Surname	Centre Number	Candidate Number
First name(s)		2

GCE A LEVEL

A420U20-1

O20-A420U20-1

THURSDAY, 15 OCTOBER 2020 – 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.	**13**	
3.	**10**	
4.	**9**	
5.	**19**	
6.	**13**	
7.	**15**	
8.	**11**	
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 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 continuation page 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 **Q3*(a)***.

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Answer **all** *questions.*

1. *(a)* Compare the movement of free electrons in a metal **before** and **after** a pd is applied to the metal. [3]

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(b) (i) The current, I, in a wire of cross-sectional area, A, is given by the formula:

$$I = nAve$$

where n is the number of free electrons per unit volume and v is the drift velocity of these electrons. Derive the formula. Include a clearly labelled diagram. [4]

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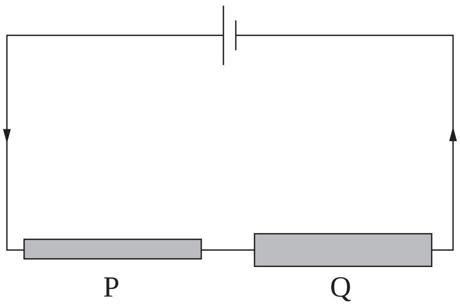
(ii) Wires P and Q are connected to a fixed voltage source. Wire Q is made of a different metal from wire P and has fewer free electrons per unit volume. [$n_P = 6.4 \times 10^{28}\,\text{m}^{-3}$ and $n_Q = 2.0 \times 10^{28}\,\text{m}^{-3}$]. The diameter of wire Q is twice the diameter of wire P.



Determine the ratio $\dfrac{v_Q}{v_P}$. [3]

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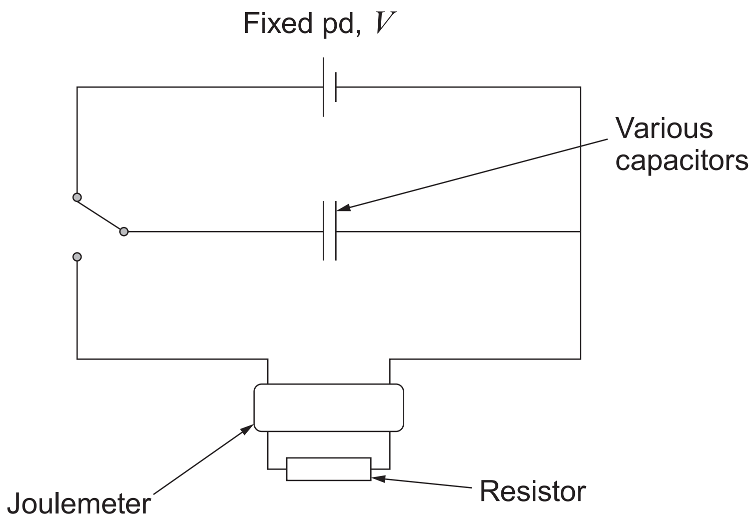
2. Zack investigates how the energy stored in a capacitor depends on the value of the capacitor, **for a fixed potential difference**, V.
He is provided with 5 capacitors of differing values.
He uses the following circuit to fully charge each of the capacitors from the fixed pd, V, and then discharges them in turn through a resistor.
The energy transferred is measured using a joulemeter.
He carries out this procedure twice for each capacitor.



Zack plots a graph of mean energy stored, U, against capacitance C.
The graph (on page 6) displays the uncertainties in the mean values of U and C.
Zack uses the **percentage tolerance (uncertainty)** information displayed on each capacitor to draw the error bars on the capacitance axis.
He notes that the percentage tolerance is the same for each capacitor.

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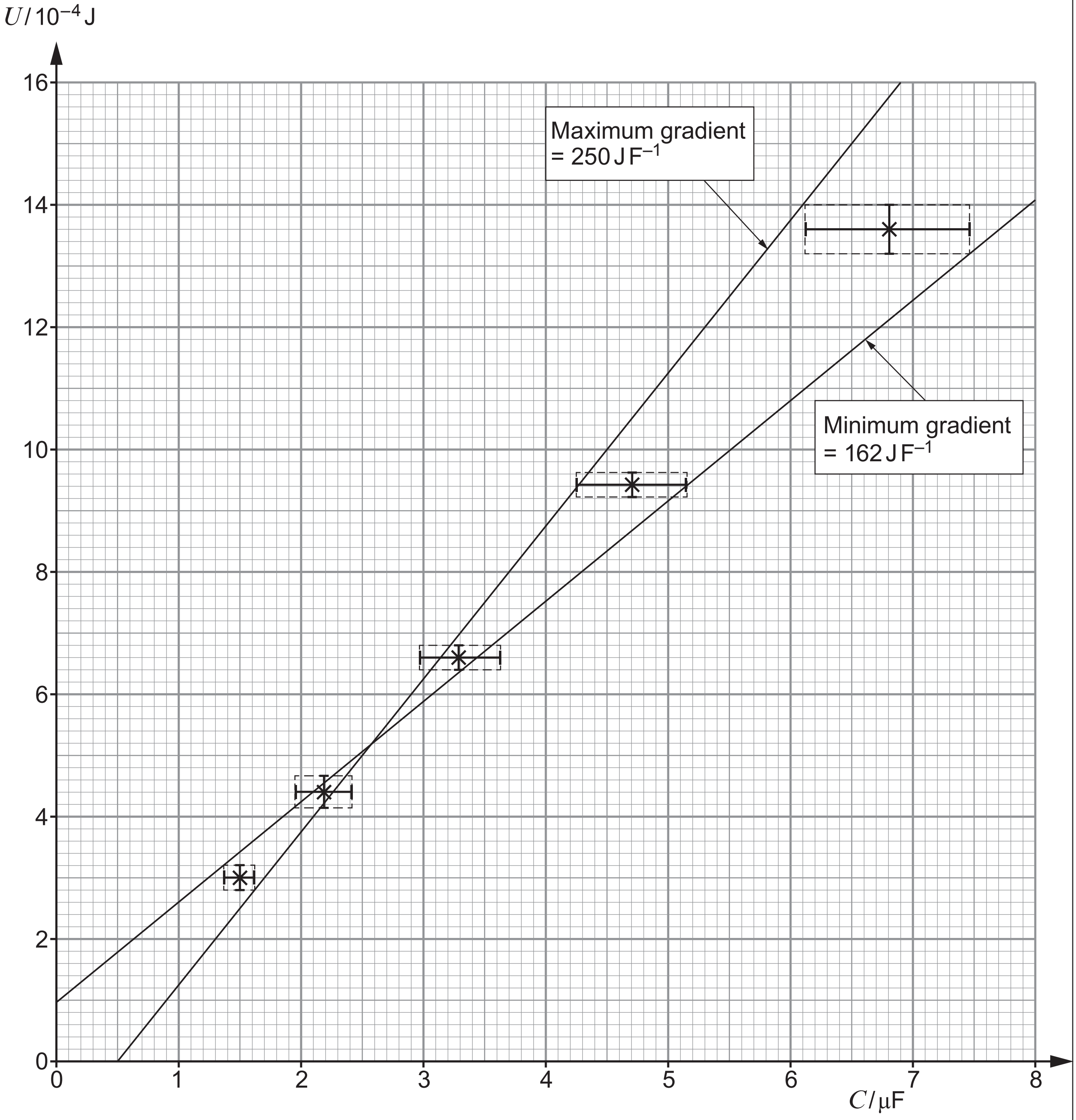

(a) (i) Zack notes that, for all of the capacitors, the joulemeter reading for the first trial was different from the reading for the second trial. Using values from **one** of the data points, explain how the **length** of the error bars on the y-axis is related to the readings. [2]

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(ii) Determine the **percentage** tolerance of the capacitors. [2]

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(b) (i) **Using the values of the gradients given** on the grid and an appropriate equation, determine the maximum and minimum values for V. [3]

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(ii) Hence determine the pd, V, along with its **absolute** uncertainty. [3]

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(c) Zack's teacher suggests that he should carry out another experiment. Zack decides to discharge the 6.8 μF capacitor through a 5.6 MΩ resistor. He notes that it took 35 seconds for the pd across the capacitor to drop to 8.0 V. Determine whether or not these results are consistent with an initial value of V = 20.0 V. [3]

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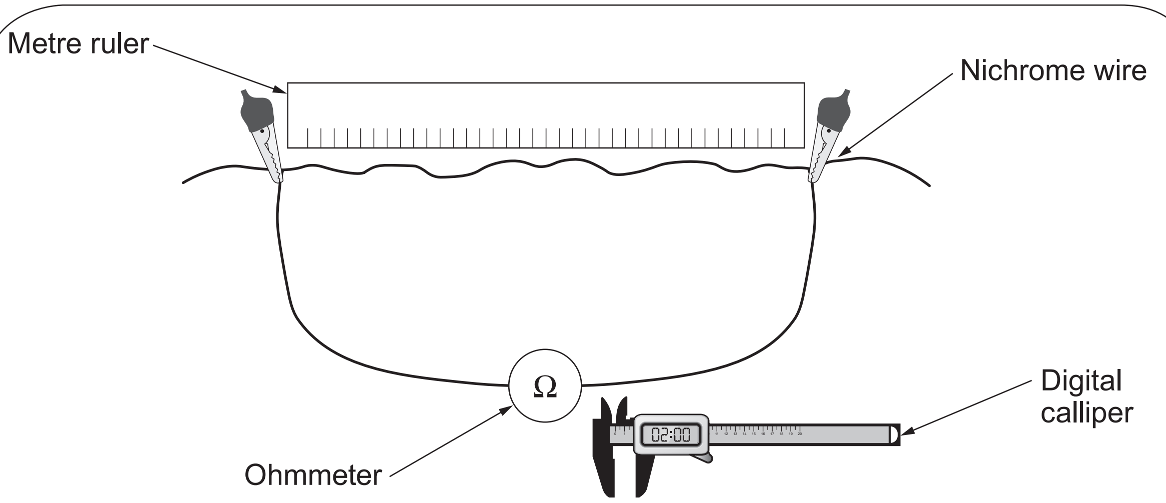
3. *(a)* Sally writes a plan for an experiment to determine the resistivity, ρ, of nichrome in a wire. Her outline plan, which includes a diagram of the apparatus is given below.



- Use the digital calliper to take a reading of the diameter, d, of the wire.
- Calculate the cross-sectional area of the wire from d.
- Take a reading of resistance at 50 cm.
- Substitute all values into $\rho = \frac{RA}{l}$ to determine the resistivity.

Sally's teacher believes the plan lacks detail, which might lead to an inaccurate value for ρ. Using the same apparatus, suggest improvements to the plan. You should include details of how to reduce the uncertainty in ρ using a graphical method. [6 QER]

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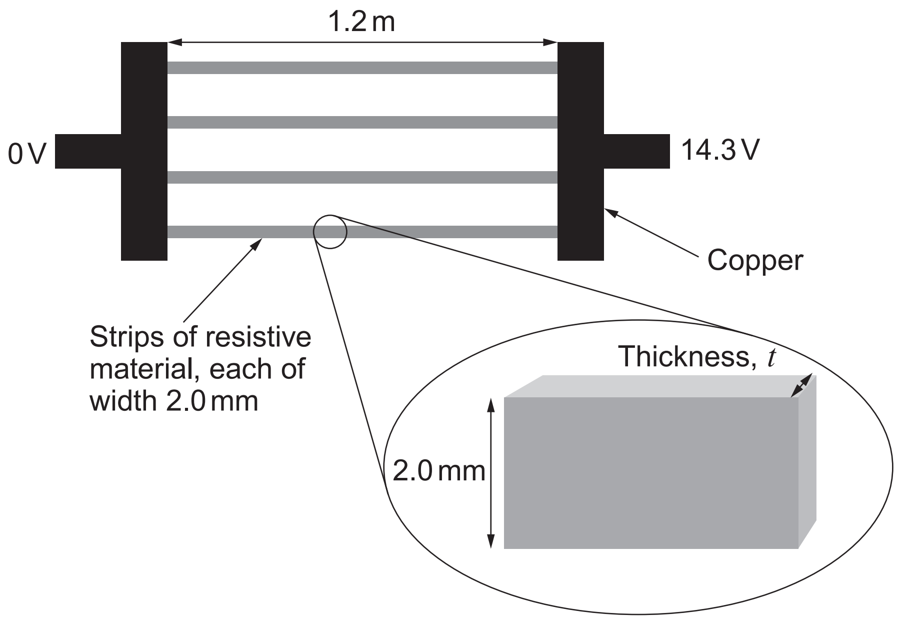
(b) A heating unit proposed for the rear window of a car is to consist of four rectangular strips of resistive material, each of length 1.2 m and width 2.0 mm, joined at their ends by strips of copper of negligible resistance as shown. The unit must generate 45 W of heat when connected to a supply of 14.3 V.
Determine whether or not this can be done using a thickness, t, of approximately 0.2 mm for the metal strips.
[Resistivity of resistive material = $6.0 \times 10^{-6}\,\Omega\,\text{m}$] [4]



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4. *(a)* Materials can be classified as being *crystalline*, *amorphous* or *polymeric*. Making reference to their microscopic structures explain what is meant by each of these terms. Give **one** example of each type of material. [3]

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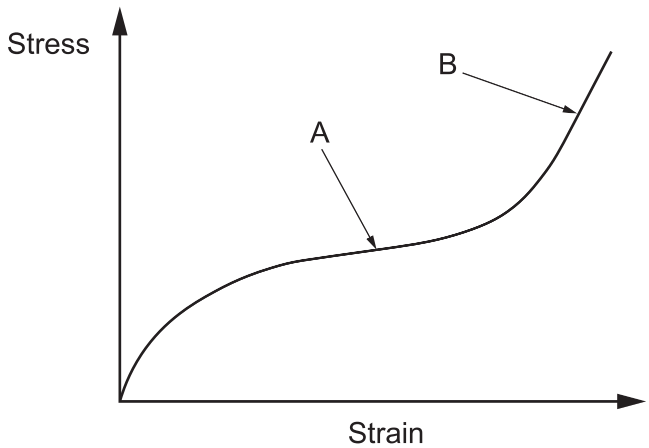
(b) Experiments are carried out on a specimen of rubber. The diagram shows a stress-strain curve for the specimen when it is gradually loaded.



(i) By referring to the molecular structure of rubber, explain why the gradient at A is less than the gradient at B. [3]

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(ii) When the specimen is gradually unloaded, it is noted that the curve for unloading is different from the curve for loading.

I. Name this phenomenon and account for it in terms of energy. [2]

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II. **Sketch the curve** for unloading on the graph opposite. [1]

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5. Two students, Simon and Natalie are investigating the mechanical properties of a steel wire of length 2.5 m and cross-sectional area 1.0 mm^2.

(a) They are given the following information.
[Young modulus, $E_{\mathrm{steel}} = 2.0 \times 10^{11}\ \mathrm{N\,m^{-2}}$, Stress, σ_{steel} (at elastic limit) $= 1.0 \times 10^{8}\ \mathrm{N\,m^{-2}}$].

(i) Show that the maximum extension possible for the wire without the elastic limit being exceeded is 1.25 mm. [2]

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(ii) Simon believes that this maximum extension (1.25 mm) of the steel wire depends on the radius of the wire. Natalie disagrees. Discuss who is correct, explaining carefully how you arrive at your answer. [3]

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(b) Natalie suspends a mass, m, from the wire vertically. The wire can be considered to be weightless.

(i) Show that the force per unit extension, k, of the wire is $80\ \mathrm{kN\,m^{-1}}$. [3]

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(ii) Determine the mass, m, that causes an equilibrium extension of 1.0 mm. [2]

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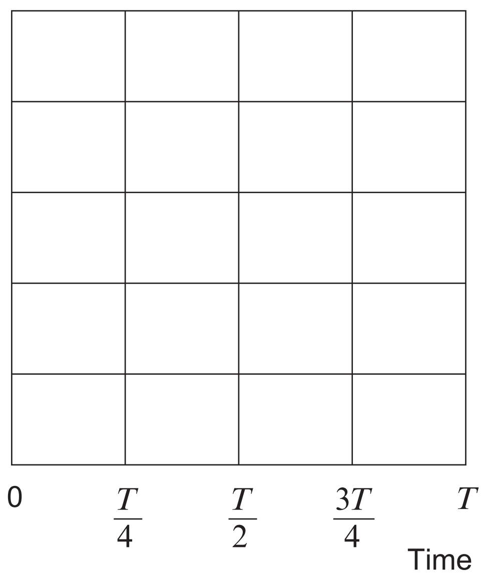
(c) This mass is given a small downward displacement and released from rest. The mass oscillates with simple harmonic motion (SHM) **provided that the maximum extension of the wire never exceeds the elastic limit**.

(i) Calculate the period of this oscillation. [2]

(ii) Calculate the maximum possible velocity of the mass, m. [3]

(iii) Assuming the mass is released when the wire is at maximum extension without exceeding the elastic limit, sketch a graph showing how the stress in the wire varies with time **for one complete oscillation** from the moment of release of the mass. Indicate appropriate numerical values on the stress axis of your graph.
Space for calculations. [4]



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6. *(a)* Describe the main features of the spectrum of a star **and** state where in the star they arise. [2]

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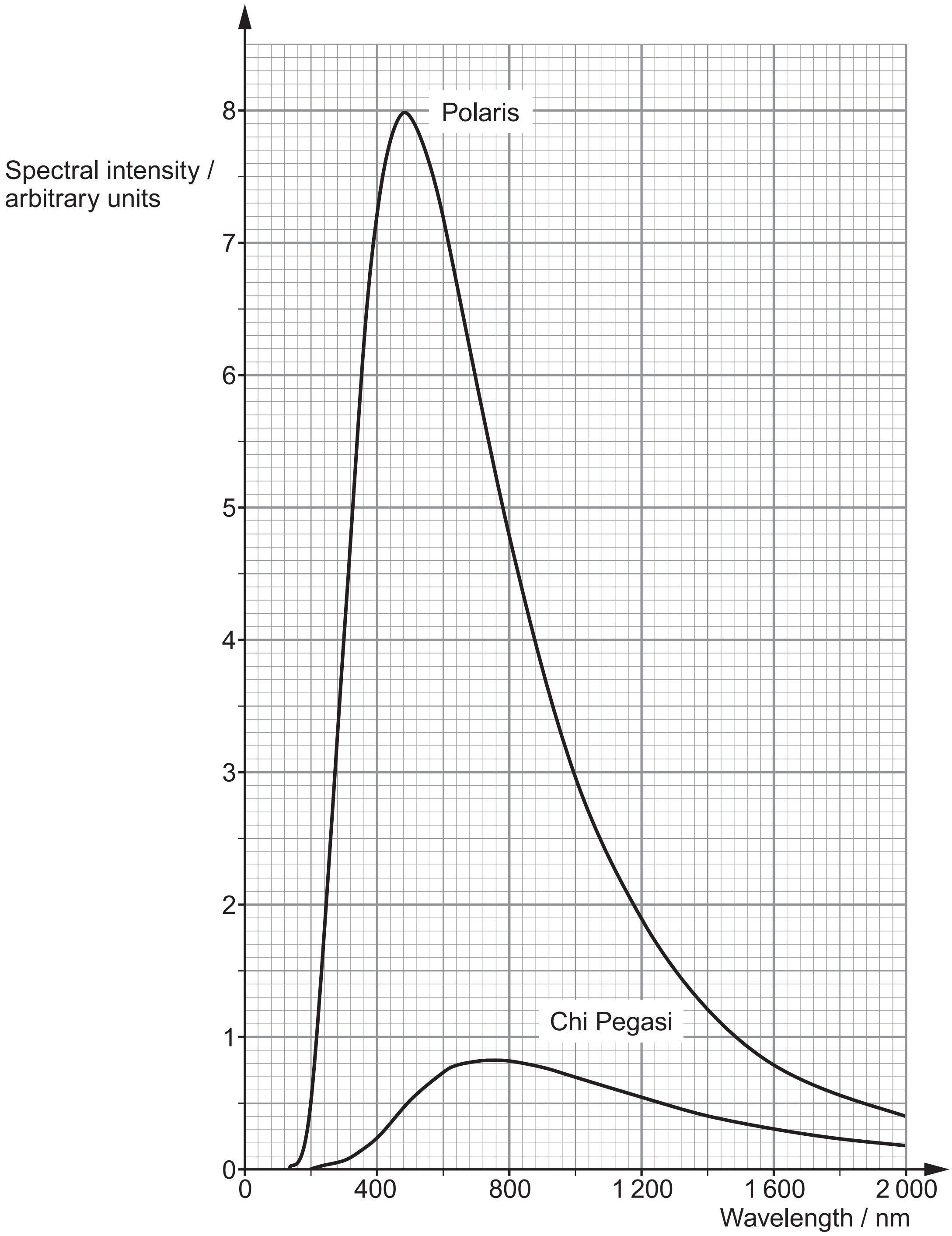
(b) The graph shows the black body radiation curves for the two stars **Polaris** (sometimes called the North Star) and **Chi Pegasi** (a red supergiant in the constellation Pegasus). **The stars are equidistant from Earth.**



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(i) Suggest **three** differences between Polaris and Chi Pegasi. [3]

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(ii) Polaris is 431 light years from Earth and the intensity of radiation received on Earth from it is $4.05 \times 10^{-9}\,\mathrm{W\,m^{-2}}$. Use this information and the graph to calculate the radius of Polaris. [1 light year = 9.46×10^{15} m] [5]

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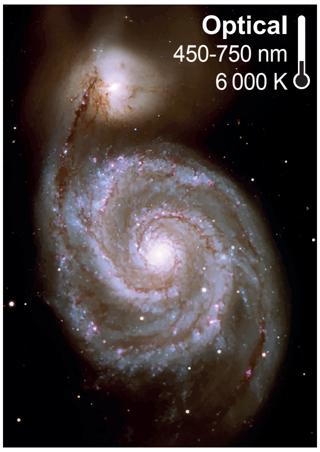
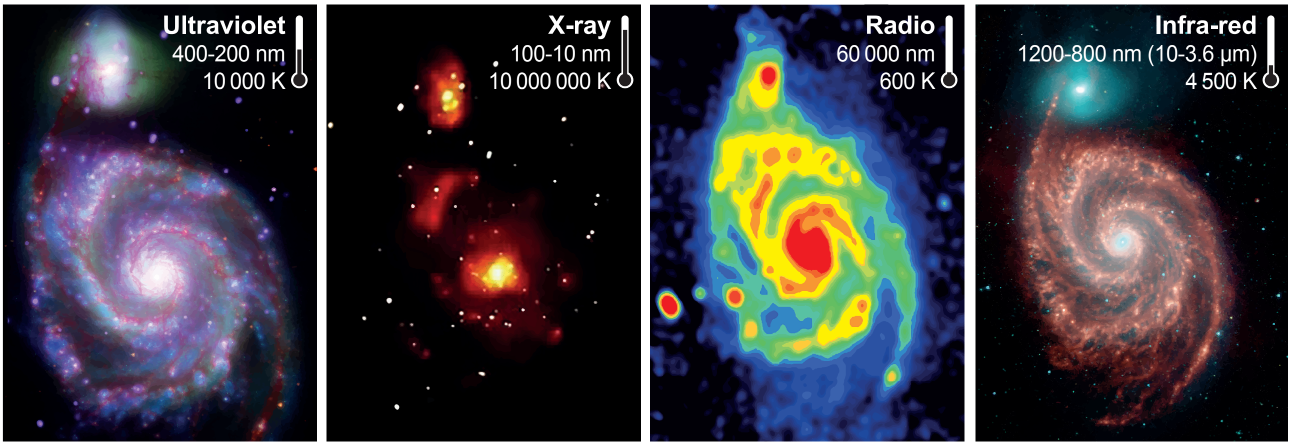
(c) The image below is of the whirlpool galaxy, M51 (or NGC 5194). This is one of the first images of the galaxy taken by astronomers.



Subsequent images of the **same galaxy** are shown below.



Describe how these developments in observational astronomy have advanced the study of the whirlpool galaxy. [3]

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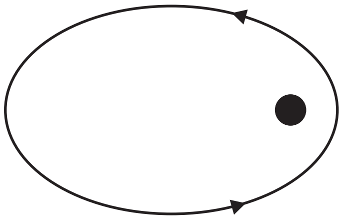
7. *(a)* The diagram shows the elliptical orbit of a planet around a star. Use the diagram (by adding to it) to explain Kepler's second law of planetary motion. [2]



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(b) Starting with Newton's law of gravitation, show that for a circular orbit, the period of orbit, T, of a planet around a star is related to its distance, r, from the centre of the star by the relationship $T^2 \alpha\, r^3$. [Assume the mass of the planet is much less than the mass of the star.] [3]

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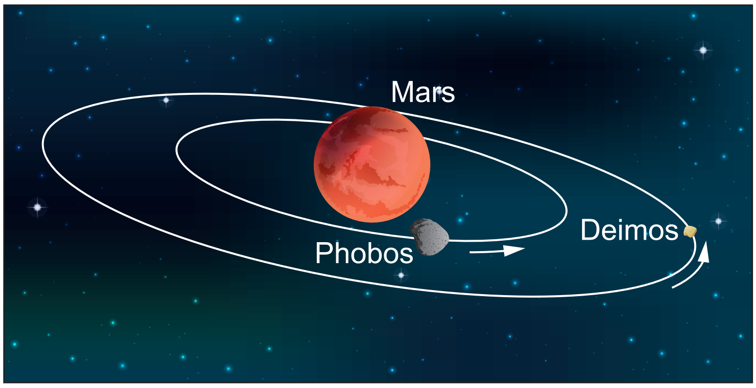
(c) Mars has two small moons, Phobos and Deimos. The diagram shows their orbital paths around Mars.



(i) Phobos has an orbital period of 7.7 hours and the radius of its orbit is 9400 km. Show that the mass of Mars is approximately 6.4×10^{23} kg. [3]

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(ii) It is proposed to send a space-probe to study Phobos and Deimos. The first part of the mission will be to place the probe in orbit around Phobos.

I. Show that the gravitational potential due to Mars at the Phobos orbit is approximately $-4.5\,\mathrm{MJ\,kg^{-1}}$. [2]

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II. The second part of the mission involves manoeuvring the space-probe into a higher orbit to enable it to study Deimos. However, on the journey to Mars the probe used more fuel than was expected. Scientists are now unsure as to whether or not the probe has enough fuel to enable it to reach the orbit of Deimos. The following information is available:

Energy available per kg of space-probe: 4.4 MJ kg^{-1}
Efficiency of fuel-burn process: 60 %
Distance of Deimos from centre of Mars: 23 500 km

Assuming the mass of the fuel is very small compared to the mass of the probe itself, and ignoring the gravitational effects of both moons, determine whether or not the scientists should attempt the manoeuvre. [4]

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(iii) Explain why it is not possible to use the equation $\Delta E_p = mg\Delta h$ when determining the change in the gravitational potential energy of the probe as it moves between these orbits. [1]

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TURN OVER FOR THE LAST QUESTION

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8. *(a)* Calculate the critical density of the universe giving appropriate units. [2]

(b) An astronomer makes the following statement:

Assuming that the rate of expansion of the universe is constant, two objects a distance R apart in space will increase their separation by nearly 15% over a 2 billion year period.
[1 billion = 1×10^9 years]
Justify this statement. [3]

(c) A star in a distant galaxy shows a bright hydrogen emission line at 475 nm. The equivalent emission line on Earth has a wavelength of 410 nm.

(i) Calculate the radial velocity of the star. [2]

(ii) Calculate the distance of the star from the Earth. [2]

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(iii) The temperature of the photosphere of the star is 7 100 K. Calculate the mean kinetic energy of particles in the photosphere. Give your answer in eV. [2]

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