Surname	Centre Number	Candidate Number
First name(s)		2

GCE A LEVEL

A420U20-1

O21-A420U20-1

THURSDAY, 14 OCTOBER 2021 – MORNING

PHYSICS – A level component 2
Electricity and the Universe

2 hours

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**10**	
2.	**12**	
3.	**17**	
4.	**16**	
5.	**15**	
6.	**6**	
7.	**13**	
8.	**11**	
Total	**100**	

A420U201 01

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. Do not use gel pen or correction fluid.
You may use a pencil for graphs and diagrams only.
Write your name, centre number and candidate number in the spaces at the top of this page.
Answer **all** questions.
Write your answers in the spaces provided in this booklet. If you run out of space, use the additional page(s) at the back of the booklet, taking care to number the question(s) correctly.

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 question **6**.

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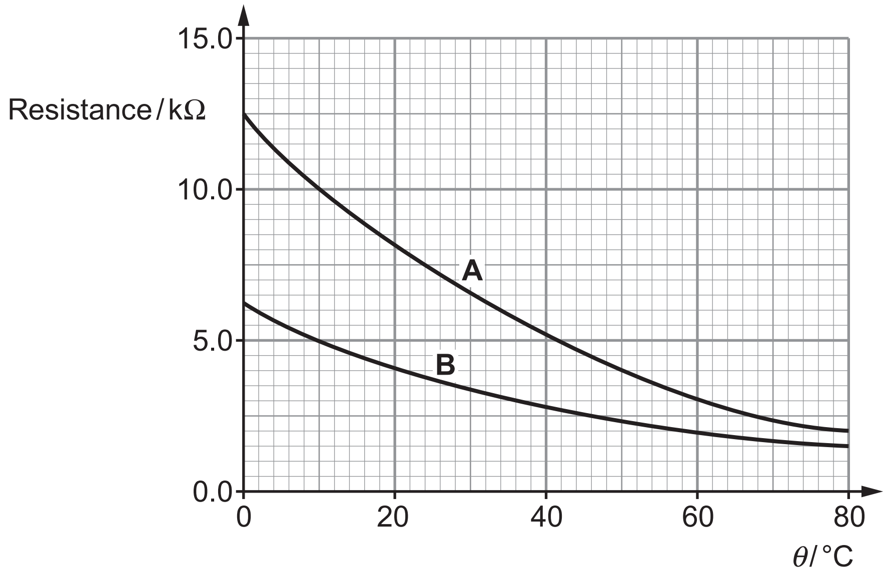
Answer **all** *questions.*

1. Thermistors are resistors which change their resistance with temperature, θ. The diagram shows how the resistance of two different thermistors (**A** and **B**), varies with θ.



(a) State which of the thermistors (**A** or **B**) would be better to use to read temperature differences between 20 °C and 60 °C, giving a reason for your answer. [1]

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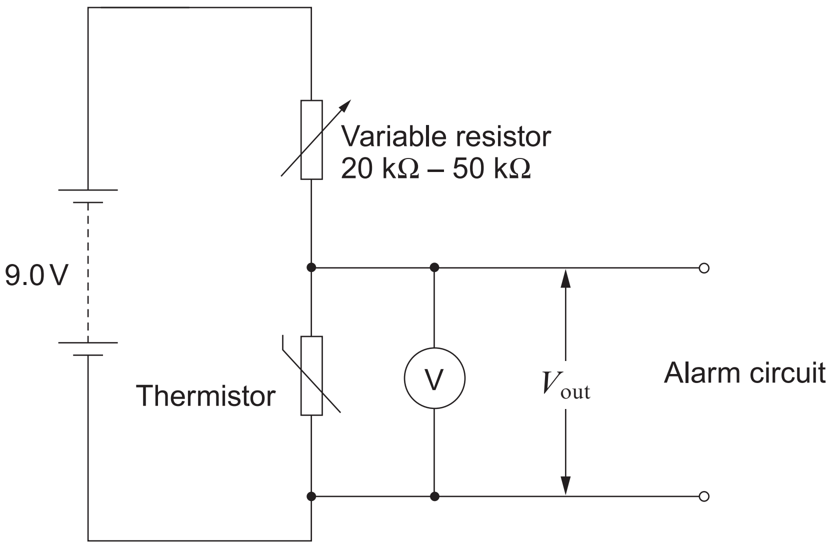
(b) Helen is a keen gardener. She builds a frost alarm to protect her plants from low temperatures. She uses a battery of emf 9.0 V and negligible internal resistance, connected in series with a thermistor and a (20 kΩ–50 kΩ) variable resistor. The voltmeter and alarm circuit have very high resistances.



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(i) Explain why V_{out} increases as the temperature decreases. [3]

(ii) The alarm will trigger when V_{out} reaches 2.0 V. Helen wishes to be able to adjust the variable resistor to enable the alarm to be triggered at **10 °C**. Determine whether thermistor **A** or thermistor **B** or both of them are suitable to use in this situation. [3]

(iii) Hence calculate the power dissipated by the variable resistor when the alarm is activated. [2]

(iv) When deciding where to locate the circuit, Helen places the variable resistor a few mm away from the thermistor. Comment on this decision in light of your answer to part (iii). [1]

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2. *(a)* Show how the unit of the time constant, RC, can be given as the 'second'. [3]

(b) A student investigates the **charging** of a 2200 μF capacitor through a 44 kΩ resistor placed in series with it. He measures the pd across the capacitor and the current as it is charged from a battery of emf 6.0 V.

(i) Sketch a diagram of the circuit he would use to obtain data. [2]

(ii) Calculate the charge on the capacitor after 20 seconds. [4]

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(iii) The reading on the voltmeter after 20 seconds is noted as 1.1 V. Determine whether or not this is consistent with your answer to part *(b)*(ii). [2]

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(c) Calculate the number of electrons transferred from the positive plate to the negative plate of the capacitor **when it is fully charged**. [1]

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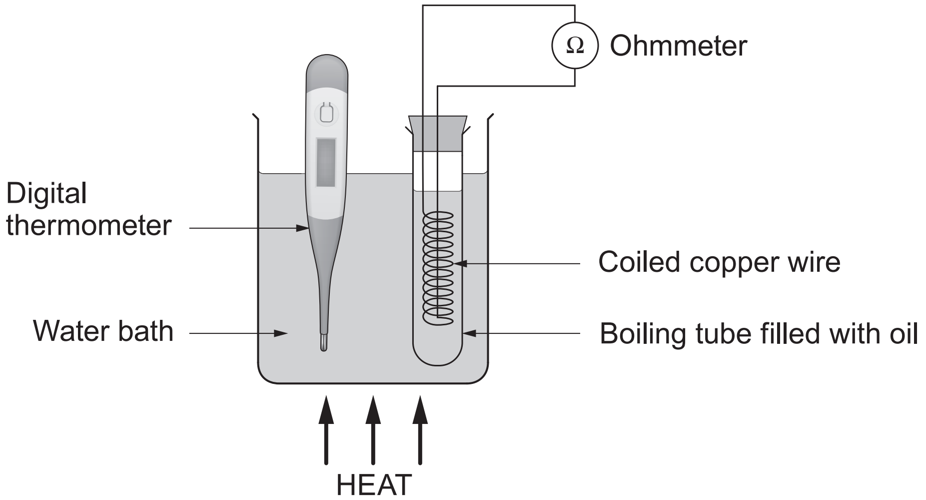
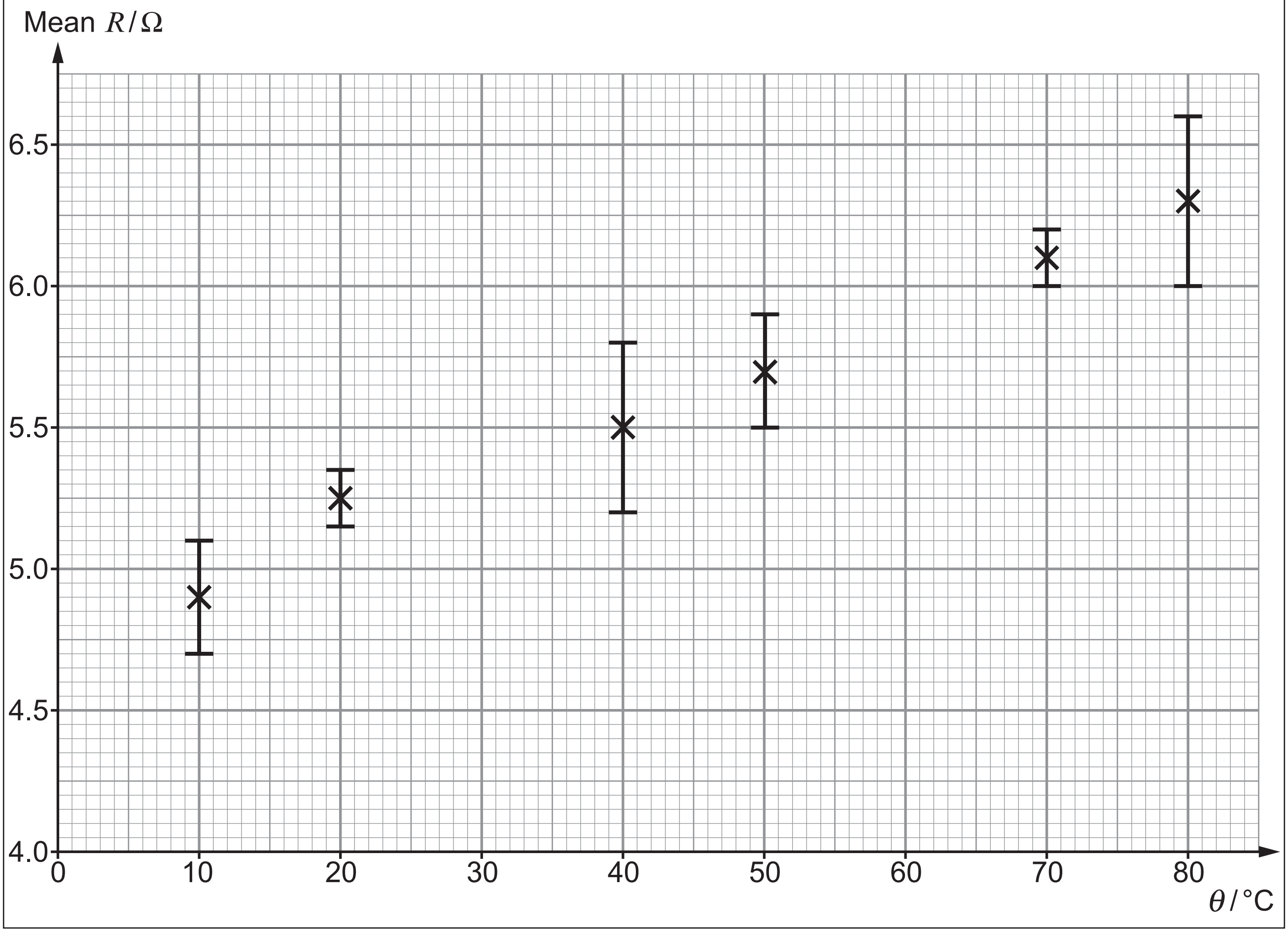
3. Tom uses the following apparatus to investigate the variation of resistance with temperature for copper in the form of a coil of wire.



Instrument	Resolution
Ohmmeter	± 0.1 Ω
Thermometer	± 0.1 °C

(a) Tom slowly heats the coil, taking readings of its temperature, θ, and resistance, R, at 10 °C intervals. He repeats the experiment while cooling the coil. Tom draws a graph of mean R against θ, plotting all of the points, other than the ones at 30 °C and 60 °C.



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(i) Tom does not plot error bars for temperature. Discuss why this is a reasonable decision to make. [1]

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(ii) At 30 °C and 60 °C the following readings for R are obtained.

Temperature / °C	Resistance / Ω	
	During heating	During cooling
30	5.1	5.5
60	5.9	5.9

Use this information to plot each point **along with its error bar** on the grid. [2]

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(iii) Draw lines of maximum and minimum gradients and determine the gradients of both lines. [3]

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(iv) Hence calculate the mean gradient and the **percentage** uncertainty in its value. [2]

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(b) A Physics textbook states that the resistance, R, of a metal is related to its temperature, θ (in degrees centigrade), by the equation:

$$R = R_0\alpha\theta + R_0$$

in which R_0 is the resistance of the metal at 0 °C and α is known as the temperature coefficient of resistance for that metal.

(i) Tom believes **incorrectly** that the answer to part *(a)*(iv) represents the temperature coefficient of resistance, α, for copper. Explain why Tom is incorrect. [2]

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(ii) Determine α for copper, along with its **absolute** uncertainty. [5]

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(c) Tom notes that some of the error bars on his graph are large. Give a possible reason for this and suggest what practical steps Tom could have taken to reduce their size. [2]

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4. *(a)* (i) Glass is a brittle material. Briefly describe the process by which glass fractures. [2]

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(ii) Car windscreens are made from pre-stressed glass. During production, jets of air cool the hot glass which causes the outside to contract and harden while the inside remains soft. Later, the inside cools and contracts, putting the outside surface under greater compression. Explain how this process makes the windscreen less likely to fracture. [2]

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(b) (i) A glass marble of mass 20 g is securely attached to a thin nylon thread of length 0.30 m and diameter 0.16 mm. Determine the extension of the thread when the marble is suspended vertically. [$E_{\text{nylon}} = 2.00 \times 10^9$ Pa] [3]

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(ii) The maximum stress that nylon can withstand before breaking is 9.00×10^7 Pa. Determine the breaking force for this thread. [2]

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(c) (i) Ian is a keen Physics student and believes he can whirl the marble, still attached to the thread, in a **vertical** circle at a rate of 0.40 seconds per complete rotation quite safely, without breaking the thread. Show that he is correct. [Assume the speed is the same throughout the rotation and the length of the thread does not change.] [3]

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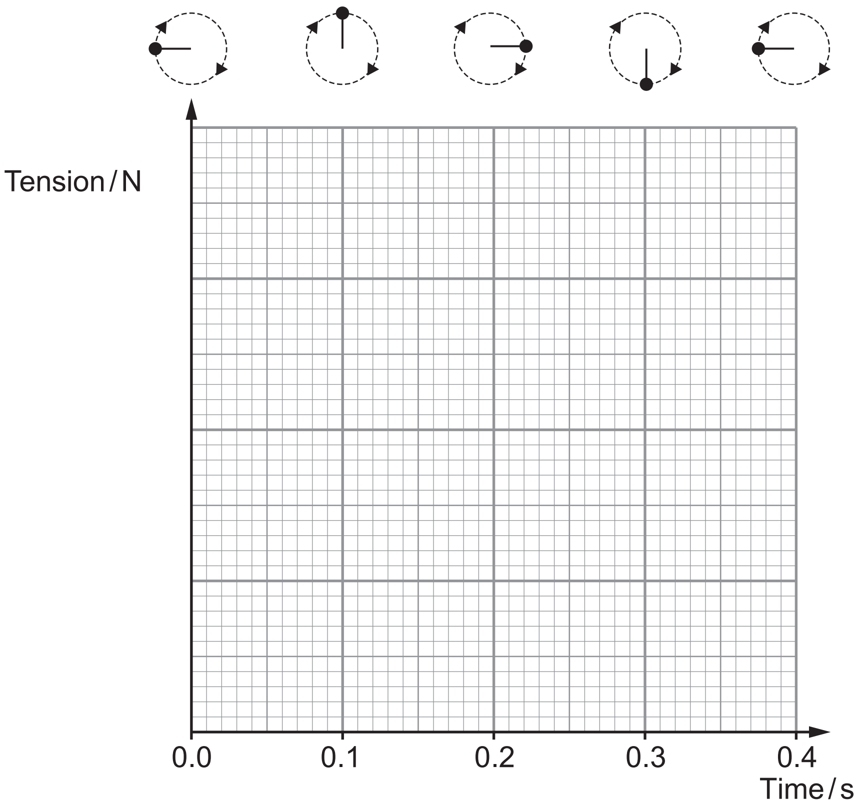
(ii) Sketch a graph on the grid below showing the variation in tension in the thread when the period is 0.40 s. Assume the marble and thread are positioned horizontally (as shown) at time = 0.00 s. *Space is provided for calculations.* [4]



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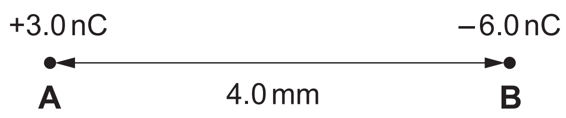
5. *(a)* The diagram shows an isolated positive charge. On the diagram **sketch** and **label**:

(i) at least 4 electric field lines, including their direction;

(ii) at least 3 equipotential surfaces. [2]

(b) Point charges of +3.0 nC and −6.0 nC are fixed at points **A** and **B** as shown below. The distance between the charges is 4.0 mm.



(i) Calculate the magnitude and direction of the force on the +3.0 nC charge. [3]

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(ii) Without further calculation, state the force on the −6.0 nC charge, giving a reason for your answer. [2]

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(c) (i) Define *electric potential*, V, at a point in an electric field. [1]

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(ii) The −6.0 nC charge is now moved directly to the right of **B** by 2.0 mm, to point **C**, and is fixed there. This is shown below.

Calculate the work done in moving the −6.0 nC charge from **B** to **C**. [4]

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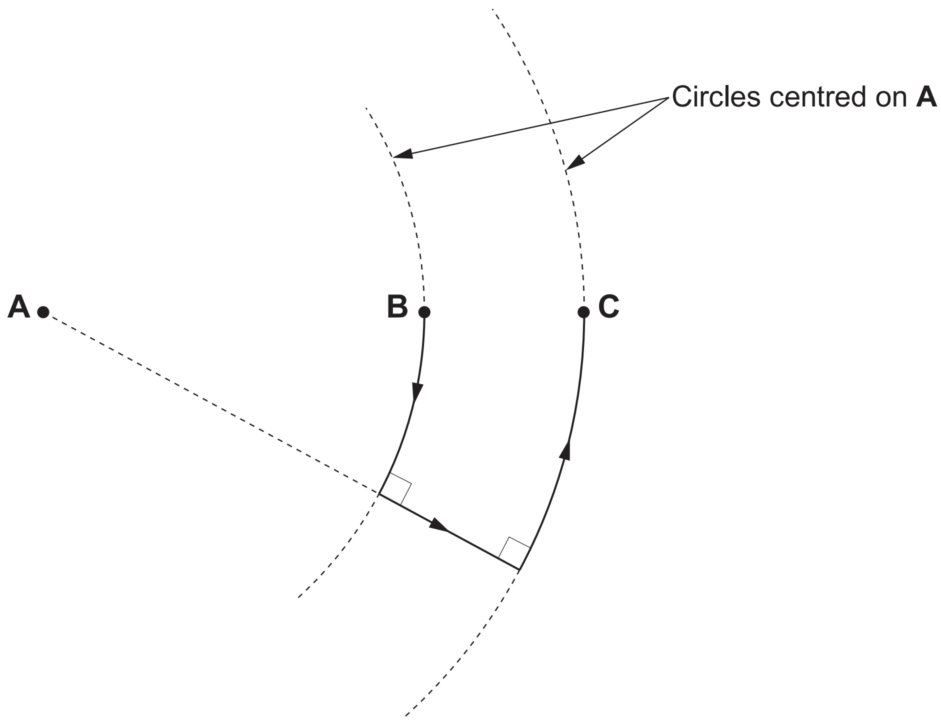
(d) In moving the −6.0 nC charge from **B** to **C**, the following alternative pathway is possible. Explain why the work done in moving the charge along this pathway is the same as calculated in part *(c)*(ii). [3]



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6. Astronomers can learn much about a star from:

- measuring the intensity of radiation originating from the star;
- knowing its distance from the Earth;
- studying its spectrum.

Explain how this information can be used to determine the properties of a star. [6 QER]

6

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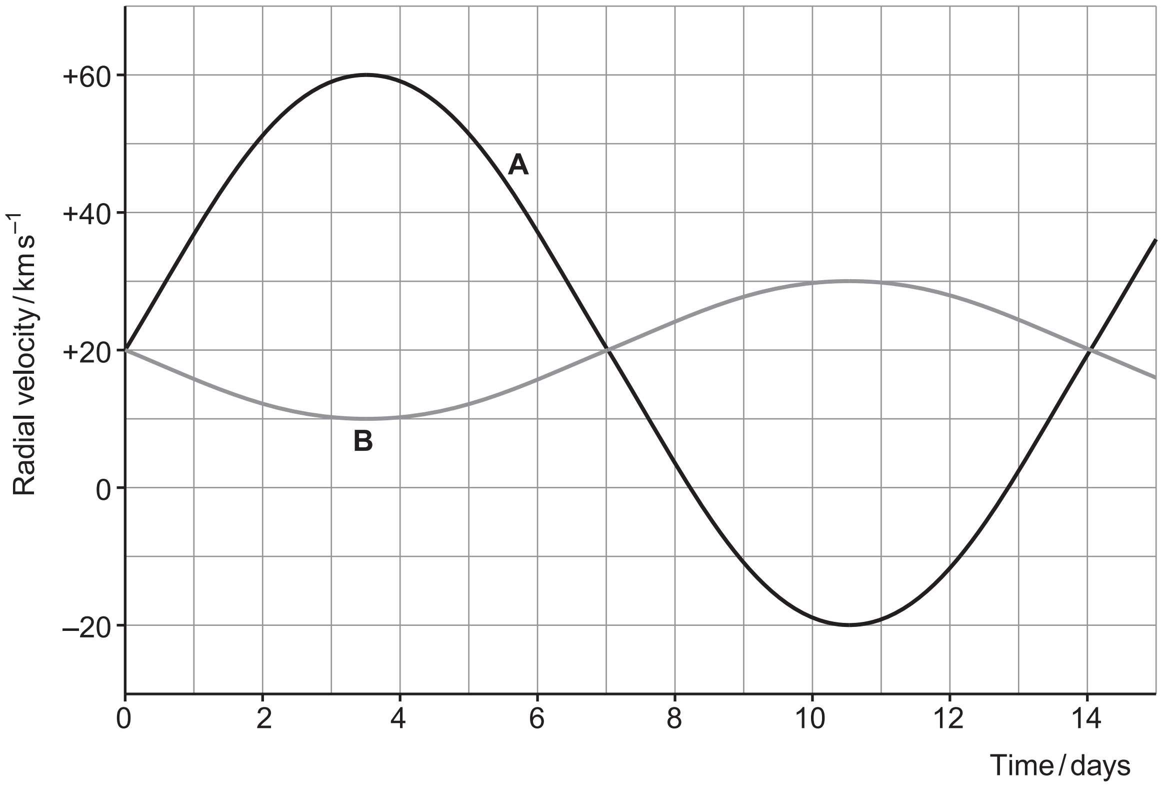
7. A binary star system consists of a pair of stars in mutual orbit. Since both stars emit light, the orbital velocities of the two stars can be determined. The following graphs show the radial velocity of two stars (**A** and **B**) in mutual orbit. The system is viewed edge-on by an observer on Earth.



(a) (i) In addition to orbiting about each other, the stars in the system are also moving away (receding) from the Earth. Use the graphs to write down the speed of recession. [1]

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(ii) Show that:

the orbiting speed of star **A** = 4 × the orbiting speed of star **B**. [2]

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(iii) Calculate the radius of the orbit of star **A**. [3]

(iv) Hence calculate the separation of the stars. [2]

(b) (i) Calculate the **total mass** of the binary star system. [3]

(ii) Explaining your reasoning, determine the individual masses of both star **A** and star **B**. [2]

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8. *(a)* A Physics textbook states:

'The universe was created about 14 billion years ago.'

Show that this statement is consistent with the current critical density of the universe of about 10^{-26} kg m^{-3}. [1 billion years = 10^9 years] [3]

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(b) The Virgo cluster contains roughly 1 300 galaxies. NGC 4152 is one galaxy in this cluster. Astronomers measure the wavelength of a specific spectral line from NGC 4152 to be 399.4 nm. The laboratory wavelength is 396.8 nm.

(i) Explain what the astronomers can deduce about the galaxy's movement in relation to the Earth. **[No calculations are required].** [2]

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(ii) Determine the distance of NGC 4152 from the Earth. [3]

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(c) The table shows data from two other galaxies in the cluster, obtained from Wikipedia.

Galaxy	Speed of recession / $km\,s^{-1}$	Distance from Earth / million light years
NGC 4216	131	55
NGC 4293	893	54

Discuss whether or not scientists can use this data to disprove Hubble's Law. [3]

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END OF PAPER

Question number	Additional page, if required. Write the question number(s) in the left-hand margin.

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