)
charge (e)	-1	0	$+\frac{2}{3}$	$-\frac{1}{3}$
lepton number	1	1	0	0

$F = BIl\sin\theta$	$B = \mu_o nI$
$F = Bqv\sin\theta$	$\phi = AB\cos\theta$
$B = \frac{\mu_o I}{2\pi a}$	flux linkage = $N\phi$

OPTION A

flux linkage = $BAN \sin \omega t$	$X_L = \omega L$
$V = -\omega BAN \cos \omega t$	$X_C = \dfrac{1}{\omega C}$
$I_{rms} = \dfrac{I_0}{\sqrt{2}}$	$Z = \sqrt{X^2 + R^2}$
$V_{rms} = \dfrac{V_0}{\sqrt{2}}$	$Q = \dfrac{V_L}{V_R} \left(= \dfrac{V_C}{V_R} \right)$
$V_{rms} = \dfrac{\omega BAN}{\sqrt{2}}$	$Q = \dfrac{\omega_0 L}{R}$

OPTION B

$I = I_0 \exp(-\mu x)$	$f = 42.6 \times 10^6 B$
$Z = c\rho$	$H = DW_R$
$\dfrac{\Delta f}{f_0} = \dfrac{2v}{c} \cos \theta$	$E = HW_T$

OPTION C

$Ft = mv - mu$	$\tau = I\alpha$
$e = \dfrac{\text{Relative speed after collision}}{\text{Relative speed before collision}}$	$J = I\omega$
$e = \sqrt{\dfrac{h}{H}}$	$KE = \frac{1}{2} I\omega^2$
$I = \frac{2}{5} mr^2$	$p = p_0 - \frac{1}{2} \rho v^2$
$I = \frac{2}{3} mr^2$	$F_D = \frac{1}{2} \rho v^2 A C_D$
$\alpha = \dfrac{\omega_2 - \omega_1}{t}$	

OPTION D

$I = \dfrac{P}{A}$	$\dfrac{\Delta Q}{\Delta t} = -AK \dfrac{\Delta \theta}{\Delta x}$
$E = \frac{1}{2} A\rho v^3$	$P = UA\Delta\theta$

Mathematical Information

SI multipliers

Multiple	Prefix	Symbol
10^{-18}	atto	a
10^{-15}	femto	f
10^{-12}	pico	p
10^{-9}	nano	n
10^{-6}	micro	μ
10^{-3}	milli	m
10^{-2}	centi	c

Multiple	Prefix	Symbol
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G
10^{12}	tera	T
10^{15}	peta	P
10^{18}	exa	E
10^{21}	zetta	Z

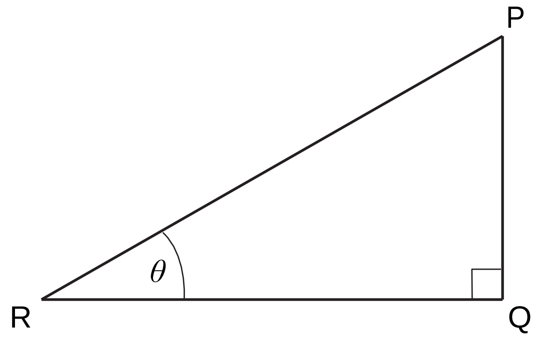
Areas and Volumes

Area of a circle = $\pi r^2 = \frac{\pi d^2}{4}$

Area of a triangle = $\frac{1}{2}$ base × height

Solid	Surface area	Volume
rectangular block	$2\,(lh + hb + lb)$	lbh
cylinder	$2\pi\, r\,(r + h)$	$\pi\, r^2\, h$
sphere	$4\,\pi\, r^2$	$\frac{4}{3}\pi\, r^3$

Trigonometry



$$\sin\theta = \frac{PQ}{PR},\quad \cos\theta = \frac{QR}{PR},\quad \tan\theta = \frac{PQ}{QR},\quad \frac{\sin\theta}{\cos\theta} = \tan\theta$$

$$PR^2 = PQ^2 + QR^2$$

Logarithms

[Unless otherwise specified 'log' can be $\log_e$ (i.e. ln) or $\log_{10}$.]

$\log(ab) = \log a + \log b$ $\log \frac{a}{b} = \log a - \log b$

$\log x^n = n \log x$ $\log_e e^{kx} = \ln e^{kx} = kx$

$\log_e 2 = \ln 2 = 0.693$

COMPONENT 1 – NEWTONIAN PHYSICS

MARK SCHEME

GENERAL INSTRUCTIONS

The mark scheme should be applied precisely and no departure made from it.

Recording of marks

Examiners must mark in red ink.

One tick must equate to one mark (except for the extended response questions).

Question totals should be written in the box at the end of the question.

Question totals should be entered onto the grid on the front cover and these should be added to give the script total for each candidate.

Marking rules

All work should be seen to have been marked.

Marking schemes will indicate when explicit working is deemed to be a necessary part of a correct answer.

Crossed out responses not replaced should be marked.

Credit will be given for correct and relevant alternative responses which are not recorded in the mark scheme.

Extended response question

A level of response mark scheme is used. Before applying the mark scheme please read through the whole answer from start to finish. Firstly, decide which level descriptor matches best with the candidate's response: remember that you should be considering the overall quality of the response. Then decide which mark to award within the level. Award the higher mark in the level if there is a good match with both the content statements and the communication statement.

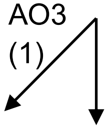
Marking abbreviations

The following may be used in marking schemes or in the marking of scripts to indicate reasons for the marks awarded.

cao = correct answer only
ecf = error carried forward
bod = benefit of doubt

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
1	*(a)*	(i)	The single point within a body at which the entire **weight** of the body may be considered to act	1			1		
		(ii)	Increase θ gradually until the block topples (1) Measure θ with a protractor just before the block topples / measure height and length of slope and calculate (1)	1 1			 2		 2
	(b)	(i)	V = 0.6 × 0.4 × 0.1 and $M = \rho \times V$ used correctly (1) Attempt at equating moments (1) ($T\sin\theta$ (1)) × 1.2 = 9.6 × 9.81 × 1.8 (1) for correct moments T = 220 [N] (1)	1 1 	 1 1 1		 5	 4	
		(ii)	F = 220 cos 40° (**ecf**) (1) F = 169 N (1) **UNIT mark**		1 1		 2	 2	
			Question 1 total	**5**	**5**	**0**	**10**	**6**	**2**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
2	*(a)*	(i)	Correct use of $v^2 = u^2 + 2ax$ (i.e. $0 = 6^2 - 2 \times 9.81 \times x$) (1) x = 1.8 [m] (1) Total height = 12.8 [m] (1)	1	 1 1		 3	 3	
		(ii)	$v^2 = 2 \times 9.81 \times 12.8$ (**ecf**) v = 15.9 [m s^{-1}] (1) $t_{up} = \left(\frac{0-6}{-9.81}\right)$ = 0.6 [s] (1) $t_{down} = \left(\frac{15.9(\text{ecf})-0}{9.81}\right)$ = 1.6 [s] (1) Total time = 2.2 [s] (1) **Alternative solution:** t_{up}: $s = ut + ½ at^2$ 1.8 = $6t - 4.9t^2$ t = 0.6 [s] (1) t_{down} : $s = ut + ½ at^2$ 12.8 = $0t + 4.9t^2$ (1) t = 1.6 [s] (1) Total time = 2.2 [s] (1)	1 1	 1 1		 4	 4	

	(b)		AO3 (1)  (1) AO2 Air resistance acts on the ball (1) AO2		1 1	1	3		
			Question 2 total	**3**	**6**	**1**	**10**	**7**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
3	*(a)*	(i)	0.50 × 40 = 0.50 × 30 + 0.16 v [or equivalent] (1) v = 31.25 [m s^{-1}] (1)	1	1		2	2	
		(ii)	External forces act upon the system [or by implication] (1) [Specifically] the shaft exerts a force upon the head of the hockey stick (1) [or any other reasonable specific force – accept air resistance]			1 1	2		
	(b)		Using Newton's 2nd law (1) $F = \frac{\Delta\text{momentum}}{\text{time to change}}$ [or by implication] (1) = 2 000 [N] [**ecf**] (1)	1 1	1		3	1	
	(c)	(i)	(½ × 0.5 × 40^2) – (½ × 0.5 × 30^2) - (½ × 0.16 × 31.25^2) = [100 J]	1			1	1	
		(ii)	Use of $E = mc\Delta T$ (1) $\Delta T = \frac{100}{0.16\text{x}850}$ = 0.74 [^{o}C] (1)	1	1		2	1	
			Question 3 total	**5**	**3**	**2**	**10**	**5**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
4	*(a)*		Force × distance moved in direction of force [or equivalent, e.g. component of force in direction of movement × distance moved, **or** $W = Fx\cos\theta$]	1			1		
	(b)	(i)	E_p lost = 70 × 9.81 × 120 $\sin$ 20° (1) [or by implication] = 28 000 [J] [28 148] (1) [Use of 10 for g – 1st mark lost]	1	1		2	2	
		(ii)	Use of E_k for either v = 6 m s^{-1} or $v = 21$ m s^{-1} (1) At A, E_k = ½ × 70 × 6^2 [= 1 260 J] and at B, E_k = ½ × 70 × 21^2 correct values of E_k calculated (1) [=15 435 J] ΔE_k = 14 175 [J] (1) [If (21 – 6)^2 calculated → 1 mark only]	1	1 1		3	2	

	(c)		Use of $W = Fx$ (1) [or by implication] Correct x [120 m] used (1) 28 184 – 14 175 (**ecf** on both) = $F \times 120$ (1) [or by implication] F = 117 [N] (1) **Alternative solution:** $mg\sin\theta$ = 234.9 [N] (1) ma = 118.1 [N] (1) Difference attempted (234.9 – 118.1) **ecf** on both values (1) F = 117 [N] (1) **Alternative solution:** $g\sin\theta$ = 3.36 [m s^{-2}] (1) $a = \frac{v^2 - u^2}{2s}$ = 1.69 [m s^{-2}] (1) Difference attempted (3.36 – 1.69) **ecf** on both values (1) F = answer × 70 kg = 117 [N] (1) N.B. × 70 kg may be included in the solution at any point	1 1	 1 1		 4	 3	
			Question 4 total	**5**	**5**	**0**	**10**	**7**	**0**

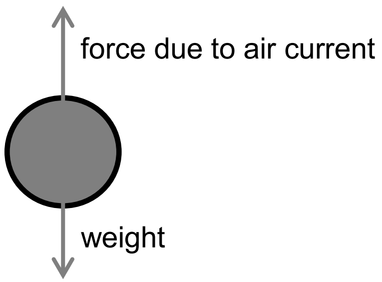
Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
5	*(a)*		All points plotted correctly (to within half a small square) (1) With error bars plotted correctly for temperature (1) Suitable scales on both axes with titles and units (1) Suitable lines of maximum gradient and minimum gradient drawn (1)		1 1 1 1		4	3	4
	(b)	(i) (ii)	Coming into contact with hot water Stir water / take readings at eye level	1 1			2		2
	(c)	(i)	Method for finding the gradient (1) maximum $= \frac{98-30}{100} = 0.68 \pm 0.02$ [°C s^{-1}] **and** minimum $= \frac{94-34}{100} = 0.60 \pm 0.02$ [°C s^{-1}] (1)	1	 1		2	1	2
		(ii)	So mean gradient = 0.64 ± 0.02 [°C s^{-1}] (1) Absolute uncertainty calculated (1) Percentage uncertainty - accept 3 to 8% (1)		1 1 1		3	2	3

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
5	*(c)*	(iii)	Equate $c = \frac{\text{Power}}{m \times \text{gradient}}$ (1) Correct calculation of c = 4 200 [J kg^{-1} °C^{-1}] (1) **ecf** Uncertainty – accept 130 – 340 (1)			1 1 1	3	3	3
	(d)		**Conclusions** C0 – As time increases, temperature increases. C1 – Values of temperature are lower. C2 – Line of graph is not straight. C3 – Gradient is decreasing. C4 – Initial temperature is the same. C5 – Value of specific heat capacity is too low or lower or less than 4 200 [J kg^{-1} °C^{-1}]. C6 – Measured value of specific heat capacity is not constant [because the gradient is not constant]. **Evaluations** E0 – Line should be straight or disagrees with theory. E1 – Results need checking, as they are not what would be expected. E2 – Statement relating to “lost” energy. E3 – Heat is lost or energy is given to the container. E4 – More heat loss occurs at higher temperatures. E5 – Due to a greater temperature difference between water and air / surroundings / outside of container. **5-6 marks** All of C1 – C4 (acceptable for C0 to be omitted) are present. Either C5 or C6 is present.			6	6		6

			E0, E3 and E4 are present (E5 may be present for the best candidates). There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured. **3-4 marks** Expect 2 from C0 – C4. Expect 2 from E0 – E3. There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure. **1-2 marks** 1 from C0 – C2 present 1 from E0 – E3 present. There is a basic line of reasoning which is not coherent, largely irrelevant, supported by limited evidence and with very little structure. **0 marks** No attempt made or no response worthy of credit.						
			Question 5 total	**3**	**8**	**9**	**20**	**9**	**20**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
6	*(a)*		A body moves with SHM if its acceleration: is directly proportional to its displacement from a fixed point (1) is always directed towards that fixed point (1)	1 1			2		
	(b)		Use of $f = \frac{1}{T}$ (1) $f = \frac{1}{0.4} = 2.5$ Hz (1) **UNIT mark**	1	1		2	1	
	(c)		$\omega = \frac{(2\pi)}{0.4} = 15.7$ [rad s^{-1}]	1			1	1	
	(d)	(i)	$v_{max} = \omega A$ (1) = (15.7)(0.05) = 0.79 [m s^{-1}] (1)	1	1		2	1	
		(ii)	$a_{max} = \omega^2 A$ (1) =(15.7^2)(0.05) = 12.3 [m s^{-2}] (1)	1	1		2	1	
		(iii)	$a = \omega^2 x$ (1) = (15.7^2)(0.02) = 4.93 [m s^{-2}] (1) Downward (1)	1	1 1		3	2	

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
6	*(e)*	(i)	Maximum deceleration [12.3 m s^{-2}] > g (1) Box's downward acceleration can't be greater than g (1) So platform slows down quicker than box (1) $mg = m\omega^2 x$ (1) So $x = \frac{9.81}{15.7^2}$ (1)			1 1 1 1 1	5	2	
		(ii)	Box acts as a moving observer and / or source (1) Wavelength shift due to the Doppler effect (accept red shift or blue shift) (1) $\Delta\lambda \propto v$ **or** $\frac{\Delta\lambda}{\lambda} = \frac{2v}{c}$ **or** $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$ explained (1)		1 1 1		3		
			Question 6 total	**7**	**8**	**5**	**20**	**8**	**0**

Question		Marking details	Marks available					
			AO1	AO2	AO3	Total	Maths	Prac
7	*(a)*	Weight or gravity identified as one of the forces (1) (diagram acceptable)	1					
		[Upward] force due to [convection] air current or drag or air resistance (accept answers similar to wind push) is the other force or diagram e.g. (1)	1					
								
		The second force depends on the [cross-sectional] area of the smoke particle (1)		1				
		Weight depends on [mass and therefore] volume (1)		1				
		The ration $\frac{\text{Area}}{\text{Volume}}$ increases when size decreases (1)		1		5		
	(b)	Lopez argument based on the energy released in a nuclear reaction (1)		1				
		Daxon argument based on the energy released in a chemical reaction (1)		1		2		

	(c)	**U-235 points** U1 – Used for nuclear bomb. U2 – Used for nuclear power stations. U3 – In fuel rods. U4 – Detonators for hydrogen bombs / fission bombs. U5 – U-235 fission nucleus. U6 – Induced fission. **Nuclear power** N1 – Dangerous (explosion risk). N2 – Leak risk or nuclear waste. N3 – Low CO_2. N4 - No acid rain. N5 – No climate change. **Nuclear bomb** B1 – Mass extinction. B2 – Deterrent to war. **Depleted uranium** D1 – Spreads radiation. D2 – Better missiles. D3 – Cheap materials. **Conclusions** C1 - Pros and cons discussed for nuclear power (no actual conclusion is necessary). C2 - Pros and cons discussed for nuclear bomb (no actual conclusion is necessary). C3 - Pros and cons discussed for DU (no actual conclusion is necessary). **ALL CONCLUSIONS MUST BE VALID AND JUSTIFIABLE.**						

		5-6 marks At least U1, U2, U3 and U5 present. At least N1, N2 and N3 present. B1 and B2 present. At least D1 present and either D2 or D3. C1, C2 and C3 present. There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured. **3-4 marks** Expect U1 and U2. Expect N1 and N2. Either B1 or B2. Either D1 or D2 or D3. Either C1 or C2 or C3. There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure. **1-2 marks** Either U1 or U2. Either N1 or N2 or N3 or N4 or N5. There is a basic line of reasoning which is not coherent, largely irrelevant, supported by limited evidence and with very little structure. **0 marks** No attempt made or no response worthy of credit.			6	6		

	(d)	Mass = 500 × $(10^{-5})^2$ (1) Activity = 12.3 × 10^6 × 0.05 = 0.63 (1) Similar **or** slightly higher **or** 50% higher (1)		1 1 1		3	2	
	(e)	Insoluble more difficult to remove / excrete (1) Therefore stays in the body longer (1) U-235 is removed from the mix to produce DU hence the increased ratio (1) Therefore the claim is correct and answer well-reasoned (1)		1 1	1 1	4		
		Question 7 total	**2**	**10**	**8**	**20**	**2**	**0**

COMPONENT 1: NEWTONIAN PHYSICS

SUMMARY OF MARKS ALLOCATED TO ASSESSMENT OBJECTIVES

Question	AO1	AO2	AO3	TOTAL MARK	MATHS	PRAC
1	5	5	0	10	6	2
2	3	6	1	10	7	0
3	5	3	2	10	5	0
4	5	5	0	10	7	0
5	3	8	9	20	9	20
6	7	8	5	20	8	0
7	2	10	8	20	2	0
TOTAL	30	45	25	100	44	22

COMPONENT 2 – ELECTRICITY AND THE UNIVERSE

MARK SCHEME

GENERAL INSTRUCTIONS

The mark scheme should be applied precisely and no departure made from it.

Recording of marks

Examiners must mark in red ink.

One tick must equate to one mark (except for the extended response question).

Question totals should be written in the box at the end of the question.

Question totals should be entered onto the grid on the front cover and these should be added to give the script total for each candidate.

Marking rules

All work should be seen to have been marked.

Marking schemes will indicate when explicit working is deemed to be a necessary part of a correct answer.

Crossed out responses not replaced should be marked.

Credit will be given for correct and relevant alternative responses which are not recorded in the mark scheme.

Extended response question

A level of response mark scheme is used. Before applying the mark scheme please read through the whole answer from start to finish. Firstly, decide which level descriptor matches best with the candidate's response: remember that you should be considering the overall quality of the response. Then decide which mark to award within the level. Award the higher mark in the level if there is a good match with both the content statements and the communication statement.

Marking abbreviations

The following may be used in marking schemes or in the marking of scripts to indicate reasons for the marks awarded.

cao	=	correct answer only
ecf	=	error carried forward
bod	=	benefit of doubt

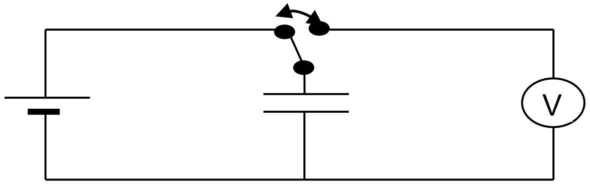
Question			Marking details	AO1	AO2	AO3	Total	Maths	Prac
				Marks available					
1	*(a)*		n – number of free electrons per unit volume [accept m^{-3}] (1) Accept 'free electron density' v – drift velocity [of free electrons] (1)	1 1			2		
	(b)	(i)	mass = 8 920 × 2.0 × 2.0 x 10^{-6} (1) [= 0.0357 kg] $\frac{0.0375}{1.05\text{x}10^{25}}$ × 1.5 = 5.1 × 10^{23} electrons (1)		1 1		2	2	
		(ii)	$n = \frac{5.1\text{x}10^{23}(\text{ecf})}{4.0\text{x}10^{6}(\text{ecf})}$ (1) [= 1.28 ×10^{29} m^{-3}] $v = \frac{1.2}{1.28\text{x}10^{29}\text{x}2.0\text{x}10^{-6}\text{x}1.6\text{x}10^{-19}}$ (subst) (1) [**ecf** on n] v = 2.9 ×10^{-5} [m s^{-1}] (1) [N.B. use of 5.1 × 10^{23} for n → 7.3[5] [m s^{-1}]	1	1 1		3	2	
	(c)		Correct strategy – determining n for each material (1) n calculated correctly for each material (1) A – 5.95 × 10^{28} B – 8.30 × 10^{28} C – 5.98 × 10^{28} Therefore B made from different material (1) **Alternative solution:** Correct strategy – realisation that e is constant (1) $\frac{I}{Av}$ calculated correctly for each material (1) Therefore B made from different material (1)		1	1 1	3	2	
			Question 1 total	**3**	**5**	**2**	**10**	**6**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
2	*(a)*	(i)	**Diagram or set-up** D1 – Wire shown along with movable contact (accept crocodile clip). D2 – Metre ruler. D3 – Method for measuring resistance shown e.g. correct circuit with ohmmeter or correct circuit with voltmeter and ammeter appropriately connected. D4 – Micrometer or digital callipers or vernier scales. **Method** M1 – Vary length. M2 – Measure resistance (or I and V). M3 – Measure diameter or thickness. M4 – Repeat readings of resistance and length and the mean values obtained. M5 – Repeat readings of diameter (or thickness) and the mean value obtained. M6 – Diameter (thickness) measured in different places along the wire. M7 – Measure zero error of ohmmeter. **Results** R1 - Plot graph of resistance against length. R2 – Measure gradient. R3 – Intercept should be zero. R4 - $\rho = \frac{RA}{l}$ quoted. R5 - ρ = gradient × area *R6* – Area = πr^2 where $r = \frac{d}{2}$ **5-6 marks** All of D1 – D4 present. All of M1 – M3 and M5 and either M6 or M7 present. All of R1, R2, R4, R5 and R6 present.	6			6		6

			There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured. **3-4 marks** Expect any 3 from D1 – D4. Expect M1, M2 and M3. Expect R1, R2 and R4. There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure. **1-2 marks** Expect any 2 from D1 – D4. Expect M1 and M2. Expect R1. There is a basic line of reasoning which is not coherent, largely irrelevant, supported by limited evidence and with very little structure. **0 marks** No attempt made or no response worthy of credit.						
		(ii)	Substitution into $R = \frac{\rho l}{A}$ (1) $\rho = 1.06 \times 10^{-7}$ [Ω m] (1)	1	1		2	2	
	(b)		Because $R \propto \frac{1}{A}$ [for equivalent lengths] (1) Therefore there is an increased resistance [per metre] (1) Therefore higher values of R for equivalent lengths lead to a **steeper gradient** (1) Resistivity does not change because the material of the wire does not change (1)		1	1 1 1	4		4
			Question 2 total	**7**	**2**	**3**	**12**	**2**	**10**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
3	*(a)*	(i)	V is the terminal pd – or clear explanation in energy terms: energy per coulomb transferred in the external circuit / [N.B. "per coulomb" / "per unit charge" required on one of (i) and (ii) if energy explanation given]	1			1		
		(ii)	pd across the internal resistance [accept lost volts – "bod"] / energy per coulomb lost / dissipated in the internal resistance / cell	1			1		
	(b)	(i)	2.4 [V]	1			1		
		(ii)	0.4 [Ω] [allow **ecf** from (b)(i)]		1		1	1	
	(c)		R_{Tot} = 2 + 0.4 (**ecf**) (1) I = 1 [A] (**ecf**) (1)		1 1		2	2	
	(d)		At (0,0) there is no pd and no current (1) At (∞,6) as n becomes large 2 Ω becomes negligible (1) Therefore equivalent to emf i.e. $r\left(\frac{E}{r}\right)$ (1) Between (0,0) and (∞,6) 2 Ω becomes less and less significant so I increases (1)		1 1 1 1		4		
			Question 3 total	**3**	**7**	**0**	**10**	**3**	**0**

Question			Marking details	Marks available					
				AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
4	*(a)*		$C = \frac{\varepsilon_0 A}{d}$ used $\left(= \frac{8.85\text{x}10^{-12}\text{x}0.163}{0.35\text{x}10^{-3}}\right)$(1)	1					
			Answer = 4.12 nF **UNIT mark** (1)		1		2	1	
	(b)	(i)	4.95 [μC] **ecf**		1		1		
		(ii)	2.97 [mJ] **ecf**		1		1	1	
	(c)		$Q = Q_0 e^{-\frac{t}{RC}}$ used **or** $T_{\frac{1}{2}} = RC\ln 2$ used (1)	1					
			Logs taken correctly e.g. $\ln\frac{Q}{Q_0} = \frac{-t}{RC}$ **or** substitute into $T_{\frac{1}{2}} = RC\ln 2$ (1)		1				
			Answer = 1.9 [ms] (1) **ecf**		1		3	3	
	(d)		Shorter since energy proportional to Q^2		1		1		

Question			Marking details	AO1	AO2	AO3	Total	Maths	Prac
				Marks available					
4	*(e)*	(i)	 Correct circuit diagram e.g. as shown (1) Charging and discharging explained (1) e.g. switch left for charging, right for discharging Measure V at various (regular) time intervals (1) Use data logging because too quick for human (1)	1 1 1 1			4		4
		(ii)	Plot a graph of $\ln V$ against t (1) Should be a straight line (1) Negative gradient / gradient = $= \frac{-1}{RC}$ / positive intercept (1)		1 1 1		3		3
			Question 4 total	**6**	**9**	**0**	**15**	**5**	**7**

Question		Marking details	Marks available					
			AO1	AO2	AO3	Total	Maths	Prac
5	*(a)*	Correct use of sin i.e. $\frac{r}{2} = 0.75\sin 10^\circ$ (1) So $r = 2\text{x}0.75\sin 10^\circ$ = 0.26 [m] (2nd mark implies first) (1)	1	1		2	2	
	(b)	$F = T\sin 10^\circ$ (1) also $mg = T\cos 10^\circ$ where $m = 5.0\times 10^{-3}$ kg (1) or equivalent Use of $F = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{r^2}$ (1) $Q = \sqrt{4\pi\varepsilon_0 (0.26)^2 F}$ and comment (1)	1		1 1 1	4	4	
	(c)	Attempt at approximation of uncertainties (1) Obtaining uncertainties for all 3 measurements (1) Identification of source of largest uncertainty (i.e. the angle) (1) Therefore a suitable improvement suggested (1)			1 1 1 1	4		4
	(d)	Oscillation about equilibrium point **or** mid-point (1) Air resistance acts on balloons (1) [Heavily] damped oscillations **or** [over] damped SHM **or** critical damping (1)	1	1	1	3		
		Question 5 total	**3**	**2**	**8**	**13**	**6**	**4**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
6	*(a)*	(i)	$\frac{F}{m} = -\frac{GM}{r^2} = -5.90\times10^{-3}$ N kg^{-1} Use of formula (1) Answer + **UNIT** (1)	1	1		2	2	
		(ii)	$-\frac{GM}{r} = -8.85\times10^{8}$ [J kg^{-1}] Use of formula (1) Answer (1)	1	1		2	2	
	(b)		Good strategy chosen involving the use of Kepler's law (1) $\frac{T^2}{r^3} = \left[\frac{(3.16\text{x}10^7)^2}{(1.5\text{x}10^{11})^3}\right]$ = 2.96 × 10^{-19} Earth **and** $\frac{T^2}{r^3} = \left[\frac{(3.74\text{x}10^8)^2}{(7.79\text{x}10^{11})^3}\right]$ = 2.96 × 10^{-19} Jupiter calculated (1) **OR** $\frac{r^3}{T^2} = \left[\frac{(1.5\text{x}10^{11})^3}{(3.16\text{x}10^7)^2}\right]$ = 3.38 × 10^{18} Earth **and** $\frac{r^3}{T^2} = \left[\frac{(7.79\text{x}10^{11})^3}{(3.74\text{x}10^8)^2}\right]$ = 3.38 × 10^{18} Jupiter calculated Conclusion that the agreement is good / excellent [this must be consistent with the calculations shown] (1)		1	1 1	3	1	
			Question 6 total	**2**	**3**	**2**	**7**	**5**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
7	*(a)*		Starting from $E = \frac{FL_0}{Ax}$ extension of bar of cross-sectional area $2A$ shown to be $\frac{F\frac{L_0}{2}}{2AE}$ **and** extension of bar of cross-sectional area A shown to be $\frac{F\frac{L_0}{2}}{AE}$ (1) Attempt at adding extensions made (1) Convincing algebra (1) e.g. common denominators shown: $\left[\frac{2FL_0}{4AE} + \frac{FL_0}{4AE}\right] = \frac{3FL_0}{4AE}$	1	1 1		3	3	3
	(b)	(i)	Line drawn correctly i.e. 2 $\times$ gradient/steepness as given line		1		1		1
		(ii)	Re-arrange for A bar, $2A$ bar or combination (1) Correct force-extension combination for each of above (1) Answer = 2 $\times 10^{11}$ [N m^{-2}] (1)		1	1 1	3	3	3
		(iii)	Use of $T = 2\pi\sqrt{\frac{m}{k}}$ (1) Gradient = $\frac{400}{8\text{x}10^{-6}}$ (1) Period = 4 m[s] (1)	1	1 1		3	3	3
			Question 7 total	**2**	**6**	**2**	**10**	**9**	**10**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
8	*(a)*		Absorbs all radiation (don't accept 'all wavelengths') falling on it. Accept emits more radiation than any other body [at that temp] / perfect emitter / perfect absorber	1			1		
	(b)	(i)	$A = 4\pi \times (8.54 \times 10^8)^2$ **or** 9.16×10^{18} [m^2] (1) $P = 5.67 \times 10^{-8} \times$ area attempt $\times 5\,790^4$ (1) $P = 5.84 \times 10^{26}$ [W] with appropriate comment on consistency (1) [–1 for slips of 2^n, 10^n] Accept other alternatives e.g. finding P from A and T or finding A from P and T			1 1 1	3	3	
		(ii)	$\lambda_{max} = \dfrac{2.9\text{x}10^{-3}}{5790}$ **or** by implication (1) λ_{max} = 500 n[m] No **ecf** (1) Graph goes through origin with zero slope and acceptable at high λ (1) Peaks at approximately 500 nm **ecf** (1)	1	1 1 1		4	2	
			Question 8 total	**2**	**3**	**3**	**8**	**5**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
9	*(a)*	(i)	T = 1 090 × 24 × 60 × 60 = 9.42 × 10^7 [s] (1) Use of $r_S = \frac{Tv_S}{2\pi}$ or equivalent (1) = 6.82 × 10^8 [m] (1)		1 1 1		3	3	
		(ii)	Use of $d = \sqrt[3]{\frac{T^2 GM_S}{4\pi^2}}$ (1) Assumption $M_S >> M_P$ (1) = 3.21 × 10^{11} [m] (1)		1 1 1		3	3	
		(iii)	Use of $M_p = \frac{r}{r+d} M_s$ (1) = 4.7 × 10^{27} [kg] (1)	1	1		2	2	

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
9	*(b)*	(i)	Modern data has smaller random errors or points closer to the line of best fit (1) Modern data (or second graph) has no negative velocities (or blue shift) (1) Modern data is correct over a far larger range of distance (2 Mpc $\rightarrow$ 500 Mpc) (1) All of the above points can be made in reverse e.g. 1929 data is very noisy or 1929 data has data showing blue shift etc			1 1 1	3		3
		(ii)	Hubble's constant is the gradient (1) Answer = 64 [± 2] (1)			1 1	2	1	
		(iii)	Age of the universe = $\frac{1}{H_0}$ (1) Answer = 15.3 billion [years] (**ecf**) (1)	1	1		2	1	
			Question 9 total	**2**	**8**	**5**	**15**	**10**	**3**

COMPONENT 2: ELECTRICITY AND THE UNIVERSE

SUMMARY OF MARKS ALLOCATED TO ASSESSMENT OBJECTIVES

Question	AO1	AO2	AO3	TOTAL MARK	MATHS	PRAC
1	3	5	2	10	6	0
2	7	2	3	12	2	10
3	3	7	0	10	3	0
4	6	9	0	15	5	7
5	3	2	8	13	6	4
6	2	3	2	7	5	0
7	2	6	2	10	9	10
8	2	3	3	8	5	0
9	2	8	5	15	10	3
TOTAL	30	45	25	100	51	34

COMPONENT 3 – LIGHT, NUCLEI AND OPTIONS

MARK SCHEME

GENERAL INSTRUCTIONS

The mark scheme should be applied precisely and no departure made from it.

Recording of marks

Examiners must mark in red ink.

One tick must equate to one mark (except for the extended response question).

Question totals should be written in the box at the end of the question.

Question totals should be entered onto the grid on the front cover and these should be added to give the script total for each candidate.

Marking rules

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Marking schemes will indicate when explicit working is deemed to be a necessary part of a correct answer.

Crossed out responses not replaced should be marked.

Credit will be given for correct and relevant alternative responses which are not recorded in the mark scheme.

Extended response question

A level of response mark scheme is used. Before applying the mark scheme please read through the whole answer from start to finish. Firstly, decide which level descriptor matches best with the candidate's response: remember that you should be considering the overall quality of the response. Then decide which mark to award within the level. Award the higher mark in the level if there is a good match with both the content statements and the communication statement.

Marking abbreviations

The following may be used in marking schemes or in the marking of scripts to indicate reasons for the marks awarded.

cao	=	correct answer only
ecf	=	error carried forward
bod	=	benefit of doubt

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
1	*(a)*	(i)	v = 2.0 [m s^{-1}] e.g. via $v = \frac{0.1}{0.05}$ **or** $\frac{0.2}{0.1}$ **or** (with **ecf**) $f\lambda$ = 5 × 0.4 (1) f = 5.0 [Hz] e.g. via $\frac{1}{T} = \frac{1}{0.20}$, **or** (with **ecf**) $\frac{v}{\lambda} = \frac{2.0}{0.4}$ (1) λ = 0.40 [m] No justification needed **ecf** if via $\lambda = \frac{v}{f} = \frac{2.0}{5.0}$ (1)		1 1 1		3	3	
		(ii)	F **and** J		1		1		
		(iii)	Oscillations **or** displacements [of cars] and direction of travel of wave **or** energy [clarity needed for this mark] (1) are perpendicular [award mark even if directions not quite clear] (1)	1 1			2		
		(iv)	Cars shown in a line, so they can roll back and forth longitudinally. Springs shown joining cars head to tail		1		1		
	(b)	(i)	$S_2Q = \sqrt{(600^2 + 135^2)}$ **or** 615 [mm] **or** by implication (1) $S_2Q - S_1Q$ = 15 [mm] (1) For Q, $n\lambda$ = 15 [mm] **and** n = 2 **or** n = 0 for P (1) λ = 7.5 [mm] (1)	1	1 1 1		4	4	

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
1		(ii)	Correct use of $\lambda = \frac{(135 \text{x} 33.75))}{600}$ (1) λ = 7.6 mm **UNIT mark** [no credit for 7.5 mm without working] (1)	1	1		2	2	
	(c)	(i)	Diagram with recognisably parallel rays leaving two adjacent slits, perpendicular dropped and θ marked (1) $n\lambda$ and d marked on diagram or associated clearly with relevant sides of triangle (1) **Either** $n\lambda$ stated to be path difference [for light from adjacent slits] **or** θ stated also to be angle between light and normal (1)	1 1 1			3		
		(ii)	Any correct and relevant first order calculation (1) Any correct and relevant second order calculation (1) Conclusion argued correctly from first or second order (1) Conclusion argued correctly and involving ± 1° (1)			1 1 1 1	4	2	
			Question 1 total	**7**	**9**	**4**	**20**	**11**	**0**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
2	*(a)*	(i)		Numerical data ($E_{k\,max}$, ϕ, h) correctly inserted into **correct** Einstein's eq. **or** the eq. transposed thus: $f = \frac{(E_{k\max} + \phi)}{h}$ **or** by implication (1) f = 7.1 × 10^{14} [Hz] (1)		1 1		2	2	
		(ii)	I	Calculation showing that 5.9 × 10^{14} Hz is above threshold **or** statement that this is assumed to be so (1) **More** photons [per second] eject more electrons [per second] (1)		1 1		2	1	
			II	$E_{k\,max}$ unaffected because extra (5.9 × 10^{14} Hz) photons are less energetic **or** equivalent **or** photons don't co-operate **or** equivalent (1)		1		1		
	(b)	(i)		Use of $\Delta E = hf$ **and** $\lambda = \frac{c}{f}$, **or** $\Delta E = \frac{hc}{\lambda}$ (1) λ = 700 n[m] **or** 695 n[m] (1)	1	1		2	2	
		(ii)		Gained by [or raises energy of] electron [**or** ion; accept atom]	1			1		
		(iii)		Any **two** of: phase, direction of travel, polarisation [direction]	1			1		
		(iv)		More electrons [**or** ions; accept atoms] in U than L	1			1		
		(v)		Population inversion needed for stimulated emission to be more probable, **or** frequent, than [**or** predominant over] absorption (1) This ensures light amplification **or** photon number increase **or** without population inversion no amplification **or** equivalent **or** by implication (1)		1 1		2		

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
2	*(c)*	(i)		Max gradient = 1.08 [± 0.03] × 10^{-6} [V m] (1) Min gradient = 0.93 [± 0.03] × 10^{-6} [V m] (1)		1 1		2	2	2
		(ii)		Use of h = gradient **or** equivalent **or** by implication (1) h = 5.4 × 10^{-34} J s **UNIT mark ecf** Accept 3 sig figs (1) Uncertainty 0.8 × 10^{-34} [J s] **ecf** including repeat of error in going from gradient to h. Accept 3 sig figs if h given to 3 sig figs. (1)		1	1 1	3	3	3
		(iii)		**Any 3 x (1) from:** • Points lie on straight line [as required] • [But] too few data points to form a valid conclusion • Accepted value of h outside range of uncertainty • Need to check if graph goes through [true] origin			3	3		3
				Question 2 total	**4**	**11**	**5**	**20**	**10**	**8**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
3	*(a)*		1.540 sin 77° = n_{clad} sin 90° or equivalent (e.g = n_{clad}) **or** by implication (1) n_{clad} = 1.500 (1)		1 1		2	2	
	(b)	(i)	$v = \frac{c}{1.540}$ **or** 1.92 × 10^8 [m s^{-1}] (1) t = 1.80 μ[s] **ecf** on wrong n (1.75 μs) or n omitted (1.17 μs) **or** multiplying c by n (0.76 μs) (1)	1	1		2	2	
		(ii)	AC = AB sin 77° (1) Zigzag distance = $\frac{350}{\sin 77^{\circ}}$ [= 359 m], or Zigzag time = 1.80 × 10^{-6} (**ecf**) sin 77° = [1.85 μs] (1) Extra time = 47 n[s] (1)		1 1 1		3	3	
	(c)		A lower n means that θ increases (or equivalent) (1) Therefore there is less lag time by different routes (1) Therefore there will be a greater frequency (1)			1 1 1	3		
			Question 3 total	**1**	**6**	**3**	**10**	**7**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
4	*(a)*	(i)	Place Hall probe varying distances from the wire (1) Hall probe placed perpendicularly to the field (1)	1 1			2		2
		(ii)	Method for calculating gradient (1) Answer =[-]1.05 [± 0.05] (1)	1	1		2	1	2
		(iii)	No mark for just stating Yes or No Straight line (1) Small scatter of points/low random error etc. (1) Gradient close to -1 and Yes stated (1)			1 1 1	3		3
		(iv)	40% is incorporated into the constants i.e. μ_0, 2π, I (1) So the intercept will be greater (1) The gradient will be the same (1)			1 1 1	3		3
	(b)		I_1 – B field into paper at P (1) I_2 – B field out of paper at P (1) Directions determined using the right hand grip rule / corkscrew rule (1) Overall direction is out due to the stronger current being I_2 (1)	1	1 1 1		4		
			Question 4 total	**4**	**4**	**6**	**14**	**1**	**10**

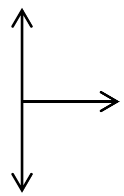
Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
5	*(a)*		Valid complete statement - 2 marks e.g. Induced emf is proportional to (or equal to) the rate of change (or cutting) of flux (linkage) e.g. Accept induced emf = change of flux / time Nearly complete statement - 1 mark e.g. emf = rate of flux cutting (missing induced) e.g. $\varepsilon = -\frac{d\phi}{dt}$ (terms not defined) e.g. Induced emf is proportional to change of flux (missing rate of)	2			2		
	(b)		$\varepsilon = -\frac{d\phi}{dt}$ **or** $\frac{\phi}{t}$ **or** $\frac{BA}{t}$ **or** $\frac{BAN}{t}$ (1) $A = \pi r^2$ used (1) $I = \frac{V}{R}$ used (1) Answer = 1 991 [A] (1)	1 1	1 1		4	3	
			Question 5 total	**4**	**2**	**0**	**6**	**3**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
6	*(a)*		No mark for agreeing or disagreeing Society should realise that the paper is not radioactive **or** society doesn't know if paper is radioactive **or** society thinks paper is radioactive (1) Radioactivity needs to be linked to health issues e.g. society should realise the paper is harmless **or** society doesn't know whether **or** not the paper might cause cancer **or** people think the radioactive paper is harmful / carcinogenic etc (1)			2	2		
	(b)		${}^{90}_{39}\mathrm{Y}$ **and** ${}^{0}_{-1}\beta$	1			1		
	(c)		$\lambda = \frac{\ln 2}{T_{\frac{1}{2}}}$ clearly selected (1) $\frac{\ln 2}{28.8\text{x}365\text{x}24\text{x}3600}$ = 7.63 $\times 10^{-10}$ [s^{-1}] (1)	1	1		2	2	
	(d)		Correct equation used i.e. some understanding of $A = A_0 e^{-\lambda t}$ **or** $A = \frac{A_0}{2^x}$ (1) Answer = 110 G[Bq] **ecf** on λ (1)	1	1		2	2	
	(e)		Use of $\frac{1}{2}mv^2 = E_k$ (1) v calculated correctly = 4.4 $\times 10^8$ [m s^{-1}] (1) Greater than speed of light and relativistic speed (1)	1	1 1		3	2	
			Question 6 total	**4**	**4**	**2**	**10**	**6**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
7	*(a)*	(i)	Attempt at LHS – RHS (1) Attempt at mass-energy conversion $\times$ 931 **or** $E=mc^2$ used (1) Answer = 7.26 MeV (1.16 $\times$ 10^{-12} J) (1)	1	1 1		3	2	
		(ii)	Scientists have gathered evidence for carbon being essential to life (1) Scientists have discovered that this is the process in stars that produces carbon (1)			2	2		
	(b)		Method for converting BE/nucleon to BE (1) Mass equivalent = 0.5857 u (1) Understanding of mass and atomic numbers i.e. 28 protons & 34 neutrons stated or implied (1) Mass of 28p & 34n = 62.49828 (1) Answer = 61.913 [u] (1) Light nuclei increase A, heavy nuclei decrease A (1)	1 1	1 1 1	1	5 2	3	
			Question 7 total	**3**	**5**	**2**	**10**	**5**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
8	*(a)*	(i)	d has charge ⅓ that of e^- d feels strong force; e^- doesn't d cannot be isolated; e^- can **or** equivalent	1 1 1			3		
		(ii)	$3 \times (-\frac{1}{3}e) = -e$. Accept $3 \times (-\frac{1}{3}) = -1$ **or** $3 \times (\frac{1}{3}) = 1$ if negative charge implied in some other way, e.g. total same as electron		1		1		
	(b)		No neutrino nor gamma emission (accept either) No change in quark flavour [and no gamma]		1 1		2		
	(c)	(i)	x is an electron and y is a[n electron] neutrino (1) Charge conservation used to identify charge of x as negative (1) Lepton number conservation used to identify y as antilepton (1)			1 1 1	3		
		(ii)	Weak as neutrino involved or quark flavour change		1		1		
			Question 8 total	**3**	**4**	**3**	**10**	**0**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
9	*(a)*	(i)	Flux (linkage) is $BAN\sin\omega t$ **or** flux (linkage) varies sinusoidally (1) Induced emf is $\omega BAN\cos\omega t$ **or** rate of change of flux also sinusoidal (1) Accept flux cutting argument e.g rate of flux cutting depends on direction (of motion of long side) and this depends on $\cos\omega t$	1	1		2		
		(ii)	Area = 8 $\times 10^{-4}$ [m^2] (1) Peak pd = ωBAN (1) Answer = 31.5 [mV] (1)	1	1 1		3	3	
	(b)		Taking valid readings e.g. 4 cycles in 10 cm and peak V ~ 3.4 cm (1) Multiplying by one correct factor i.e. 0.02 or 50 $\times 10^{-6}$ (1) Answers i.e. 68 ± 4 [mV] and 125 ± 5 [μs] (1)		1	1 1	3	3	
	(c)	(i)	At resonance $Z=R$ **or** all pd across R **or** equivalent (1) $I = \frac{30}{67}$ (1)	1	1		2	1	
		(ii)	$V = IX_L$ and $X_L = \omega L$ (1) Answer = 99 [V] (1) **ecf** on I	1	1		2	2	

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
9		(iii)	Answer = 99 [V] **ecf**		1		1		
		(iv)	Answer = $\frac{99}{30}$ = 3.3 **ecf**		1		1		
		(v)	Decrease R **or** increase L and decrease C (1) Because this increases Q ditto for alternative (1) Because ω depends only on L and C **or** $f = \frac{1}{2\pi\sqrt{LC}}$ (1)			1 1 1	3	1	
	(d)		Basic shape ok (1) Vectors labelled (1) V_L bigger than V_C (1) 	1 1	1		3	1	
			Question 9 total	**6**	**9**	**5**	**20**	**11**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
10	*(a)*	(i)	Continuous background spectrum (1) At least one line spectrum **and** minimum wavelength not at (0,0) (1)	1 1			2		
		(ii)	Rearrangement of $V = \frac{hc}{e\lambda}$ (1) V = 82 500 [V] (1) The energy of the electron is transferred into the energy of the photon (1)	1	1 1		3	2	
	(b)		CT X-ray machine rotates [about the body] **and** produces a 3D image (1) Justification: High radiation [ionizing] dose (1)	1		1	2		
	(c)		At centre B = 1.25 [T] (1) Use of f = 42.6 × 10^6 × 1.25 = 53.22 [MHz] (1) $\lambda = \frac{c}{f}$ = 5.64 [m] (1)	1	1 1		3	3	
	(d)	(i)	Alternating voltage applied (1) To piezoelectric crystal (1)		1 1		2		
		(ii)	Z_1 = 442 and Z_2 = 1 700 × 10^3 (1) f approximately = 1 (1) [Almost] all ultrasound reflected (1) Gel should have a similar impedance (1)		1 1	1 1	4	2	

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
10	*(e)*	(i)	Use of $I = I_0 \exp(-\mu x)$ (1) I = 0.208 [mW cm^{-2}] **and** 0.169 [mW cm^{-2}] (1)	1	1		2	2	
		(ii)	0.208 × 0.08 = 0.017 and 0.169 × 0.12 = 0.020 (1) The tissue 9.8 cm below the skin receives a higher effective dose hence more likely to develop cancer (1)			1 1	2	2	
			Question 10 total	**6**	**9**	**5**	**20**	**11**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
11	*(a)*		Both feet apart and in line (1) Centre of gravity acts between both feet (1)	 1	1		 2		
	(b)		$(T \times 28.5) = (20 \times 9.5) + (560 \times 21)$ i.e. principle of moments applied correctly (1) $T = 419$ [N] (1)	1	 1		 2	 2	
	(c)		Correct selection of equations to determine the time of flight and range (1) Correct method to determine the time of flight and range (1) No.6 iron $x = 186$ [m] (1) No.7 iron $x = 151$ [m] (1) Choose No.7 iron – need conclusion (**no ecf**) (1)	1 1		1 1 1	5	3	
	(d)	(i)	Forces clearly identified as lift, drag and weight (1) Backspin provides more lift or equivalent e.g. air pressure reduced behind the ball (1) Description of ball landing e.g. ball spins back or stops suddenly so ball will not travel far on landing (or roll forward)(1) Well argued conclusion (1)		1 1	1 1	4		
		(ii)	$\omega = 2\pi 50 = 314$ [rad s^{-1}] (1) Correct use of density formula (1) $I = \frac{2}{5} \times 0.046 \times (0.0214)^2$ i.e. correct substitution (1) Rotational KE = 0.4 [J] (1)	 1	1 1 1		4	4	
		(iii)	Angular acceleration $\alpha = 628\,000$ [rad s^{-2}] (1) Using correct equation to determine, torque, $\tau = I\alpha$ (1) Torque $\tau = 529$ [Nm] (1)	 1	1 1		3	2	
			Question 11 total	**6**	**9**	**5**	**20**	**11**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
12	*(a)*	(i)	Object totally or partially immersed in a fluid (accept liquid or gas) is buoyed (accept lifted, upward force, upthrust) by a force equal to the weight of the displaced fluid	1			1		
		(ii)	Volume of whole iceberg replaces submerged volume - negligible effect on sea level (1) Water from ice sheet flows to sea - greater effect on sea level (1)		1	1	2		
	(b)	(i)	$340 \times 2.6 \times 10^{14}$ (1) $= 8.84 \times 10^{16}$ [W] (1)	1	1		2	2	
		(ii)	8.84×10^{16} [W]	1			1		
		(iii)	Correct substitution into $I = \frac{P}{4\pi r^2}$ [1] e.g. $r^2 = \frac{8.84 \text{x} 10^{16}}{170 \text{x} \pi \text{x} 4}$ $r = 6.4 \times 10^6$ [m] [**ecf** on P] (1)	1	1		2	2	

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
12	*(c)*	(i)	**Any 2 x (2) from:** Easily controllable (accept: no chain reaction) (1) Because can switch off protons/hydrogen (1) **Or** No radioactive by-products **or** products are alpha particles (1) Any good relevant detail e.g. no storage costs for thousands of years **or** alpha particles easily contained etc. (1) **Or** Fuel cheaper than fuel for fission (1) Detail e.g. per MJ output, H from the sea, no isotope enrichment needed, selling the He would help pay for the fuel (1) **Or** Fuel supplies would last longer than for fission (1) Detail: sensible remarks about U and H (1)	2		2	4		
		(ii)	30 000 000 × 300 keV (in whatever units) (1) Conversion so that answer and reaction energy in the same units (i.e. 9 million MeV or equivalent e.g. 2.74×10^{-12} and 1.44×10^{-6}J) (1) Comment implying far less energy out than in (1)		1 1	1	3	2	
		(iii)	$7 \times 1.66 \times 10^{-27}$ seen (1) Answer $[\frac{10^{16}}{7u}] = 8.6 \times 10^{41}$ (1)		1 1		2	2	

Question			Marking details	Marks available					
				AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
12		(iv)	Answer (iii) × 17.1 MeV (or its J equivalent 2.74×10^{-12}) (1) Tolerate slips in powers of 10; answer mark will be lost. Previous answer / 5×10^{20} (regardless of mixed units) (1) Answer = 4.7×10^{9} and comment that claim is valid (1)		1 1	1	3	3	
			Question 12 total	**6**	**9**	**5**	**20**	**11**	**0**

COMPONENT 3: LIGHT, NUCLEI AND OPTIONS

SUMMARY OF MARKS ALLOCATED TO ASSESSMENT OBJECTIVES

Question	AO1	AO2	AO3	TOTAL MARK	MATHS	PRAC
1	7	9	4	20	11	0
2	4	11	5	20	10	8
3	1	6	3	10	7	0
4	4	4	6	14	1	10
5	4	2	0	6	3	0
6	4	4	2	10	6	0
7	3	5	2	10	5	0
8	3	4	3	10	0	0
SECTION A TOTAL	**30**	**45**	**25**	**100**	**43**	**18**
9 (option A)	6	9	5	20	11	0
10 (option B)	6	9	5	20	11	0
11 (option C)	6	9	5	20	11	0
12 (option D)	6	9	5	20	11	0
OVERALL TOTAL	**36**	**54**	**30**	**120**	**55**	**18**