OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS
Advanced GCE

PHYSICS A 2825/01

Cosmology

Thursday **26 JANUARY 2006** Morning 1 hour 30 minutes

Candidates answer on the question paper.
Additional materials:
Electronic calculator

Candidate Name	Centre Number	Candidate Number

TIME 1 hour 30 minutes

INSTRUCTIONS TO CANDIDATES

- Write your name in the space above.
- Write your Centre number and Candidate number in the boxes above.
- Answer **all** the questions.
- Write your answers in the spaces provided on the question paper.
- Read each question carefully and make sure you know what you have to do before starting your answer.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets [ ] at the end of each question or part question.
- You may use an electronic calculator.
- You are advised to show all the steps in any calculations.
- The first nine questions concern Cosmology. The last question concerns general physics.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	4	
2	14	
3	5	
4	9	
5	7	
6	7	
7	9	
8	9	
9	6	
10	20	
TOTAL	90	

This question paper consists of 18 printed pages and 2 blank pages.

Registered Charity Number: 1066969
[Turn over

Data

speed of light in free space,	$c = 3.00 \times 10^{8}\ \text{m s}^{-1}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \text{H m}^{-1}$
permittivity of free space,	$\epsilon_0 = 8.85 \times 10^{-12}\ \text{F m}^{-1}$
elementary charge,	$e = 1.60 \times 10^{-19}\ \text{C}$
the Planck constant,	$h = 6.63 \times 10^{-34}\ \text{J s}$
unified atomic mass constant,	$u = 1.66 \times 10^{-27}\ \text{kg}$
rest mass of electron,	$m_e = 9.11 \times 10^{-31}\ \text{kg}$
rest mass of proton,	$m_p = 1.67 \times 10^{-27}\ \text{kg}$
molar gas constant,	$R = 8.31\ \text{J K}^{-1}\ \text{mol}^{-1}$
the Avogadro constant,	$N_A = 6.02 \times 10^{23}\ \text{mol}^{-1}$
gravitational constant,	$G = 6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$
acceleration of free fall,	$g = 9.81\ \text{m s}^{-2}$

Formulae

uniformly accelerated motion, $s = ut + \frac{1}{2}at^2$

$v^2 = u^2 + 2as$

refractive index, $n = \frac{1}{\sin C}$

capacitors in series, $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots$

capacitors in parallel, $C = C_1 + C_2 + \ldots$

capacitor discharge, $x = x_0 e^{-t/CR}$

pressure of an ideal gas, $p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$

radioactive decay, $x = x_0 e^{-\lambda t}$

$t_{\frac{1}{2}} = \frac{0.693}{\lambda}$

critical density of matter in the Universe, $\rho_0 = \frac{3H_0^2}{8\pi G}$

relativity factor, $= \sqrt{(1 - \frac{v^2}{c^2})}$

current, $I = nAve$

nuclear radius, $r = r_0 A^{1/3}$

sound intensity level, $= 10 \lg\left(\frac{I}{I_0}\right)$

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For Examiner's Use

Answer **all** the questions.

1 **(a)** **(i)** State any **two** characteristics of the Copernican model of the solar system.

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..... [2]

(ii) Give a **physical** reason that might have been used in objection to the model when it was first proposed.

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..... [1]

(b) The average orbital radius of Jupiter is approximately 5.2 AU.
Calculate the orbital radius of Jupiter in metres.

radius = ... m [1]

[Total: 4]

[Turn over

2 The total energy emitted each second by a star is called its luminosity. The Sun has a luminosity L_{Sun} of 3.90×10^{26} W.

(a) State **two** factors which determine a star's luminosity.

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..... [2]

(b) The absolute magnitude of five stars and their luminosity L_{star} are given in Fig. 2.1.

star	absolute magnitude	L_{star}/W	$\lg\left[\frac{L_{star}}{L_{Sun}}\right]$
Rigel	−7.1	2.38×10^{31}	4.79
Antares	−4.1	1.38×10^{30}	3.55
Regulus	−0.3	4.21×10^{28}	2.03
Altair	2.3	3.72×10^{27}	
Castor	7.4	3.60×10^{25}	

Fig. 2.1

(i) Using the value for the Sun's luminosity given above, complete the last column of the table in Fig. 2.1. [2]

(ii) Plot a graph of the star's absolute magnitude against $\lg\left[\frac{L_{star}}{L_{Sun}}\right]$ using the axes provided in Fig. 2.2. [1]

(iii) Draw the best straight line through the points on the graph. [1]

(iv) The absolute magnitude M and ratio of luminosities L_{star}/L_{Sun} is expected to follow a relationship of the form

$$M = a \lg\left[\frac{L_{star}}{L_{Sun}}\right] + b$$

where a and b are constant numbers.

Use the graph to find the numerical values of a and b.

a = ...

b = ... [3]

For Examiner's Use

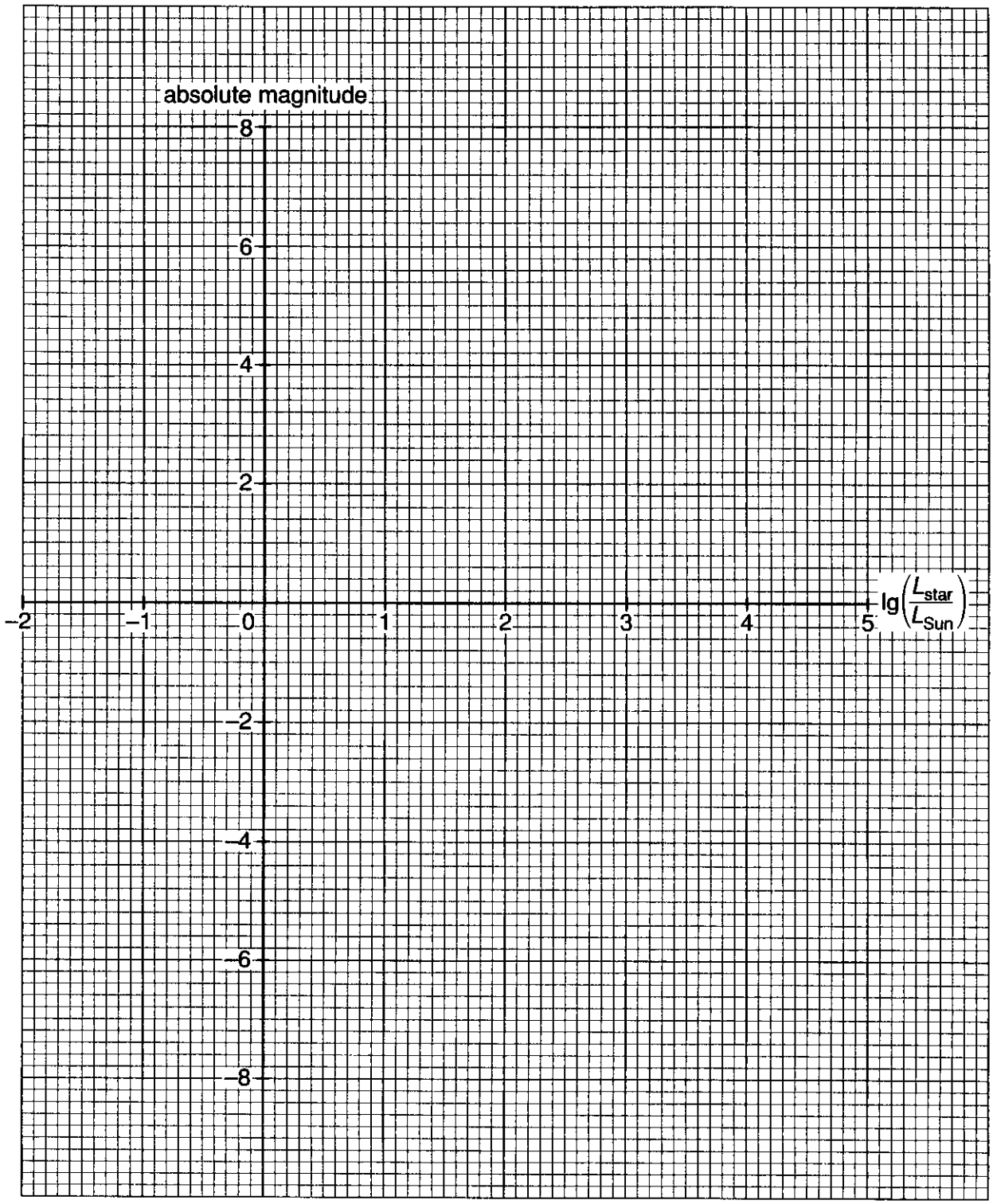

Fig. 2.2

Question 2 continued over the page

[Turn over

For Examiner's Use

(v) Determine a value for the absolute magnitude of the Sun.

absolute magnitude = ... [2]

(vi) Discuss how the absolute magnitude of a star may alter when it becomes a red giant.

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..... [3]

[Total: 14]

For Examiner's Use

3 Describe and explain the stages which take place in the birth of a Main Sequence star.

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[Total: 5]

4 **(a)** A part of the Sun's spectrum is shown in Fig. 4.1. It is crossed by a number of dark lines.

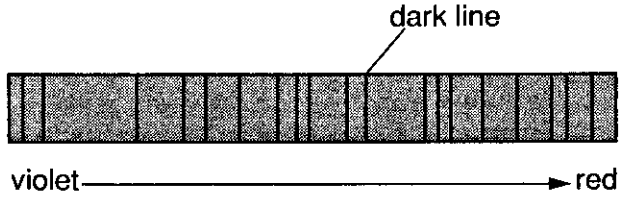

Fig. 4.1

(i) Explain how the dark lines are formed.

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..... [2]

(ii) How may the spectrum be used to identify the constituents of a star?

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..... [1]

[Turn over

(b) The graphs in Fig. 4.2 show the variation of intensity with wavelength for part of the Sun's spectrum and for the same part of the spectrum from a distant star.

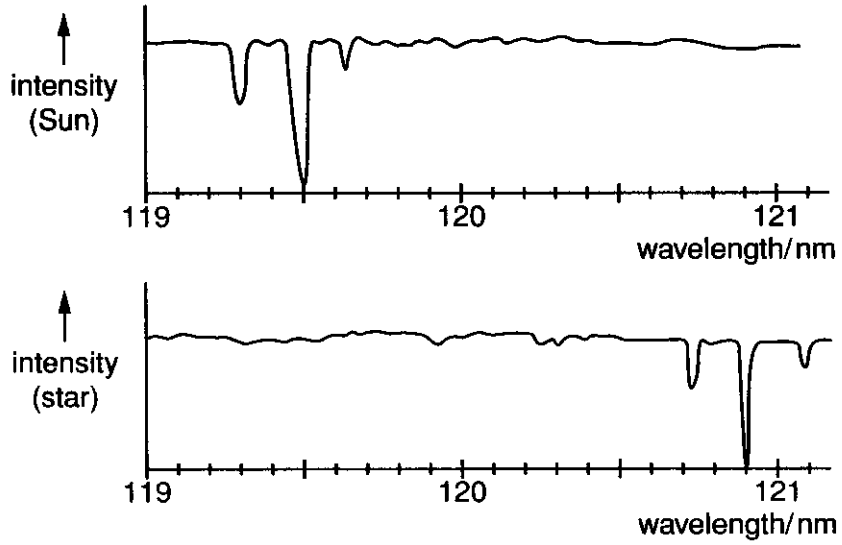

Fig. 4.2

(i) Explain how the star's motion causes corresponding minima of intensity to occur at different wavelengths.

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..... [2]

(ii) Use the graphs in Fig. 4.2 to calculate the velocity of the star.

velocity = ... $m\,s^{-1}$ [4]

[Total: 9]

For Examiner's Use

5 **(a)** Information about the Universe has been gained through the analysis of waves across the entire electromagnetic spectrum. Fig. 5.1 is a representation of the relative penetration of electromagnetic waves through the Earth's atmosphere.

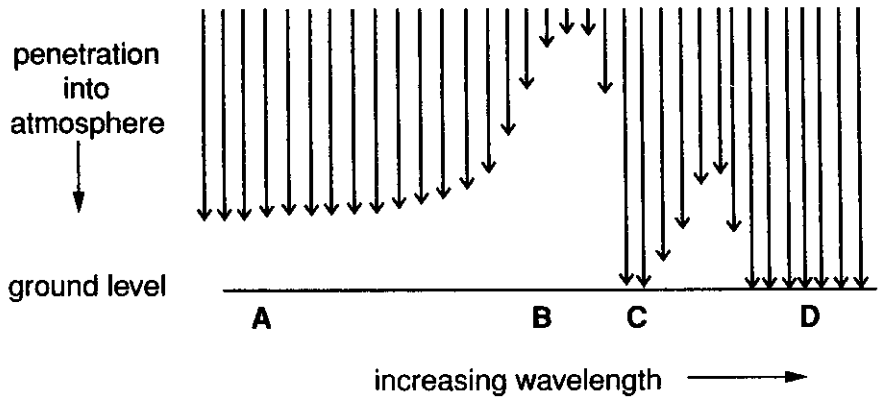

Fig. 5.1

Name the regions of the electromagnetic spectrum represented at **A**, **B**, **C** and **D**.

A .....

B .....

C .....

D ..... [4]

(b) CoBE (the Cosmic Background Explorer) is a satellite designed to take measurements of the cosmic background microwave radiation.

(i) What is the most significant property of this background microwave radiation and for what event in the evolution of the Universe does it provide evidence?

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..... [2]

(ii) Why is a satellite being used to take these measurements?

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..... [1]

[Total: 7]

[Turn over

For Examiner's Use

6 **(a)** State Hubble's law and define any symbols used.

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..... [2]

(b) Describe Olbers' paradox and explain how the work of Edwin Hubble provides an answer.

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..... [5]

[Total: 7]

For Examiner's Use

7 **(a)** **(i)** Describe the shape and structure of our galaxy. Illustrate your answer with a sketch.

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..... [2]

(ii) Mark **X** on your sketch at the approximate position of the Sun within the galaxy. [1]

(b) Some Cosmologists have estimated that as much as 90% of the total mass of a galaxy is made up of **gas**, referred to as dark matter.

(i) Suggest the nature and origin of this gas.

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..... [2]

(ii) The precise amount of dark matter in the Universe is unknown. Explain how the presence of dark matter affects the average density of the Universe and thus has a role in determining the ultimate fate of the Universe itself.

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..... [4]

[Total: 9]

[Turn over

For Examiner's Use

8 **(a)** Within the Special Theory of Relativity, what is meant by an *inertial frame of reference*?

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..... [1]

(b) Describe a thought experiment to illustrate length contraction.

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..... [5]

(c) Astronauts travelling within a spacecraft measure its length as 45.0 m. An observer outside and stationary with respect to the spacecraft would measure the length as 44.5 m.
Calculate the velocity of the spacecraft.

velocity = ... $m\,s^{-1}$ [3]

[Total: 9]

For Examiner's Use

9 **(a)** The space rocket shown in Fig. 9.1 is very far from the influence of any star or planet. A lamp **L** sends light waves towards an astronaut at **P**.

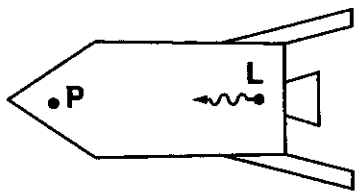

Fig. 9.1

When the light reaches **P** its wavelength is observed to have increased.

(i) Describe the motion of the rocket.

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..... [1]

(ii) What change, if any, will occur in the observed frequency of the light? Explain why.

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..... [2]

(b) The rocket has now landed on the surface of a large planet as shown in Fig. 9.2. The lamp continues to send out light waves.

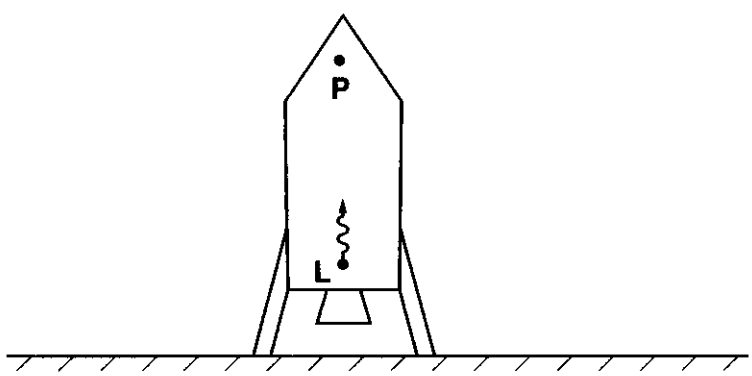

Fig. 9.2

(i) State the principle of equivalence.

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..... [1]

(ii) Compare the observation of the wavelength at **P** in Fig. 9.2 with that made in Fig. 9.1.

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..... [2]

[Total: 6]

[Turn over

For Examiner's Use

10 This question is about the design and use of Christmas tree lights.

Design of bulbs

An engineer intends to design light bulbs for use in a set of Christmas tree lights to be powered by a 240 V mains supply.

Each bulb, when operating normally, will use 0.50 W and will have a filament 6.0 mm long, made of tungsten.

resistivity of tungsten at normal working temperature = $1.1 \times 10^{-6}\,\Omega\,m$

(a) State **one** advantage of connecting these bulbs in parallel, rather than in series.

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..... [1]

(b) Suppose the bulbs are connected in **parallel**. Calculate

(i) the current through each bulb

current = ... A [2]

(ii) the resistance of each bulb filament

resistance = ... Ω [2]

(iii) the radius of each bulb filament.

radius = ... m [3]

(iv) Hence suggest why these bulbs are impractical.

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..... [1]

For Examiner's Use

Use of bulbs

A householder has two sets of Christmas tree lights.

Set A consists of 24 bulbs, each of resistance 200 Ω, connected in series.

Set B consists of 48 bulbs, each of resistance 50 Ω, connected in series.

All bulbs fail when their power dissipation reaches 0.75 W.

(c) **Set A** is connected to a 240 V mains supply. Fig. 10.1 shows the wiring of four of these bulbs.

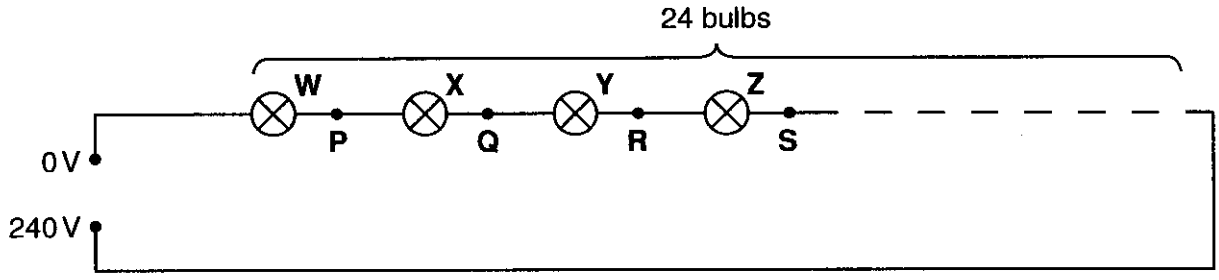

Fig. 10.1

During use, the filament of bulb **Y** fails and its resistance becomes infinite. In order to find which bulb has failed, the householder connects one terminal of a voltmeter to the 0 V terminal of the mains and notes the voltmeter reading when its other terminal is connected successively to points **P**, **Q**, **R** and **S**.
Enter in the table the voltmeter reading for each connection.
Explain your answer.

connection	reading / V
P	
Q	
R	
S	

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..... [4]

[Turn over

For Examiner's Use

(d) (i) The householder has no correct replacement bulbs for **Set A**. Each time a **Set A** bulb fails, it is replaced by a **Set B** bulb.
Explain why this is unsatisfactory and what will happen as more bulbs are replaced in this way.

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..... [3]

(ii) Calculate how many bulbs from **Set A** can be replaced by **Set B** bulbs before the system fails altogether.
Assume that the resistance of each bulb is independent of the current.

number = ... [4]

[Total: 20]

END OF QUESTION PAPER

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