Surname	Centre Number	Candidate Number
First name(s)		2

GCE A LEVEL

A420U20-1

S23-A420U20-1

eduqas
Part of WJEC

FRIDAY, 9 JUNE 2023 – MORNING

PHYSICS – A level component 2

Electricity and the Universe

2 hours

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**9**	
2.	**12**	
3.	**17**	
4.	**15**	
5.	**13**	
6.	**11**	
7.	**9**	
8.	**14**	
Total	**100**	

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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) Define the potential difference between two points in an electric circuit. [1]

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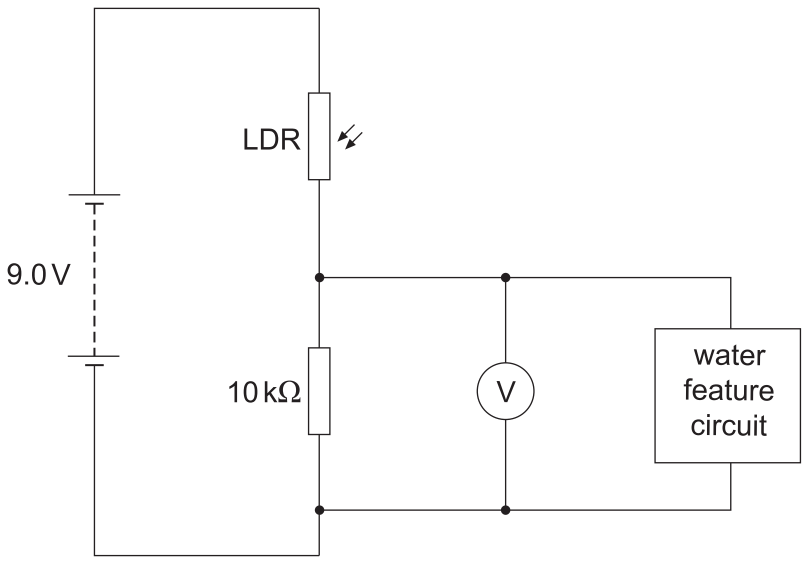
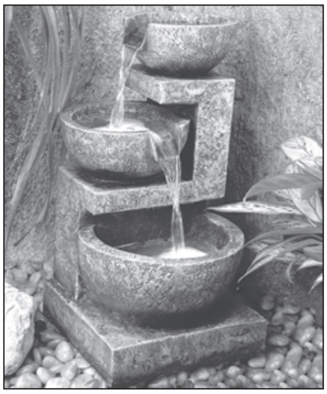
(b) The diagram shows a simple control circuit for a garden water feature, which is also shown. It consists of a 9.0 V battery with negligible internal resistance connected in series with a light dependent resistor (LDR) and a 10 kΩ fixed resistor. The voltmeter and water feature circuit have very high resistances.
The LDR has a resistance of 200 kΩ **in the dark** and 200 Ω **in full sunlight**.





(i) The circuit allows the water feature to operate during daylight. State and explain what happens to the reading on the voltmeter when the intensity of the light incident on the LDR increases. [3]

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(ii) The water feature is activated when the reading on the voltmeter reaches 2.0 V. Calculate the resistance of the LDR at this activation point. [2]

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(iii) A gardener notes that, on some days, the water feature is activated throughout the day. He wishes to control the circuit manually so that he can turn the feature off if required. He intends to include an additional component, a 0-40 kΩ variable resistor, in the circuit.

I. Sketch the modified circuit with the variable resistor appropriately positioned. [1]

II. Determine whether this modification will allow him to switch the water feature off **in full sunlight**. [2]

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2. (a) The size of a current in a wire, for a given pd, depends on its resistance. State, in terms of free electrons, how this resistance arises. [1]

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(b) (i) A 2.0 m length of copper wire has a mass of 36.0 g and a cross-sectional area, A, of $2.0 \times 10^{-6}\,\text{m}^2$. Each copper atom has a mass of 1.05×10^{-25} kg and contributes, on average, one free electron per atom. Show that the number of free electrons per unit volume, n, is approximately $9 \times 10^{28}\,\text{m}^{-3}$. [2]

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(ii) A pd, V, is applied across the wire. Show that the drift velocity, v, can be given by:

$$v = \frac{V}{\rho l n e}$$

where ρ is the resistivity of copper and l is the length of the wire. [3]

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(iii) Calculate v when a 1.2 V pd is applied across the wire.
(Resistivity of copper, $\rho = 1.7 \times 10^{-8}\,\Omega\,\text{m}$) [2]

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(c) A second copper wire has the same volume as part (b) but is longer. Matthew considers how some properties in the longer wire compare with the original when a 1.2 V pd is applied across the longer wire. He determines whether the properties (given below) are **bigger**, **smaller** or **the same** for the longer wire. His conclusions are given in the table.

Property	Matthew concludes that for the longer wire, this property is…
A	smaller
n	bigger
ρ	the same
v	the same

Determine to what extent he is correct. [2]

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(d) Many scientists from around the world are searching for a superconducting material which has a critical temperature above 273 K. Discuss the benefits to society if this were achieved. [2]

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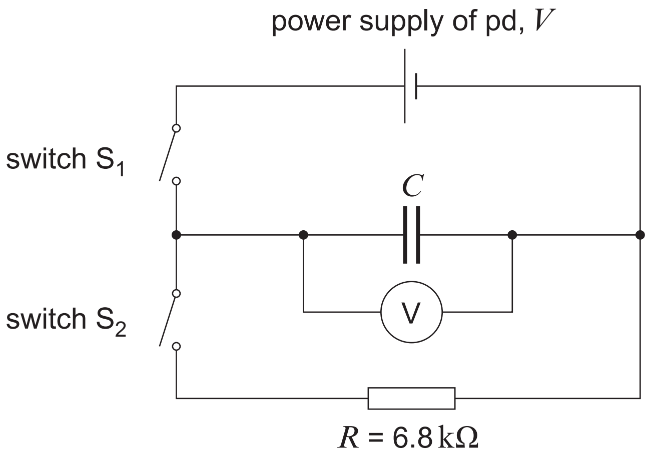
3. Laura uses the following circuit to investigate the discharging of a capacitor of unknown capacitance, C, through a 6.8 kΩ resistor. During the discharging she uses a stopwatch and a voltmeter to take measurements for 1 minute.



(a) Briefly outline the experimental steps Laura should take to obtain her results. [3]

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(b) Laura rearranges the equation $V = V_0 e^{-\frac{t}{CR}}$ into the form:

$$\ln V = -\frac{t}{CR} + \ln V_0$$

She plots a graph of $\ln V$ against t. She plots all points apart from the point at $t = 60$ s, the measurements for which are given in the table.

t/s	$V_{\text{reading 1}}$/V	$V_{\text{reading 2}}$/V	ln ($V_{\text{reading 1}}$/V)	ln ($V_{\text{reading 2}}$/V)	Mean ln (V/V)
60 ± 1	1.73	1.92	0.55		

Complete the table **and** plot the point on the grid along with the horizontal and vertical error bars. Space is provided for calculations. [2]

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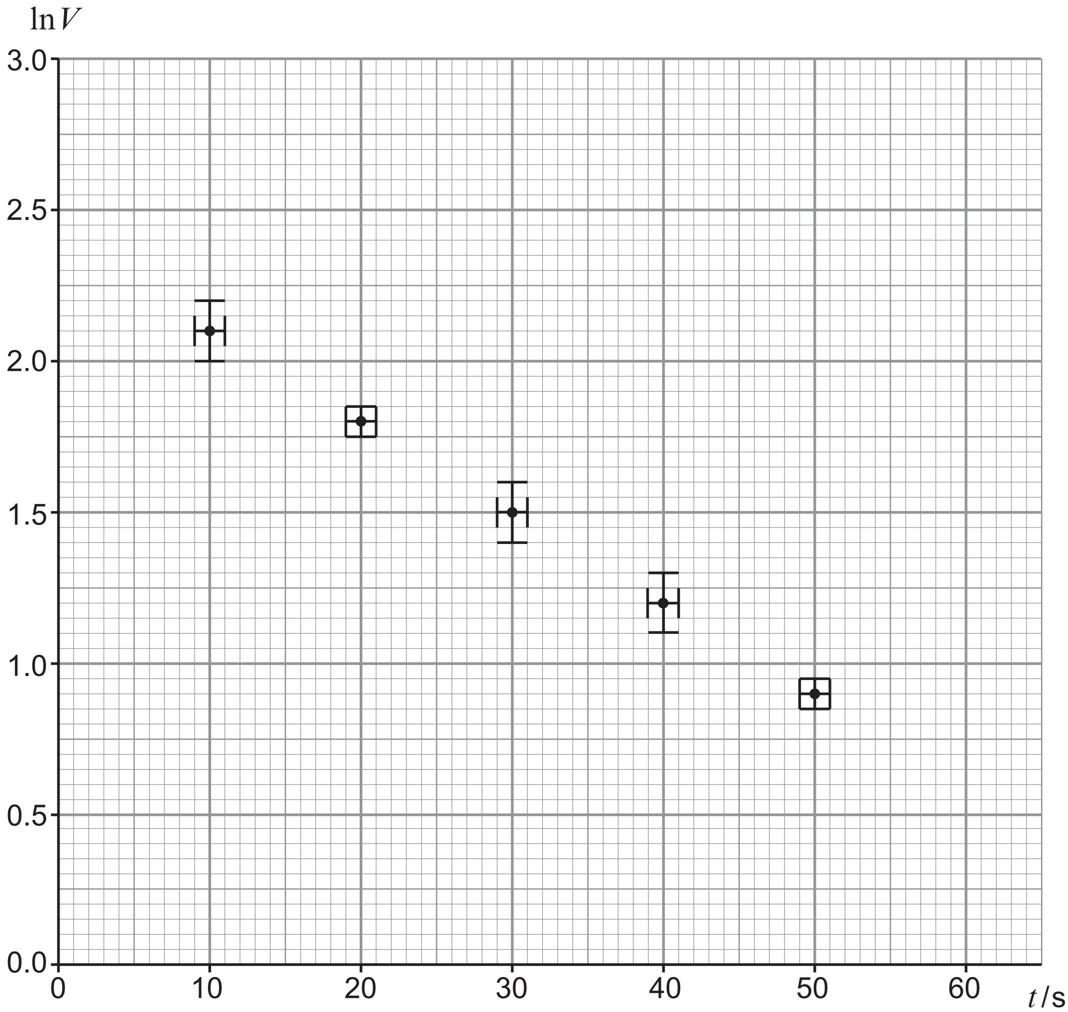

(c) (i) Draw lines of maximum and minimum gradients and determine the gradients of both lines. [3]

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

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(d) (i) Determine a value for the capacitance, C, of the capacitor along with its **absolute** uncertainty. Assume that the resistor has a tolerance (uncertainty) of 5%. Give your answer to an appropriate number of significant figures. [5]

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(ii) Determine the pd, V, of the power supply along with the **absolute** uncertainty in its value. [2]

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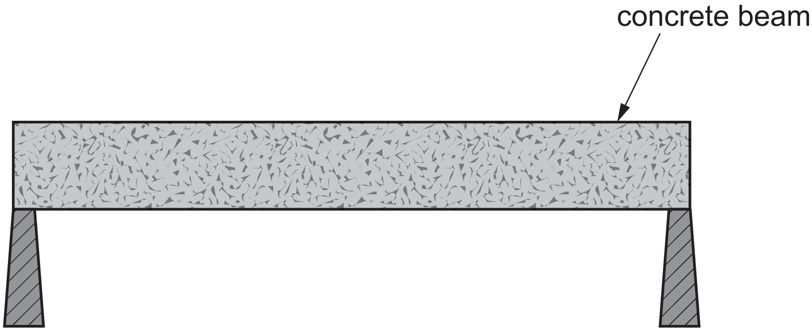
4. (a) The diagram shows how a gap can be bridged using a concrete beam.



(i) Inserting a pre-stressed steel bar into the concrete would strengthen the beam. **On the diagram**, draw a pre-stressed steel bar in an appropriate position. [1]

(ii) Explain how the steel bar strengthens the beam. [2]

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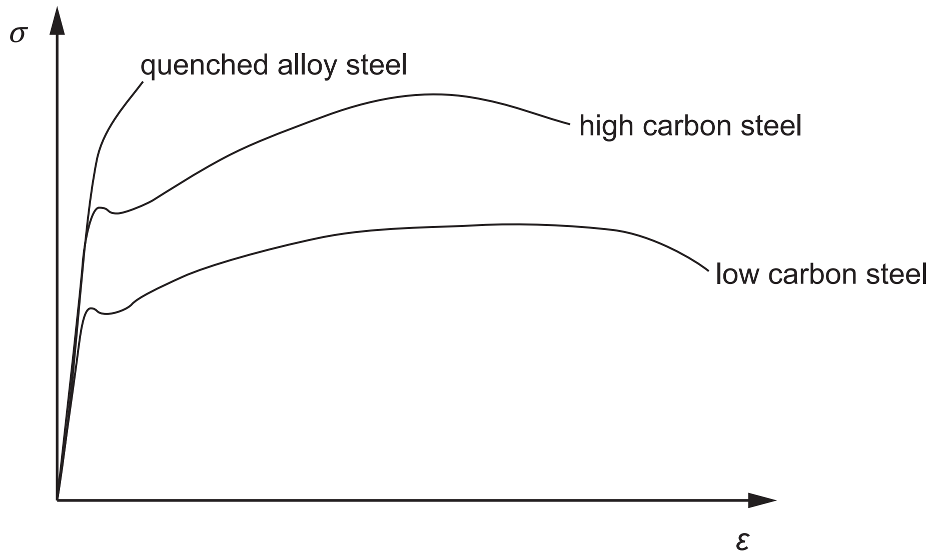
(b) Stress (σ) versus strain (ε) curves for three kinds of steel are shown.



(i) All three steels have the same Young modulus. State how the graphs support this statement. [1]

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(ii) Compare the physical properties of high carbon steel with low carbon steel and explain these properties in terms of their molecular structure. [3]

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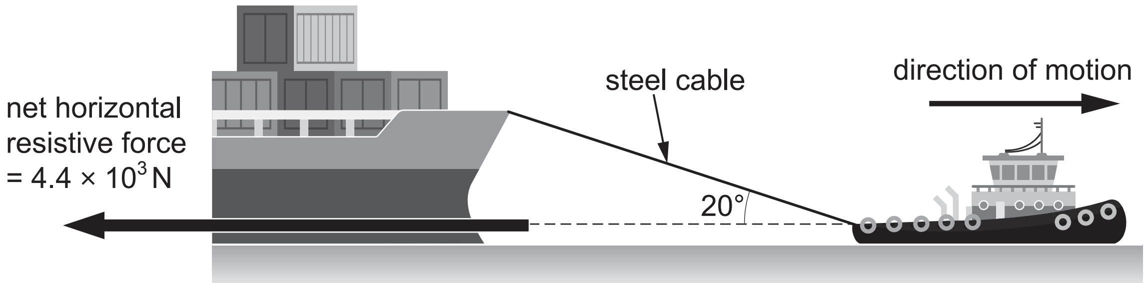
(c) A tugboat uses a cable made of quenched steel to tow a large ship at constant speed.



(i) Use information from the diagram and the following data to show that the extension in the cable is approximately 2 mm. [4]

Young modulus of steel = 210 GPa
Length of cable = 40.0 m
Diameter = 2.4 cm

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(ii) Calculate the energy stored in the extended cable. [2]

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(iii) The tugboat operator decides to replace the quenched steel cable with a cable made from low carbon steel of the same length and diameter. Using the graphs in part (b) as guides, suggest why this may be a mistake. (No further calculations are required.) [2]

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Turn over.

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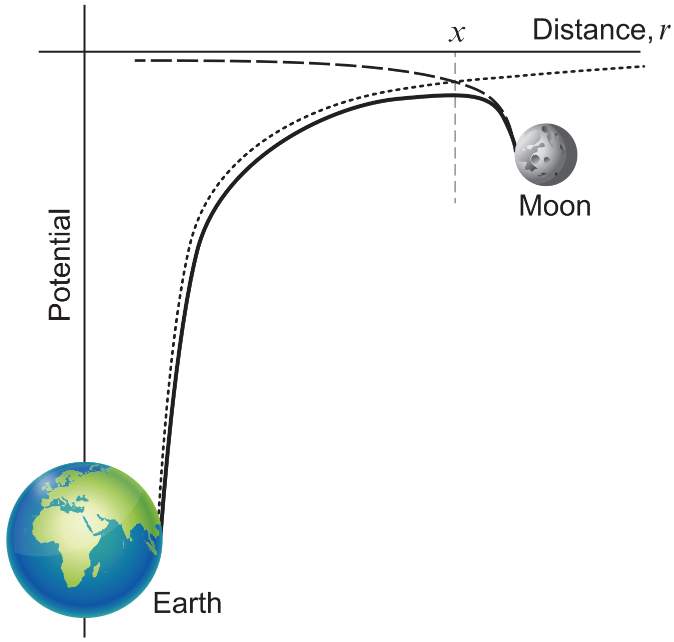
5. (a) Curves of gravitational potential versus distance from the surfaces of the Earth (---------) and Moon (– – –) are shown along with the curve for the combined potential due to the Earth and Moon (———). Explain the shape of each curve and give a full account of the information which could be obtained from them if numerical scales were provided on the axes. [6 QER]



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(b) The **'Mars Sample Return Programme'** is a proposed joint mission by NASA and the European Space Agency to return a sample of Martian soil to the Earth for analysis. The mission would involve a robotic lander collecting a sample of the soil, loading it onto a small rocket, which would then be launched vertically to link with an orbiting spacecraft. The spacecraft, with sample on board, would then return to Earth.

(i) Use the following data to calculate the speed with which the rocket must be launched from the surface of Mars to reach the height of the orbiting spacecraft. Ignore any resistive forces due to the Martian atmosphere.

Mass of Mars: 6.4×10^{23} kg
Radius of Mars: 3.4×10^{6} m
Height of spacecraft above surface: 300 km [4]

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(ii) When the rocket has reached a height of 300 km, it is given a sideways thrust so that it can 'catch up' with the orbiting spacecraft. This is illustrated below. Show that the orbital speed, v, of the rocket must be approximately 3500 m s^{-1} or greater for it to successfully catch up and link with the spacecraft. [3]

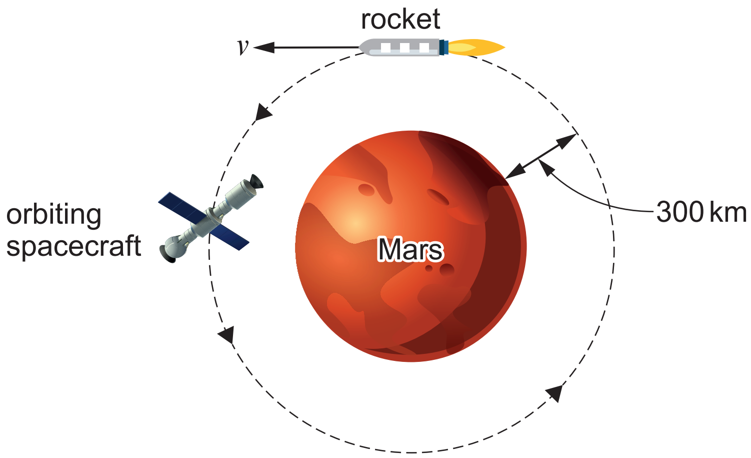

Diagram not drawn to scale

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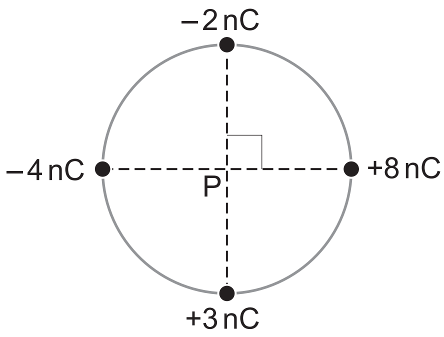
6. Point P is the centre of a circle of radius 0.3 m. Charges are placed as shown.



(a) Calculate the magnitude and direction of the resultant electric field strength at P. [5]

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(b) Calculate the potential at P. [3]

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(c) An electron released from rest from a point where the potential is +50 V follows a path that takes it through point P. John calculates that, at P, the electron's speed is nearly 2% of the speed of light. Determine whether he is correct. [3]

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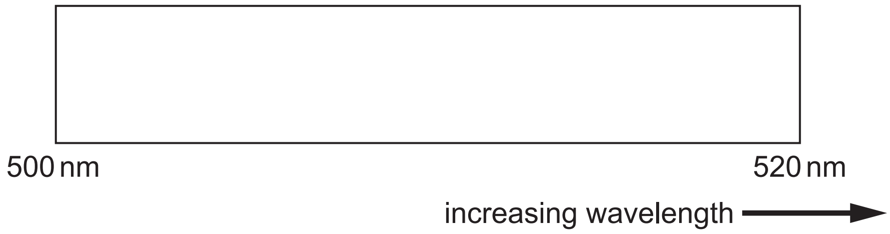
7. (a) Part of the line absorption spectrum for light from the Sun is shown.



A star, similar to our Sun, is detected in a nearby galaxy which is moving away from the Earth. **Sketch a possible spectrum** for this star in the blank spectrum provided above. [2]

(b) Cepheid variables are types of stars that 'pulsate' regularly, varying in luminosity, diameter and temperature as they change. At a particular time, one such star has a diameter of 6.3×10^{10} m and a surface temperature of 6000 K.

(i) Calculate the wavelength at which the greatest spectral intensity is emitted by the star **and** state in which part of the electromagnetic spectrum this wavelength lies. [2]

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(ii) Calculate the star's luminosity. [2]

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(c) During the evolution of a star, its diameter **doubles** and its luminosity increases by a factor of **three**. Show that this change decreases the temperature by less than 10%. [3]

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8. (a) (i) Use the Principle of Conservation of Energy to show that the critical density, ρ_c, of the universe is given by: [4]

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

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(ii) The critical density of the universe corresponds to about 5 atoms of hydrogen per m^3. Evaluate whether this agrees with the value of the Hubble constant given in the Data Booklet. [3]

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(b) The Comet galaxy is 3.2×10^9 light years from Earth.

(i) Show that the galaxy is receding at approximately 65 000 km s^{-1}. [2]
(1 light year = 9.5×10^{12} km)

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(ii) One of the lines in the hydrogen spectrum has a wavelength of 656.3 nm when measured in a laboratory on Earth. Calculate the wavelength of the same line in the observed spectrum of the Comet galaxy. [3]

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(c) The Hubble space telescope can detect a portion of the infra-red and ultraviolet spectrum, as well as the visible spectrum. It has been used to study the Comet galaxy. Explain why it is more useful to use the Hubble telescope than to attempt to study the galaxy using telescopes sensitive only to visible light. [2]

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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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