Surname	Centre Number	Candidate Number
First name(s)		2

GCE A LEVEL

A420U20-1

S24-A420U20-1

eduqas Part of WJEC

THURSDAY, 6 JUNE 2024 – MORNING

PHYSICS – A level component 2

Electricity and the Universe

2 hours

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**16**	
2.	**8**	
3.	**10**	
4.	**12**	
5.	**15**	
6.	**10**	
7.	**15**	
8.	**14**	
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 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**(a).

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Answer **all** questions.

1. (a) State 'Ohm's law'. [2]

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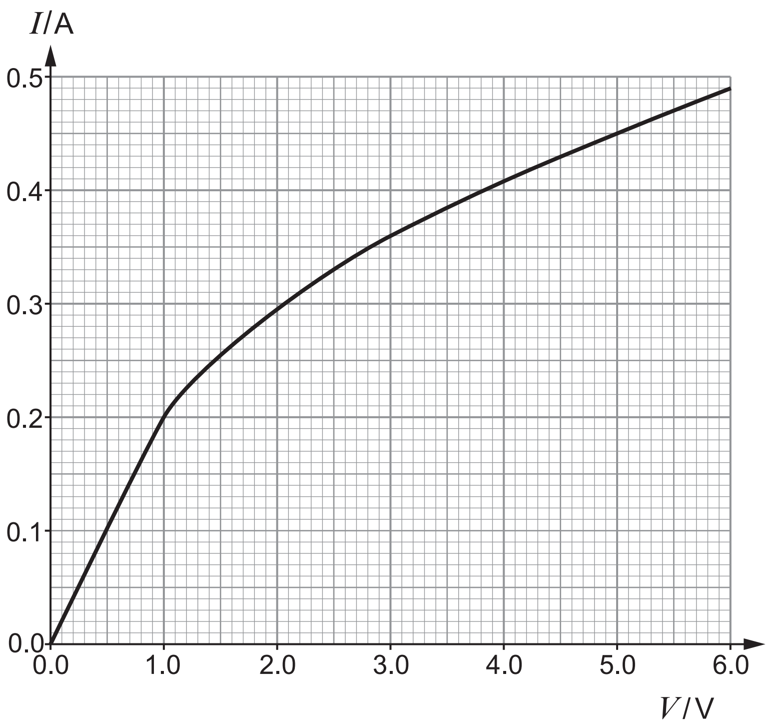
(b) Tom investigates the electrical properties of a lamp with a metal filament. He varies the potential difference across the lamp and measures the corresponding current in it. A graph of his results is shown.



(i) Tom states the following:

"Ohm's law does apply between 0 V and 0.5 V, but not for the full range given."

Explain **how the graph** confirms the statement. [2]

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(ii) Show by calculation, that the resistance of the lamp is different when the pd across it is 2.5 V and when it is 5.0 V, and explain, in terms of particles, why this is to be expected. [5]

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(c) Tom connects the lamp in series with **three** identical cells, each of emf 1.2 V. He measures the pd across the lamp to be 3.0 V. Show that the internal resistance of each cell is approximately 0.5 Ω. [3]

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(d) In the early 20th century physicists started investigating the effects of very low temperatures on the resistance of metals. These experiments led to the discovery of superconductors.

(i) What is superconductivity? [1]

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(ii) A material becomes superconducting when it is placed in liquid helium. **Sketch a graph** of resistance against temperature for this material, labelling any key features of your graph. [3]

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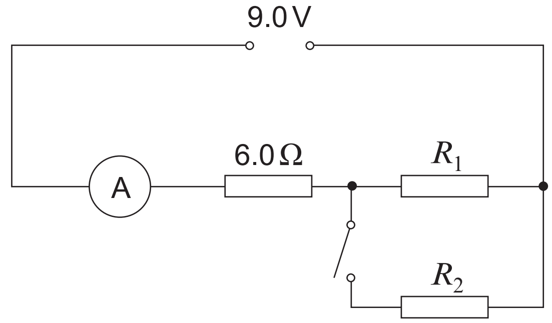

(a) For the above circuit, with the switch open (as shown), the ammeter reads 0.50 A. Show that $R_1 = 12.0\,\Omega$. [1]

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(b) (i) With the switch closed the ammeter reading increases to 0.75 A. Show that this current is consistent with $R_1 = R_2$. [2]

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(ii) With the 6.0 Ω resistor still in place, further identical resistors are placed in parallel with R_1 and R_2 until a current of 1.2 A is measured by the ammeter. Calculate the total number of parallel resistors. [3]

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(iii) A student makes the following comment:

"No matter how many resistors are added in parallel with R_1 and R_2, the reading on the ammeter will not go above a certain value."

Discuss the validity of this statement. [2]

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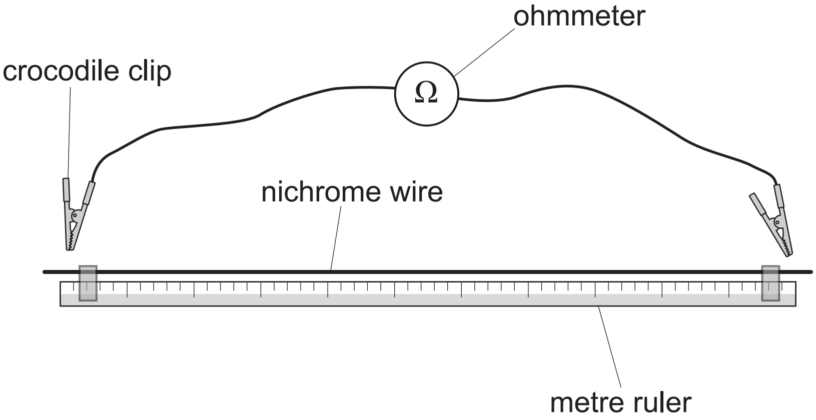
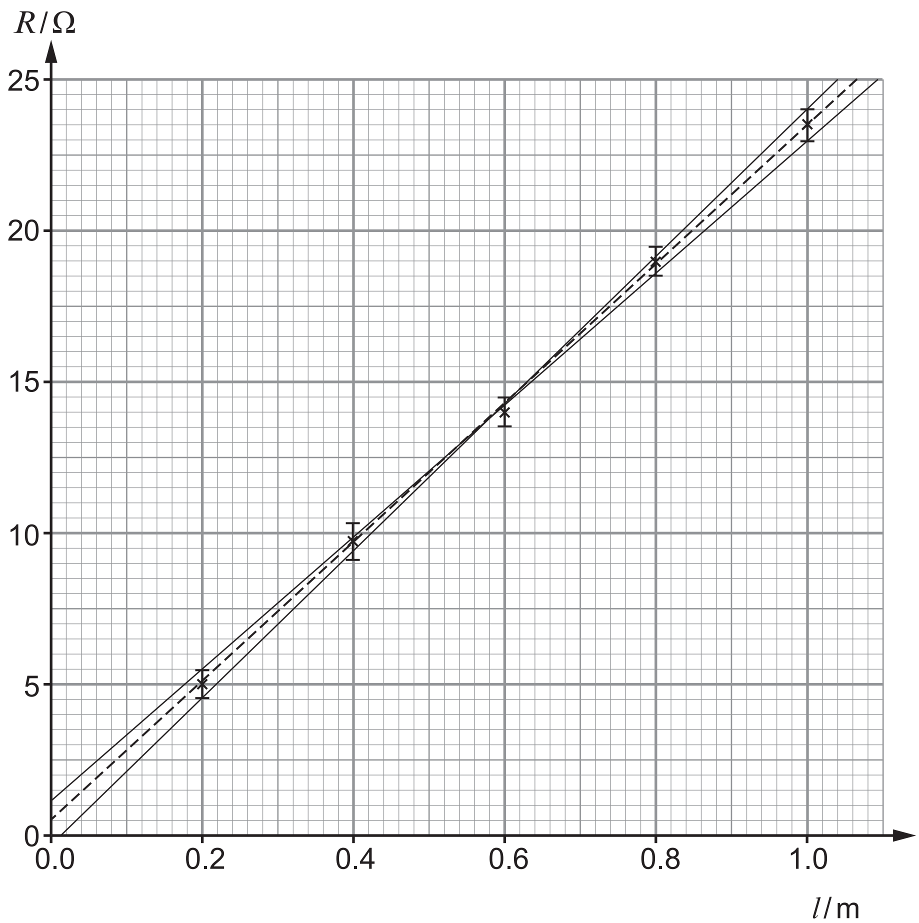
3. Emma carries out an experiment to determine the resistivity of a sample of nichrome in the form of a wire. She uses the following apparatus to take measurements of the resistance of various lengths of wire.



Emma repeats her readings and plots a graph of resistance, R, versus length, l, along with error bars determined from the uncertainties in her readings.



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(a) (i) Emma draws lines of maximum and minimum gradients. She also draws an estimated line of best fit through the data points (**dotted line**) and notices that it does not pass through the origin. Emma's teacher states that this is due to a systematic error in her procedure or in the apparatus. Suggest **two** possible sources for the systematic error. [2]

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(ii) The teacher also states that the systematic error need not affect the result for the resistivity. State why the teacher is correct. [1]

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(b) Emma determines the cross-sectional area of the wire to be $(4.8 \pm 0.4) \times 10^{-8}\,\text{m}^2$. Determine the resistivity of nichrome along with its **absolute** uncertainty, giving your answer to an appropriate number of significant figures. [7]

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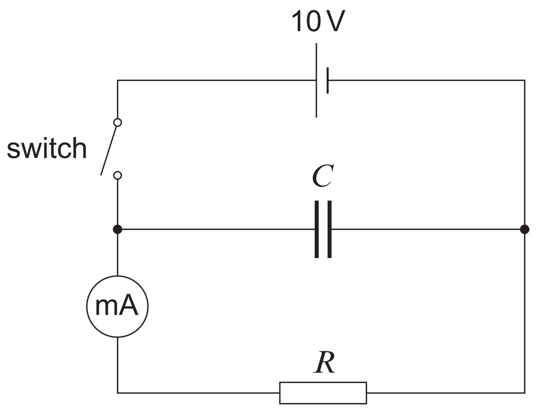
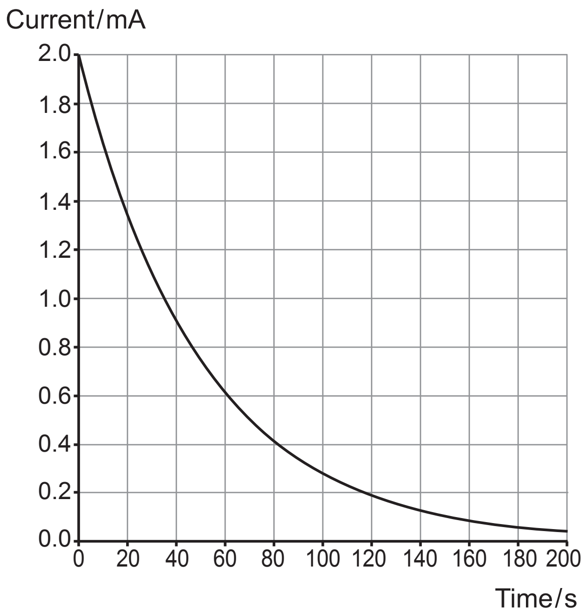
4. A student carries out an experiment to investigate the discharge of a capacitor, C, through a resistor, R. He uses the circuit shown.





The switch is closed, and the capacitor allowed to charge fully. The switch is then opened at time $t = 0$ seconds and the capacitor allowed to discharge through R. The graph shows how the reading on the milliammeter changes with time.

(a) Use the graph to confirm that the charge on the capacitor is approximately 100 mC at time $t = 0$ s. [2]

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(b) The following equation represents the voltage, V, across the capacitor as a function of time, t, for this circuit:

$$V = V_0 e^{-\frac{t}{CR}}$$

(i) Using information from the diagram and graph, determine values for V_0, C and R. [3]

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(ii) Hence determine the pd across the capacitor when t is equal to the time constant, and confirm that your answer is consistent with the milliammeter reading at this time. [3]

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(c) (i) $U = \frac{1}{2} QV$ is a formula for the energy, U, stored in a capacitor.
Show clearly that $U = \frac{1}{2} CV^2$ is an equivalent formula. [2]

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(ii) Determine the energy stored in the capacitor at $t = 60\,\text{s}$. [2]

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Turn over.

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5. (a) Gravitational fields and electric fields have many features in common but also have several differences. For both gravitational and electric fields, describe their common features and their differences. In your answer you should consider:

- the force acting between particles;
- gravitational field strength and electric field strength;
- gravitational potential and electric potential. [6 QER]

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(b) A small sphere of mass 24 mg is suspended by an insulating string of length, L, in a uniform electric field produced by two vertical metal plates connected to a 1.0 kV power supply. The plates are separated by a distance, $d = 10$ cm. The sphere is made to touch the negative plate where it receives a charge. It is then repelled from the negative plate and hangs in equilibrium when the angle, θ, between the vertical and the string is 15° as shown.

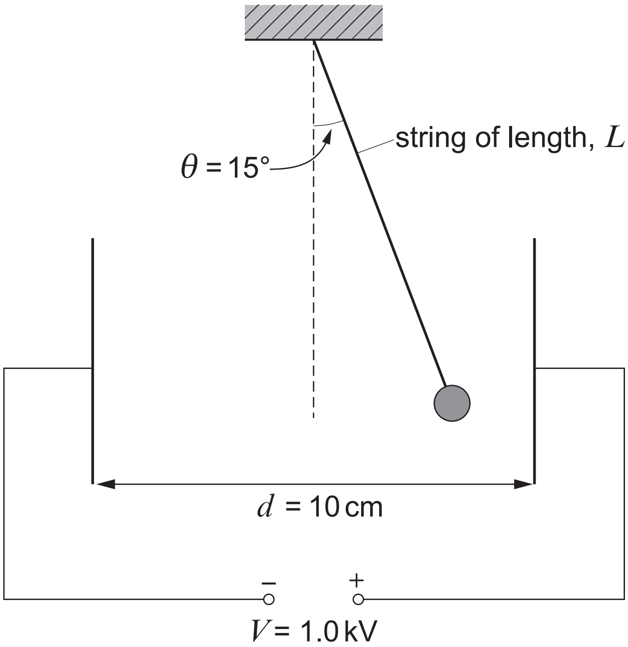

Diagram not drawn to scale

(i) Show that the electric field strength between the plates is 10 kN C^{-1}. [1]

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(ii) **On the diagram above**, **draw arrows** to represent the **three** forces acting on the sphere. Label each arrow with the name of the force it represents. [3]

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(iii) Hence calculate the charge on the sphere. [4]

(c) A physics student comments:

"The charge on the sphere corresponds to trillions of electrons being placed on it."

Determine whether the student's comment is justified. [Take trillion to mean 10^{12}.] [1]

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6. (a) A metal cylinder is subjected to an increasing tension until it fractures. The sample exhibits **necking** at the point of fracture.

(i) Sketch a diagram to illustrate the term **necking**, indicating the direction of the stretching forces. [1]

(ii) Explain, in terms of stress, why the metal fractures at this point. [2]

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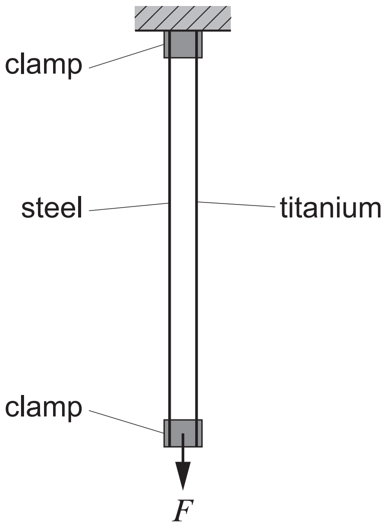
(b) Two wires, one made from steel and the other from titanium, are firmly clamped together at their ends. The wires have the **same diameter** and **unstretched length**. One of the clamped ends is fixed to a rigid support, while a force, F, is applied to the other end so that the wires hang vertically. The wires are firmly clamped together so that the extension in each wire is **the same**.



(i) Show that:

$$\frac{F_{titanium}}{F_{steel}} = 2$$

where $F_{titanium}$ and F_{steel} are the respective forces on the titanium and steel wires.
[$E_{titanium}$ = 400 GPa and E_{steel} = 200 GPa] [2]

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(ii) The diameter of each wire is 1.4 mm and the unstretched length is 1.2 m. Determine the extension produced in one of the wires when $F = 30\,\text{N}$. [3]

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(iii) A physics student assumes that, since the wires extend by the same amount, they must possess the same amount of elastic potential energy. Determine whether the student's assumption is correct. [2]

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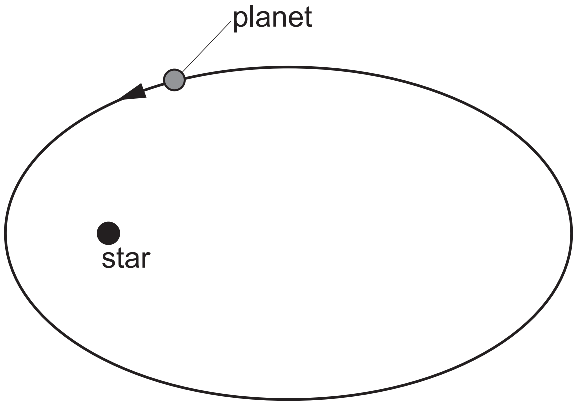
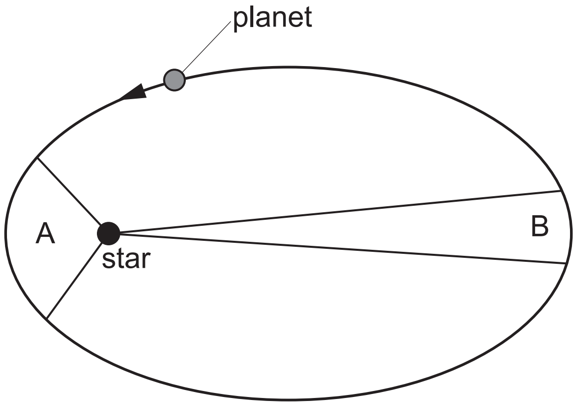
7. (a) (i) A planet is in an elliptical orbit around a star as shown. **Mark on the diagram** with the letter X another possible location for the star. [1]



(ii) In the diagram below, the area of section A = area of section B.



Referring to Kepler's 2nd law of planetary motion, describe the motion of the planet as it passes through sections A and B. [2]

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(b) The table shows data about two of Jupiter's moons, Io and Ganymede.

Moon	Period of orbit, T/s	Mean radius of orbit, r/m
Io	1.53×10^5	4.22×10^8
Ganymede	6.15×10^5	1.07×10^9

(i) Show that the data are consistent with Kepler's 3rd law of planetary motion. [2]

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(ii) Determine the mass of Jupiter. [3]

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(c) A spiral galaxy is estimated to have a mass of 2×10^{42} kg.

(i) Calculate the orbital speed of a dust particle at a distance of 8.2×10^{20} m from the centre of the galaxy. [2]

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(ii) The observed velocity is **greater** than the calculated velocity. Explain how the Higgs boson was thought by some to be responsible for the difference in the velocities. [3]

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(d) In 2021 the following article appeared in an astronomical publication.

Evidence emerges for dark-matter free galaxies

Date: December 6, 2021
Source: Royal Astronomical Society

Astronomers have found no trace of dark matter in the galaxy AGC 114905, despite taking detailed measurements over a course of forty hours with state-of-the-art telescopes.

The astronomers concluded that the motions of the gas in AGC 114905 can be completely explained by just normal matter.

They commented: "This is, of course, what we thought and hoped for because it confirms our previous measurements, but now the problem remains that the theory predicts that there must be dark matter in AGC 114905, but our observations say there isn't. In fact, the difference between theory and observation is only getting bigger."

Suggest how the scientific community should proceed. [2]

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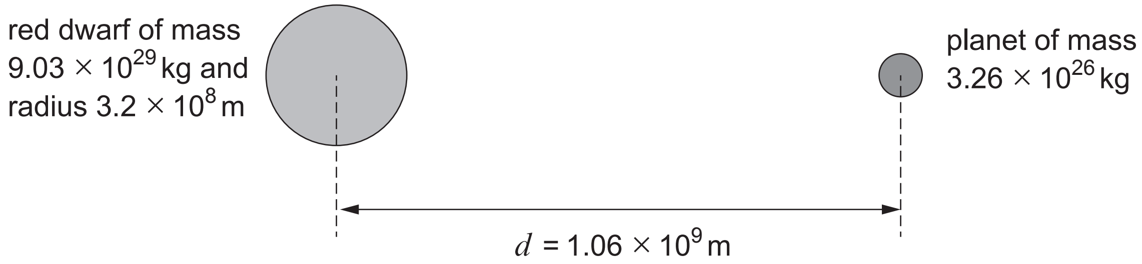
8. All the planets in our solar system orbit around the Sun. Planets that orbit around other stars are called exoplanets. A rocky exoplanet orbits a red dwarf star 28.5 light years from Earth. The diagram showing the system is not to scale.



(a) The star and planet orbit their mutual centre of mass. Show that the distance of the centre of mass from the centre of the star is approximately 400 km. [2]

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(b) The maximum shift in wavelength measured by astronomers on Earth, when light of wavelength 656 nm from the star is analysed, is found to be about 0.20 pm. Using your answer from part (a), show that this wavelength shift is consistent with the mutual orbital period of the system, which is over 7 hours. [4]

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(c) The temperature at the surface of the star is 3522 K.

(i) Calculate the luminosity of the star. [2]

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(ii) Hence determine the intensity of the radiation from the star at the Earth's surface. [1 light year = 9.5×10^{15} m.] [3]

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(iii) With the aid of a calculation, explain why the star appears red in colour. [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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