THIS IS A LEGACY SPECIFICATION

OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE

PHYSICS A
Cosmology

2825/01

Candidates answer on the question paper

OCR Supplied Materials:
None

Other Materials Required:
- Electronic Calculator

Tuesday 16 June 2009
Afternoon

Duration: 1 hour 30 minutes

Candidate Forename		Candidate Surname	

Centre Number						Candidate Number				

INSTRUCTIONS TO CANDIDATES

- Write your name clearly in capital letters, your Centre Number and Candidate Number in the boxes above.
- Use black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure that you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- Write your answer to each question in the space provided, however additional paper may be used if necessary.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets **[ ]** at the end of each question or part question.
- The total number of marks for this paper is **90**.
- You may use an electronic calculator.
- You are advised to show all the steps in any calculations.
- The first six questions concern Cosmology. The last question concerns general physics.
- This document consists of **20** pages. Any blank pages are indicated.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	**6**	
2	**11**	
3	**11**	
4	**19**	
5	**12**	
6	**11**	
7	**20**	
TOTAL	**90**	

Data

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

Formulae

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

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

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

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

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

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

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

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

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

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

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

current, $I = nAve$

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

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

Answer **all** the questions.

1 **(a)** **(i)** What is meant by the *phases of Venus*?

....

....

.... **[1]**

(ii) Explain how the phases of Venus occur.

....

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.... **[1]**

(b) Explain why Galileo's observations of the planet Jupiter supported the heliocentric theory of the Universe.

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.... **[2]**

(c) An object released from rest falls **vertically** towards the Earth. Explain why, at the time of Galileo, this motion was thought to show that the Universe could not be heliocentric.

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.... **[2]**

[Total: 6]

2 Kepler's third law states that the square of the orbital period of a planet is proportional to the cube of its average distance from the Sun.

(a) What are Kepler's other two laws of planetary motion?

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....

....

.... **[3]**

(b) A Low Earth Orbit (LEO) satellite is one which has a relatively small orbital radius.
The table in Fig. 2.1 shows the period T and average orbital radius r for some LEO satellites.

T / 10^3 s	r / 10^6 m	T^2 / 10^7 s^2	r^3 / 10^{20} m^3
6.3	7.4	4.0	4.05
6.7	7.7	4.5	4.57
7.0	7.9	4.9	4.93
7.2	8.1	5.2	
7.6	8.4	5.9	

Fig. 2.1

(i) Complete the final column of Fig. 2.1 by calculating r^3. **[1]**

(ii) Plot a graph of T^2 against r^3 on the axes of Fig. 2.2. Draw the best straight line through the points. **[2]**

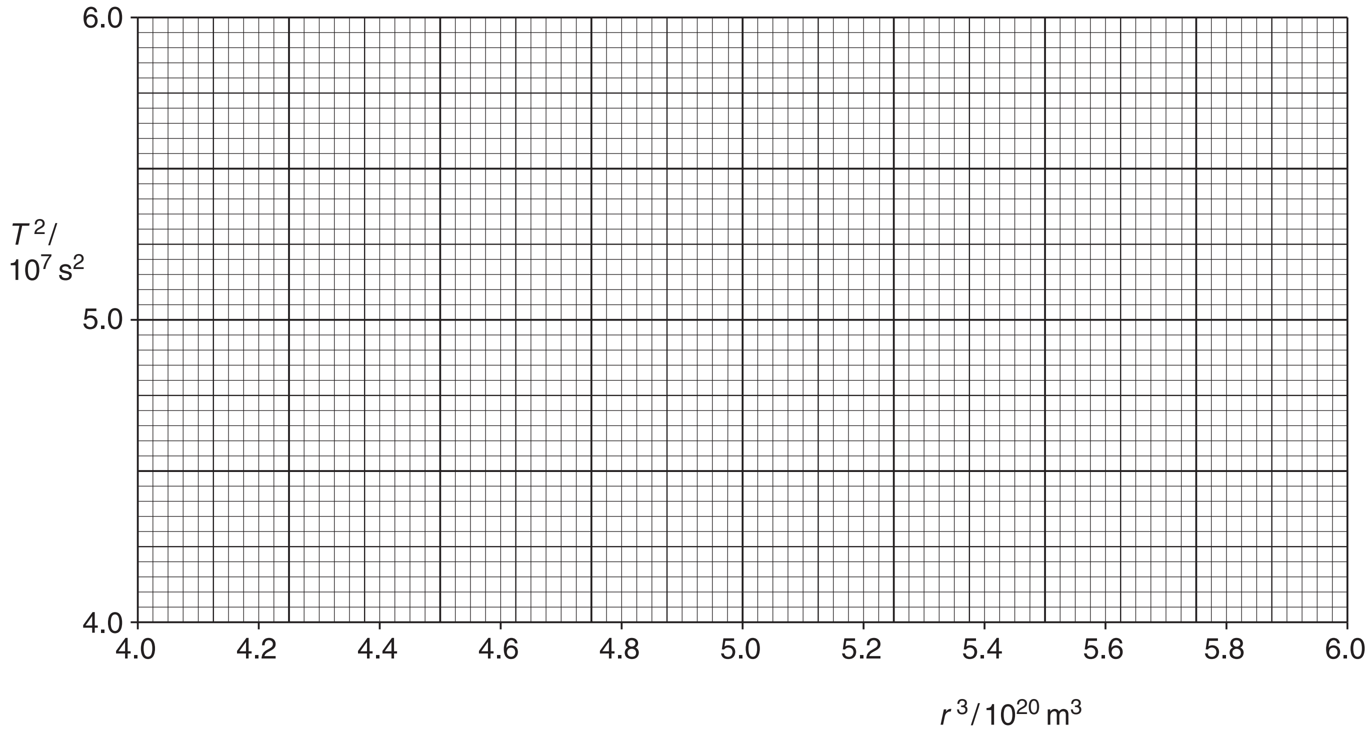

Fig. 2.2

The relationship between T and r is given by

$$T^2 = \frac{4\pi^2 r^3}{GM}$$

where M is the mass of the Earth.

(iii) Use your graph to calculate a value for M, showing all your working.

$M =$ .... kg **[2]**

(iv) Suggest a possible advantage of using **Low** Earth Orbit satellites to observe objects outside the solar system.

....

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.... **[1]**

(v) State and explain how, if at all, the gradient of the graph changes if the satellites were orbiting the planet Jupiter, not the Earth?

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....

....

.... **[2]**

[Total: 11]

3 **(a)** What is meant by the *absolute magnitude* of a star?

....

....

.... **[2]**

(b) The first spiral galaxy shown to exist beyond the limits of the Milky Way is called Andromeda. It has an apparent magnitude of 3.5 and is 700 kpc from the Earth.

(i) What is the distance of Andromeda from Earth in light-years?

distance = ... ly **[1]**

(ii) Calculate the absolute magnitude of Andromeda.

absolute magnitude = ... **[3]**

(iii) Andromeda is a *spiral galaxy*. Explain what is meant by a spiral galaxy.

....

.... **[1]**

(iv) State **one** other type of galaxy.

.... **[1]**

(c) Sketch the shape of our own galaxy, seen edge-on, and mark the approximate position of the Sun using the letter **X**.

[3]

[Total: 11]

4 **(a)** Describe the main energy-generating process that occurs within the Sun.

....

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.... **[3]**

(b) The graph of Fig. 4.1 shows the ratio $\frac{\text{luminosity of light from star}}{\text{luminosity of light from Sun}}$

plotted against the surface temperature of Main Sequence stars.

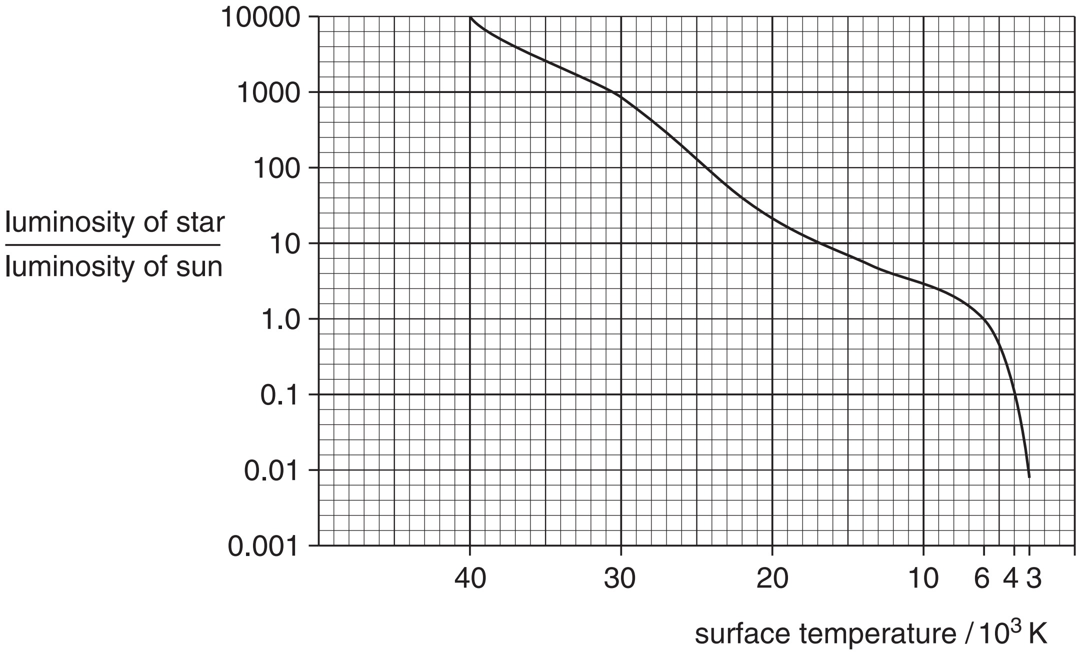

Fig. 4.1

(i) Using the letter **X** mark the position of the Sun on Fig. 4.1 and find its surface temperature.

surface temperature of Sun = ... K **[2]**

(ii) Using the letter **Z** mark the position where a Main Sequence star, having a mass significantly greater than that of the Sun, would appear on Fig. 4.1. **[1]**

(iii) State and explain how the time spent on the Main Sequence by the star **Z** compares to the Main Sequence lifetime of the Sun.

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.... **[2]**

(c) Explain what happens to the luminosity **and** surface temperature of a Main Sequence star when it evolves into a red giant.

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.... **[2]**

(d) The star Betelgeuse is a red super giant with a diameter of approximately 3.6 AU.

What is the meaning of the term *Astronomical Unit*? State its value in SI units.

....

....

value = ... unit .... **[2]**

(e) Mark the approximate position of Betelgeuse on Fig. 4.1 using the letter **B**. **[1]**

(f) The mass of Betelgeuse is approximately 14 times greater than that of the Sun. Describe and explain the possible further evolution of Betelgeuse.

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.... **[6]**

[Total: 19]

5 **(a)** A line in the hydrogen absorption spectrum has a wavelength of 656.3 nm when measured in the laboratory. Observation of a star shows the same absorption line to have a wavelength of 651.0 nm.

(i) Calculate the velocity of the star relative to Earth.

velocity = ... m s^{-1} **[3]**

(ii) What else can be deduced about the star's motion from these measurements?

Explain your answer.

....

.... **[1]**

(iii) How did Edwin Hubble use calculations of this type, together with other data, to develop our understanding of the Universe?

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.... **[5]**

(b) What are the important properties of the cosmic microwave background radiation and how have these contributed to our understanding of the origin of the Universe?

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.... **[3]**

[Total: 12]

6 **(a)** What is meant by a *frame of reference* within the Special Theory of Relativity?

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.... **[1]**

(b) Describe a **thought** experiment which illustrates length contraction.

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.... **[5]**

Turn over

(c) A particle moving at a constant velocity of $0.9c$ passes along a straight tube of length 1500 m.

(i) Calculate the time taken for the particle to move along the tube as measured by an outside observer.

time taken = ... s **[2]**

(ii) Calculate the length of the tube as measured in the reference frame of the particle.

length of the tube = ... m **[3]**

[Total: 11]

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7 A Physics student receives a present of a torch which requires neither batteries nor a filament light bulb. The basic arrangement of the torch is shown in Fig. 7.1 and has the following features:

- a rechargeable capacitor instead of batteries
- a fixed coil of wire through which a powerful magnet can move inside the body of the torch
- a circuit board with diodes and the rechargeable capacitor

The capacitor can be charged by making the magnet move back and forth through the coil.
The capacitor can be discharged through an LED to provide the light.

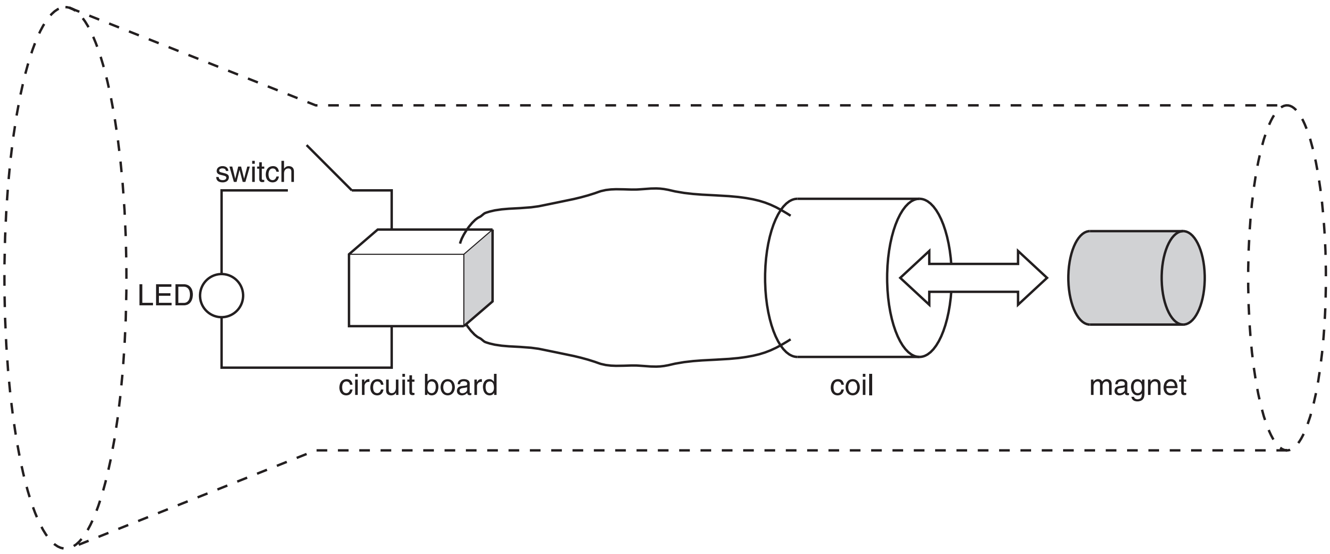

Fig. 7.1

To charge the capacitor in the circuit board, the torch is repeatedly inverted. In this way, the magnet is lifted through a vertical height *h* and then allowed to fall through the coil. It is then lifted through *h* again and allowed to fall. The process is shown in Fig. 7.2.

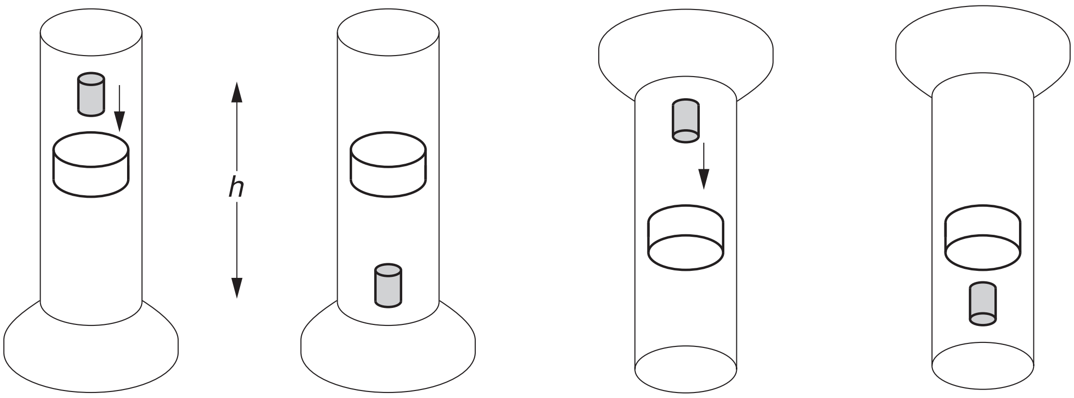

Fig. 7.2

(a) The mass of the magnet is 240 g and the height h through which it falls is 6.0 cm.

(i) Calculate the loss in gravitational potential energy in each fall.

loss in GPE = ... J **[2]**

(ii) Calculate the work done on the magnet in making 84 inversions.

work done = ... J **[1]**

(iii) Explain why the total work done by the student will be much greater than your answer to **(ii)**.

....

.... **[1]**

(b) The energy stored in the capacitor after 84 inversions is 10.5 J
The mean power dissipation of the LED in the torch is 55 mW.

Calculate how long the light will operate after the 84 inversions.

time = ... s **[2]**

(c) To find out more about the torch, the student connects a voltmeter and data logger to the coil when the magnet falls through it. The magnet is released from rest at time **A** and finishes at rest at time **C**. The resulting induced e.m.f. is shown in Fig. 7.3.

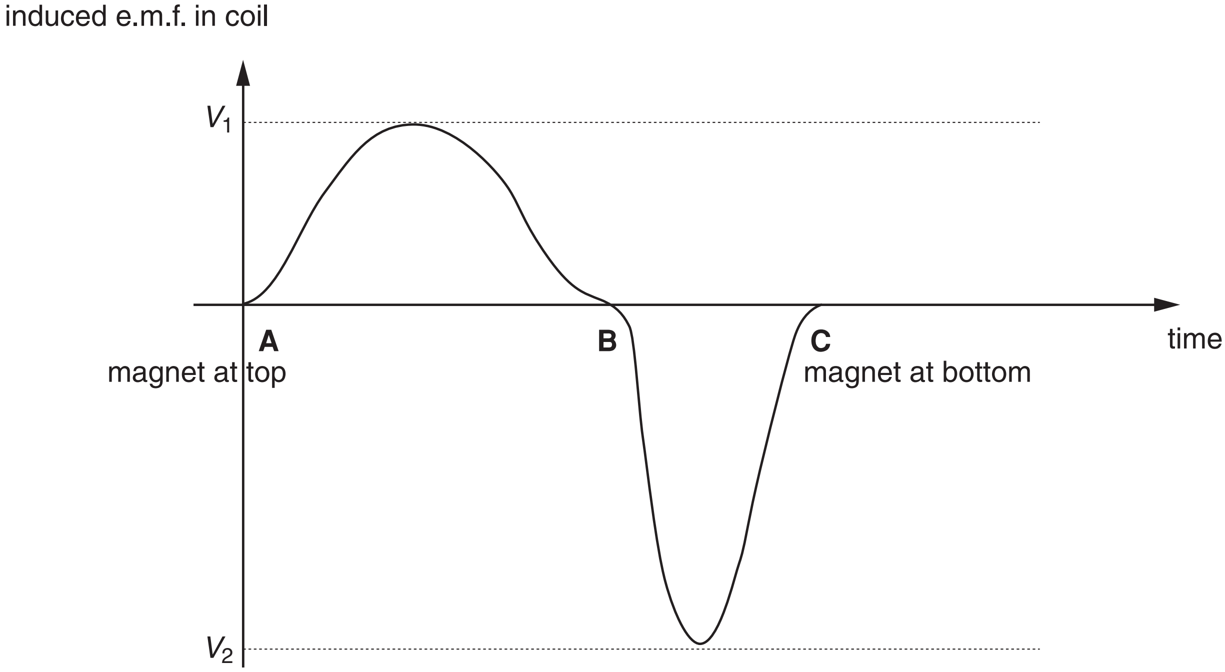

Fig. 7.3

Explain the following:

(i) The time **AB** in the positive region is greater than the time **BC** in the negative region.

....

.... **[2]**

(ii) Why an e.m.f is induced in the coil.

....

.... **[1]**

(iii) The peak induced e.m.f. V_1 is less than the peak induced e.m.f. V_2.

....

.... **[2]**

(iv) The induced e.m.f. consists of a positive voltage region and a negative voltage region.

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.... **[1]**

(d) The characteristics of the magnet, coil and capacitor are as follows:

- magnetic flux ϕ emerging from one pole of magnet — 0.54 mWb
- number of turns N on coil — 420
- resistance R of coil and circuit — 28 Ω
- capacitance C of capacitor — 88 mF

(i) The average current I charging the capacitor during the positive voltage time interval **AB** is given by

$$I = \frac{Q}{t}$$

where Q is the total charge which has flowed and t is the time interval **AB**.

The mean induced e.m.f. E is given by

$$E = \frac{N\phi}{t}.$$

1 Show that the total charge Q is given by

$$Q = \frac{N\phi}{R}.$$

[2]

2 Show that the charge Q on the capacitor at time **B** is about 8 mC.

[1]

(ii) Explain why diodes are necessary between the coil and the capacitor.

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.... **[1]**

(iii) Explain why a charge of about 16 mC is stored on the capacitor after one fall of the magnet.

....

.... **[1]**

Question continues on the next page.

(iv) Show that 10.5 J of energy are stored in the capacitor after the student makes 84 inversions.
You may assume the capacitor is initially uncharged and that the diodes are ideal.

[3]

[Total: 20]

END OF QUESTION PAPER

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