GCE AS/A LEVEL

WJEC GCE AS/A LEVEL in

PHYSICS

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SPECIMEN ASSESSMENT MATERIALS

Teaching from 2015

For teaching from 2015

GCE AS and A Level PHYSICS

SPECIMEN ASSESSMENT MATERIALS

Contents

Candidate Name	Centre Number					Candidate Number				
						0				

AS PHYSICS

AS UNIT 1
Motion, Energy and Matter

SPECIMEN PAPER

(1 hour 30 minutes)

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	12	
2.	11	
3.	14	
4.	9	
5.	15	
6.	11	
7.	8	
Total	80	

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 5*(b).*

*Answer **all** questions.*

1. (a) When a net force F pushes a body of mass m through a distance D the body acquires a speed v. The following relationship is proposed:

$$F = \frac{mv^2}{2D}$$

Show that the equation is correct as far as units are concerned. [3]

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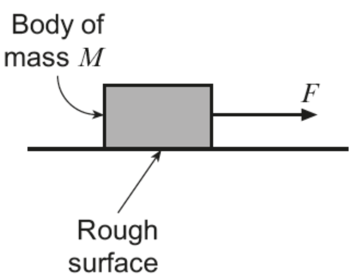
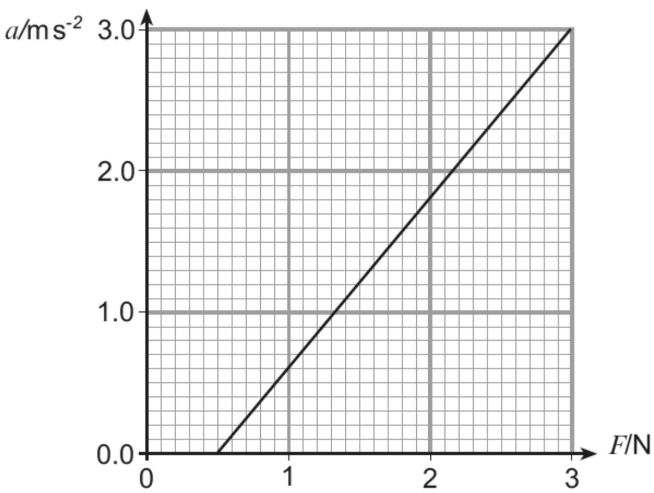
(b) A body of mass M is placed on a rough surface and a horizontal force, F, is applied to it as shown. Data-logging apparatus is used to determine the acceleration of the body for different values of F. The results are shown in the graph.





(i) Explain why the acceleration of the body is 0 when the applied force, F, is less than 0.5 N. [2]

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(ii) Use the graph to determine the value of M. [3]

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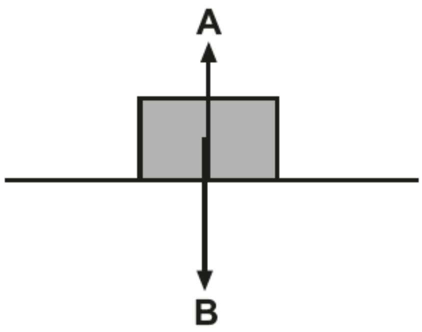
(c) (i) Label forces (A) and (B) acting on the body. [2]



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(ii) State the Newton third law reaction to force (B) and the body upon which it acts. [2]

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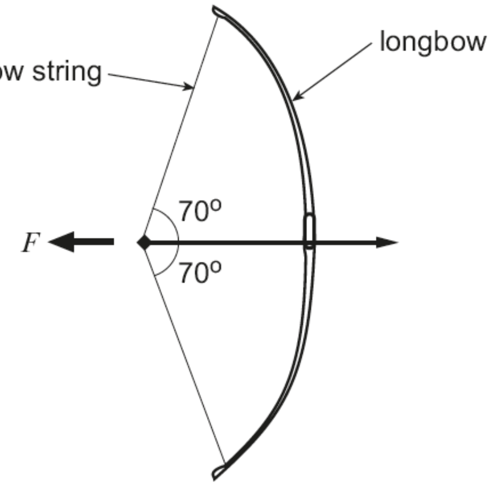
2. *(a)* The medieval longbow used by the Llantrisant bowmen was a devastatingly effective weapon. Assuming that a horizontal force F of 800 N is needed to draw back the bow string, show that the tension T in the string is approximately 1 170 N. [2]



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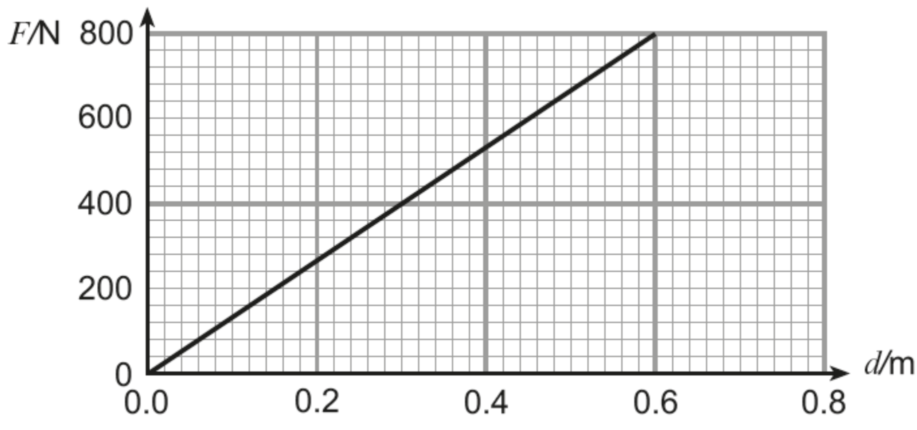
(b) (i) The graph shows the variation of F with d for the longbow, where d is the distance the centre of the string is pulled back. Calculate the energy stored in the bow when the tension in the string is 1 170 N. [2]



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(ii) Hence, **stating any assumptions you make**, show that the speed of the arrow as it leaves the bow is about 100 m s^{-1}. Take the mass of the arrow to be 50×10^{-3} kg. [3]

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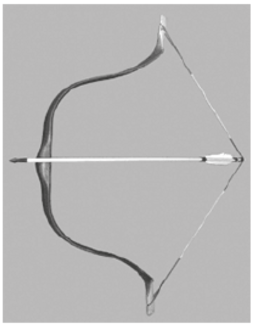
(c) The Turkish war-bow of the 15th and 16th centuries (pictured) was also a fearsome weapon, able to shoot lightweight arrows great distances. A copy of the graph on page 7 is shown below which has included on it a curve to represent the draw force versus 'pull back distance' for a typical Turkish bow.



Use the graph to compare the effectiveness of the Turkish bow in relation to the longbow. Your answer could refer to the ease of use of each bow, the energy stored and the effect this has on the motion of an arrow.
Calculations are not required. [4]

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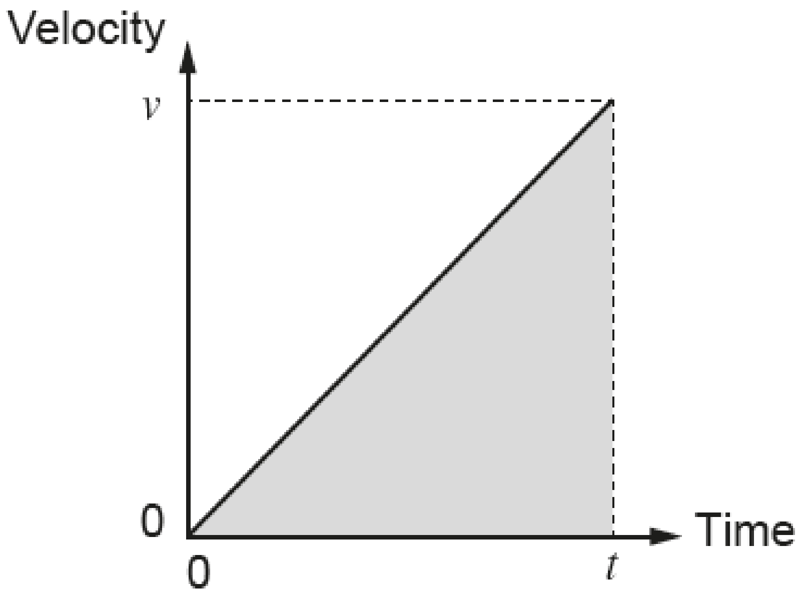
3. *(a)* A velocity-time graph is given for a body which is accelerating from rest in a straight line.



(i) Use the graph to show that, using the usual symbols: [3]

$$x = ½at^2$$

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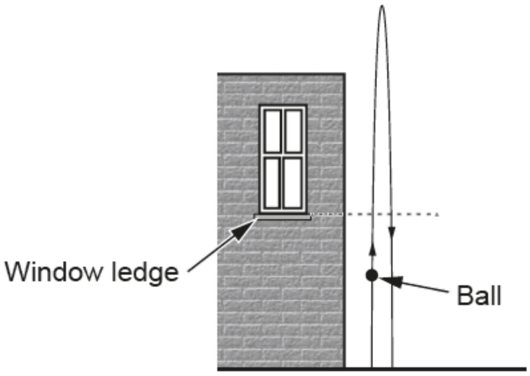
(ii) An actual car starts to accelerate uniformly but then air resistance increases and decreases its acceleration. Sketch a graph of the expected motion of the car **on the above graph.** [1]

(b) Iestyn throws a ball vertically upwards at Castell Coch and it passes a window ledge 0.3 s after being released. It passes the window ledge on its way back down, 1.6 s **later** (i.e. 1.9 s after being released). *Ignore the air resistance*.



(i) Determine the time of flight of the ball. [1]

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(ii) Calculate the initial velocity of the ball when it is released. [3]

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(iii) Calculate the height of the window ledge above the ground. [2]

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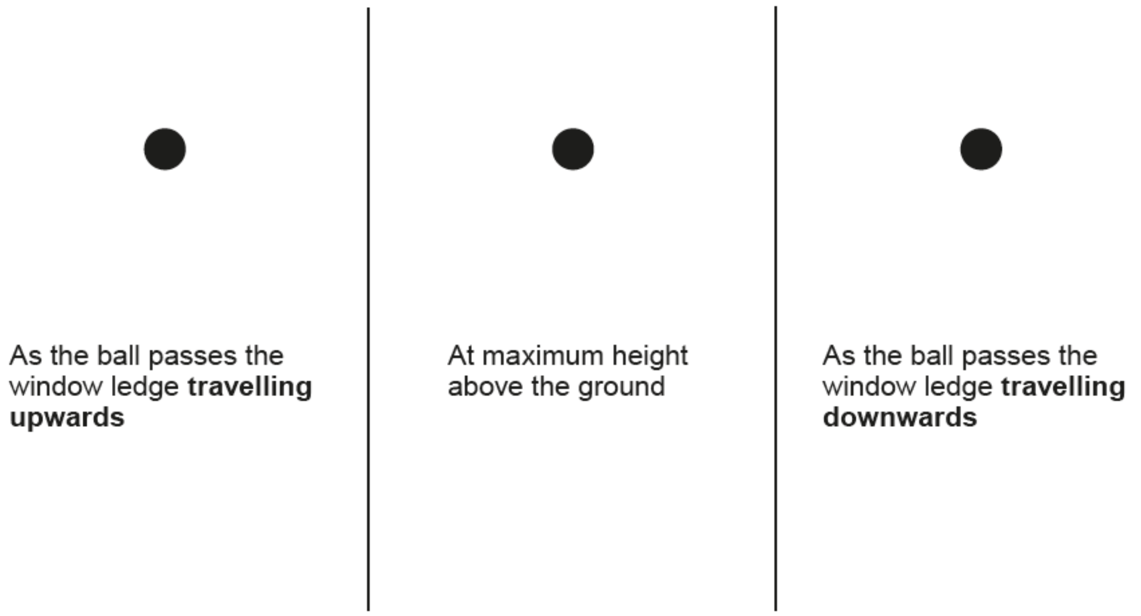
(c) In reality, air resistance also acts on the ball. In the spaces provided draw **three** free body diagrams showing the forces acting on the ball at the positions indicated. **Label** these forces. [4]

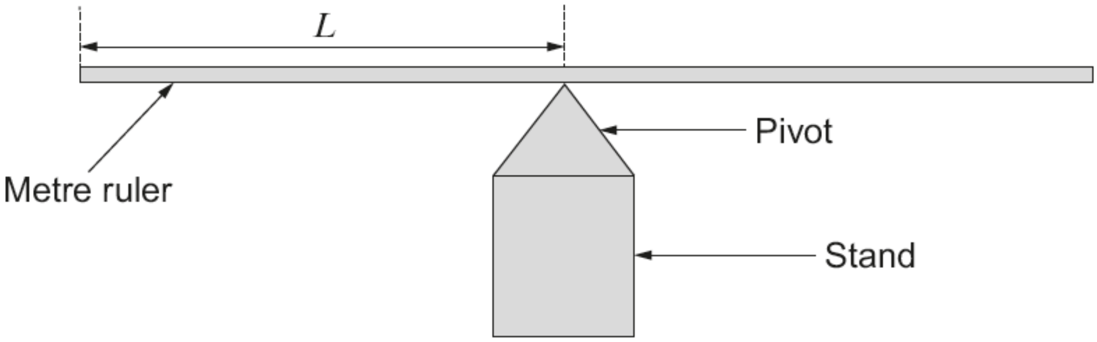


14

4. *(a)* A student uses the following apparatus to determine the mass of a small metal ball bearing.

- A metre ruler
- A tall pivot and stand
- A 0.2 N weight
- A test tube, into which the ball bearing can be placed

The apparatus is set up as shown.



(i) The ruler is adjusted until it is balanced at its Centre of Gravity. State what is meant by '*Centre of Gravity*'. [1]

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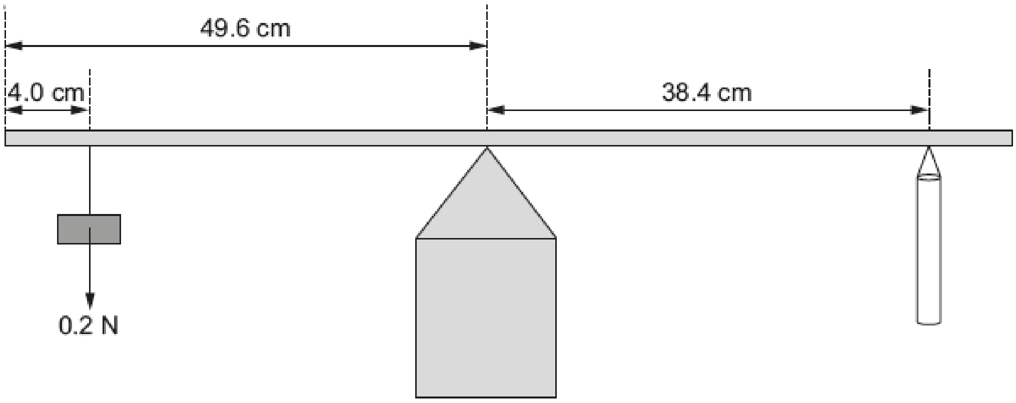
(ii) The length L at balance is found to be 49.6 cm. With the ruler at balance the 0.2 N weight is suspended 4.0 cm from the left hand end and the empty test tube is suspended a distance of 38.4 cm from the pivot so as to keep the ruler balanced. This is shown below.



The ball bearing is placed inside the test tube and the above procedure is repeated, keeping the 0.2 N weight a distance of 4.0 cm from the left hand end. The ruler is again balanced, this time with the test tube containing the ball bearing suspended a distance of 24.5 cm from the pivot.

Show, in clear steps, that the **mass** of the ball bearing is approximately 14 grams. [4]

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(b) The student measures the diameter of the ball bearing to be 1.50 cm. Use this information and the information in the table to determine the material of the ball bearing. Justify your answer. [4]

Material	**Density / kg m^{-3}**
Aluminium	2 800
Iron	7 950
Copper	8 900
Lead	11 300

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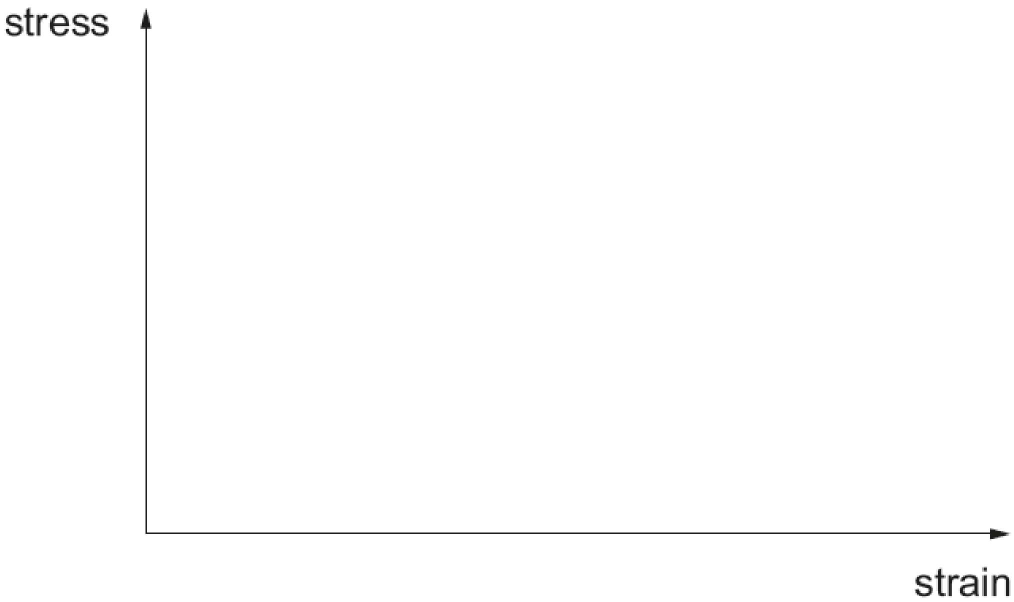
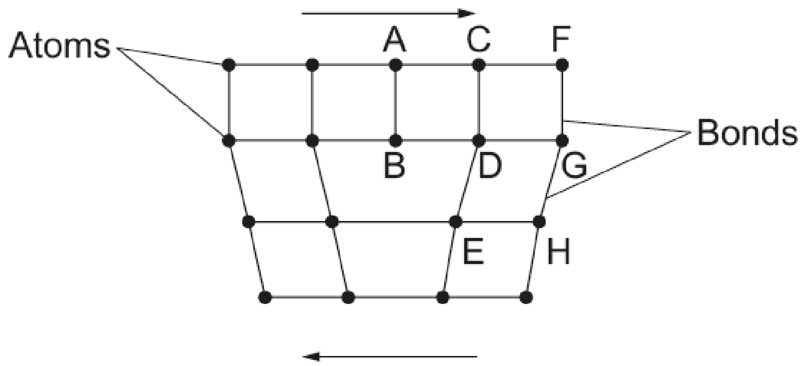
5. *(a)* Sketch a typical stress-strain graph for the stretching to breaking point of a malleable metal such as copper. Label on your graph:

(i) the elastic limit;
(ii) the yield point;
(iii) the region of plastic deformation. [4]



(b) The diagram shows the arrangement of atoms in a metal crystal in the region of a dislocation.



Explain how plastic deformation takes place in ductile metals when forces are applied as shown by the arrows. Explain how the addition of a foreign atom affects this process. [6 QER]

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(c) A student obtains the following values and uses them to determine the tensile stress in a metal wire:

Tension in wire = 122 ± 2 N

Cross-sectional area = 0.64 ± 0.08 ($\times$ 10^{-6}) m^2

(i) Determine the tensile stress in the wire. [1]

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(ii) By considering the uncertainties in the measurements, determine the maximum and minimum possible values of the tensile stress. [2]

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(d) The student repeats this experiment with a much thicker wire and using a force of approximately 1 000 times greater. Evaluate the associated benefits and risks of this additional experiment. [2]

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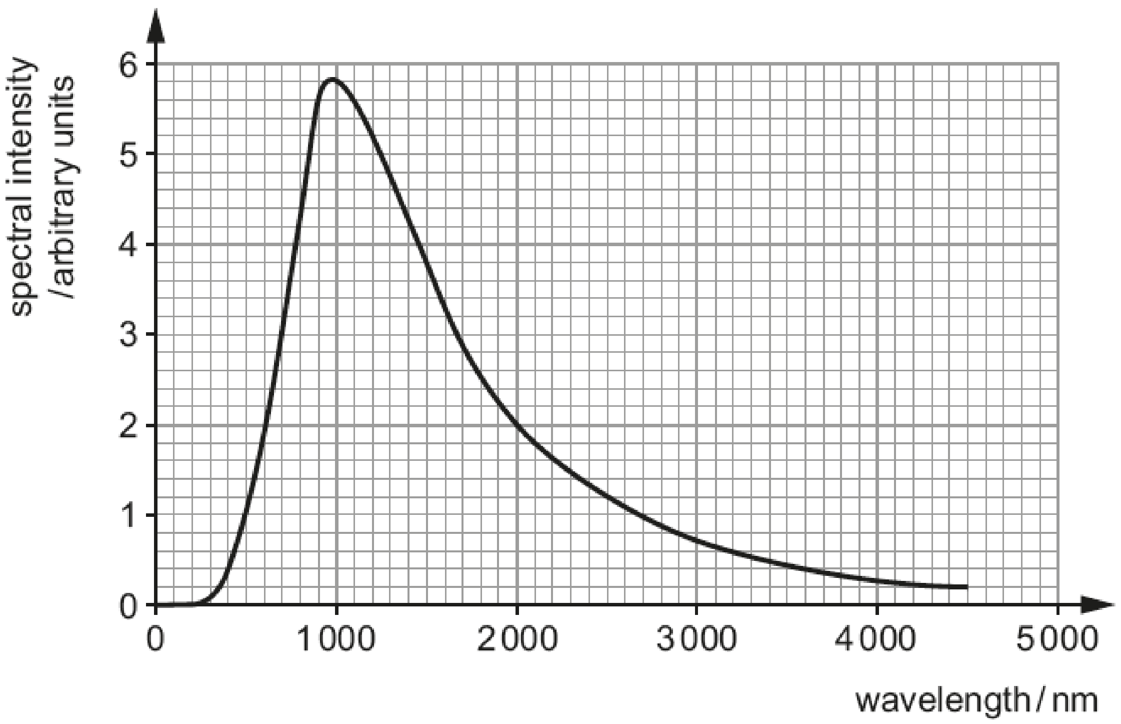
6. The nearest star to the Sun is a ‘red dwarf’, *Proxima Centauri*. The graph shows its spectrum.



(a) Use the data to show clearly that the temperature of the star is about 3000 K. [3]

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(b) The range of visible wavelengths is 400 nm – 700 nm.

(i) Explain why you would expect *Proxima Centauri* to be ‘red’. [1]

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(ii) Name the region of the electromagnetic spectrum containing most of the power radiated. [1]

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(iii) Astrophysicists believe that *Proxima Centauri* will become hotter in the distant future. Estimate the temperature it would have to reach in order for the intensity of its radiation to be roughly the same at each end of the **visible** region of the spectrum (so the star appears white). Show your working clearly. [3]

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(c) Use Stefan's law to calculate the total power of electromagnetic radiation emitted from *Proxima Centauri* (at its present temperature) if its effective radius is 1.01×10^8 m. [3]

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7. *(a)* An electron and a positron can annihilate (destroy) each other, in this interaction:

$$e^- + e^+ \rightarrow \gamma + \gamma$$

(i) Explain how lepton number is conserved in this interaction. [2]

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(ii) State which force (strong, weak or electromagnetic) is involved in this interaction, giving a reason for your answer. [1]

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(b) A proton and an antiproton can annihilate each other, in this **strong** interaction:

$$p + \bar{p} \rightarrow \pi^+ + x$$

By applying conservation rules, suggest the identity of particle x. [2]

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(c) The π^+ is unstable. It can decay, thus:

$$\pi^+ \rightarrow y + \nu_e$$

(i) Identify y. [1]

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(ii) Which force is involved? [1]

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(d) Show below, as an equation, how the π^- might decay. [1]

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Candidate Name	Centre Number					Candidate Number				
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AS PHYSICS

AS UNIT 2
Electricity and Light

SPECIMEN PAPER

(1 hour 30 minutes)

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	13	
2.	12	
3.	10	
4.	11	
5.	12	
6.	10	
7.	12	
Total	80	

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 7*(c).*

*Answer **all** questions.*

1. (*a*) A student wishes to investigate how the potential difference, V, across a battery depends on the current, I, it is supplying. In effect, she is investigating the equation: $E = V + Ir$. Draw a diagram of a circuit she might use. [2]

(*b*) The student's measurements are plotted on the graph below.
Describe briefly what the student did to obtain the measurements. [1]

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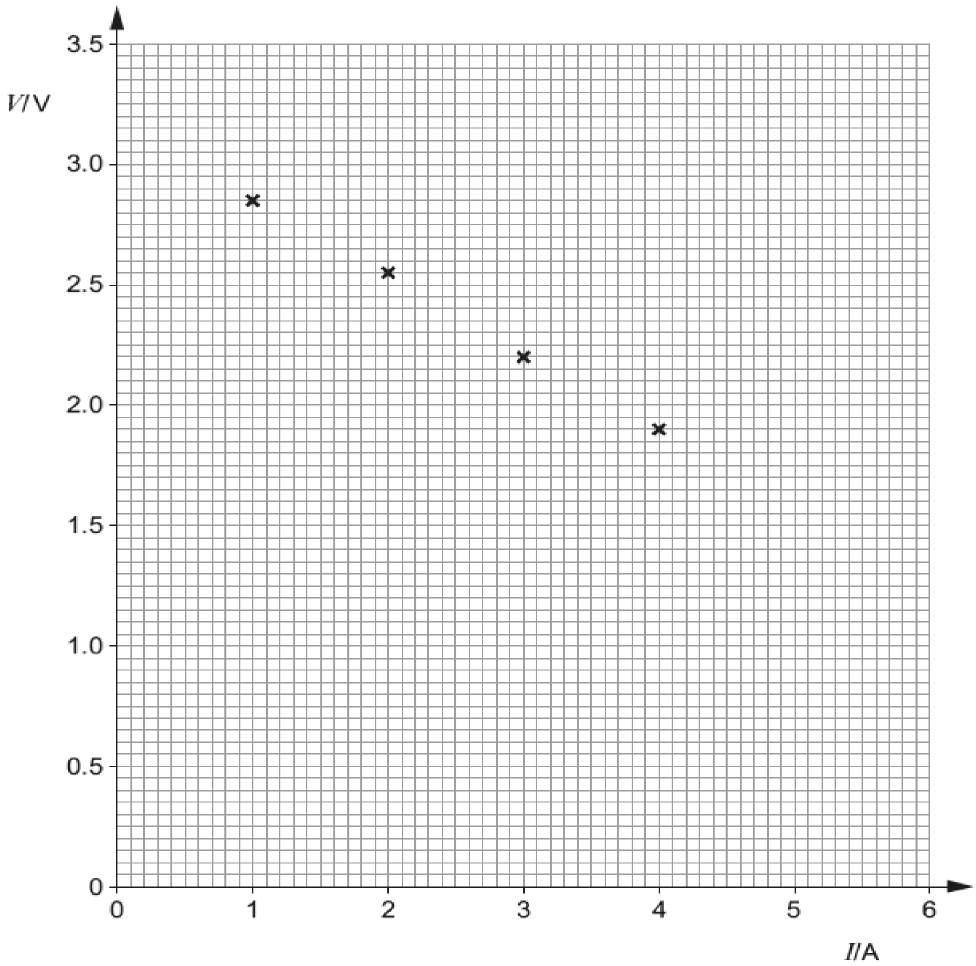

(*c*) (i) Draw a line of best fit on the graph on page 22 and determine the y-intercept and gradient. [3]

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(ii) State what properties of the battery these represent: [2]

(I) gradient;

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(II) y-intercept.

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(*d*) Comment on the quality and adequacy of the data obtained. [2]

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(e) In a separate experiment the student connects a voltmeter across the battery and measures a pd of 3.20 V. She then connects a 1.50 Ω resistor across the battery and measures the pd to be 2.62 V. Investigate whether or not these readings are consistent with your results from part (*c*). [3]

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2. *(a)* State Ohm's law in terms of current and potential difference. [2]

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(b) To operate correctly, a light emitting diode (LED) requires a pd of 1.8 V across it. The current through it is then 15 mA.

In order to run the LED correctly using a 6.0 V supply, a series resistor, S, is needed. Calculate the resistance of S. [3]

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(c) (i) Calculate the drift velocity of free electrons through an aluminium wire of **diameter** 1.80 mm when there is a current of 3.00 A through the wire. [Note: 1.00 m^3 of aluminium contains 6.02×10^{28} aluminium atoms, each of which contributes 3 free electrons.] [3]

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(ii) State what current there would have to be in an aluminium wire of diameter 3.60 mm, for the drift velocity to be the same. [1]

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(d) Calculate the pd which must be applied across a 70.0 m length of aluminium wire of diameter 1.80 mm in order to produce a current of 3.00 A. [Resistivity of aluminium = $28.2 \times 10^{-9}\ \Omega\,\text{m}$] [3]

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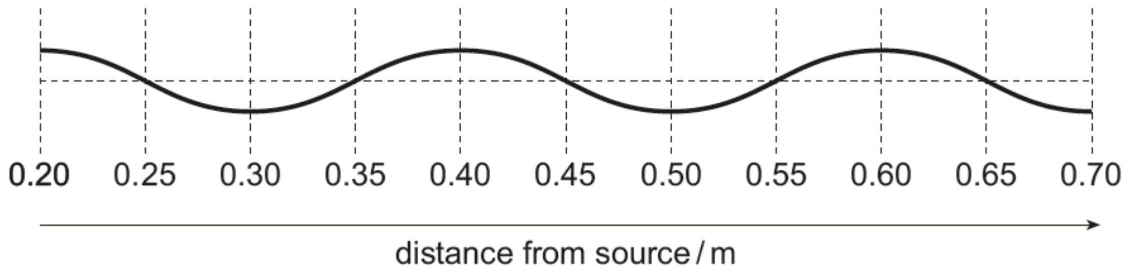
3. *(a)* A transverse wave is travelling from left to right along a stretched string. The diagram shows part of the string at one instant.



(i) The frequency is 50 Hz.

(I) Calculate the speed of the waves. [2]

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(II) Calculate the time taken for 1 cycle of oscillation. [1]

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(III) **On the diagram above**, draw the string at a time of 0.005 s later. [2]

(ii) Explain why the waves are called transverse. [2]

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(b) It is also possible to set up a stationary wave on a stretched string. Describe how progressive waves and standing waves differ in regard to:

(i) transfer of energy along the string; [1]

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(ii) **variation** of amplitude with distance along the string. [2]

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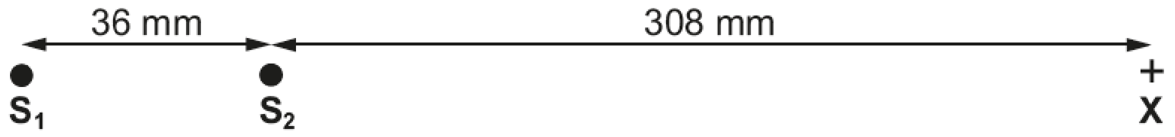
4. *(a)* In the set-up shown below, the in-phase sources, **S_1** and **S_2**, are emitting, in all directions, microwaves of wavelength 12 mm.



(i) State what is meant by *in-phase sources*. [1]

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(ii) Justify whether there is constructive interference, destructive interference or neither at **X**. [2]

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(iii) Discuss whether or not the observed signal strength would change if a microwave detector were moved to the right, from point **X**. [2]

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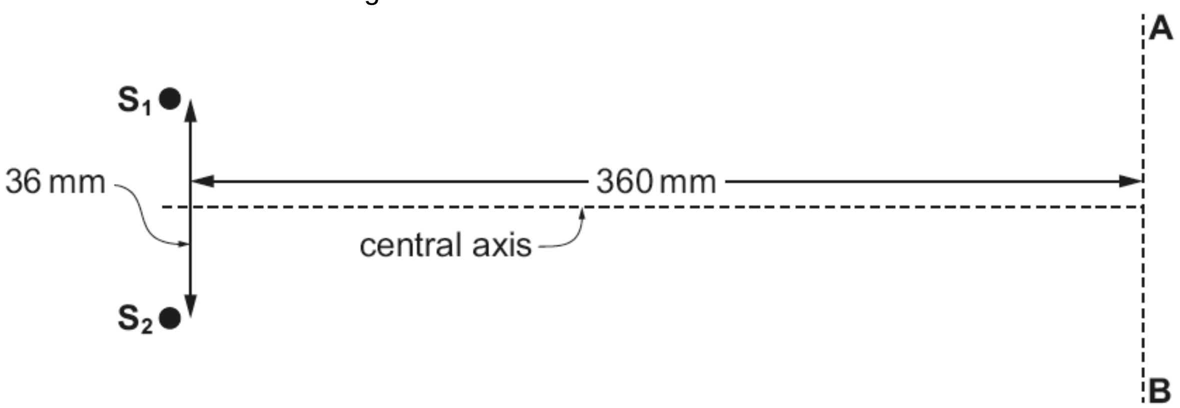
(b) The same microwave sources are now arranged as shown, and the detector is moved along the line **AB**.



Use the equation for double slit interference to determine the approximate spacing between points of maximum microwave intensity. [2]

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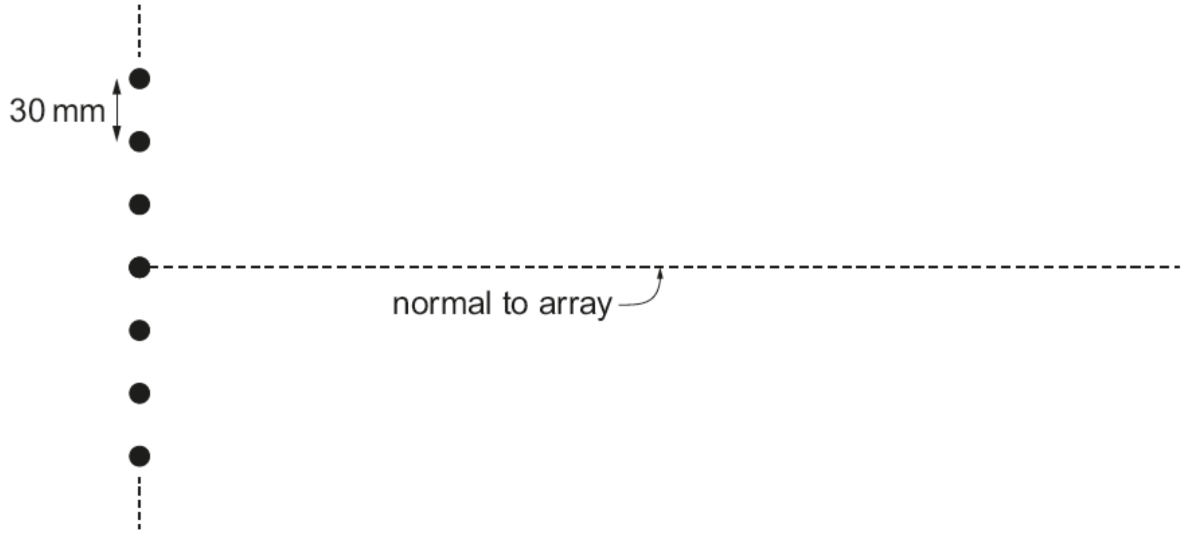
(c) An 'array' of regularly spaced, in-phase wave sources produces an interference pattern similar to that of a diffraction grating, that is sharply defined beams (maxima) of waves at specific angles to the normal.

In the array shown the sources emit waves of wavelength 12 mm.



Determine all the angles to the normal at which beams (maxima) occur. [4]

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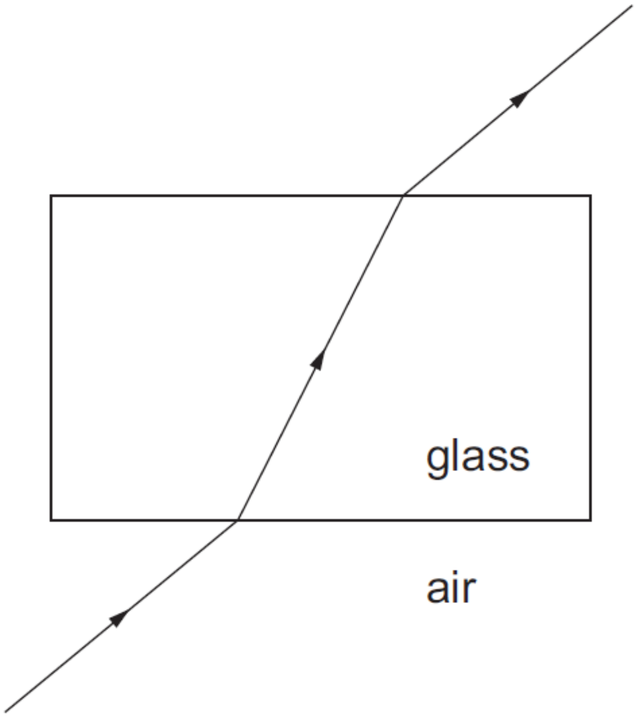
5. The diagram shows the path of a narrow beam of light through a glass block.



(a) The diagram shown is drawn to scale. By measuring suitable angles, calculate the refractive index of the block. [3]

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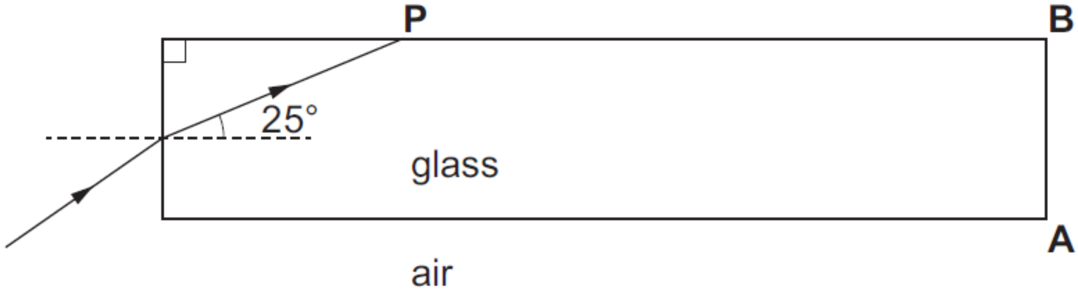
(b) The diagram shows a narrow beam of light entering a solid block of glass of refractive index 1.52.



(i) The beam does not emerge into the air at **P**. Justify this statement. [3]

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(ii) Carefully **complete the path** of the beam, showing it eventually reaching the face **AB**, emerging into the air and travelling through the air. [1]

(iii) **Indicate clearly on the diagram** sections of the **whole** path that are parallel to each other. [2]

(c) (i) Explain what is meant by *multimode dispersion* in optical fibres, and what causes it. [2]

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(ii) Explain why multimode dispersion prevents the accurate transmission of data as a rapid stream of pulses through a long 'thick' fibre. [1]

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6. *(a)* (i) The work function of caesium is 3.0×10^{-19} J. Explain what this statement means. [1]

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(ii) Calculate the frequency of radiation needed to eject electrons of maximum kinetic energy 6.0×10^{-19} J from a caesium surface. [2]

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(iii) **Explain** in terms of photons what effect, if any, increasing the intensity of this radiation would have on the number of electrons ejected per second, and on their maximum kinetic energy. [3]

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(b) In 1902, Einstein's equation: $E_{k\,\max} = hf - \phi$ was revolutionary because it gave strong evidence for light behaving as particles. Explain why this theory was controversial in 1902, but is now accepted as standard pre-university physics. [4]

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7. *(a)* A laser emits light with a photon energy of 3.14×10^{-19} J.

(i) Calculate the wavelength of the light. [2]

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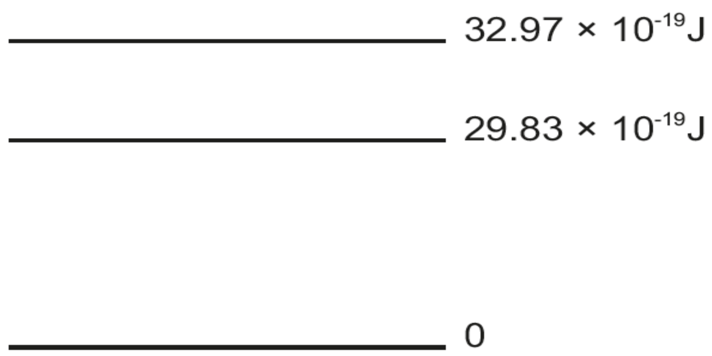
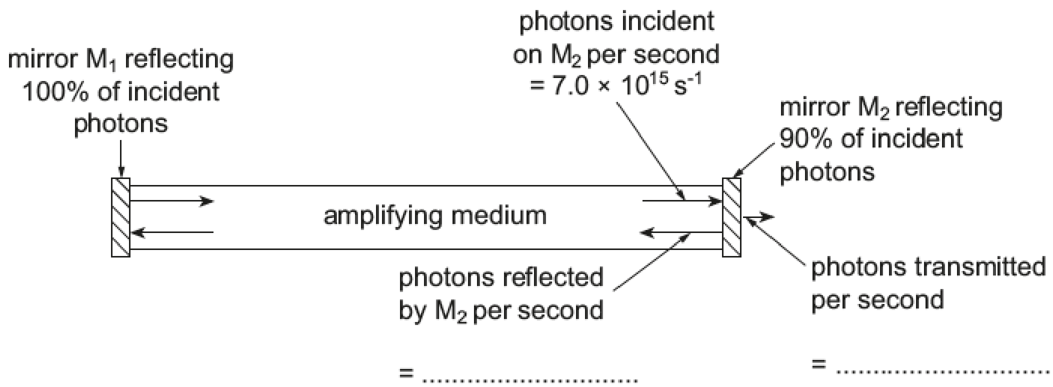
(ii) A simplified energy level diagram for the amplifying medium of the laser is given. **Add an arrow** to show the transition giving rise to these photons. [1]



(b) The (simplified) diagram shows the cavity of the laser.



(i) Mirror M_2 is only partially reflecting. The light that it does not reflect is transmitted through it.
Complete the diagram to show the numbers of photons per second reflected and transmitted. [1]

(ii) Calculate the power output of the laser. [2]

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(c) Explain how a laser works. [6 QER]

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Candidate Name	Centre Number					Candidate Number				
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A LEVEL

PHYSICS

A2 UNIT 3
Oscillations and Nuclei

SPECIMEN PAPER

(2 hours 15 minutes)

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1.**	12	
	2.	18	
	3.	8	
	4.	12	
	5.	8	
	6.	16	
	7	6	
Section B	**8.**	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 question 8*(a).*

SECTION A

*Answer **all** questions*

1. *(a)* According to the kinetic theory of gases, the pressure, p, of a gas in a container of volume V is given by:

$$pV = \tfrac{1}{3} Nm\overline{c^2}$$

(i) State the meaning of: [1]

N ....

m ....

(ii) Hence show clearly that an equivalent form of the equation is: [2]

$$p = \tfrac{1}{3} \rho\overline{c^2}$$

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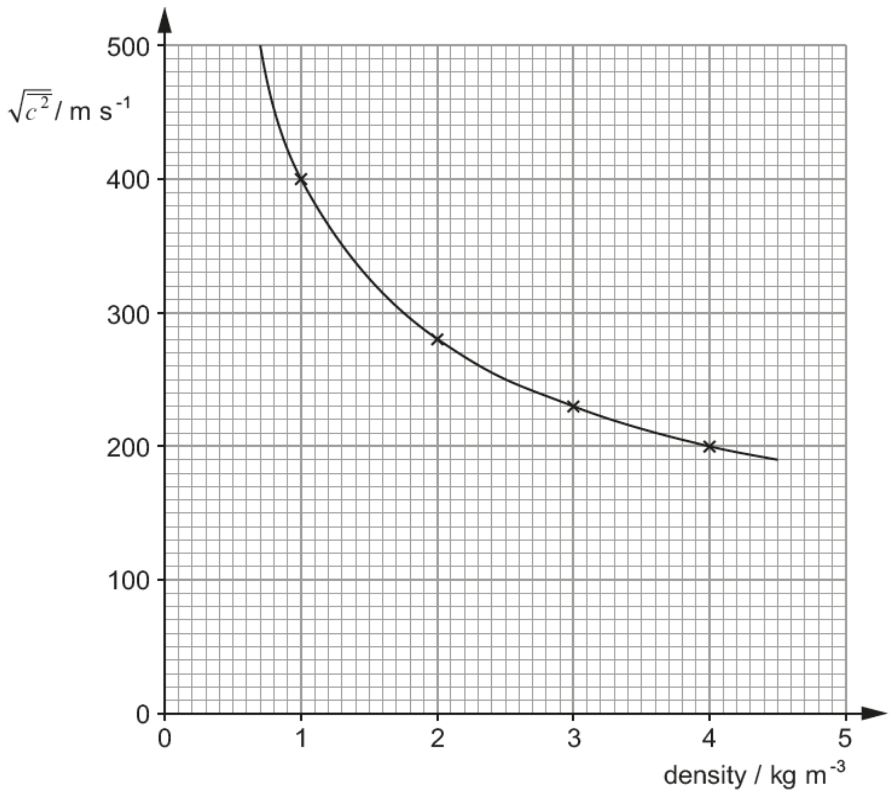
An experiment is carried out at constant pressure. The rms speed of molecules is obtained for gases of different density. The following results are obtained.



(iii) Explain briefly whether or not the results agree with the equation:

$$p = \tfrac{1}{3}\rho\overline{c^2}$$ [3]

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(b) A cylinder of volume 0.050 m^3 contains 0.025 kg of helium gas (relative molecular mass 4.00) at a pressure of 3.0×10^5 Pa. Calculate:

(i) the rms speed of the molecules; [2]

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(ii) the mean kinetic energy per molecule. [4]

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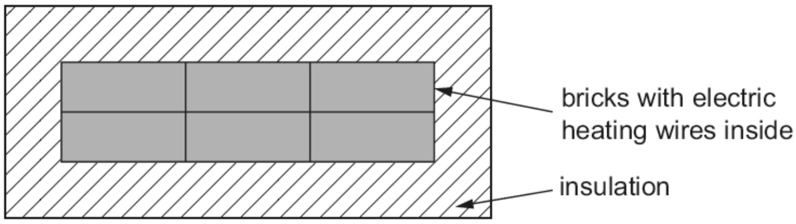
2. *(a)* In an electric storage heater, special bricks are heated overnight by passing electric current through wires embedded in the bricks. The bricks are surrounded by thermal insulation.

PLAN



The wires convert energy at a rate of 2.0 kW for a time of 7.0 hours. During this time the temperature of the bricks rises from 20 °C to 320 °C. The total mass of the bricks is 84 kg and their specific heat capacity is 1 600 J kg^{-1} $°C^{-1}$.

The makers of the heater claim that less than a quarter of the energy supplied is given off as heat during the 7.0 hour overnight period. Investigate this claim, setting out your reasoning and calculations clearly. [6]

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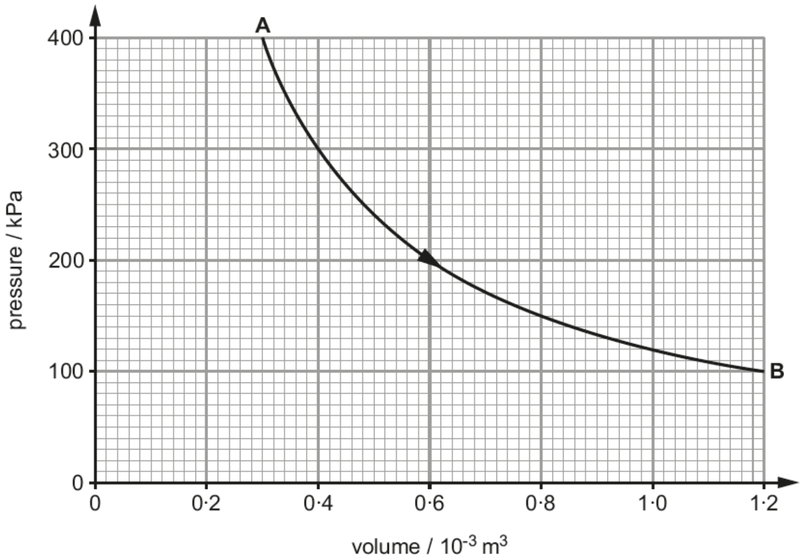
(b) 0.050 mole of helium gas is contained in a cylinder fitted with a leak-proof piston. The piston moves slowly outwards, resulting in the variation of pressure shown in the graph.



(i) Verify that the temperature of the gas does not change, and calculate this temperature. Evaluate to what extent the curve is a true isothermal. [5]

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(ii) By approximating the curve on the graph to a straight line, or by any other method, calculate approximately how much work is done by the gas as it expands from A to B, explaining whether your result is likely to be too high or too low. [4]

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(iii) The first law of thermodynamics may be written as:

$$\Delta U = Q - W$$

State the meanings of: [1]

ΔU ....

Q ....

W ....

(iv) State the values of these terms (ΔU, Q, W) for the expansion AB (your answer to *(b)*(ii) should be one of these. [2]

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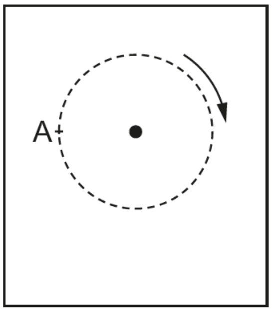
3. The drum of a washing machine is a hollow perforated cylinder with an inside radius of 0.45 m. On its 'spin cycle' it rotates (about the axis of the cylinder) at a rate of 2 400 revolutions per minute.



LOOKING FROM THE FRONT

(a) Calculate the angular velocity of the drum in radians per second. [2]

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(b) (i) Calculate the force that must act on a wet sock of mass 0.080 kg in contact with the cylinder wall. Neglect gravitational forces. [2]

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(ii) Investigate whether or not it is justifiable to neglect gravitational forces. [2]

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(c) (i) State the direction of the force on the sock. [1]

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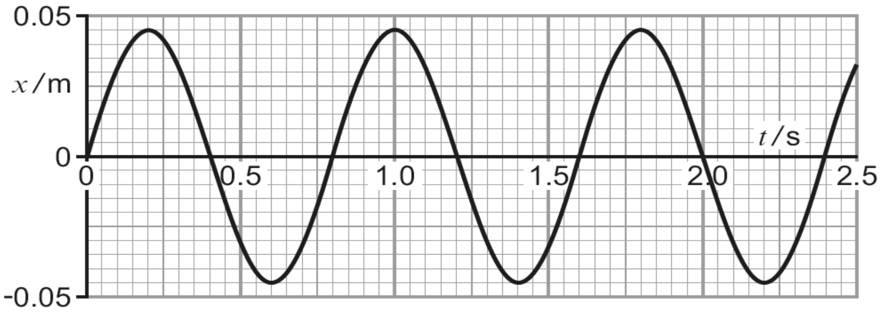
(ii) A water drop escapes through a hole in the cylinder at A. **Draw on the diagram** the first part of the path of the drop when it is free of the cylinder. [1]

8

4. A graph of displacement (x) against time (t) is given for a body performing simple harmonic motion in a vertical direction.



(a) Consider the body at a time of 0.10 s. Use the graph to determine the next time at which the body achieves the same:

(i) speed; .... [1]

(ii) velocity. .... [1]

(b) The relationship between x and t is of the form: $x = A\sin(\omega t + \varepsilon)$. Use the graph to determine the values of:

(i) A .... [1]

(ii) ω .... [2]

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(iii) ε .... [1]

(c) (i) **Sketch, on the same grid** as the graph above, a graph of acceleration against time for the body. No scale is needed on the vertical (acceleration) axis. [2]

(ii) A grain of sand is placed on top of the body when it is at its lowest point. Investigate whether or not it will separate from the body as it oscillates. [4]

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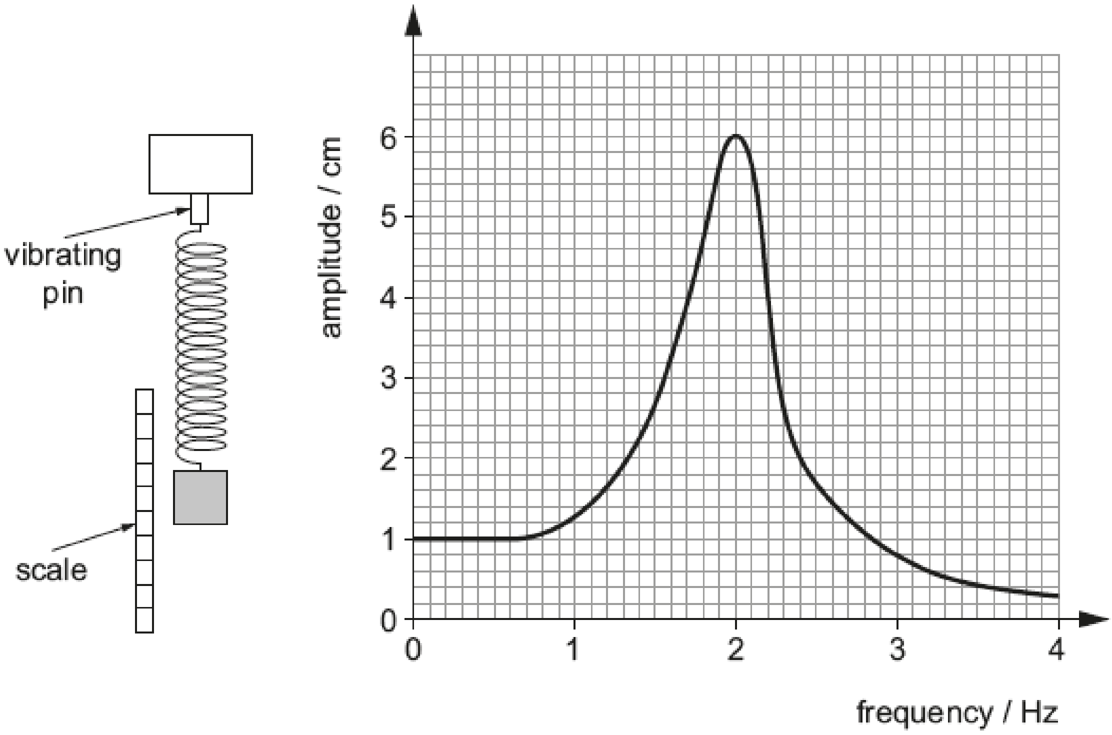
5. A helical spring, loaded with a mass of 0.10 kg, hangs from the moving pin of a vibration generator which is powered by a signal generator. The amplitude of the (vertical) oscillations of the mass is measured at several frequencies of the vibration generator. The results are shown in the graph.



(a) Explain what is meant by resonance in a mechanical system. [2]

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(b) Determine the spring stiffness, k (the force per unit extension). [4]

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(c) Suppose that the experiment were now to be repeated with greater damping on the mass-spring system. Sketch on the same grid a possible new graph of amplitude against frequency. [2]

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6. Radon gas ($^{222}_{86}\text{Ra}$) is radioactive and can be a significant health hazard in some areas of Mid Wales that have a high natural concentration of the gas. Radon decays to a stable form of lead (Pb) via 4 alpha decays and 4 beta decays and radon has a half-life of 3.8 days.

(a) (i) Calculate the mass number and atomic number of this stable isotope of lead (Pb). [2]

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(ii) Radon gas is known to be carcinogenic because it caused increased cancer rates in an experiment carried out on rats. State some benefits and ethical issues related to this experiment. [3]

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(b) Calculate the time taken for the number of radon gas particles to decrease to 9.0% of their initial number. [4]

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(c) When radon gas is kept in a lead lined container for 3.8 days, the number of radon gas particles halves. However, the activity inside the container is considerably higher than half the original activity. Suggest a reason why. [1]

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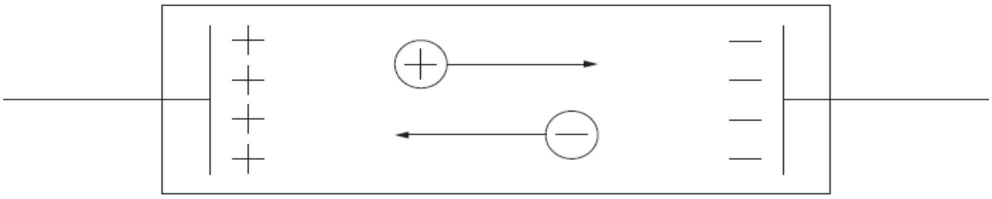
(d) The radon gas produces 250 alpha particles in a detector per second. Each of these alpha particles produces 1.15×10^6 ionised molecules on average. These ions provide a current between the plates. Calculate this current, stating any assumption that you make. [3]



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(e) $^{222}_{86}\text{Ra} \rightarrow {}^{218}_{84}\text{Po} + {}^{4}_{2}\text{He} + 5.59\text{ MeV}$

When a radon-222 nucleus emits an alpha particle the energy emitted in the reaction is 5.59 MeV. Calculate the mass of a polonium-218 nucleus to 7 significant figures. [3]

(mass of $^{222}_{86}\text{Ra}$ nucleus = 221.9773 u; mass of $^{4}_{2}\text{He}$ nucleus = 4.0015 u; 1 u = 931 MeV)

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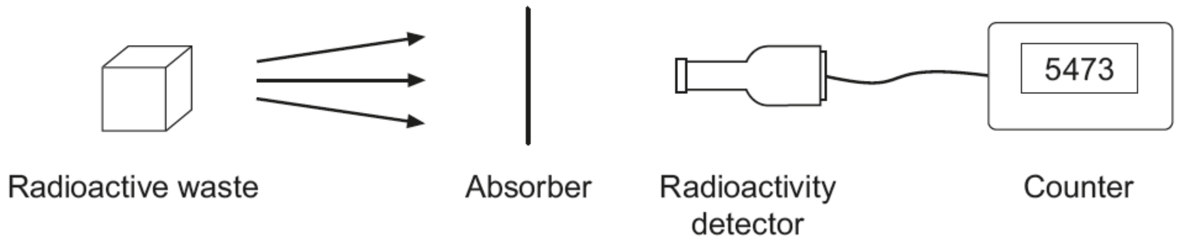
7. A student devises an experiment to determine which radiations α, β, and γ are emitted by a sample of radioactive waste. The student measures and records the detected count rate using the set-up below.



The results obtained are summarised in the table.

Absorber	**Count rate / s^{-1}**
None	8 894
3 sheets of paper	5 473
None	8 921
0.5 mm of aluminium foil	5 455
None	8 860
10 cm of lead	439
None	8 888

(a) Explain which types of radiation are present in the radioactive waste. [4]

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(*b*) Suggest two reasons why the student measured the count rate without an absorber several times. [2]

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SECTION B

*Answer **all** questions*

Read through the following article carefully.

Freely adapted from:

What If I Double It?
By Thomas Humphrey

Why does size matter?

To find out more, let's cook a turkey.

Suppose you are responsible for cooking a turkey. You have a 9 kg turkey, but your cookbook only tells you how long it takes to cook a 4·5 kg turkey.

How long do you cook your turkey?

Since the 9 kg turkey is twice the size of a 4·5 kg bird, at first the answer might seem obvious. Simply double the cooking time suggested for a 4·5 kg turkey. But is that really the right thing to do?

The way I see it, there are three ways to answer this question:

- *(a)* you can call and ask your grandmother;
- *(b)* you can get a new cookbook;
- *(c)* you can thumb through your physics books for the turkey equation.

I began by gathering cookbook data. My cookbook says that when you double the weight of a turkey, you don't have to double the cooking time. You only have to increase it from 4 hours for the small bird to 6 ½ hours for the big one. So even though the 9 kg turkey is twice the weight of the 4·5 kg turkey, you only have to cook it about 1·6 times as long. Why would that be?

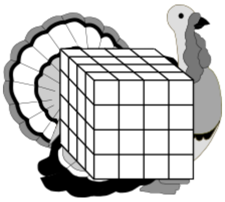
Let's take a more detailed look at our question. What is the "it" that we are doubling? What kind of "its" does a turkey have?

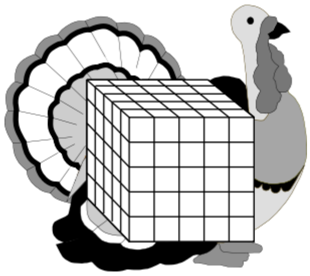
The turkey has a width, a surface area, a volume, and a weight. It has a density, a thermal conductivity (how well it transfers the oven's heat into its interior), and a specific heat capacity (how much heat it needs to climb one degree Celsius in temperature). A turkey has a lot of "its." How do some of these factors change in going from a 4·5 kg turkey to a 9 kg turkey?

Let's imagine that my turkey is shaped like a cube. This will make it easier to see how the various factors change.

Take a look at the cubical turkeys on the next page. Try to figure out how the weight, surface area, and width differ. If you count the number of small cubes in the 4·5 kg turkey, you will find that there are 4 × 4 × 4, or 64 cubes. The number of cubes in the 9 kg turkey is 5 × 5 × 5, or 125 cubes. That's not exactly double, but it's pretty close. So now we know that the 9 kg cube turkey is about twice the volume of the 4·5 kg cube turkey (that is, it has twice as many little cubes), and therefore it weighs about twice as much.

But when you double the size of a turkey, what happens to its width and surface area? Do they double, too?





If you look at the cube turkeys above, you can see that the widths of the two turkeys are 4 and 5 blocks respectively. So the bigger turkey is about 25 percent wider than the smaller one. It did not double.

If we look at surface area, the small turkey has 6 sides × 16 blocks per side, or 96 blocks. The surface area of the big turkey has 6 sides × 25 blocks per side, or 150 blocks. That means the big turkey has about 50 percent more blocks in it than the small turkey. So that measurement didn't double, either. More precisely, on a real turkey, the width and all the other linear dimensions increase by a factor of 1·26 and the surface area increase by a factor of 1·59.

How do some of these "its" – weight, surface area, and thickness – influence the turkey's cooking time?

Well, first of all, the 9 kg turkey, because it has doubled in volume, has twice as much stuff (including stuffing) to heat up, so we need to put twice as much heat into it. Fair enough. How does the heat get in? It is transferred across the surface of the turkey, and it must travel all the way into the centre of the bird. The bigger turkey has more surface. That should speed up the transfer of heat, but the heat must travel a longer way to the centre. That will slow things down. The net result is that it doesn't take twice as long to cook the twice-as-heavy turkey. The physicists agree with the home economist.

Increase in cooking time If you put the three factors together, the cooking time increases by 2 × 0·63 × 1·26 = 1·59. (4 hrs. × 1·59 = 6·4 hrs.) My cook book says to increase the time to 6·5 hours, or by a factor of 1·62. (6·5 hrs. / 4 hrs. = 1·62). That's pretty close!

So now we know how to cook a turkey. But in this little foray into the physics of cooking we discovered that the seemingly innocuous question, "What happens if you double it?" has turned out to be quite complex. We must be very specific about which feature of the turkey we are doubling because we don't seem to be able to double everything at once!

The fact that we cannot double every feature of the turkey at the same time is one example of a very general behaviour in nature, a behaviour that leads to consequences even more important than the difference between a perfect turkey and an overcooked one. When we compare similar objects, one large and one small, not all features of the object are magnified or reduced by the same ratio. This has dramatic consequences for natural behaviour.

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

   (a) Explain how the three factors of weight (mass), surface area, and thickness affect the cooking time of the turkey. Include in your answers scientific reasons for these variations (see lines 42-47). [6 QER]

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   (b) An important factor is missing from the explanation of specific heat capacity. Modify the statement to make it accurate (lines 21-22). [1]

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   (c) The smaller (4.5 kg) turkey has a width of 22 cm. Calculate the width of the larger (9.0 kg) turkey (lines 36-40). [1]

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   (d) The larger turkey (9.0 kg) has a surface area of 0.46 m^2. Calculate the surface area of the smaller (4.5 kg) turkey (lines 36-40). [1]

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(e) The turkeys are considered to be cooked when their mean temperature has risen 90 ^{o}C.

(i) How much thermal energy does this require for the 9.0 kg turkey? (Specific heat capacity of turkey = 3 200 J kg $^{o}C^{-1}$.) [2]

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(ii) The electrical power supplied to the cooking oven was 2 200 W. If all this energy was transferred as thermal energy to the turkey, how long should the 9.0 kg turkey have taken to cook? [2]

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(iii) Why is there such a large difference between the answer to *(e)*(ii) and the time given in the passage? [2]

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(iv) Determine the efficiency of the cooking process for the 9.0 kg turkey. [2]

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(v) Would you expect the efficiency of the cooking process for the 4.5 kg turkey to be greater than, less than or the same as that of the 9.0 kg turkey? Justify your answer using data from the article. [3]

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	Centre Number					Candidate Number				
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A LEVEL

PHYSICS

A2 UNIT 4
Fields and Options

SPECIMEN PAPER

(2 hours)

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1.**	10	
	2.	9	
	3.	11	
	4.	10	
	5.	12	
	6.	14	
	7.	14	
Section B	Option	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.

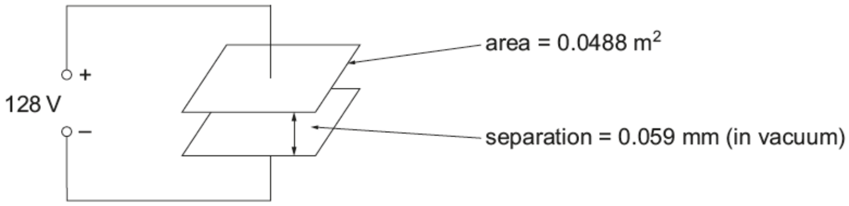
INFORMATION FOR CANDIDATES

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; 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.
The assessment of the quality of extended response (QER) will take place in question 6*(e).*

SECTION A
*Answer **all** questions*

1. *(a)*



(i) Calculate the charge stored by the capacitor. [3]

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(ii) Use (i) to calculate the energy stored by the capacitor. [1]

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(iii) Calculate the electric field strength (E) between the plates. [2]

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(b) After the capacitor is charged it is isolated from the power supply so that the charge stored remains constant. Then the plates are pulled further apart.

(i) Explain what happens to the capacitance of the capacitor and hence the energy stored by the capacitor. [2]

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(ii) A student claims that this process contravenes the principle of conservation of energy. Explain why the student is wrong in this case. [2]

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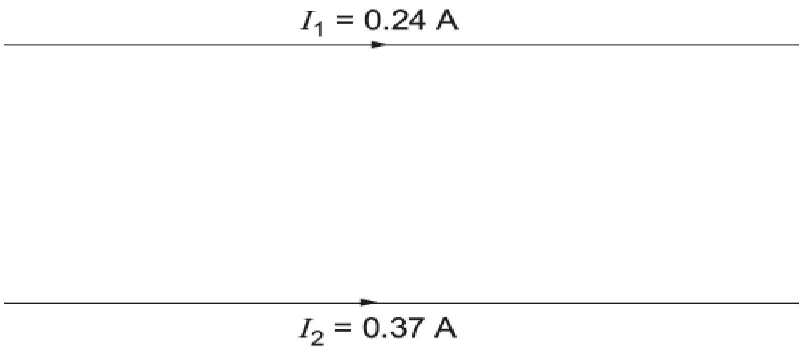
2. *(a)* A long solenoid of length 1.45 m has 9 560 turns. Calculate the magnetic field strength (B) inside the solenoid when it carries a current of 320 mA. [2]

(b) Determine the **direction** of the resultant magnetic field strength (B) half way between the two long wires shown and explain how you obtained your answer. [4]



(c) The currents in the wires are varied sinusoidally so that the magnetic field varies at a high frequency. Electromagnetic waves of wavelength 2.23 m are produced. Calculate the energy of the photons produced in eV. [3]

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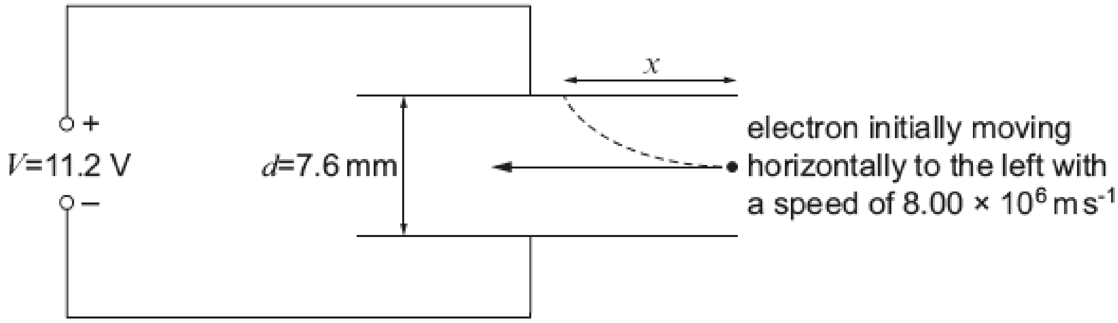
3. An electron enters the uniform electric field half way between the plates of a capacitor as shown. The electron is travelling in a vacuum.



(a) Show that the vertical acceleration of the electron is $\frac{Ve}{m_e d}$. [3]

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(b) (i) Explain why the horizontal speed of the electron remains constant. [1]

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(ii) Explain why the vertical acceleration of the electron is constant. [1]

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(c) Electronic sensors detect electrons striking the upper plate 5.0 ± 0.5 ns after the electrons enter the capacitor. Determine whether or not this time agrees with the above data. [4]

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(d) Explain why the amount of kinetic energy gained by the electron before striking the plate is 5.6 eV. [2]

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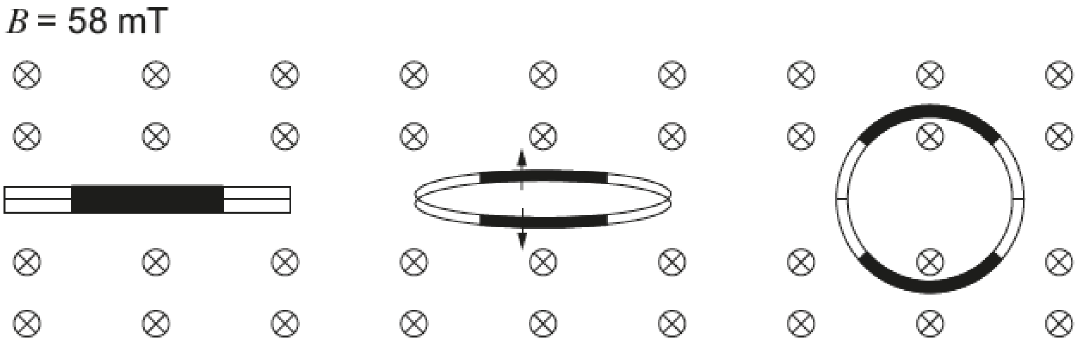
4. A magician's metallic wand can spring apart into the shape of a circular hoop (see below).



(a) The hoop is in a magnetic field. Explain why an emf is induced in the hoop as it expands. [3]

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(b) Explain why the current flows anticlockwise in the diagram. [2]

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(c) The hoop, of radius 31.0 cm, is in a region of uniform magnetic flux density (B) of 58 mT and expands from the wand shape to the hoop in a time of 63 ms. Calculate the mean current flowing in the hoop as it expands if the resistance of the hoop is 0.44 Ω. [5]

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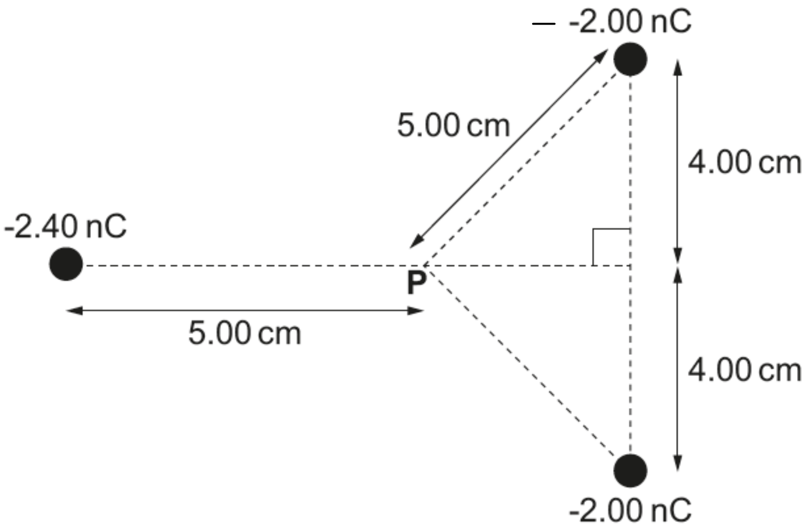
5. Three negative charges are arranged as shown.



(a) Draw arrows at **P** to represent the three electric fields due to the three charges. [2]

(b) Show that the resultant electric field at **P** is zero. [4]

(You may use the approximation $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9\ \text{F}^{-1}\ \text{m}$.)

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(c) Calculate the electric potential at **P**. [3]

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(d) An electron starts to accelerate from rest from point **P** (in a direction out of the plane of the paper). Calculate its speed when it arrives at another point where the potential is -200 V. [3]

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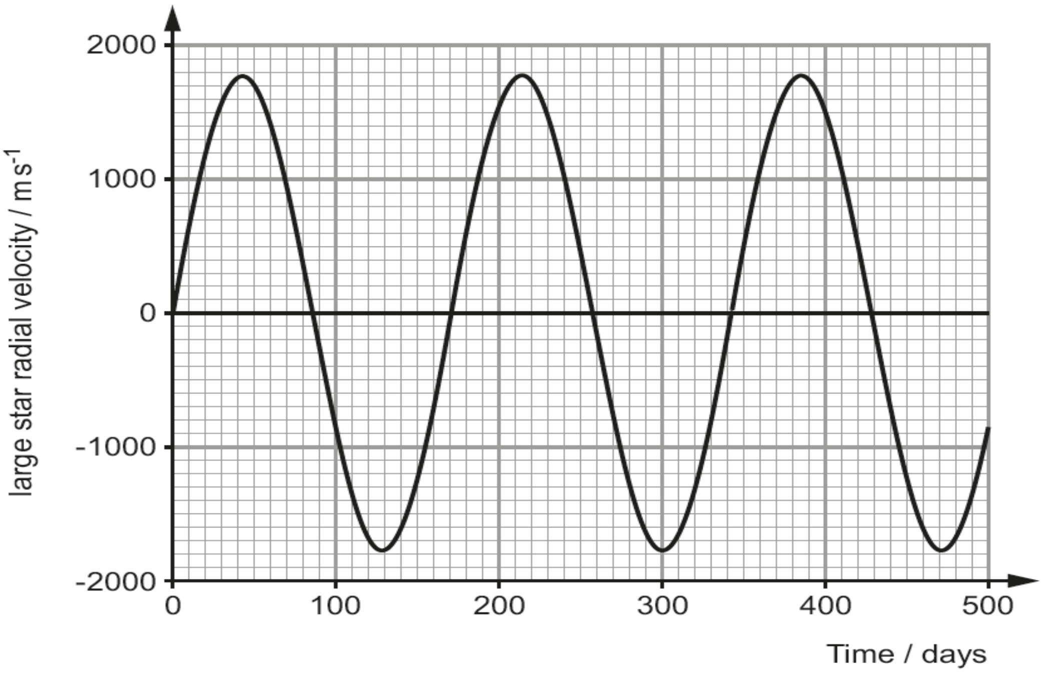
6. In 2008, a large planet was discovered orbiting a large star using the following data obtained from spectral observations of the large star. The graph shows the large star's radial velocity versus time (here, radial velocity is the component of the Star's velocity towards the Earth).



(a) With the use of a diagram, explain why this variation in radial velocity occurs. [2]

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(b) Show that the radius of the orbit of the large star is approximately 4×10^{9} m. [2]

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(c) The mass of the large star is 8.0×10^{29} kg and you may assume that this is far greater than that of the planet. Show that the distance, d, between the large star and the planet is around 7×10^{10} m. [2]

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(d) Calculate the mass of the planet. [2]

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(e) Explain how data for the star and the planet might lead scientists to conclude whether or not life exists on the planet. [6 QER]

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7. *(a)* Use Hubble's law ($v = H_0 d$) and conservation of energy to show that the critical density of the universe is given by: [4]

$$\rho = \frac{3H_0^2}{8\pi G}$$

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(b) Calculate a value of the critical density of the universe and estimate the number of hydrogen atoms per m^3 that this density corresponds to. [2]

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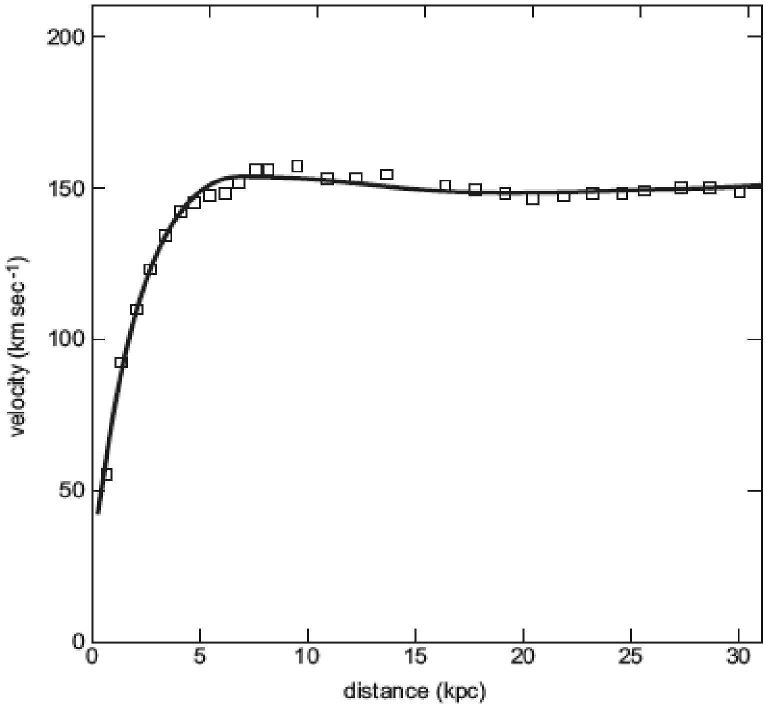
(c) Rotational data for a large spiral galaxy are shown in the diagram. Use data from the graph to calculate the time it takes for an object a distance of 30 kpc from the centre of the galaxy to complete one full orbit of the galaxy ($1\,\text{kpc} = 3.1 \times 10^{19}\,\text{m}$). [3]



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(d) If the spiral galaxy whose data are shown above were a distance of 2.17×10^{22} m from the Earth. Calculate the maximum and minimum possible red shift (or blue shift) for particles a distance of 30 kpc from the centre of the galaxy with a wavelength of 656 nm. [3]

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(e) By considering the data shown in the graphs below, explain briefly how the scientific community have checked the validity and integrity of data relating to Hubble's law. [2]

Figure 1 – Hubble's data (1929)

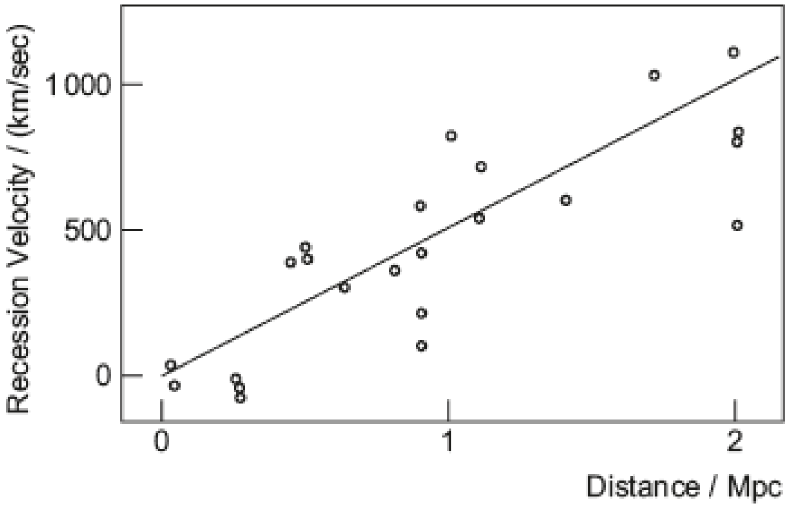
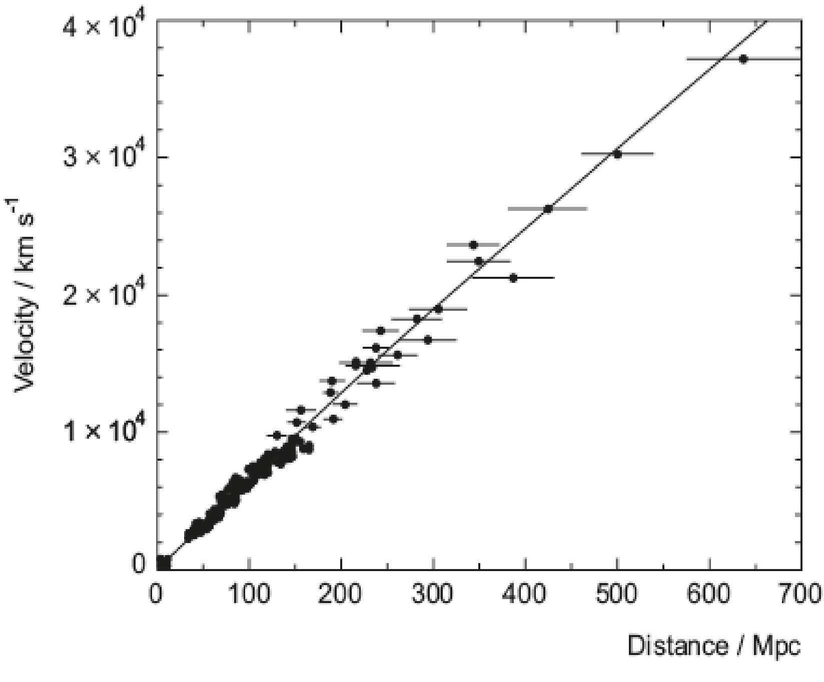


Figure 2 – Recent data based on Type 1a supernovae



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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**

8. *(a)* (i) Explain why a rotating coil in a uniform field produces an alternating emf. [2]

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(ii) Explain how the period of rotation of the coil, its area and the strength of the magnetic field affect the emf that is produced. [3]

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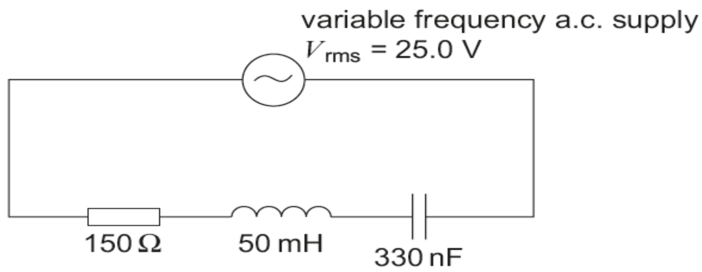
(b) For the following circuit:



(i) calculate the resonance frequency; [2]

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(ii) calculate the rms pd across each component at resonance. [4]

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(c) The frequency of the a.c. supply is now set to 1.80 kHz.

(i) Calculate the rms current. [3]

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(ii) The Q factor of the circuit is too small. Evaluate two different methods of increasing the Q factor. [3]

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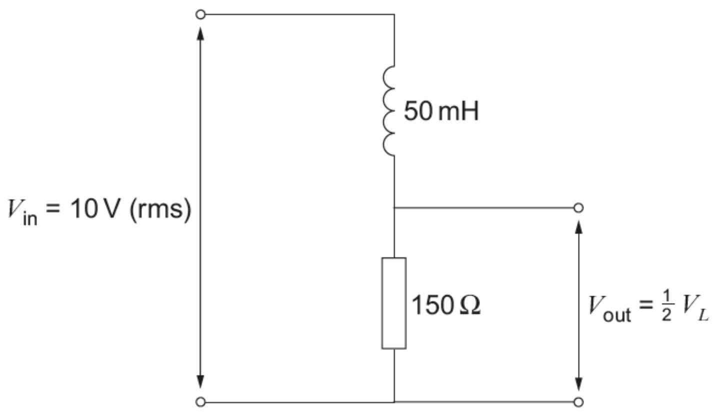
(d) In the circuit shown the rms output pd is ½ of the rms pd across the inductor.



Calculate the frequency of the input pd. [3]

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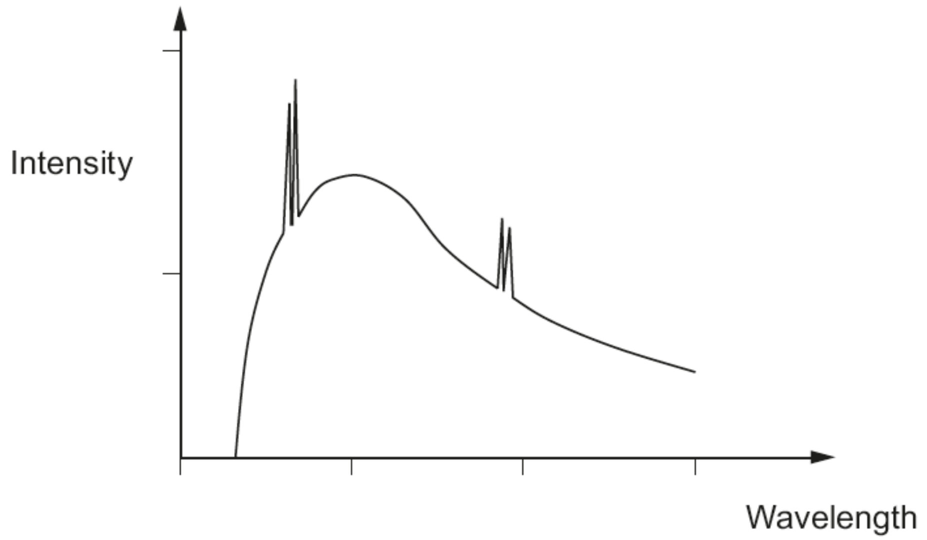
Option B – **Medical Physics**

9. *(a)* The diagram below is a typical X-ray emission spectrum for an X-ray tube with a tungsten target.



(i) Draw on the graph another curve that would be typical for the tube when operated at a lower potential difference. [1]

(ii) What difference would there be if molybdenum was used as the target instead of tungsten? [1]

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(iii) The X-ray tube has a working potential difference of 75 000 V. Calculate the minimum wavelength of an X-ray photon emitted from the tube. [2]

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(iv) If the anode current was 0.15 A and the X-ray tube has an efficiency of 0.5%, calculate the rate of production of heat at the anode. [2]

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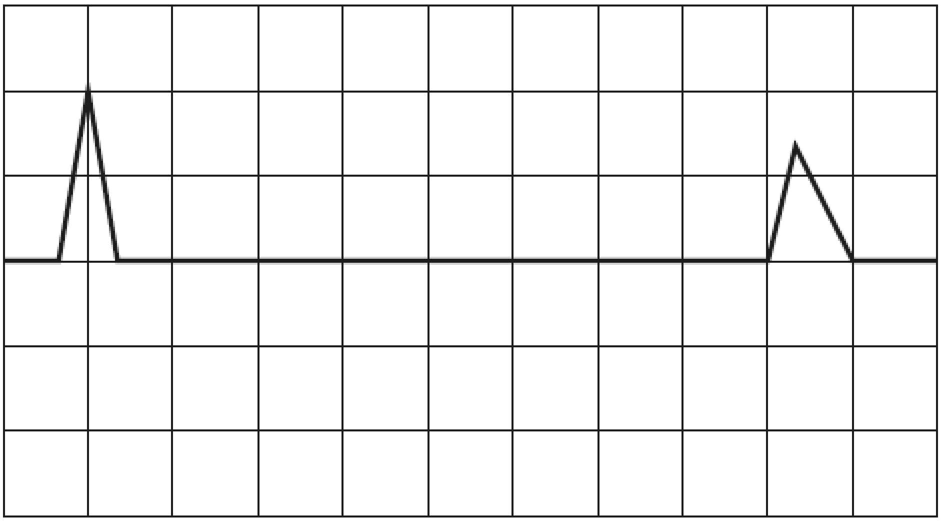
(b) An ultrasound A-scan is used to determine the depth of a layer of fat in a patient's body. The grid below shows the interval between the initial pulse and the reflected pulse on a cathode ray oscilloscope (CRO). The time base is set so that each full square represents 2 μs.



(i) If the speed of ultrasound in fat is 1.45×10^3 m s^{-1} calculate the thickness of the fat. [3]

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(ii) The fraction of ultrasound reflected at a boundary is given by the reflection coefficient, R, where $R = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$ and Z = acoustic impedance.

Calculate the reflection coefficient between air and the skin of a patient using the following information. [2]

Medium	Density / kg m⁻³	Velocity / m s⁻¹
Air	1.30	340
Skin	1 075	1 600

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(iii) Is it possible for ultrasound scans to be used to study a patient's lung? Explain your answer. [2]

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(c) (i) Explain, briefly, how magnetic resonance imaging (MRI) is able to produce detailed images of slices through the body. [2]

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(ii) An MRI scan would be unsuitable to image a lung tumour for a patient wearing a pacemaker. Explain why this is the case, and suggest a suitable imaging technique, justifying your choice. [3]

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(d) Write down an equation linking equivalent dose and effective dose. Define any new terms that appear in the equation, and give the unit for both. [2]

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Option C – **The Physics of Sports**

10. *(a)* (i) Explain what is meant by the statement “the coefficient of restitution between a cricket bat and the ball is 0.73”. [2]

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(ii) Calculate the height of the second bounce of a cricket ball falling from a height of 12.6 m if the coefficient of restitution is 0.65. [2]

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(iii) Explain why a bowler applies spin to the ball when bowling. Your answer should include the forces acting on the ball during flight. You can include diagrams in your explanation. The effects of air resistance should be considered for this part. [3]

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(b) (i) A diver makes 2.5 revolutions on a dive from a 10 m high platform to the water. Assuming that the initial vertical velocity is zero; calculate the mean angular velocity of the diver during the dive. [3]

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(ii) Another diver initially is rotating with an angular velocity 3.0 rad s^{-1} so that the moment of inertia is 4.0 kg m^2. The moment of inertia is reduced to 1.8 kg m^2. Calculate the increase in the rotational kinetic energy gained by the diver. You may ignore the effects of air resistance. [3]

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(iii) Using an appropriate definition, explain clearly how the diver referred to in part (ii) reduces her moment of inertia. [3]

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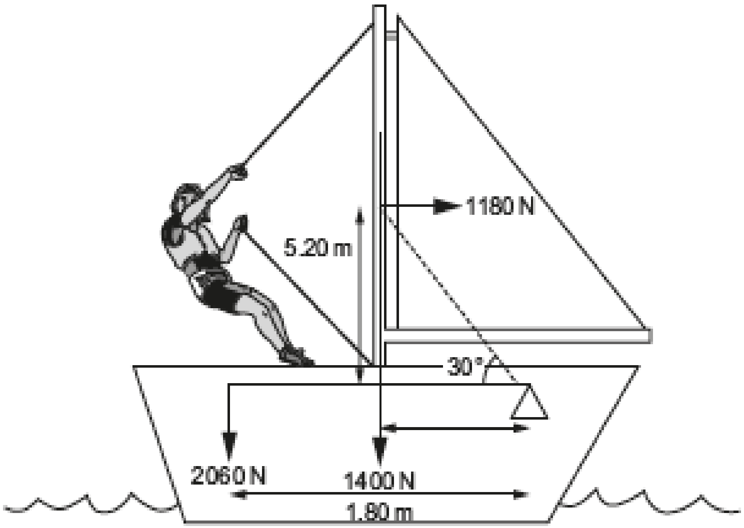
(c) The forces acting on a sailing boat are as shown in the diagram below. The wind provides an effective force of 1 180 N acting at a height of 5.20 m. The weight of the boat is 1 400 N. Three members of the crew of combined weight 2 060 N are used to counter balance the boat. Explain clearly the motion of the boat. [4]



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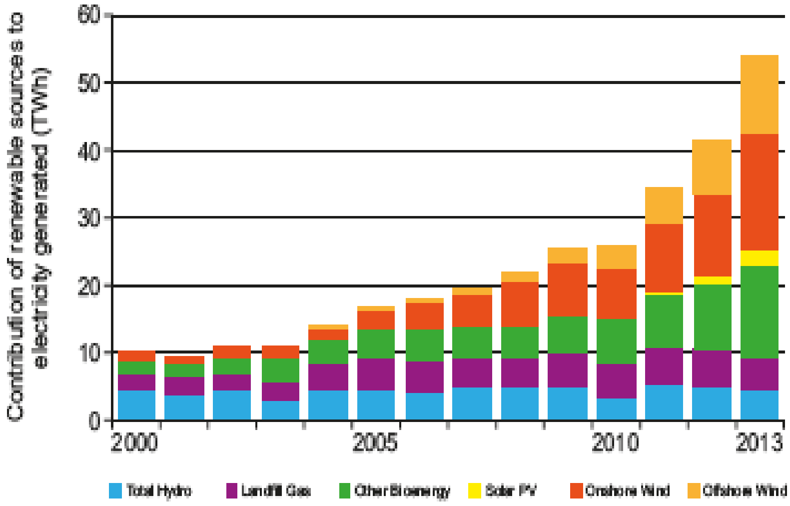
Option D – **Energy and the Environment**

11. *(a)* The chart shows the growth in the contribution of renewable sources of energy to the electricity produced in the UK between 2000 and 2013.



Source: Department of Energy and Climate Change; Energy Trends June 2014

(i) State three conclusions that you can draw from this chart. [3]

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(ii) Show that the energy produced from all renewable sources in 2000 is approximately 3.6×10^{16} J. [2]

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(iii) In 2013 the UK produced 1.9×10^{17} J of electrical energy from renewable sources. Use the chart to estimate the % contribution that offshore wind turbines made to this total. [2]

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(iv) Gwynt y Môr offshore wind farm uses turbines of radius 50 m which are exposed to a mean annual wind speed of 9.0 m s^{-1}.

(I) Write down an expression for the power available from a fluid of density ρ, moving with a speed of v, through cross-sectional area A. [1]

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(II) Estimate the number of offshore wind turbines required to produce a mean output power of 1 TW. Assume each turbine is 45% efficient and the density of air = 1.2 kg m^{-3}. [4]

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(b) (i) The thermal conductivity of a material is given by:

$$K = \frac{\Delta Q}{\Delta t}\frac{\Delta x}{A\Delta\theta}$$

Explain what is meant by: [1]

$\frac{\Delta Q}{\Delta t}$ ....

$\Delta\theta$ ....

(ii) The ceiling of a house is made of a wooden board which is 16 mm thick and measuring 18 m × 15 m. The thermal conductivity of the board is 0.16 $W\,m^{-1}K^{-1}$. The temperature inside the house is kept at 20°C whilst that of the loft is 5 °C. Calculate the rate at which thermal energy is transferred through the board. [3]

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(iii) Calculate the U value for the board. [3]

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(iv) State one factor which affects the U value of a material and suggest how your chosen factor may reduce the energy lost through the ceiling. [1]

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A LEVEL

PHYSICS

A2 UNIT 5
Practical Examination

Experimental Task
TESTS 1 and 2
INSTRUCTIONS TO TEACHERS / EXAMS OFFICERS

SPECIMEN PAPER

Confidential

To be opened on receipt for immediate use by
TEACHERS / EXAMS OFFICERS

This document should be stored securely by the exams officer when not in use by the teacher. Its contents should not be divulged except to those concerned with the preparation of the assessment.

A. General Instructions

1. The Experimental Task will consist of one session of 90 minutes duration. Two versions of the test will be set for use on dates specified by WJEC as follows:

Test 1 - ……………………………(date)
Test 2 - ……………………………(date)

An individual candidate may undertake only one of these tests. Where all the candidates can be accommodated in a single session, centres are advised to use Test 1 as early as is convenient on the first day. Where centres require more than one session, they may choose to use additional sessions on day 1 and/or day 2. Where more than one session is used on a single day, centres should ensure that candidates in later sessions have no opportunity to communicate with those who have already taken the test.

2. The test should be supervised at all times by a member of staff responsible for teaching A level Physics. Centres may use additional laboratories, provided that a subject teacher is available to supervise all groups at all times.

3. Teachers should ensure that each candidate has adequate working space and that the candidates are set a reasonable distance apart. Each candidate requires uninterrupted access to the allocated apparatus – one set of apparatus per candidate.

4. Centres will receive sufficient copies of the papers for Tests 1 and 2. Teachers may open the **"Setting up Instructions"** document 1 week before Test 1 (i.e. date). **This is for the purpose of ensuring that the apparatus functions well enough for the candidates to complete the assessment fully. Teachers are encouraged to try out the task, whilst preserving the confidentiality of the assessment.** The full version of the examination paper will not be available until the day of the examination (i.e. date).

5. Candidates should write their answers in the spaces provided on the question paper. Should there be a need for additional space then a standard extension/answer booklet should be provided.

6. Teachers need to ensure that the teacher assessed marks are recorded on each candidate's paper. Guidance on the awarding of these marks will be provided in the "Setting up Instructions" document.

7. After the assessments have taken place, the completed examination papers must be securely stored by the exams officer before they are sent to the examiner by ……………… at the latest. Teachers should not be given access to the completed examination papers after the actual assessments have taken place.

8. The examination papers will be externally marked by a WJEC examiner. The name and address of the examiner will be issued to centres by the end of April.

9. Monitoring visits will take place on a random sample of centres to ensure the practical examination is being administered correctly. Visiting monitors will require access to candidates' "lab books" on the day(s) of the examination.

B. Specific Instructions

Details of the apparatus and materials required for the tests follow.

If any difficulty is experienced in providing the apparatus, the WJEC should be informed as soon as possible.

Contacts:

Subject Officer Helen Francis, 029 2026 5081, helen.francis@wjec.co.uk
Support Officer Matthew Roberts, 029 2026 5380, matthew.roberts@wjec.co.uk

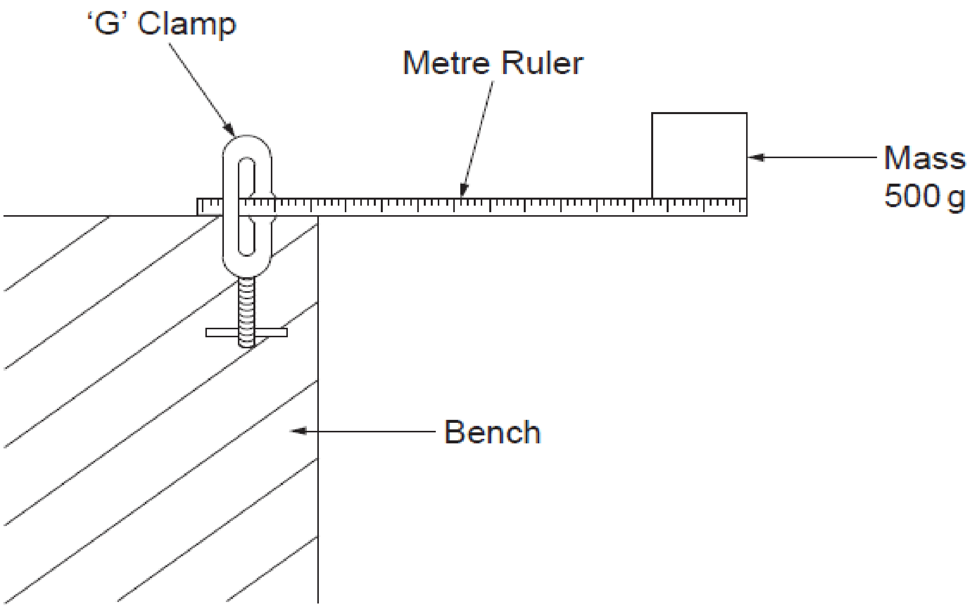
Apparatus Required

Test 1

The task is to carry out an investigation on an oscillating wooden metre ruler.
The apparatus should not be set up in advance for each candidate.

The following apparatus is required for each candidate:

1 × wooden metre ruler resolution (± 1 mm) with 500 g mass attached at one end using sellotape or rubber bands
1 × stopwatch (± 0.01 s)
1 × micrometer or digital callipers (± 0.01 mm)
1 × 'G' clamp available to secure metre ruler to bench



Test 2

The task is as in Test 1.
The apparatus required is as in Test 1 except the metre ruler should be made from plastic with 300 g mass attached at one end using sellotape or rubber bands

The numerical values of the various components are intended as a guide only and teachers may use their discretion if these sizes are not readily available.

A LEVEL

PHYSICS

A2 UNIT 5
Practical Examination

Experimental Task
TESTS 1 and 2

SETTING UP INSTRUCTIONS

SPECIMEN PAPER

Confidential

To be opened on …………………… (date) by TEACHERS

This document should be stored securely by the exams officer when not in use by the teacher. Its contents should not be divulged except to those concerned with the preparation of the assessment.

TEST 1

Theory shows that the period T (in seconds) of a loaded oscillating wooden metre ruler is directly proportional to the square root of the length of overhang, l, cubed:

$$T\alpha\sqrt{l^3}$$

Your task is to design, and carry out an experiment to confirm (or not) this relationship.

(a) Write out a plan of how you will carry out an investigation to do this.
Include a diagram and risk assessment with your plan. [6]

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Risk assessment

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BEFORE PROCEEDING YOUR TEACHER MUST APPROVE THE RISK ASSESSMENT AND THE SET-UP OF YOUR APPARATUS.

	Yes (✓) No (✗)
Risk assessment correct	
Apparatus set-up correctly	

(b) Using the apparatus take sufficient measurements to complete this task. [5]

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The remainder of the examination paper is not required for the purpose of checking the setting up of the task.

TEST 2

All of the above applies except a plastic metre ruler is used instead of a wooden metre ruler.

Awarding of teacher assessed marks

Risk assessment correct	Award 1 mark if a risk is identified and control specified e.g. ruler breaking so don’t over extend ruler. Do not award if the candidate does not work safely during the practical.
Apparatus set-up correctly	Award 1 mark if no help is needed to set up the apparatus

In order that the work of each candidate may be correctly assessed, information is required about the materials used in the tests. Please ensure that the “**Information required from centres**” sheet on page 85 is completed and given to the exams officer to be sent to the examiner with the completed examination papers.

A LEVEL

PHYSICS

A2 UNIT 5
Practical Examination

Experimental Task

INFORMATION REQUIRED FROM CENTRES

Centre Number ....

(Please detach and send with the completed examination papers to the **examiner.**)

TEST 1

Width (*b*) of metre ruler

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Thickness (*d*) of metre ruler

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TEST 2 (if applicable)

Width (*b*) of metre ruler

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Thickness (*d*) of metre ruler

....

Surname	Centre Number	Candidate Number
Other Names		

A LEVEL

PHYSICS

A2 UNIT 5
Practical Examination

Experimental Task
TEST 1

SPECIMEN PAPER

(1 hour 30 minutes)

For Examiner's use only		
	Maximum Mark	**Mark Awarded**
Total	**25**	

ADDITIONAL MATERIALS

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

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen.
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.

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

*Answer **all** questions*

1. Theory shows that the period T (in seconds) of a loaded oscillating wooden metre ruler is directly proportional to the square root of the length of overhang, l, cubed:

$$T \alpha \sqrt{l^3}$$

Your task is to design, and carry out an experiment to confirm (or not) this relationship.

(a) Write out a plan of how you will carry out an investigation to do this.
Include a diagram and risk assessment with your plan. [6]

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Risk assessment

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BEFORE PROCEEDING YOUR TEACHER MUST APPROVE THE RISK ASSESSMENT AND THE SET-UP OF YOUR APPARATUS.

	Yes (✓) No (✗)
Risk assessment correct	
Apparatus set-up correctly	

(b) Using the apparatus take sufficient measurements to complete this task. Draw a table to show your results clearly, including uncertainties and the resolution of all apparatus used. You may assume the uncertainty in $\sqrt{l^3}$ is negligible. [5]

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(c) Plot your data on a suitable graph to check the relationship. Remember to **include** error bars on the graph **and** draw a line of maximum gradient and a line of minimum gradient. [4]

(d) Determine the mean gradient of your graph and its **percentage** uncertainty. [3]

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(e) Further theory states that:

$$\text{gradient} = \sqrt{\frac{9}{Ebd^3}}$$

where:
E = Young modulus;
b = width of ruler (in metres);
d = thickness of ruler (in metres).

Determine the Young modulus of the material making up the ruler along with its **absolute** uncertainty. [7]

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Surname	Centre Number	Candidate Number
Other Names		

A LEVEL

PHYSICS

A2 UNIT 5
Practical Examination

Experimental Task
TEST 2

SPECIMEN PAPER

(1 hour 30 minutes)

For Examiner's use only		
	Maximum Mark	Mark Awarded
Total	25	

ADDITIONAL MATERIALS

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

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen.
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.

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

*Answer **all** questions*

1. Theory shows that the period T (in seconds) of a loaded oscillating plastic metre ruler is directly proportional to the square root of the length of overhang, l, cubed:

$$T \alpha \sqrt{l^3}$$

Your task is to design, and carry out an experiment to confirm (or not) this relationship.

(a) Write out a plan of how you will carry out an investigation to do this. Include a diagram and risk assessment with your plan. [6]

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Risk assessment

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BEFORE PROCEEDING YOUR TEACHER MUST APPROVE THE RISK ASSESSMENT AND THE SET-UP OF YOUR APPARATUS.

	Yes (✓) No (×)
Risk assessment correct	
Apparatus set-up correctly	

(b) Using the apparatus take sufficient measurements to complete this task. Draw a table to show your results clearly, including uncertainties and the resolution of all apparatus used. You may assume the uncertainty in $\sqrt{l^3}$ is negligible. [5]

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(c) Plot your data on a suitable graph to check the relationship. Remember to **include** error bars on the graph **and** draw a line of maximum gradient and a line of minimum gradient. [4]

(d) Determine the mean gradient of your graph and its **percentage** uncertainty. [3]

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(e) Further theory states that:

$$\text{gradient} = \sqrt{\frac{7}{Ebd^3}}$$

where:
E = Young modulus;
b = width of ruler (in metres);
d = thickness of ruler (in metres).

Determine the Young modulus of the material making up the ruler along with its **absolute** uncertainty. [7]

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Surname	Centre Number	Candidate Number
Other Names		

A LEVEL

PHYSICS

A2 UNIT 5
Practical Examination

Practical Analysis Task

SPECIMEN PAPER

(1 hour)

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	3	
2.	3	
3.	19	
Total	**25**	

ADDITIONAL MATERIALS
In addition to this paper you will require a calculator and a **Data Booklet**.

INSTRUCTIONS TO CANDIDATES
Use black ink or black ball-point pen.
Write your name, centre number and candidate number in the spaces at the top of the 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.

Answer ***all*** *questions*.

1. An oscilloscope is used to display a sinusoidal signal from a microphone of amplitude 17 mV and frequency 50 Hz. The oscilloscope settings are 5 mV per division (y-scale) and 5 ms per division (x-scale). Sketch the trace that might be seen on the oscilloscope. (Space is provided for your workings.) [3]

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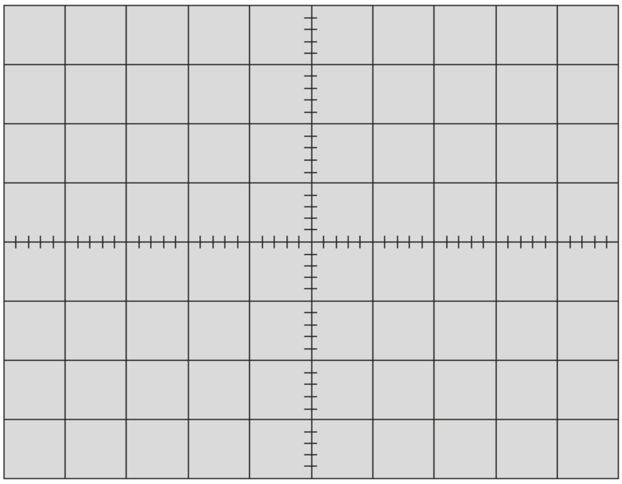
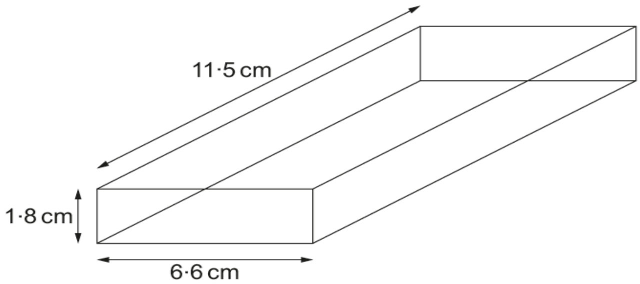


2. A rectangular glass block is measured with a ruler of resolution 1 mm and the results are given below. Calculate the volume of the block along with its **absolute** uncertainty.

Length	=	11.5 cm
Width	=	6.6 cm
Depth	=	1.8 cm

[3]



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3. The measured count rate due to a sample of radioactive waste from Trawsfynydd nuclear power station depends on the distance from the counter to the source. The relationship between the count rate, C, and the distance, d, can be expressed as

$$C = kd^{n}$$

(a) Explain which graph should be plotted to determine k and n. [2]

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The following data shows the mean count rate of the source at various distances.

Distance (d)/mm	**Mean Count Rate (C)/Bq**
13	215
17	125
20	94
25	59
30	44
50	19

(b) Use your answer to part (*a*) and the above data to obtain suitable values which will enable a graph to be plotted to determine k and n. (Space is provided for a new table of data.) [2]

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(c) Draw a suitable graph to determine k and n. [4]

(d) Use your graph to determine values for k and n. [6]

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(e) Write an equation linking count rate to distance. [1]

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(f) Theory states that the equation for the count rate with distance for a radioactive source is given by the following equation:

$$C = \frac{k}{d^2}$$

(i) Explain whether your value for n from part (*d*) is consistent with the above equation. [2]

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(ii) Explain whether background radiation would affect the value of n determined in part (*d*). [2]

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WJEC
CBAC

AS / A level PHYSICS

Data Booklet

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

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

Values and Conversions

Avogadro constant	$N_A = 6{\cdot}02 \times 10^{23}\ \text{mol}^{-1}$
Fundamental electronic charge	$e = 1{\cdot}60 \times 10^{-19}\ \text{C}$
Mass of an electron	$m_e = 9{\cdot}11 \times 10^{-31}\ \text{kg}$
Molar gas constant	$R = 8{\cdot}31\ \text{J mol}^{-1}\ \text{K}^{-1}$
Acceleration due to gravity at sea level	$g = 9{\cdot}81\ \text{m s}^{-2}$
Gravitational field strength at sea level	$g = 9{\cdot}81\ \text{N kg}^{-1}$
Universal constant of gravitation	$G = 6{\cdot}67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$
Planck constant	$h = 6{\cdot}63 \times 10^{-34}\ \text{J s}$
Boltzmann constant	$k = 1{\cdot}38 \times 10^{-23}\ \text{J K}^{-1}$
Speed of light in vacuo	$c = 3{\cdot}00 \times 10^{8}\ \text{m s}^{-1}$
Permittivity of free space	$\varepsilon_0 = 8{\cdot}85 \times 10^{-12}\ \text{F m}^{-1}$
Permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\ \text{H m}^{-1}$
Stefan constant	$\sigma = 5{\cdot}67 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4}$
Wien constant	$W = 2{\cdot}90 \times 10^{-3}\ \text{m K}$
Hubble constant	$H_0 = 2.30 \times 10^{-18}\ \text{s}^{-1}$

$T/\text{K} = \theta/°\text{C} + 273{\cdot}15$

$1\ \text{u} = 1{\cdot}66 \times 10^{-27}\ \text{kg}$

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

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

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

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

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

OPTION B

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

OPTION C

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

OPTION D

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

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

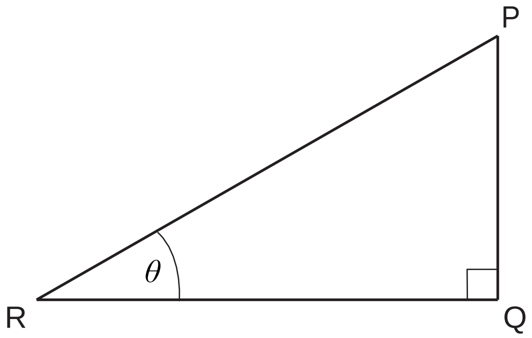
Areas and Volumes

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

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 $\log_{10}$.]

$\log(ab) = \log a + \log b$

$\log \frac{a}{b} = \log a - \log b$

$\log x^n = n \log x$

$\log_e e^{kx} = \ln e^{kx} = kx$

$\log_e 2 = \ln 2 = 0.693$

AS UNIT 1 – Motion, Energy and Matter

MARK SCHEME

GENERAL INSTRUCTIONS

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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.

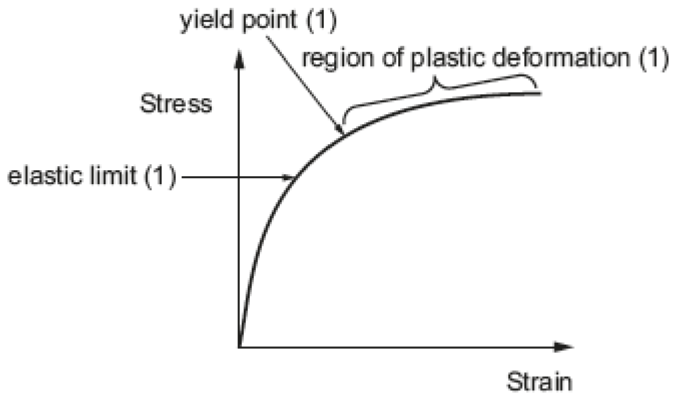
cao = correct answer only
ecf = error carried forward
bod = benefit of doubt

Question				Marking details	AO1	AO2	AO3	Total	Maths	Prac
					Marks available					
1	*(a)*			Force unit: kg m s^{-2} (1) v^2 unit: m^2s^{-2} **or** (m $s^{-1})^2$ (1) Clear algebra (1)	1 1	1		3	1	
	(b)	(i)		Resultant force = 0 (1) Due to frictional force (1)		1	1	2		2
		(ii)		$\frac{1}{\text{gradient}}$ attempted (1) Correct substitution, e.g. $\frac{3.0-0.5}{3.0}$ (1) m = 0.8[3] kg **unit mark** (1)			3	3	3	3
	(c)	(i)		A = contact force of surface on body [accept <u>normal</u> reaction] (1) B = gravitational force of Earth on body (1) [accept: weight /mg]	2			2		
		(ii)		<u>Gravitation force of body (mass)</u> (1) on Earth (1)	1	1		2		
				Question 1 total	**5**	**3**	**4**	**12**	**4**	**5**

Question				Marking details	AO1	AO2	AO3	Total	Maths	Prac
2	*(a)*			Use of cos 70° (1) $2T\cos 70° = 800$ (1) [→ T = 1 170 N]		2		2	2	
	(b)	(i)		Area under graph attempted **or** ½Fx **or** ½ kx^2 (1) 240 [J] (1)	1	1		2	2	
		(ii)		Initial energy stored in bow converted entirely to E_k of arrow (1) Use of $\frac{1}{2}mv^2$ (1) Manipulation leading to v = 98 [m s^{-1}] shown (1)	1	1 1		3	2	
	(c)			Greater [initial] force [or equiv] required to pull the Turkish bow string [through a given distance] (1) [or more work / energy needed] Greater area under the Turkish bow curve (1) [leading to] more [elastic] potential energy stored (1) Arrows will leave Turkish bow with a greater speed / velocity (1) [accept converse arguments] [**Alternative to 2nd marking point**: linking to 1st marking point because gradient of graph greater for Turkish bow]			4	4		
				Question 2 total	**2**	**5**	**4**	**11**	**6**	**0**

Question				Marking details	AO1	AO2	AO3	Total	Maths	Prac
3	*(a)*	(i)		Distance = area (or implied) (1) Shaded area = ½tv (1) $v = at$ and clear substitution (1)	1 1	1		3	2	
		(ii)		Line starts linearly and gradient decreases			1	1		
	(b)	(i)		2.2 [s]		1		1		
		(ii)		Valid substitution into $v = u + at$ (e.g. $0 = u - g \times 1.1$ **or** $2u = 2.2g$ etc) (1) Or any other valid kinematic equation (**ecf** on t from (i)) Correct algebra / manipulation (1) u = 10.8 [m s^{-1}] (1)	1	1 1		3	3	
		(iii)		Correct substitution into $x = ut + \frac{1}{2}at^2$ (i.e. $x = 10.8 \times 0.3 - \frac{1}{2} \times 9.81 \times 0.3^2$) (**ecf** on 10.8 m s^{-1}) (1) x = 2.8 [m] (1)	1	1		2	2	
	(c)			Weight acting downwards always (1) Forces labelled correctly (1) Air resistance opposing motion (1) At top, no air resistance (1)	1 1	1 1		4		
				Question 3 total	**6**	**7**	**1**	**14**	**7**	**0**

Question				Marking details	AO1	AO2	AO3	Total	Maths	Prac
					Marks available					
4	*(a)*	(i)		Point where entire **weight** of the body acts	1			1		
		(ii)		$0.2 \times (49.6 - 4)$ = test tube $\times$ 38.4 **or** $0.2 \times (45.6) = (0.2375 + \text{ball}) \times 24.5$ (1) test tube = 0.2375 [N] (1) ball bearing = 0.1347 [N] (1) $F = mg$ used (1)	1 1	1 1		4	4	4
	(b)			Calculating volume = $\frac{4}{3}\pi r^3$ (1.77×10^{-6} m^3) (1) Density = 7 790 – 7 950 [kg m^{-3}] (1) 7 797 (using 13.8 g) **or** 7 909 (using 14 g) so therefore iron **(ecf)** (1) Correct comment regarding closeness of answers e.g. within the limits of experimental error (1)			4	4	2	4
				Question 4 total	**3**	**2**	**4**	**9**	**6**	**8**

<table>
<tr><th colspan="4" rowspan="2">Question</th><th rowspan="2">Marking details</th><th colspan="6">Marks available</th></tr>
<tr><th>AO1</th><th>AO2</th><th>AO3</th><th>Total</th><th>Maths</th><th>Prac</th></tr>
<tr><td>5</td><td>(a)</td><td></td><td></td><td>Curve: elastic (straight) and inelastic regions shown (1)

</td><td>4</td><td></td><td></td><td>4</td><td></td><td></td></tr>
<tr><td></td><td>(b)</td><td></td><td></td><td>Bonds
B1 – Extra stress at DE.
B2 – DE breaks.
B3 – BE forms.
B4 – Extra stress at HG.
B5 – HG breaks.
B6 – HD forms.
B7 – Dislocation moves towards the right.

Foreign atoms
F1 – Foreign atoms fixed.
F2 – Dislocations cannot move.</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

				5-6 marks At least 5 of B1 – B7. At least 1 of F1 and F2. There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured. **3-4 marks** Expect 3 – 4 of B1 – B7. Either F1 or F2. There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure. **1-2 marks** Expect 1 – 2 of B1 – B7. 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.	2	4		6		
	(c)	(i)		Stress = 1.9×10^8 [N m^{-2}]		1		1	1	1
		(ii)		Max stress = 2.2×10^8 [N m^{-2}] (1) Min stress = 1.6×10^8 [N m^{-2}] (1)		2		2	2	2
	(d)			Benefit – testing over a wider range (1) Risk – large force is a hazard (whiplash) which could lead to injury (1)			2	2		2
				Question 5 total	**6**	**7**	**2**	**15**	**3**	**5**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
6	*(a)*			λ_{max} = 950 [± 50] [nm] [or by implication] (1) $T = \frac{2.90\text{x}10^{-3}}{950\text{x}10^{-9}}$ (1) [**ecf** on λ_{max}] = 3 050 [K] (1)		1 1	1	3	3	
	(b)	(i)		Spectral intensity [far] greater at 700 nm [than at 400 nm]		1		1		
		(ii)		Infra-red	1			1		
		(iii)		Use of $\lambda_{max} = \frac{W}{T}$ (1) λ_{max} = 550 nm [accept 500 – 600 nm] (1) T = 5 300 [K] (1) [**ecf** from λ_{max} but only if λ_{max} is between 400 and 700 nm]	1	1 1		3	3	
	(c)			Knowledge of meaning of symbols in $P = \sigma AT^4$ demonstrated (1) $A = 4\pi \times (1.01 \times 10^8 \text{ m})^2 = 1.28 \times 10^{17}$ [m^2] (1) $P = 6.3 \times 10^{23}$ W **unit mark** (1) [**ecf** on T from (*a*)] [1 mark lost if answer adrift by a factor of π or 2^n, or if the answer to (*b*)(iii) used instead of 3 000 K] Accept other alternatives e.g. finding P from A and T or finding A from P and T	1	1 1		3	3	
				Question 6 total	**3**	**7**	**1**	**11**	**9**	**0**

Question				Marking details	AO1	AO2	AO3	Total	Maths	Prac
7	*(a)*	(i)		Correct lepton numbers used i.e. e^-: +1 e^+: -1 γ: 0 (1) Correct application of conservation law (1)	1	1		2		
		(ii)		Electromagnetic : γ involvement **(both needed for the mark)**	1			1		
	(b)			π^- (1) <u>because either</u> charge of x = -e [accept -1] and x must be a hadron / can't be a lepton **or** u number = 0 – 1 = -1, d number = 0 – (-1) = 1 or equivalent (1)		2		2		
	(c)	(i)		e^+ or positron		1		1		
		(ii)		Weak	1			1		
	(d)			π^- [accept μ or $\bar{u}d$] → e^- + $\bar{\nu}_e$ (accept + $\bar{\nu}$) [In fact, $\pi^- \rightarrow \mu^- + \nu_\mu$ much more likely]		1		1		
				Question 7 total	**3**	**5**	**0**	**8**	**0**	**0**

AS UNIT 1: Motion, Energy and Matter - SUMMARY OF ASSESSMENT OBJECTIVES

Question	AO1	AO2	AO3	TOTAL MARK	MATHS	PRAC
1	5	3	4	12	4	5
2	2	5	4	11	6	0
3	6	7	1	14	7	0
4	3	2	4	9	6	8
5	6	7	2	15	3	5
6	3	7	1	11	9	0
7	3	5	0	8	0	0
TOTAL	**28**	**36**	**16**	**80**	**35**	**18**

AS UNIT 2 – Electricity and Light

MARK SCHEME

GENERAL INSTRUCTIONS

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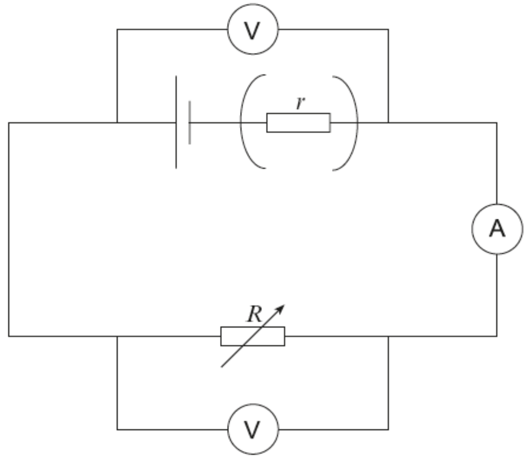
bod = benefit of doubt

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
1	*(a)*			 Ammeter and either voltmeter correct (1) Variable resistor in series / R in series but stated that it can be changed (1)	1 1			2		2
	(b)			Read V and I, adjust variable resistor, [read V and I etc.]	1			1		1
	(c)	(i)		Straight line drawn through points and judged by eye to be the best possible fit (1) y - intercept between 3.15 - 3.25 [V] (1) Gradient between 0.30 – 0.34 [Ω] (1)		3		3	3	3
		(ii)		Gradient = r (1) y - intercept = emf (1)	2			2		2
	(d)			**Any 2 × (1) from:** • Points lie close to straight line therefore quality acceptable • Extra points needed with lower current (or higher R or higher V) • Extra points needed with higher current (or lower R or lower V)			2	2		2

	(e)			3.20 [V] (**or** initial voltmeter reading) is emf **and** is in good agreement (**ecf**) with (*c*) (1) $I = \frac{2.62}{1.50}$ = 1.75 A [± 0.05 A] **or** $R + r$ = 1.8[2] Ω (1) Argument clearly set out with conclusion (1) Valid arguments include check of $V = E - Ir$, **or** $V = \frac{ER}{R+r}$ **or** $\frac{V}{R} = \frac{E}{R+r}$			3	3	2	3
				Question 1 total	**5**	**3**	**5**	**13**	**5**	**13**

Question				Marking details	AO1	AO2	AO3	Total	Maths	Prac
2	*(a)*			Current proportional to pd (1) Provided temperature is constant (1)	1 1			2		
	(b)			pd across S = 4.2 [V] or by implication (1) Use of $V = IR$ (1) S = 280 [Ω] (1) **Alternative solution:** R_{LED} = 120 [Ω] or by implication (1) R_{total} = 420 [Ω] or by implication (1) S = 280 [Ω] (1)	1	1 1		3	3	
	(c)	(i)		Use of $A = \pi r^2$ (1) n = 18[.0] × 10^{28} m^{-3} (1) v = 4.1 × 10^{-5} m s^{-1} (1) Penalise wrong powers of 10 or 2 or factor of 3 omitted in n once only	1	1 1		3	3	
		(ii)		12 [A]		1		1		
	(d)			$R = \frac{28.2\text{x}10^{-9}\text{x}70}{2.54\text{x}10^{-6}}$ **ecf** on A **or** by implication (1) R = 0.78 [Ω] **ecf** on A **or** by implication (1) V = 2.3 [V] **ecf** on A and arithmetic slips in finding R (1)		3		3	3	
				Question 2 total	**4**	**8**	**0**	**12**	**9**	**0**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
3	*(a)*	(i)	(I)	λ = 0.20 [m] or by implication (1) 10 m s^{-1} **unit mark ecf** on λ (1)		1 1		2		
			(II)	0.020 [s]		1		1		
			(III)	Attempt at sinusoid **and** same amplitude (1) Wave shifted 0.05 m to the right (1)		2		2	2	
		(ii)		Direction of displacement (or oscillation or particle movement or equivalent) and direction of wave (or energy) travel (1) are at right angles to each other (1)	2			2		
	(b)	(i)		Progressive wave: energy travels. Stationary wave: it doesn't	1			1		
		(ii)		Progressive wave: amplitude constant **or** falls steadily (1) stationary wave: amplitude varies periodically **or** sinusoidally **or** goes up and down [regularly] **or** equivalent (1)	2			2		
				Question 3 total	**5**	**5**	**0**	**10**	**2**	**0**

Question				Marking details	AO1	AO2	AO3	Total	Maths	Prac
					Marks available					
4	*(a)*	(i)		Same point in cycle at same time **or** equivalent	1			1		
		(ii)		Path difference = 36 mm (1) which is 3λ [accept $n\lambda$] so therefore constructive interference (1)			2	2		
		(iii)		[Path difference does not change so] always constructive (1) [But] signal strength will decrease as we go further from sources (1)			2	2		
	(b)			Use of equation: $y = \frac{12\text{x}360}{36}$ even if units confused (1) y = 120 mm **unit mark** (1)		1 1		2	2	
	(c)			Use of $d\sin\theta = n\lambda$ (1) 24° (1) 53° **or** both angles wrong but because of same arithmetic error (1) **Either** 0° **or** ± 24° and ± 53° **or** equivalent (1)	1	1 1 1		4	3	
				Question 4 total	**2**	**5**	**4**	**11**	**5**	**0**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
5	*(a)*			Measure angles (50° and 27°) (1) Application of $n_1 \sin\theta_1 = n_2 \sin\theta_2$ (1) Answer = 1.69 (1)	1	1 1		3	2	3
	(b)	(i)		Angle of incidence at **P** = 65° (1) Calculation of critical angle = 41° **or** 1.52 sin 65° = 1.37 **or** 1.52 sin 65° > 1 (1) 65° > 41° **or** no possible angle of refraction into air (1)			3	3	2	
		(ii)		One further reflection on bottom surface at some point **Q**, such that **AQ** < ½ **BP**, and ray emerges from AB bent away from normal		1		1		
		(iii)		Incident and emergent rays marked as parallel (1) First and last portions inside glass marked as parallel (1)		2		2		
	(c)	(i)		Light travelling by different paths takes different times (1) because some paths shorter (or straighter) than others **or** equiv (1)	2			2		
		(ii)		Pulses may overlap **or** equivalent		1		1		
				Question 5 total	**3**	**6**	**3**	**12**	**4**	**3**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
6	*(a)*	(i)		3.0×10^{-19} J [accept the work function] is the [minimum] energy needed to eject an electron from caesium [**or** the surface **or** the metal **not** caesium atom]	1			1		
		(ii)		Correct transposition, equivalent to $f = \frac{E_{k\,max} + \phi}{h}$ at any stage (1) $f = 1.4 \times 10^{15}$ [Hz] (1)		2		2	2	
		(iii)		More electrons ejected per second, $E_{k\,max}$ unaffected (1) More electrons per second because more photons per second (1) Same $E_{k\,max}$ because individual photon energies unaffected (1)	1 1	1		3		
	(b)			P1 – Controversial because different / disagreed with current (then) theory. P2 – Many experiments on photoelectrons since 1902. P3 – Show excellent agreement with new theory. P4 – Old theories cannot explain observations. P5 – Old theory predicted that if enough energy was given, electrons would be emitted. P6 – New theory – light comes in packets of energy (photons). **3 - 4 marks** Expect 4 or more points from P1 – P6 with a sequenced discussion **1 - 2 marks** Expect 1 – 3 points from P1 – P6 with a more fragmented argument.			4	4		
				Question 6 total	**3**	**3**	**4**	**10**	**2**	**0**

Question				Marking details	AO1	AO2	AO3	Total	Maths	Prac
					Marks available					
7	*(a)*	(i)		Application of $E = \frac{hc}{\lambda}$ **or** $E = hf$ and $c = f\lambda$ ***or*** equivalent **or** f = 4.7 × 10^{14} [Hz] (1) λ = 630 [nm] (1)		1 1		2	2	
		(ii)		Downward arrow between top two levels		1		1		
	(b)	(i)		Transmitted 7 × 10^{14} [s^{-1}], reflected 6.3 × 10^{15} [s^{-1}]		1		1		
		(ii)		Attempt based on number of photons per second × E_{phot} (1) 2.0 mW **unit mark** (1)		2		2	2	
	(c)			**Energy levels** E0 – More electrons in higher energy levels than lower energy levels. E1 – Population inversion mentioned. E2 – Population inversion between U and L. E3 – L is initially (nearly) empty. E4 – Transition from P to U is instantaneous. E5 – U is a metastable state **or** long lived. E6 – Transition from L to the ground state is instantaneous. **Stimulated emission** S1 – Incident photon causes an electron to drop. S2 – Photon emitted when an electron drops. S3 – Stimulated emission mentioned. S4 – After stimulated emission there are 2 photons instead of 1 photon. S5 – Incident photon of correct energy **or** frequency **or** wavelength is required. S6 – Intensity **or** number (can increase exponentially). **Cavity** C0 – One mirror slightly transparent. C1 – Light / photons traverse the cavity many times. C2 – Intensity increases in cavity.						

				5-6 marks All of E0 – E3 and 1 from E4 – E6 are present. All of S1 – S6 are present. 1 from C0 – C2 is present. There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured. **3-4 marks** 2 or 3 from E0 – E3 are present. 3 from S1 – S6 are present. 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 E0 – E3 is present. 1 or 2 from S1 – S6 are 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.	6			6		
				Question 7 total	**6**	**6**	**0**	**12**	**4**	**0**

AS UNIT 2: Electricity and Light - SUMMARY OF ASSESSMENT OBJECTIVES

Question	AO1	AO2	AO3	TOTAL MARK	MATHS	PRAC
1	5	3	5	13	5	13
2	4	8	0	12	9	0
3	5	5	0	10	2	0
4	2	5	4	11	5	0
5	3	6	3	12	4	3
6	3	3	4	10	2	0
7	6	6	0	12	4	0
TOTAL	**28**	**36**	**16**	**80**	**31**	**16**

A2 UNIT 3 – Oscillations and Nuclei

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)		N = number of molecules **and** m = mass of molecule	1			1		
		(ii)		Use of $\rho = \frac{Nm}{V}$ or equivalent clearly distinguishable (1) Statement that Nm is mass of gas or that ρ is density (1)	2			2	1	
		(iii)		$\sqrt{\overline{c^2}}$ should be α $\sqrt{\frac{1}{\rho}}$ **or** equivalent e.g. ρc^2 calculated **or** $p = \frac{1}{3}\rho\overline{c^2}$ = 53 000 [Pa] (1) Quoting of data points e.g. (1,400) and (4,200) (1) When ρ is 4×, $\sqrt{\overline{c^2}}$ is halved **or** ρc^2 constant **or** ρ = constant (1)			3	3	2	
	(b)	(i)		Substitution of $\overline{c^2} = \frac{3\text{x}3.0\text{x}10^5}{0.5}$ (1) $c_{\text{rms}} = 1.34 \times 10^3$ [m s^{-1}] (1)	1	1		2	2	
		(ii)		**Either:** Use of $n = \frac{0.025}{4\text{x}10^{-3}} = 6.25$ (1) $N = 6.25 \times 6.02 \times 10^{23} = 3.76 \times 10^{24}$ (1) Mass of molecule = $\frac{0.025}{3.76\text{x}10^{24}} = 6.6 \times 10^{-27}$ [kg] (1) Mean KE per molecule = ½ × $6.6 \times 10^{-27} \times (1.34 \times 10^3)^2$ = 5.9×10^{-21} [J] (1) **Or:** Use of $pV = nRT$ (1) $T = \frac{3\text{x}10^5\text{x}0.05\text{x}4\text{x}10^{-3}}{0.025\text{x}8.3}$ (1) = 289 [K] (1) Mean KE per molecule = $\frac{3}{2} \times 1.38 \times 10^{-23} \times 289 = 5.9 \times 10^{-21}$ [J] (1)	1	1 1 1		4	4	
				Question 1 total	**5**	**4**	**3**	**12**	**9**	**0**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
2	*(a)*			Attempt to use: Electrical energy supplied = power × time (e.g. 2 × 7) (1) 50.4 [MJ] (1) Use of $\Delta U = mc\Delta T$. Tolerate mistakes such as ΔT = 320, 573 (1) ΔU = 40.3 [MJ] (1) Statement or clear implication that 10.1 [MJ] **(ecf)** has escaped from the bricks as heat (1) Clear conclusion that statement is true **(ecf)** available, but if electrical energy < ΔU a comment on its impossibility is needed (1)			6	6	2	
	(b)	(i)		Calculation of one pV **or** T (1) Calculation of second pV **or** T (1) Correct value of T obtained 289 [± 5K] (1) Calculation of third pV **or** T (1) Correct conclusion regarding agreement of values (their data) (1)		1 1 1 1	1	5	4	
		(ii)		Work done = area (1) Method clear (e.g. rectangle + triangle, counting squares) (1) W between 135 [J] and 225 [J] if correct from method used (1) W in range 166 ± 20 [J], **or** if outside, comment on whether likely to be too high or too low (1)	1	1 1 1		4	2	
		(iii)		ΔU = increase (accept *change*) in internal energy **and** Q = heat *in* **and** W = work *out* (**or** work done by system)	1			1		
		(iv)		ΔU = 0 [since gas is ideal and ΔT = 0] (1) Q = answer to *(b)*(ii) so in range 166 ± 20 [J] (1)		2		2		
				Question 2 total	**2**	**9**	**7**	**18**	**8**	**0**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
3	*(a)*			Use of $\omega = 2\pi f$ tolerate mistakes over units but not attempts to incorporate 0.45 m or omission of 2π (1) 251 [rad s^{-1}] (1)	1	1		2	2	
	(b)	(i)		Use of $mr\omega^2$ **or** $\frac{mv^2}{r}$ with $v = \omega r$ (1) 2 270 [N] **(ecf)** from *(a)* (1)	1	1		2	2	
		(ii)		For the sock, mg = 0.8 [N] (1) Comment that mg << [resultant] force or equivalent (1)			2	2		
	(c)	(i)		Towards cylinder axis (accept circle centre)	1			1		
		(ii)		Straight line towards top of page	1			1		
				Question 3 total	**4**	**2**	**2**	**8**	**4**	**0**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
4	*(a)*	(i)		0.3 [s]		1		1		
		(ii)		0.9 [s]		1		1		
	(b)	(i)		0.045 [m]	1			1		
		(ii)		T = 0.80 s **or** by implication (1) ω = 7.85 [rad s^{-1}] tolerate error due to misreading of T (1)		2		2	1	
		(iii)		0 **or** zero		1		1		
	(c)	(i)		Reasonable attempt at sinusoid with period of 0.8 s (1) Inverted displacement-time graph (1)	2			2	2	
		(ii)		Acceleration = $\omega^2 A$ at lowest point (1) So $a = (7.85)^2 \times 0.045$ (1) a = 2.77 [m s^{-2}] (1) **(ecf)** on A and ω $a < g$ so therefore it will not separate (1) **(ecf)**			4	4	2	
				Question 4 total	**3**	**5**	**4**	**12**	**5**	**0**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
5	(a)			System [capable of oscillation] subjected to [‘driving’] force (1) Maximum amplitude of oscillation [accept maximum response] at one frequency [of driving force] (1)	2			2		
	(b)			Natural frequency = 2.0 [Hz] (1) Substitution into $T = 2\pi\sqrt{\frac{m}{k}}$ (1) $k = 4\pi^2 mf^2$ **or** $k = \frac{4\pi^2 m}{T^2}$ **or** equivalent re-arrangement of equation at any stage (1) k = 15.8 N m^{-1} **unit mark** (1)	1 1	1 1		4	3	
	(c)			Peak lower and at same frequency or lower (1) Low frequency amplitude unaffected, high frequency amplitude lower or unaltered, so curve blunter (1)	2			2		
				Question 5 total	**6**	**2**	**0**	**8**	**3**	**0**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
6	*(a)*	(i)		Mass number = 206 (1) Atomic number = 82 (1)		2		2		
		(ii)		**Any 3 × (1) from:** • More data on radon dosage • More data on types of cancer • Safe dosage known • Measurable life of lab rate • Killing animals to get data • Encourages animal terrorism	3			3		
	(b)			Use of $\lambda = \frac{\ln 2}{T_{\frac{1}{2}}}$ e.g. λ = 0.182 day^{-1} (2.11 × 10^{-6} s^{-1}) or $t = nT_{\frac{1}{2}}$ (1) Logs taken correctly e.g. $\ln A = \ln A_0 - \lambda t$ **or** $\ln A = \ln A_0 - n\ln 2$ (1) Algebra correct e.g. $t = \frac{1}{\lambda}\ln\frac{A_0}{A}$ **or** $n = \frac{1}{\ln 2}\ln\frac{A_0}{A}$ **or** implied (1) Correct answer 13.2 days **unit mark** (1.14 × 10^{6} s) (1)	1	1 1 1		4	4	
	(c)			Product nuclei give added activity		1		1		
	(d)			Current = rate of flow of charge **or** equivalent (1) 250 × 1.15 × 10^{6} × 1.6 × 10^{-19} = 4.6 × 10^{-11} [A] (1) Assumption – all charges contribute to the current **or** all ions are single charges (1)	1	1 1		3	1	
	(e)			Subtraction of masses (221.9773 – 4.0015 = 217.9758) (1) Conversion of 5.59 MeV to mass (i.e. 0.0060 u **or** 9.9671 × 10^{-31} kg) (1) Answer = 217.9698 [u] (**or** 3.618299 × 10^{-25} kg depends on u) (1)	1	1 1		3	2	
				Question 6 total	**6**	**10**	**0**	**16**	**7**	**0**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
7	*(a)*			Alpha present because significant drop after paper (1) Beta not present because no **additional** drop after Al (1) Gamma present because significant **after** Al **or** Pb (1) Absorbers **explained** e.g. paper stops alpha, beta stopped by ~1 mm of Al, 15 cm of Pb for gamma (1)	1		1 1 1	4		4
	(b)			As a check/ensure fair test **or** equivalent (1) In case source activity changing/distance changed/apparatus disturbed etc (1)			2	2		2
				Question 7 total	**1**	**0**	**5**	**6**	**0**	**6**

<table>
<tr><th colspan="4" rowspan="2">Question</th><th rowspan="2">Marking details</th><th colspan="6">Marks available</th></tr>
<tr><th>AO1</th><th>AO2</th><th>AO3</th><th>Total</th><th>Maths</th><th>Prac</th></tr>
<tr><td>8</td><td>(a)</td><td></td><td></td><td>Factor explanations
F0 – Energy required α mass or $E = mc\Delta T$.
F1 – Heat in α surface area.
F2 – Increasing thickness – heat must travel further or smaller temperature gradient.

Time
T0 – Energy α time or energy = power $\times$ time (of oven).
T1 – Time α mass.
T2 – Time α 1/area.
T3 - Time increases as thickness increases.

5-6 marks
All of F0 – F2 are present.
At least 3 from T0 – T3 are present.

There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.

3-4 marks
Expect 2 from F0 – F2.
Expect 2 from T0 – T3.

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 F0 – F2 is present.
1 from T0 – T3 is 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.</td><td></td><td>6</td><td></td><td>6</td><td></td><td></td></tr>
</table>

	(b)			Per unit mass is missing	1			1		
	(c)			22 × 1·26 = 27·7 [cm]		1		1		
	(d)			$\frac{0.46}{1.59} = 0.29$ [m²]		1		1		
	(e)	(i)		$E = mc\Delta T$ used e.g. = 9 × 3 200 × 90 (1) Answer = 9 × 3 200 × 90 = 2·59 [MJ] (1)	1	1		2	2	
		(ii)		$P = \frac{E}{t}$ [or by implication] (1) $t = \frac{2\,590\,000}{2200} = 1200\,\text{s}$ (1)	1	1		2	2	
		(iii)		Some detailed account of the 'lost' energy (1) e.g. All the oven and air also need rise in temperature Heat escapes from the oven to the kitchen/room/surroundings Energy goes to change of state of fat/water Clear statement that most of the energy is lost (1)			1 1	2		
		(iv)		Electrical energy used: 2 200 × 6.4 × 60^2 (1) [=50 688 000 J] Efficiency = 2 590 000 / 50 688 000 **(ecf)** = 0.051 **or** 5.1% (1)		1 1		2	2	
		(v)		Less than (1) Thermal energy required is only ½ that of 9.0 kg turkey (1) But cooking time >½ that required (1)			1 1 1	3		
				Question 8 total	**3**	**12**	**5**	**20**	**6**	**0**

A2 UNIT 3: Oscillations and Nuclei - SUMMARY OF ASSESSMENT OBJECTIVES

Question	AO1	AO2	AO3	TOTAL MARK	MATHS	PRAC
1	5	4	3	12	9	0
2	2	9	7	18	8	0
3	4	2	2	8	4	0
4	3	5	4	12	5	0
5	6	2	0	8	3	0
6	6	10	0	16	7	0
7	1	0	5	6	0	6
8	3	12	5	20	6	0
TOTAL	**30**	**44**	**26**	**100**	**42**	**6**

A2 UNIT 4 – Fields and Options

MARK SCHEME

GENERAL INSTRUCTIONS

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

<u>Recording of marks</u>

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.

<u>Marking rules</u>

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.

<u>Extended response question</u>

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.

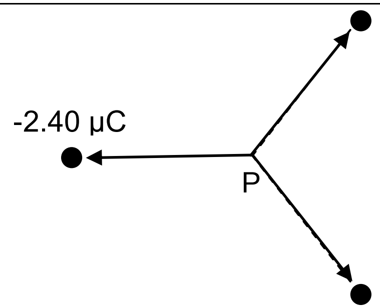
cao = correct answer only
ecf = error carried forward
bod = benefit of doubt

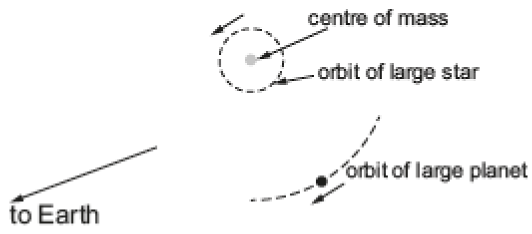
Question				Marking details	AO1	AO2	AO3	Total	Maths	Prac
1	*(a)*	(i)		Values substituted into $C=\frac{\varepsilon_0 A}{d}$ [= 7.32 × 10^{-9} F] (1) $Q = CV$ (or implied) note $C=\frac{Q}{V}$ not good enough (1) Answer = 9.37 × 10^{-7} [C] (1)	1	1 1		3	3	
		(ii)		Answer = 6.0 × 10^{-5} [J]		1		1	1	
		(iii)		Use of $E=\frac{V}{d}$ (1) Answer = 2 170 000 V m^{-1} **unit mark** (1)	1	1		2	2	
	(b)	(i)		Capacitance decreases (independent) (1) Energy stored increases (independent) (1)		2		2		
		(ii)		Work done by separating forces (independent) (1) Equal to increase in stored energy (1)			2	2		
				Question 1 total	**2**	**6**	**2**	**10**	**6**	**0**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
2	*(a)*			$n = \frac{9560}{1.45}$ (1) Correct answer = 2.65 m[T] (1)	1	1		2	2	
	(b)			$B = \frac{\mu_0 I}{2\pi a}$ used (e.g. 2.82 × 10^{-6} T or 4.35 × 10^{-6} T or 10^{x} slips) (1) Subtracting or adding fields (1) 1.53 × 10^{-6} T **unit mark (no ecf)** (1) Out of paper (1)	1	1 1 1		4	2	
	(c)			Application of $E = \frac{hc}{\lambda}$ **or** $E = hf$ and $c = f\lambda$ ***or*** equivalent (1) Division by e (i.e. conversion) (1) Answer = 5.57 × 10^{-7} [eV] (1)		3		3	3	
				Question 2 total	**2**	**7**	**0**	**9**	**7**	**0**

Question				Marking details	AO1	AO2	AO3	Total	Maths	Prac
					Marks available					
3	*(a)*			$F = Eq$ (or eE) used **or** implied (1) $E = \frac{V}{d}$ quoted or implied **and** $a = \frac{F}{m}$ used or implied (1) Algebra leading clearly to $a = \frac{Ve}{m_e d}$ (1)	1 1	1		3	3	
	(b)	(i)		No horizontal forces or field has no horizontal component		1		1		
		(ii)		Constant vertical force or uniform electric field		1		1		
	(c)			Correct application of $s = ut + ½at^2$ or equivalent (1) Time correct = 5.4 n[s] (1) Correct conclusion e.g. agrees with 5.0 ± 0.5 ns (1) Value is inside range of uncertainty or equivalent (1)		1 1	1 1	4	2	
	(d)			Valid method e.g. definition of eV, force x distance, getting resultant velocity and finding change in $\frac{1}{2}mv^2$ (1) Answer = 5.6 eV (which can simply be written for full marks) (1) **or** 8.96×10^{-19} J (answer of 11.2 eV gets 1/2 marks)		2		2	2	
				Question 3 total	**2**	**7**	**2**	**11**	**7**	**0**

Question				Marking details	AO1	AO2	AO3	Total	Maths	Prac
4	*(a)*			Flux increases **or** flux cutting (1) Because area increases **or** direction of cutting mentioned for top and bottom sides (1) Analysis of evidence in light of Faraday's law so correct conclusion from previous argument (1)		1 1	1	3		
	(b)			Anticlockwise gives field out **or** correct explanation (using FLHR or FRHR) for current left on top **and** right on bottom (1) Using right hand grip rule **or** FLHR **or** FRHR (1)	1	1		2		
	(c)			Area = πr^2 used (1) $V = \frac{BA}{t}$ **or** $\frac{d}{dt}(BAN)$ etc (1) $I = \frac{V}{R}$ used (1) Algebra e.g. $I = \frac{B\pi r^2}{tR}$ (1) Answer = 0.63 [A] (1)	1 1 1	1 1		5	5	
				Question 4 total	**4**	**5**	**1**	**10**	**5**	**0**

Question				**Marking details**	**Marks available**					
					AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
5	*(a)*			All arrows correct ✓✓ (1) Directions in line with dotted lines but some (or all) directions inverted (1) 	1 1			2		
	(b)			$E = \dfrac{Q}{4\pi\varepsilon_0 r^2}$ used (1) The 2 vertical components cancel or no field into or out of page **and** Pythagoras or trig e.g. $\sqrt{5^2 - 4^2} = 3$ **or** recognising 3,4,5 triangle (1) (equivalent is to realise cosθ = 3/5 or θ = 53^o etc.) 2 nC charge field ×2 **and** ×3/5 (for horizontal components) (1) Calculations all ok e.g. 8 640 = 7 200 ×2 × 3/5 or equivalent shown (1)	1	1 1 1		4	4	
	(c)			$V = \dfrac{Q}{4\pi\varepsilon_0 r}$ used (1) Attempt at adding all 3 potentials (1) - 360 -360 - 432 = - 1 152 [V] (1)	1	1 1		3	3	
	(d)			Use of PE = $q\Delta V$ must be a change (1) Rearrangement i.e. $v^2 = \dfrac{2\text{xPE}}{m}$ allow **ecf** on V (1) Answer = 18.3 × 10^6 [m s^{-1}] (**ecf** only if a ΔV used) (1)	1	1 1		3	3	
				Question 5 total	**5**	**7**	**0**	**12**	**10**	**0**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
6	*(a)*			 Reasonable orbit of star and companion in mutual orbit shown with Earth shown or direction towards Earth (1) In position shown star moves towards Earth therefore radial velocity is maximum towards Earth, ½ orbit later radial velocity is maximum away from Earth (1)	2			2		
	(b)			170 (± 2) days quoted/obtained/used (1) $r = \frac{1700\text{x}170\text{x}24\text{x}3600}{2\pi}$ [=3.97 × 10^9] (1)			2	2	1	
	(c)			$T = 2\pi\sqrt{\frac{d^3}{G(M+m)}}$ **or** $\sqrt{\frac{d^3}{GM}}$ used (1) Convincing algebra and substitution [= 6.63 × 10^{10}] (1)	1	1		2	2	
	(d)			Correct method e.g. $m_1r_1 = m_2r_2$ used **or** $r_1 = (m_1+m_2) / d$ used (1) Correct answer 4.8, 5.1 or 4.4 × 10^{28} [kg] (depending on approximation and value of radius taken) (1)	1	1		2	2	

	(e)			**Star theory** S0 – Need luminosity (or power output) of star. S1 – Star is a black body. S2 – Total power calculated using Stefan's law (or $P = 4\pi r^2 \sigma T^4$) S3 – Assume star is main sequence. S4 – Data can be obtained from spectrum / magnitude (mass, temperature, power). **Planet theory** P0 – Need star-planet distance. P1 – Inverse square law for intensity at planet. P2 – Stefan's law can (again) be used to obtain planet temperature. P3 – Planet not a black body or albido must be guessed. **Life conditions** L0 – Need moderate temperature (~ 300 K). L1 – Need water. L2 – Needs atmosphere. L3 – Planet needs to be large enough (for atmosphere). L4 - Planet shouldn't be too large / too strong a gravitational field. L5 – Assuming life similar to Earth. **5-6 marks** Expect 2 from S0 – S4 to be present. Expect 2 from P0 – P3 to be present. Expect 2 from L0 – L5 to be present. There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured. **3-4 marks** Expect 1 from S0 – S4 to be present. Expect 1 from P0 – P3 to be present. Expect 1 from L0 – L5 to be present. There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure.			6	6		

				1-2 marks Expect any 2 points to be made. 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 6 total	**4**	**2**	**8**	**14**	**5**	**0**

Question				Marking details	AO1	AO2	AO3	Total	Maths	Prac
					Marks available					
7	*(a)*			$\frac{1}{2}mv^2 = \frac{GMm}{R}$ (1) Mass = $\frac{4}{3}\pi r^3 \times \rho$ (1) Substitution of $v = H_0 d$ (1) Convincing algebra (1)	4			4	4	
	(b)			Answer = 9.5×10^{-27} (1) 5 or 6 H atoms (1)		2		2	1	
	(c)			$v = \frac{2\pi R}{T}$ quoted/used **or** $v = \omega r$ and $T = \frac{2\pi}{\omega}$ (1) 150 km/s and $30 \times 3.1 \times 10^{19}$ used (1) Answer = 3.9×10^{16} s / 1.2 (billion year) (1)			3	3	3	3
	(d)			$v = H_0 d$ = 50 000 [m/s] (1) Use of $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$ even if with irrelevant velocity e.g. 50 000 (1) Answers = - 0.22 n[m] (0.22 nm blue shift) and 0.44 n[m] (red shift) (1)			3	3	3	3
	(e)			Hubble's experiment repeated or further experiments carried out (1) Data obtained is improved (more accurate etc) or Hubble's law valid over a wider range (1)			2	2		2
				Question 7 total	**4**	**2**	**8**	**14**	**11**	**8**

Question				Marking details	AO1	AO2	AO3	Total	Maths	Prac
					Marks available					
8	*(a)*	(i)		Flux linkage is continually varying **or** flux continually being cut (1) Flux dependent on angle between normal [of area] and B-field **or** cutting direction continually changing as coil rotates (1)		2		2		
		(ii)		Increasing area increases emf because of more flux [linkage] (1) Increasing B increases emf because of more flux [linkage] (1) Increasing T decreases emf due to decreasing rate of change (1)			3	3		
	(b)	(i)		$\omega L = \frac{1}{\omega C}$ **or** $f = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$ (1) Answer = 1 239 [Hz] (1)	1	1		2	2	
		(ii)		V_R = 25 [V] (1) I = 0.167 [A] (1) $V_L = I\omega L$ **or** $V_C = I \text{x} \frac{1}{\omega C}$ (1) V_L = 71.5 [V] **and** V_C = 71.5 [V] or implied e.g. V_C = same (1)	1 1	1 1		4	3	
	(c)	(i)		$Z = \sqrt{(X_L - X_C)^2 + R^2}$ used (1) Z = 333 [Ω] (1) Current = $\frac{25}{333}$ = 75 [mA] (1)	1	1 1		3	3	
		(ii)		Equation for Q factor e.g. $Q = \frac{\omega_0 L}{R}$ (1) Decreasing R (1) Decreasing L or increasing C (1)	1		1 1	3		

	(d)			$\frac{R}{X_L} = \frac{1}{2}$ (1) $X_L = 2\pi fL$ **or** $X_L = \omega L$ and $\omega = 2\pi f$ (1) Answer = 955 [Hz] (1)	1	1 1		3	2	
				Question 8 total	**6**	**9**	**5**	**20**	**10**	**0**

Question				Marking details	Marks available					
					AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
9	*(a)*	(i)		Same shape curve below original with bigger minimum wavelength and line spectra in the same place/missing		1		1		
		(ii)		Line spectrum would change	1			1		
		(iii)		$eV = \frac{hc}{\lambda}$ (1) $\lambda = 1.65 \times 10^{-11}$ [m] (1)		2		2	2	
		(iv)		Power = IV = 9 375 [W] (1) 99.5% heat = 0.995 × 9 375 = 9 328 [W] (1)		2		2	2	
	(b)	(i)		Time = $\frac{17\text{x}2\text{x}10^{-6}}{34\text{x}10^{-6}}$ [s](1) Distance = 0.0493 [m] **(ecf)** for time (1) Thickness = $\frac{0.0493}{2}$ or 0.0259 **(ecf)** for distance (1)		3		3	3	
		(ii)		Z_{air} = 442 and Z_{skin} = 1 720 000 (1) R = 0.99[8] (1)	1	1		2	2	
		(iii)		No (no mark for merely quoting No) Due to large impedance difference (1) All ultrasound reflected off first air pocket (1)			2	2		
	(c)	(i)		Nuclei precess / wobble around field lines / radio waves cause resonance (1) Relaxation time explained (1)	2			2		
		(ii)		Uses very powerful magnets / no metal inside MRI (1) CT scan most suitable (1) Distinguishes soft tissue well (1)			3	3		
	(d)			Effective dose = Equivalent dose × W_T where W_T = tissue weighting factor (1) Units Sieverts / Sv (1)	2			2	1	
				Question 9 total	**6**	**9**	**5**	**20**	**10**	**0**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
10	*(a)*	(i)		The relative speed (of the ball) after hitting the bat (1) is equal to 0.73 x relative speed before collision (1)		2		2		
		(ii)		Equation $e = \sqrt{\frac{h}{H}}$ applied correctly (1) Height after second bounce = 2.2 [m] (1)	1	1		2	2	
		(iii)		**Any 2 × (1) from:** • Forces clearly labelled as lift, drag and weight • Spin provides more lift **or** gives friction on contact with the floor **or** gives stability when moving through air • Air pressure reduced behind the ball **or** to the side (can produce 'swing') **Third mark:** Description e.g. the ball deviates from normal trajectory depending on spin; can be implied from diagram (1)	2		1	3		
	(b)	(i)		Using appropriate equation of motion to determine t = 1.42 [s] (1) Recall and using angular velocity $\omega = \frac{\theta}{t}$ (1) Mean angular velocity = 11 [rad s^{-1}] (1)	1	1 1		3	3	
		(ii)		Conservation of angular momentum applied correctly i.e. ω = 6.7 [rad s^{-1}] (1) Use of rotational KE $(= \frac{1}{2} I\omega^2)$ (1) Correct final answer 22 [J] (1)		3		3	3	
		(iii)		Definition of moment of inertia (implied) (1) Reduce radius of rotation (1) Valid comment e.g. diver adopts a tuck position, draws in arms and legs (1)	1 1		1	3		

	(c)			Clockwise moment of wind = 1 180 × 5.2 = 6 136 [N m] (1) Anticlockwise moment of crew & height of boat = [(2 060 × 1.8) + (1 400 × 0.9)] (1) = 4 968 [N m] (1) Therefore boat topples in a clockwise direction (1)		1	1 1 1	4	2	
				Question 10 total	**6**	**9**	**5**	**20**	**10**	**0**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
11	*(a)*	(i)		Any three reasonable and appropriate statements e.g. • Significant (or equivalent or > $\times$ 5) increase in generation by renewable sources between 2000 and 2013 (1) • Biggest increase due to offshore and/or onshore wind sources (or numerical analysis) (1) • Little/no contribution from solar PV pre 2010 (or converse) (1)			3	3		
		(ii)		10 TWh produced in 2000 - from chart (1) $10 \times 10^{12} \times (60)^2$ (1) = [3.6×10^{16} J]		2		2	1	
		(iii)		Contribution from offshore wind ≈ 10 TWh from graph (**or use of** 3.6×10^{16} J) (1) $\frac{3.6 \times 10^{16}}{1.9 \times 10^{17}} \times 100\%$ = 18.9% (1)		2		2	1	
		(iv)	(I)	$\rho = ½ A\rho v^3$	1			1		
			(II)	Energy per second from each turbine = $½ A\rho v^3$ = $½ \times \pi \times 50^2 \times 1.2 \times 9^3$ [substitution (1)] = 3.44×10^6 [J s^{-1}] **(x 0.45 used appropriately)** (1) $1.55 \times 10^6 \times 3\,600 \times 24 \times 365.25$ = 4.88×10^{13} [J] (1) $n = \frac{3.6\text{x}10^{16}}{4.88\text{x}10^{13}} \approx 740$ (1)		1 1	 1 1	4	4	

	(b)	(i)		$\frac{\Delta Q}{\Delta t}$ Energy flowing through material per second **and** $\Delta\theta$ Temperature difference across the material	1			1		
		(ii)		Correct substitution into $\frac{\Delta Q}{\Delta t} = \frac{KA\Delta\theta}{l}$ (1) Conversion of units from mm into m (16 mm →0.016 m) **and** calculation of A (18 m × 15 m) (1) $\frac{\Delta Q}{\Delta t}$ = 40.5 kW (1)	1	1 1		3	2	
		(iii)		U = rate of energy transfer/$A\Delta\theta$ (1) U = 10 (1) W m^{-2} K^{-1} (1)	1 1	1		3	2	
		(iv)		**Either:** Reduce temperature difference between interior and loft space by reducing interior temperature **or** use material with lower U value as insulation in loft space	1			1		
				Question 11 total	**6**	**9**	**5**	**20**	**10**	**0**

A2 UNIT 4: Fields and Options - SUMMARY OF ASSESSMENT OBJECTIVES

Question	AO1	AO2	AO3	TOTAL MARK	MATHS	PRAC
1	2	6	2	10	6	0
2	2	7	0	9	7	0
3	2	7	2	11	7	0
4	4	5	1	10	5	0
5	5	7	0	12	10	0
6	4	2	8	14	5	0
7	4	2	8	14	11	8
8	6	9	5	20	10	0
9	6	9	5	20	10	0
10	6	9	5	20	10	0
11	6	9	5	20	10	0
TOTAL	**29**	**45**	**26**	**100**	**61**	**8**

A2 UNIT 5 – Practical Examination

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.

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.

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

Experimental Task

Question				Marking details	AO1	AO2	AO3	Total	Maths	Prac
1	(a)			Labelled diagram (1) Trial readings taken for $l \leq 0.60$ m **and** $l \geq 0.80$ m (1) Suitable range and intervals chosen and stated (1) Length of overhang stated and minimum of five oscillations (1) **Don't award any marks from the table for any of the above** **Teacher assessed marks:** A risk is identified and control specified e.g. ruler breaking so don't over extend ruler. Do not award the mark if the candidate does not work safely during the practical (1) No help needed to set up the apparatus (1)	1 1	1 1 1	1	6		6
	(b)			Clear headings and units (1) $\sqrt{l^3}$ correct (1) Minimum of five readings with repeats and sequential (1) Uncertainties correct to 1 or 2 sig figs (1) Resolutions correct (1)	1 1	1 1 1		5	2	5
	(c)			Titles and units on axis with suitable scale (1) All points plotted correctly to within ½ small square division (1) Error bars correct (1) Correct max / min lines of fit (1)	1	1 1 1		4	3	4
	(d)			Single gradient correct from graph (1) Mean gradient correct (1) % uncertainty correct to a max of 2 sig figs (1)		3		3	2	3

	(e)			$E = \frac{9}{\text{gradient}^2 bd^3}$ (1) b and d measured correctly in agreement with centre value (± 0.02 mm) (1) Repeat readings taken for b and d (1) E calculated correctly (1) % uncertainty of b and d (1) % uncertainty based on gradient (1) Correct % uncertainty (1) If same values accept resolution to calculate % uncertainty			7	7	3	7
				Question total	**5**	**12**	**8**	**25**	**10**	**25**

Practical Analysis Task

Question				Marking details	AO1	AO2	AO3	Total	Maths	Prac
1				Correct sinusoidal shape (1) Sinusoid with peak 3.4 squares high (1) Sinusoid period of 4 squares (1)	1	1 1		3		
2				Percentage uncertainty determined using resolution (0.9%, 1.5%, 6%) (1) Combined percentage uncertainty = 8% (1) Volume = 137 ± 11 cm^3 (2 sig figs for abs unc **and** unit correct) (1)		3		3	2	
3	*(a)*			Taking logs to give $\ln C = n \ln d + \ln k$ (1) Graph to be plotted should be $\ln C$ (y-axis) against $\ln d$ (x-axis) or explicit comparison with $y = mx + c$ (accept any logarithm) (1)	1	1		2	2	
	(b)			All values of $\ln d$ and $\ln C$ correct with no units (accept $\ln(d/\text{mm})$ and $\ln(C/\text{Bq})$ (1) 2 d.p. used consistently for all columns of data (1)		2		2	1	
	(c)			Axes labelled correctly – and no units (1) Suitable scale – so that data points occupy half of each axis (1) All points plotted correctly to within ½ small square division (1) Good line of fit consistent with the data (1)	1	1 1 1		4	3	
	(d)			**Determining *n*** Large triangle (should be close to extremities of the line of best fit i.e. over half the line used) (1) Gradient calculated correctly with negative sign (1) Gradient = n clearly stated (1) **Determining *k*** Data point identified from line to determine $\ln k$ (1) Value inserted into equation $\ln C = n \ln d + \ln k$ (1) k calculated correctly (1)			6	6	4	
	(e)			Equation consistent with values of k and n obtained			1	1	1	

	(f)	(i)		Yes (stated in conjunction with any of the following 2 points) Gradient is negative (1) *n* is approximately equal to 2 (1) Award 2 marks for: *n* is equal to -2			2	2		
		(ii)		Any valid comment (1) Effect on *n* explained (1) e.g. Background count provides a <u>systematic</u> uncertainty for the values of *C* (1) Therefore does not affect *n* (1) **or** Background count data should be subtracted from all values (1) Difficult to answer since taking logs (1) **or** Taking logs of count rate ± background (1) Correct conclusion e.g. significant effect for low count rate values (1)			2	2		
				Question total	**3**	**11**	**11**	**25**	**13**	**0**

A2 UNIT 5 – Practical Examination - SUMMARY OF ASSESSMENT OBJECTIVES

	Question	AO1	AO2	AO3	TOTAL MARK	MATHS	PRAC
Experimental Task	**TOTAL**	**5**	**12**	**8**	**25**	**10**	**25**
Practical Analysis Task	1	1	2	0	3	0	0
	2	0	3	0	3	2	0
	3	2	6	11	19	11	0
	TOTAL	**3**	**11**	**11**	**25**	**13**	**0**
	OVERALL TOTAL	**8**	**23**	**19**	**50**	**23**	**25**