Surname	Centre Number	Candidate Number
Other Names		2

GCE A LEVEL – NEW

A420U20-1

S17-A420U20-1

PHYSICS – A level component 2
Electricity and the Universe

WEDNESDAY, 21 JUNE 2017 – MORNING

2 hours

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**12**	
2.	**14**	
3.	**15**	
4.	**10**	
5.	**11**	
6.	**14**	
7.	**12**	
8.	**12**	
Total	**100**	

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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.
Write your answers in the spaces provided in this booklet.
Write your name, centre number and candidate number in the spaces at the top of this page.
Answer **all** questions.

INFORMATION FOR CANDIDATES

The total 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 **Q8***(a)*.

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Answer **all** *questions.*

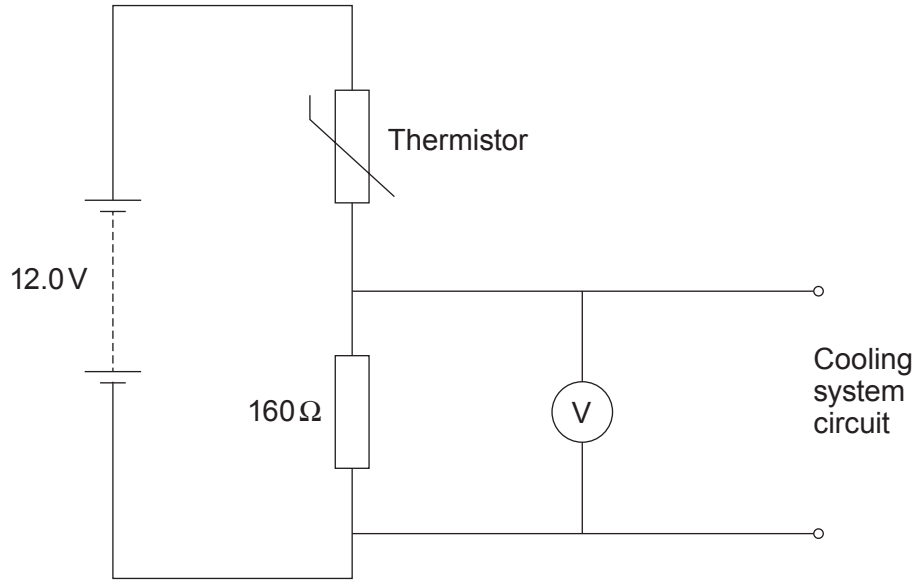
1. *(a)* Define the *potential difference* across two points in an electric circuit. [1]

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(b) The diagram shows a possible control circuit for a cooling system. It consists of a battery of emf 12.0 V and negligible internal resistance connected in series with a thermistor and a 160 Ω fixed resistor. The voltmeter and cooling system circuit have very high resistances.



Calculate the resistance of the thermistor when the voltmeter reads 2.4 V. [3]

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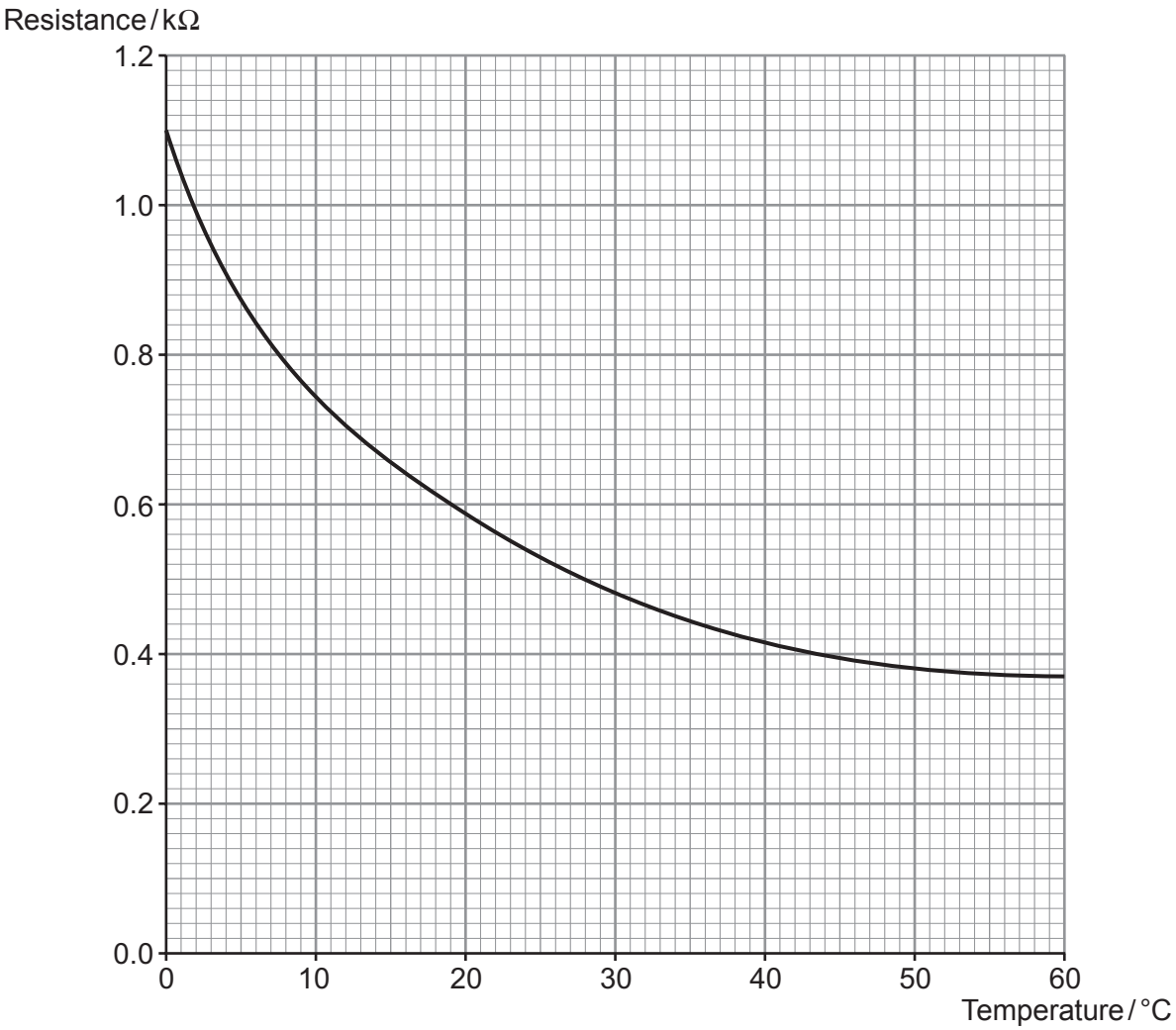
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(c) The graph shows how resistance varies with temperature for this thermistor.



(i) The reading on the voltmeter increases when the temperature of the thermistor increases. Explain why this is the case. [2]

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Turn over.

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(ii) The cooling system can only be activated when the voltage across the 160 Ω resistor rises above 2.8 V. An engineer suggests that this thermistor and resistor combination is suitable to use in a car cooling system and should activate when the temperature reaches 30 °C. Check this claim. [4]

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(d) The arrangement can also be used as a basis for a thermometer. By considering the shape of the graph on page 3 discuss whether this thermistor arrangement would be more effective at measuring changes in temperature between 0 °C and 10 °C or between 50 °C and 60 °C. [2]

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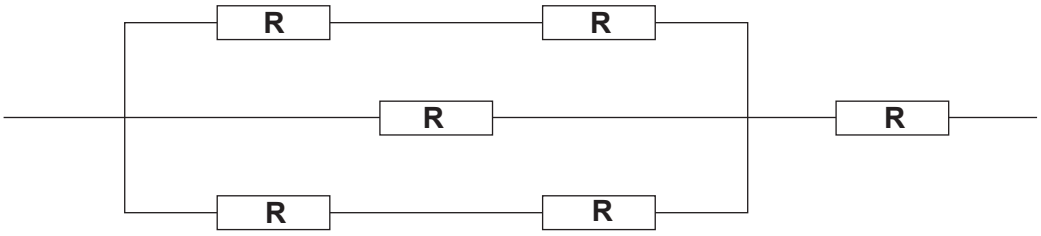
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2. *(a)* The resistor network shown consists of six identical resistors, each of value **R** Ω.



(i) Determine, **in terms of R**, the total resistance of the network. [3]

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(ii) **Draw a circle** around the resistor which dissipates the greatest power when a pd is applied across the arrangement. Explain your answer. [2]

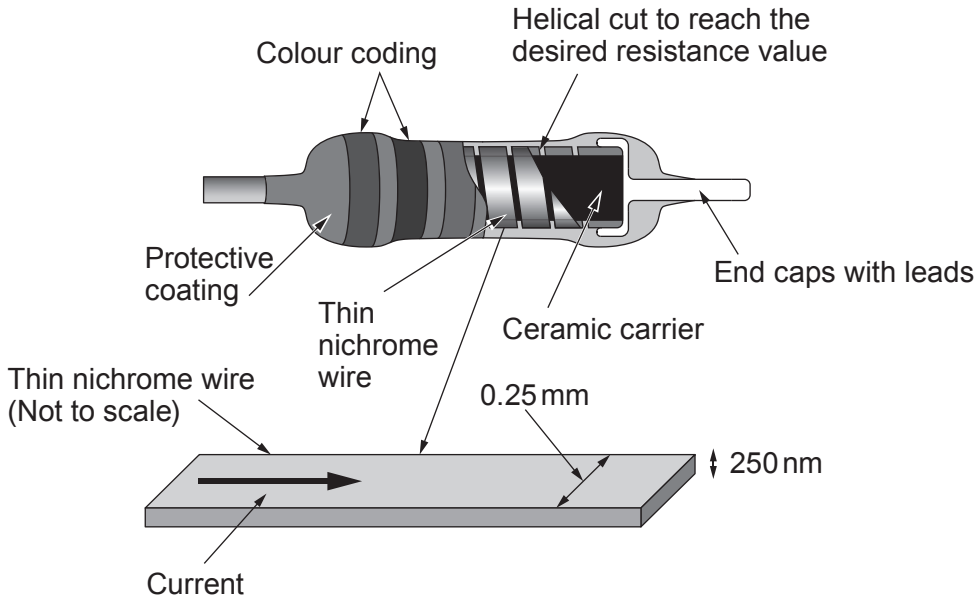
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(b) The alloy nichrome is commonly used to make 'Metal Film Resistors'. A cross-section through such a resistor is shown. The value of the resistor is determined by the length of the nichrome wire used in it.



The wire used in such a resistor has a rectangular cross-section as shown. Determine the length of nichrome wire required to make a 2.0 kΩ resistor.
[Resistivity of nichrome = $1.20 \times 10^{-6}\,\Omega\,\text{m}$] [2]

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(c) The current I through a wire is related to the drift velocity, v, of free electrons through the wire by the equation:

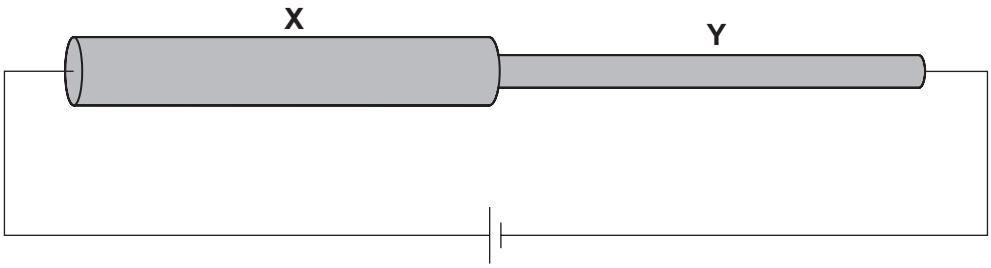
$$I = nAve$$

(i) State the meaning of n. [1]

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(ii) Two pieces of nichrome wire, **X** and **Y**, are joined end to end and connected to a battery as shown. The wires are of the same length but the diameter of **X** is **double** that of **Y**.



The table below shows the ratios of the values of n, I and v in the two wires. Write in the table the value of each ratio, giving an explanation for each of your answers. *Space is provided for calculations.* [3]

Ratio	Value	Explanation
$\frac{n_X}{n_Y}$		
$\frac{I_X}{I_Y}$		
$\frac{v_X}{v_Y}$		

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(iii) Wire **Y** is replaced with another wire **Z** of the same cross-sectional area as **Y** but double the length and made of a material with resistivity half that of **X**. Calculate the ratio:

$$\frac{\text{Power dissipated in wire } \mathbf{Z}}{\text{Power dissipated in wire } \mathbf{X}}$$

[3]

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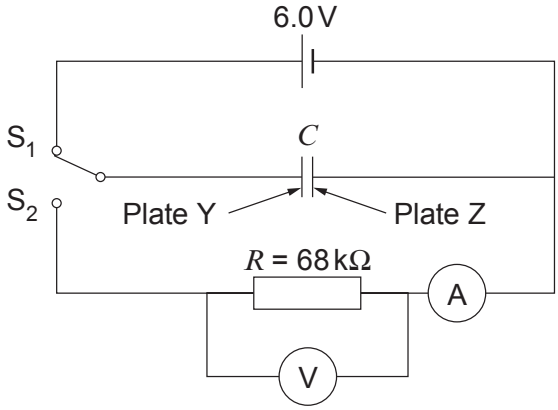
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3. Katie uses the following circuit to investigate the discharging of a capacitor of unknown value C.



(a) The plates of the capacitor are labelled Y and Z. When the switch is moved to S_1, explain how each plate becomes charged in terms of the movement of charges in the circuit. [2]

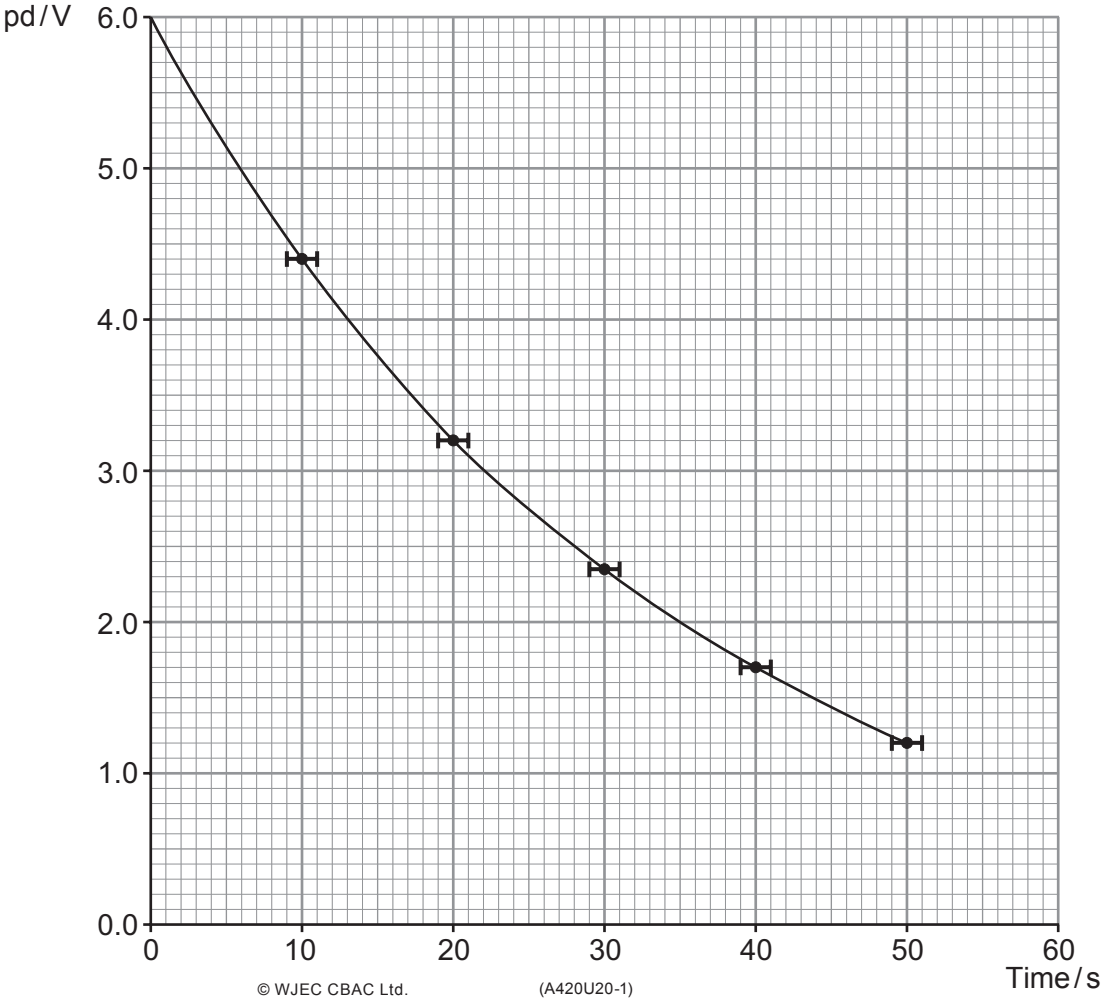
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(b) The switch is now moved to S_2 and the capacitor is allowed to discharge through the resistor. Katie takes readings of pd every 10 s for a period of 50 s and plots her results on the following grid.



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(i) The initial current in the circuit was 88 μA. Show that this is consistent with the value R = 68 kΩ. [1]

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(ii) Katie took **single** readings of pd. She used a voltmeter with a resolution of 0.01 V. Explain why it was not appropriate to include error bars when plotting pd. [2]

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(iii) She uses a stopwatch of resolution 1 second. State how this is represented on the graph. [1]

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(iv) Show that the time constant of the circuit is approximately 30 s. [2]

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(v) The resistor manufacturer states that the resistors are accurate to ± 3% of their given values. Use this information to calculate C along with its **absolute** uncertainty. [Take the absolute uncertainty in the time constant as being the same as the absolute uncertainty in the readings of time.] [4]

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(vi) Determine a value for pd at a time t = 55 s and state whether this is consistent with the trend shown by the graph. [3]

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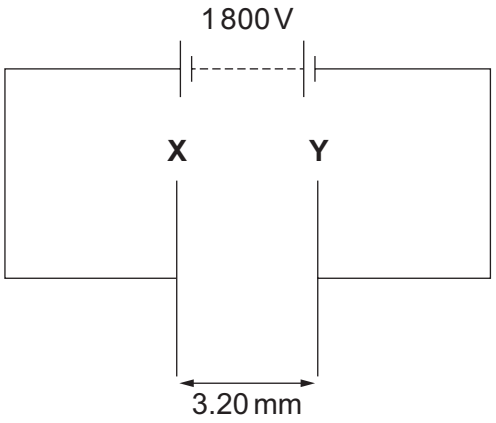
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4. A scientist investigating electric fields places two parallel plates **X** and **Y** a distance 3.20 mm apart and connects them to a high voltage supply as shown. There is a vacuum between the plates.



(a) **Sketch the electric field pattern** between the plates indicating clearly the direction of the field. [1]

(b) Electrons are accelerated from plate **Y** to plate **X**. Calculate:

(i) the force on an electron; [2]

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(ii) the gain in kinetic energy of an electron as it travels from **Y** to **X**; [2]

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(iii) the time it takes for an electron to travel from **Y** to **X**. Assume the electron starts from rest at plate **Y**. [3]

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(c) The separation between the plates is now halved but the pd is unchanged. The scientist believes that the gain in kinetic energy of an electron travelling (from rest) from **Y** to **X** will be unchanged. Verify this claim. [2]

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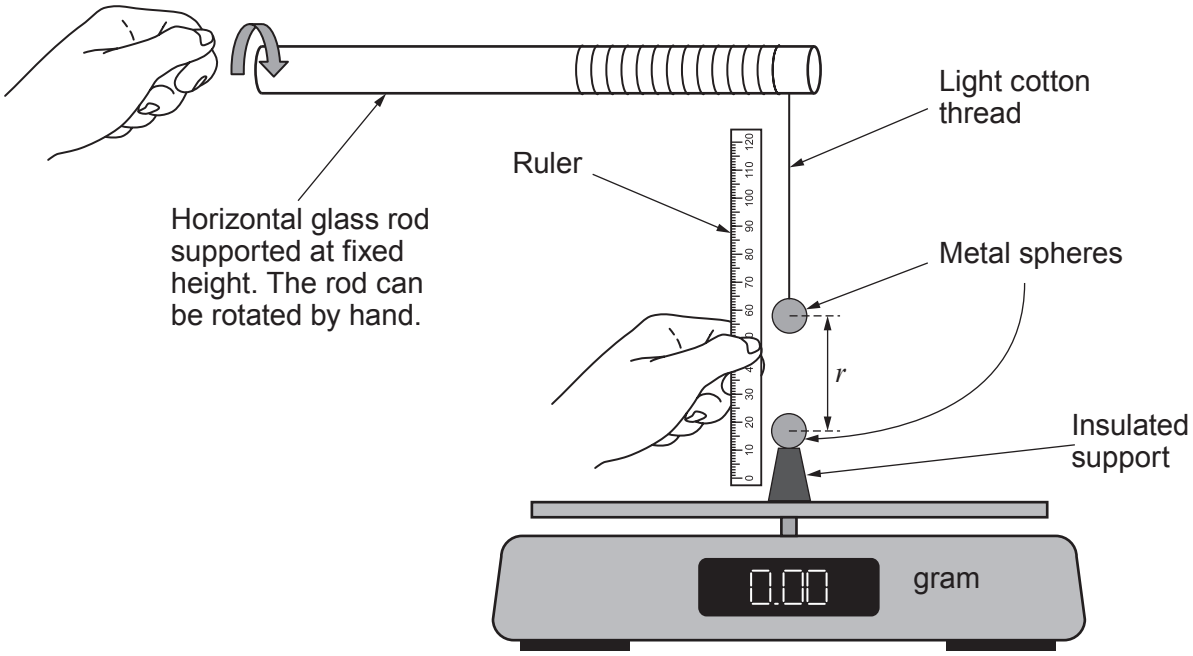
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5. Two students, Ben and Sarah, use the following apparatus to investigate the 'inverse square' nature of Coulomb's law.



The **same** negative charge is placed on both spheres. The distance, r, between the centres of the spheres is varied and the reading on the top pan balance is noted. Sarah and Ben disagree on the best method to measure r.

Ben favours using a ruler with a resolution of 1 mm to measure it directly.

Sarah suggests measuring the diameter of the glass rod with Vernier calipers, with a resolution of 0.01 mm, to determine the circumference of the rod. The rod can then be rotated by hand, with each complete rotation corresponding to the calculated circumference.

(a) (i) State an advantage and a disadvantage of each method. [4]

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(ii) Suggest an improvement to **one** of the techniques which would increase the accuracy of measuring r. [1]

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(b) When r = 20 mm, the reading on the top pan balance is 0.01 gram.

(i) Show that the value of Q_1Q_2, the product of the charges on the spheres, when r = 20 mm is approximately 4.4×10^{-18} C^2. [3]

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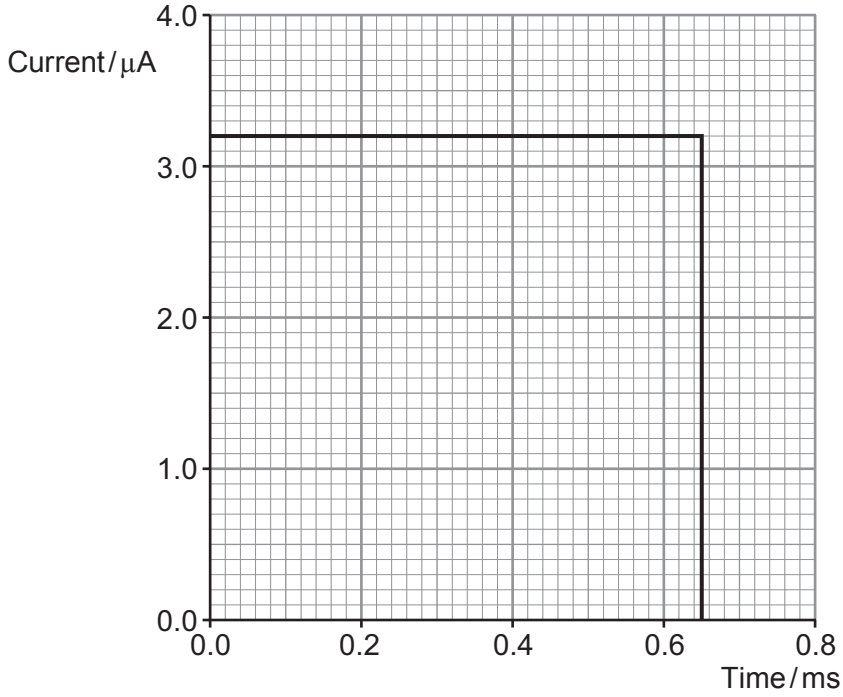
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(ii) One of the spheres is now discharged. The graph shows how the discharge current varies with time.



Show that the values given on the graph are consistent with the product Q_1Q_2 in *(b)*(i). [2]

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(iii) Hence, estimate the number of electrons on **one** sphere when the reading on the balance is 0.01 gram and r = 20 mm. [1]

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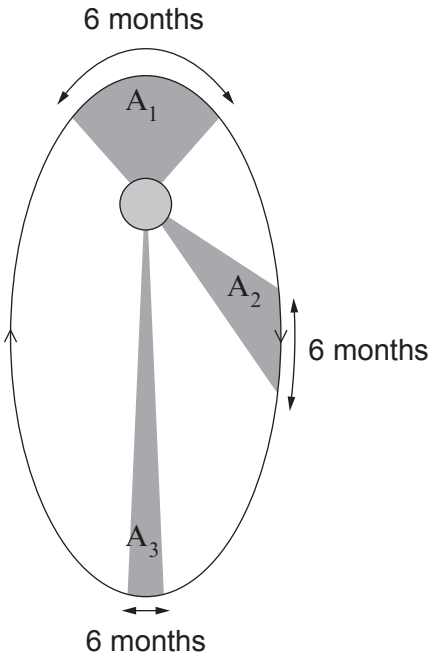
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6. Johannes Kepler devoted much of his life to the study of planetary motion. In the process he discovered three laws which describe the motion of any orbital body.

(a) The diagram is taken from a physics text book. Describe how it is used to explain Kepler's 2nd law. [3]



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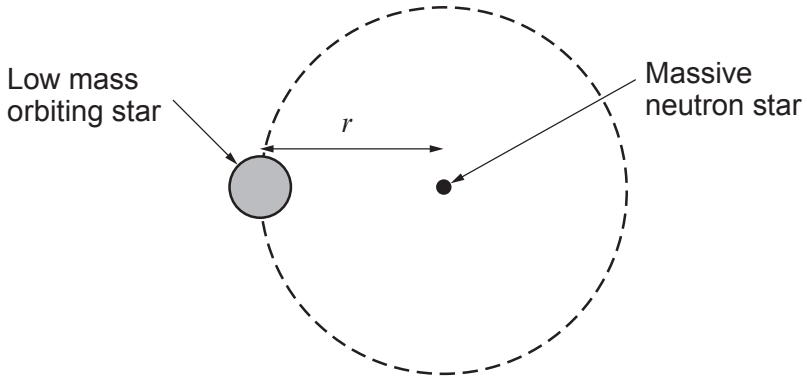
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(b) Use a formula for centripetal acceleration and Newton's law of gravitation to show that, for a planet in circular orbit of radius, r, around a star of mass, M:

$$T^2 = \frac{4\pi^2 r^3}{GM}$$

where T is the period of the planet's orbit. [3]

(c) A binary star system consists of a star of low mass orbiting a far more massive neutron star in a circular orbit of radius, r.



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(i) When analysing light from the low mass star, a hydrogen line at λ = 486.140 nm has a maximum Doppler shift of 0.052 nm. Further experimental measurements show that the orbital period is 1.45 years. Show that the radius of the low mass star's orbit is approximately 2.3×10^{11} m. [4]

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(ii) Astronomers believe that the mass of the neutron star is 1.8 times the mass of the Sun. Determine whether or not this is correct, stating any assumption you make. [Mass of Sun = 2.0×10^{30} kg] [4]

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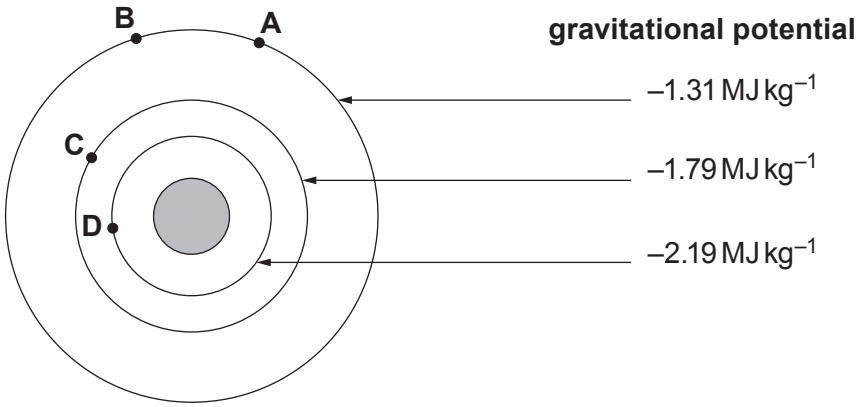
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7. *(a)* The diagram shows a series of equipotentials around the Moon showing values of the gravitational potential. **A**, **B**, **C** and **D** are four points on the equipotentials.



(i) Explain why the potentials have negative signs. [2]

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(ii) A spacecraft of mass 300 kg orbits the Moon. Determine, showing your reasoning, the changes in the gravitational potential energy of the spacecraft when it moves from:

I. **A** to **B**; [2]

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II. **B** to **C**. [2]

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(iii) The spacecraft is now directed from point **D** towards the Moon's surface with an initial speed of $0\,m\,s^{-1}$ in this direction. Calculate the speed at which the spacecraft impacts with the Moon's surface.
[Mass of Moon = 7.35×10^{22} kg. Radius of Moon = 1 740 km] [4]

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(b) Many space agencies have deliberately crashed their spacecraft on to the Moon for scientific purposes. The Lunar Crater Observation and Sensing Satellite (LCROSS) is one example which, along with its companion rocket, Centaur, impacted with the Moon in 2009. The following extract is taken from the space agency press release about the mission:

The primary goal of LCROSS is to measure the concentration of water (ice) in permanently shadowed lunar soil. When the Centaur, weighing up to 2 366 kg hits the floor of a permanently shadowed crater there will be an initial flash followed by the creation of a debris plume. If water is present on the floor of the crater, it will be thrown skyward. The LCROSS spacecraft, following four minutes behind, will collect and transmit data back to Mission Control about the debris plume before itself impacting the surface. A possible result of both of the impacts is the creation of a temporary thin atmosphere of hydroxyl ions. This resulting atmosphere could be detectable using telescopes on Earth.

[NASA LCROSS press kit June 2009]

Discuss the benefits and cost to society of such missions. [2]

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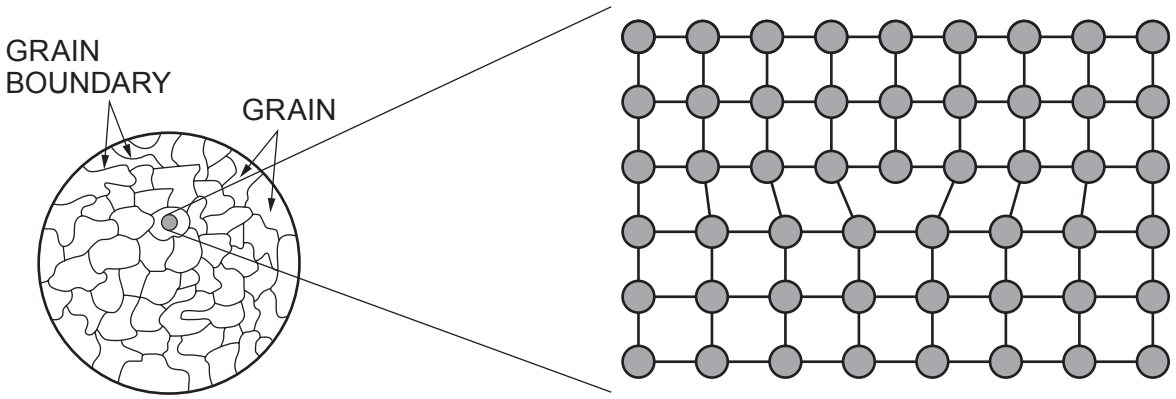
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8. *(a)* The diagrams show a microscopic view and an atomic representation of the crystalline structure of a typical metal.



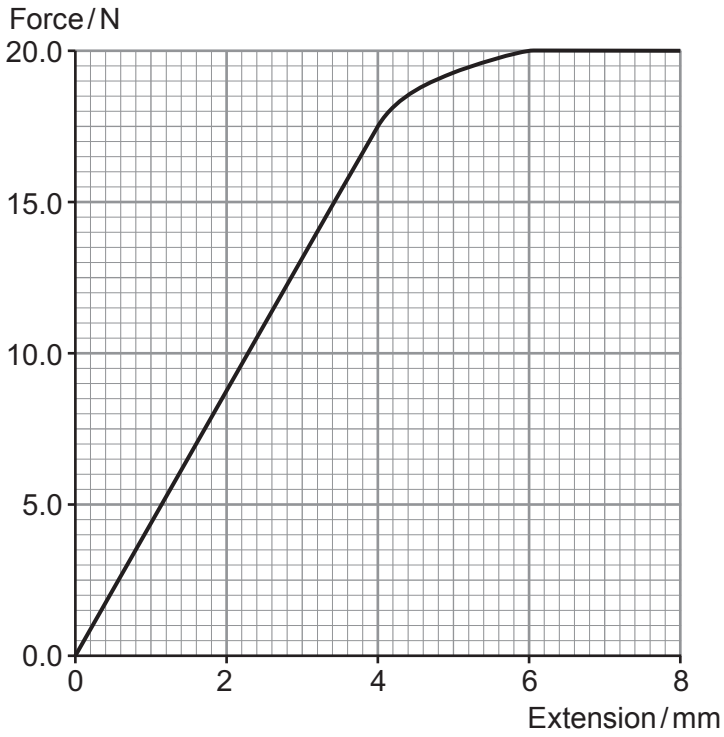
Microscopic view

Atomic representation

Describe how plastic deformation takes place in ductile metals and explain methods for increasing the strength of ductile metals. [6 QER]

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(b) A student investigates the force-extension properties of copper wire. He measures the diameter of the wire to be 0.32 mm and the original length to be 2.2 m. He measures the extension of the wire for various loads applied to it, up to a maximum load of 20.0 N. He draws a graph of force against extension from his results.



(i) Determine whether or not these measurements are consistent with copper having a Young Modulus of 120 GPa. [3]

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(ii) Estimate the work needed to produce a strain of 0.2% in the wire. [2]

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(iii) **Sketch a line on the graph** to show the possible behaviour of the wire when the 20 N force is removed. [Assume the wire has been stretched beyond its elastic limit.] [1]

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