OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE UNIT **2825/05**

PHYSICS A

Telecommunications

FRIDAY 26 JANUARY 2007 Morning

Time: 1 hour 30 minutes

Additional materials: Electronic calculator

Candidate Name

Centre Number

Candidate Number

INSTRUCTIONS TO CANDIDATES

- Write your name, Centre Number and Candidate number in the boxes above.
- Answer **all** the questions.
- Use blue or black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure you know what you have to do before starting your answer.
- Do **not** write in the bar code.
- Do **not** write outside the box bordering each page.
- WRITE YOUR ANSWER TO EACH QUESTION IN THE SPACE PROVIDED. ANSWERS WRITTEN ELSEWHERE WILL NOT BE MARKED.

INFORMATION FOR CANDIDATES

- The number of marks for each question 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 five questions concern Telecommunications. The last question concerns general physics.

FOR EXAMINER'S USE

Qu.	Max.	Mark
1	18	
2	13	
3	11	
4	12	
5	16	
6	20	
TOTAL	90	

This document consists of **16** printed pages.

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,	$n = \frac{1}{\sin C}$
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,	$p = \frac{1}{3}\frac{Nm}{V}<c^2>$
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,	$= 10 \lg \left(\frac{I}{I_0}\right)$

Answer **all** the questions.

1 Fig. 1.1 shows the output voltage from a sensor which is monitoring the temperature inside a small oven during a period of four minutes.

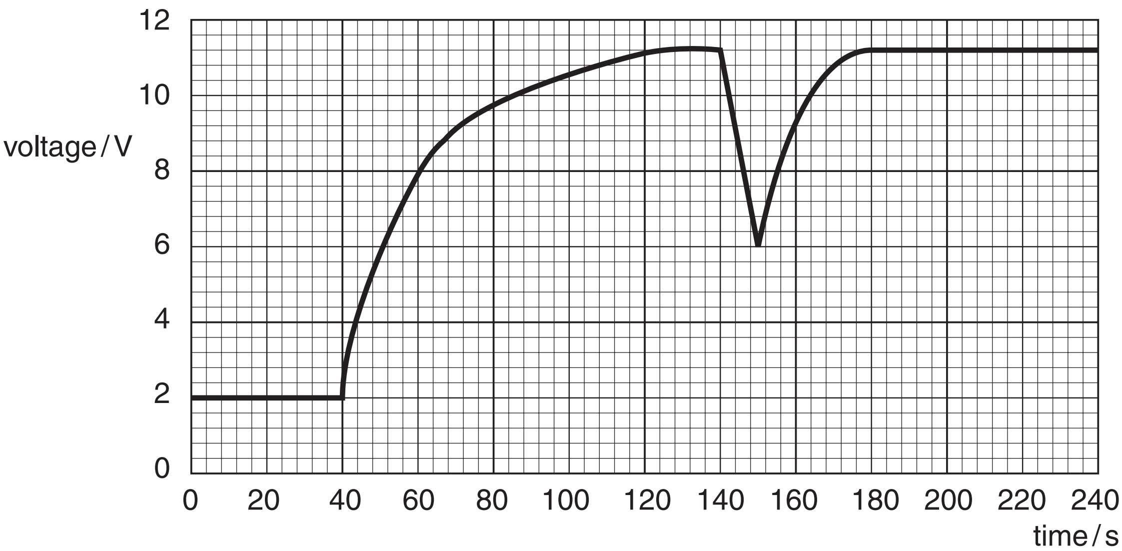

Fig. 1.1

At 0 s the oven door is closed and at 40 s the oven heater is switched on. At 140 s the oven door is opened and at 150 s the oven door is closed again. The variation in temperature is recorded by storing a number of sample voltages digitally.

(a) State the name in words of the electronic circuit required to digitise a sampled voltage.

.... [1]

(b) The voltage is sampled at 60-second intervals starting at time 0 s. Each sample is turned into a 4-bit code and stored in a memory. In the spaces below, write down the corresponding 4-bit code for each sample.

time 0 s	time 60 s	time 120 s	time 180 s	time 240 s

Draw an arrow pointing to the most significant bit of the first sample. [5]

(c) Now the stored data is replayed from the memory in an attempt to reproduce the original. State the name in words of the electronic device required to change each binary code back to the original sampled voltage.

.... [1]

(d) The five sample voltages in part **(b)** are now used to create a smooth graph of the temperature variation in the oven during the four minute period. Draw the resulting graph on Fig. 1.2.

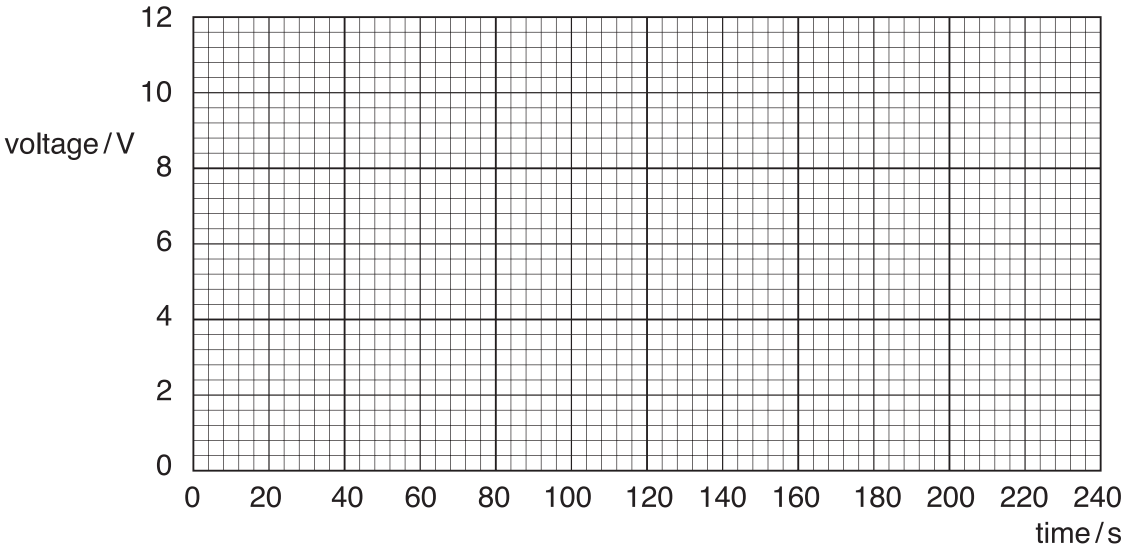

Fig. 1.2 [3]

(e) State **three** differences between Fig. 1.1 and Fig. 1.2. Explain why they do not perfectly resemble each other.

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.... [4]

(f) Suggest and explain a suitable minimum sampling frequency which will allow an accurate reproduction of the variation of voltage of Fig. 1.1.

minimum sampling frequency = ... Hz

....

.... [2]

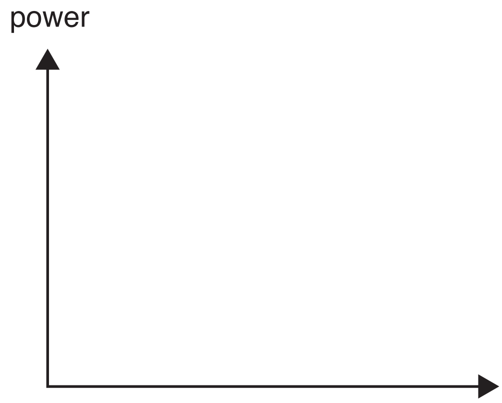
(g) For your sampling frequency chosen in **(f)**, calculate the total number of bits which would be stored in memory during the 240 seconds.

total number of bits = ... [2]

[Total: 18]

2 Some radio stations broadcasting in the Long Wave (LW) region of the electromagnetic spectrum use amplitude modulation (AM) on frequencies between 140 kHz and 280 kHz. These stations must limit their *sidebands* to within ± 4 kHz of their *carrier frequency*.

(a) Explain, with the aid of a labelled sketch graph on the axes provided, the meaning of the terms in italics. Label the horizontal axis.



....

....

....

.... [5]

(b) State the bandwidth of each station. Provide a suitable unit for your answer.

bandwidth = ... unit .... [2]

(c) Calculate the maximum number of stations which could transmit in this LW region.

maximum number of stations = ... [2]

(d) Explain why AM, rather than FM, is used on LW transmissions.

....

....

.... [2]

(e) Explain why it is impossible to broadcast normal analogue domestic television in the LW region.

....

....

.... [2]

[Total: 13]

3 Fig. 3.1 shows a microphone, an operational amplifier and a 0 V line.

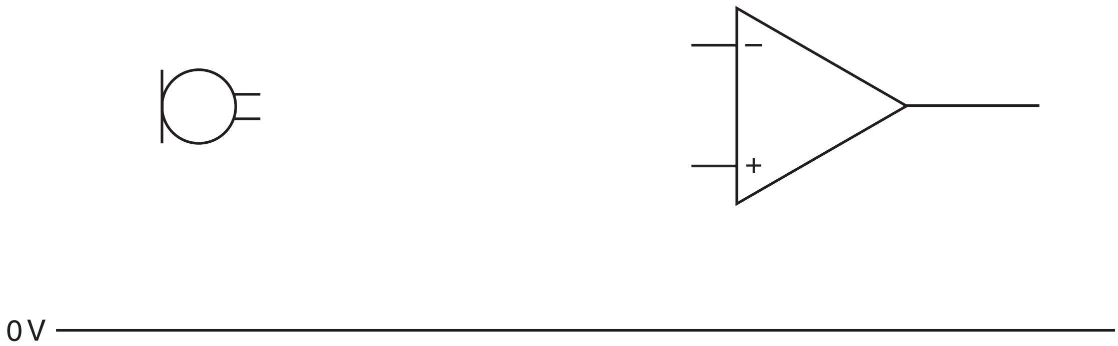


Fig. 3.1

(a) Label the microphone **M**. [1]

(b) The op-amp is to be run from ± 15 V supplies. State the maximum op-amp output voltage.

maximum output voltage = ... V [1]

(c) Draw a circuit diagram on Fig. 3.1 to show how the op-amp can be used to make an inverting amplifier for use with the microphone. [4]

(d) For the loudest sound input, the microphone generates a voltage of 35 mV.

Calculate a suitable voltage gain for your amplifier in Fig. 3.1 so that the loudest sound to the microphone produces an output voltage of 10.5 V from the amplifier.

voltage gain = ... [2]

(e) Your amplifier in Fig. 3.1 is to have an input resistance of 2.2 kΩ.

Label all resistors in your diagram with their appropriate values.

Show any necessary calculations.

[3]

[Total: 11]

4 The first successful transatlantic telegraph cable was laid in 1866. This cable was effectively a continuous length of insulated copper wire lying on the sea bed. There were no amplifiers in the cable because these had not yet been invented. The cable was used to transmit simple on/off currents from the UK to the USA.

Fig. 4.1 shows the basic arrangement where a key pressed at one end caused an electromagnet to operate at the other. Only a single copper conductor was laid with the current returning through the ocean.

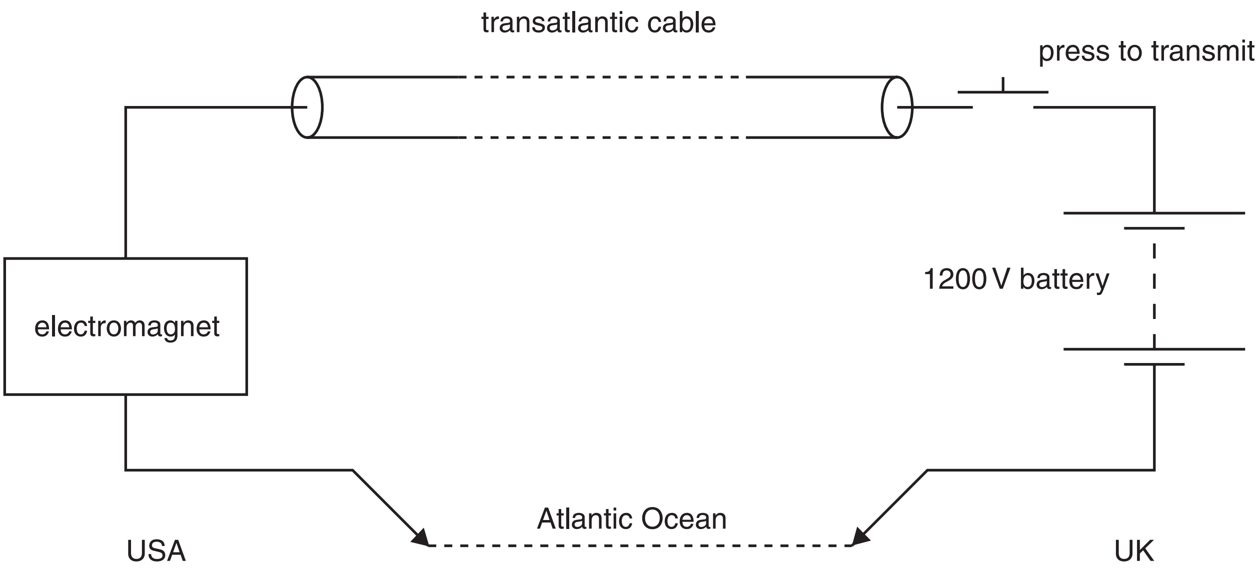


Fig. 4.1

(a) The electromagnet has a resistance of 48 Ω and is energised by a current of 200 mA. Show that the required p.d. across the electromagnet, when the key is pressed, is less than 1% of the 1200 V battery voltage.

[2]

(b) The resistance of the ocean is negligible compared with the resistance of the cable.

Show that the cable resistance is about 6 kΩ.

[1]

(c) The length of the cable is 3000 km. The resistivity of copper is $1.7 \times 10^{-8}\,\Omega\,m$. Show that the diameter of the copper conductor in the cable is about 3.5 mm.

[4]

(d) The density of copper is $8930\,kg\,m^{-3}$. Calculate the mass of copper used in the cable.

mass of copper = ... kg [2]

(e) Calculate the ratio, in dB, of the power received by the electromagnet in the USA to the power supplied by the battery in the UK.

power ratio = ... dB [2]

(f) Suggest **one** reason why the return current was allowed to pass through the ocean.

.... [1]

[Total: 12]

5 Fig. 5.1 shows a light source in front of a section of step-index multimode glass fibre.

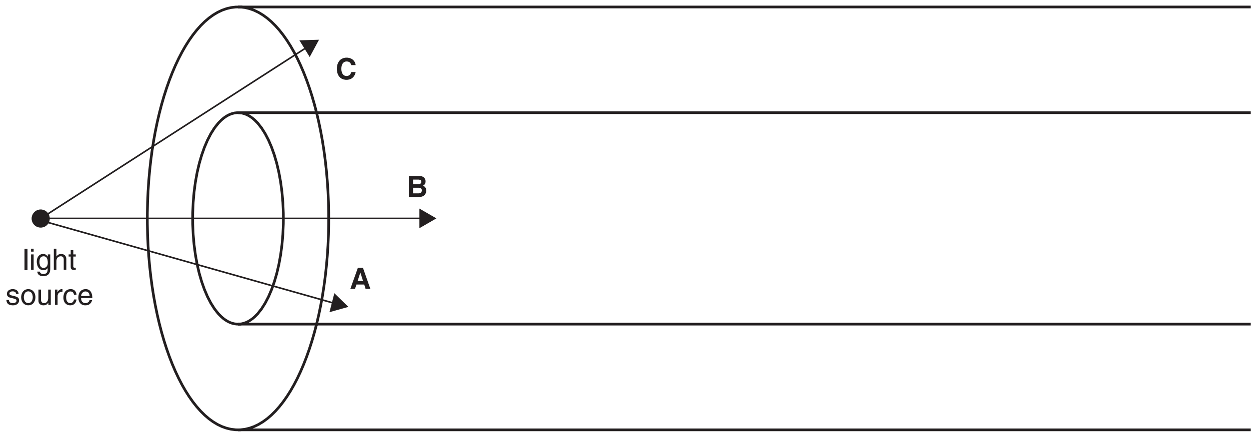


Fig. 5.1

(a) Explain, making reference to the refractive index in the different regions, how light propagates along the fibre.

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.... [4]

(b) Fig. 5.1 shows three rays **A**, **B** and **C**, entering the fibre.

(i) Complete the paths of rays **A** and **B** along the fibre. [2]

(ii) State what happens to ray **C**.

....

.... [1]

(c) (i) Explain the nature of the distortion produced when light pulses are sent, one after another, at high frequency down a multimode optic-fibre.

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.... [5]

(ii) Monomode optic-fibres reduce this distortion.

Explain how this is done and why it is important to society that the telecommunications industry uses monomode fibres rather than multimode fibres.

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.... [4]

[Total: 16]

6 A champion BMX cyclist wishes to become a professional and seeks help from an A-level Physics student in creating an act. The student suggests two stunts; one involving a horizontal take-off on to a sloping ramp and the other involving a loop-the-loop manoeuvre.

(a) The student begins by finding out the maximum speed the cyclist can produce on level ground. Two flags are positioned 240 m apart on a flat road. The cyclist is told to accelerate to the first flag and to pedal as hard as he can until the second flag is passed. This is shown in Fig. 6.1.

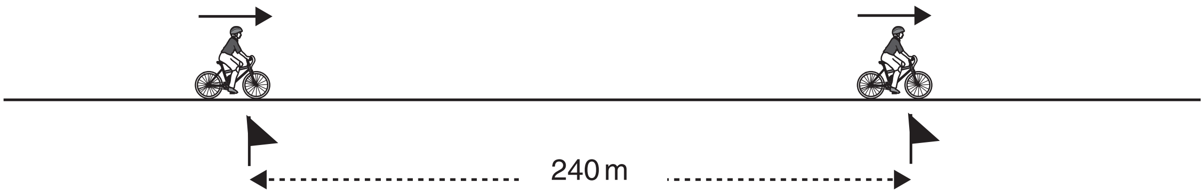

Fig. 6.1

The student gets the cyclist to repeat the test three times and records the following results:

14.8 s   17.2 s   15.6 s

Show that the mean speed the cyclist can maintain over the 240 m is about $15\,m\,s^{-1}$.

[2]

(b) The student designs the stunt shown in Fig. 6.2 where the cyclist must take off at $15\,m\,s^{-1}$ from a horizontal launch pad and land smoothly just at the edge of a sloping ramp.

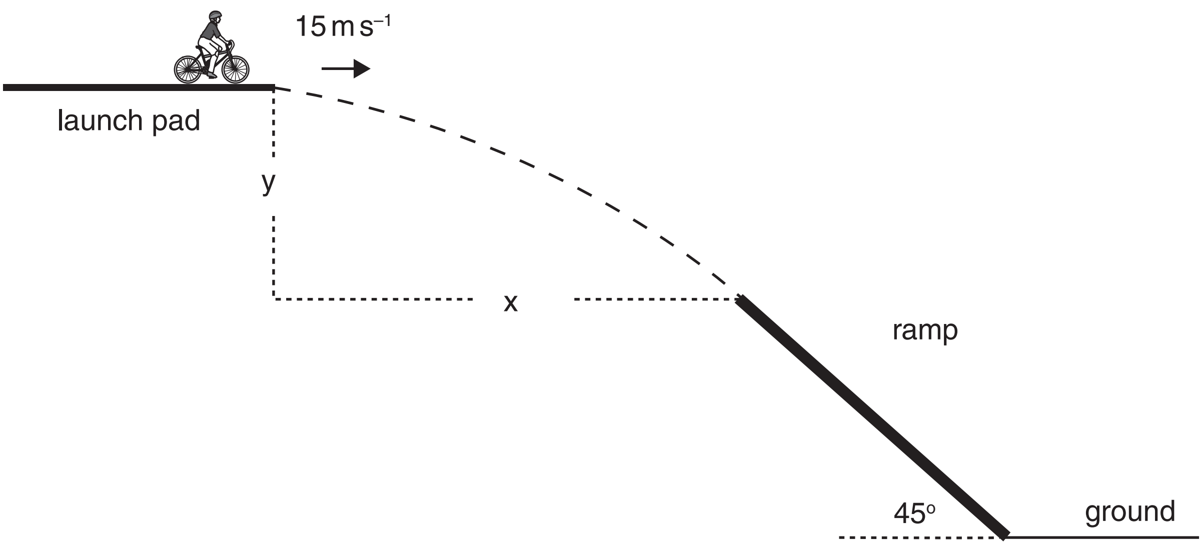

Fig. 6.2

The student reasons that in order to land smoothly, the direction of the velocity of the cyclist on reaching the edge of the ramp must be at the same 45° angle as the ramp itself.
Ignore air resistance in all calculations.

(i) Explain why the vertical component of velocity on reaching the ramp must be 15 m s^{-1}.

....

....

.... [1]

(ii) The student calculated the vertical fall y to the ramp to be about 11 m. Show how he arrived at this result.

[2]

(iii) The student calculated the horizontal jump x to the ramp to be about 23 m. Show how he arrived at this result.

[1]

(iv) The total mass of the cyclist and bike is 86 kg. Show that the kinetic energy of the cyclist on reaching the ramp is about 19 kJ.

[3]

(c) The student next designs a loop-the-loop stunt shown in Fig. 6.3. The cyclist must enter the circular runway at the same $15\,m\,s^{-1}$ speed in order to exit from it smoothly.

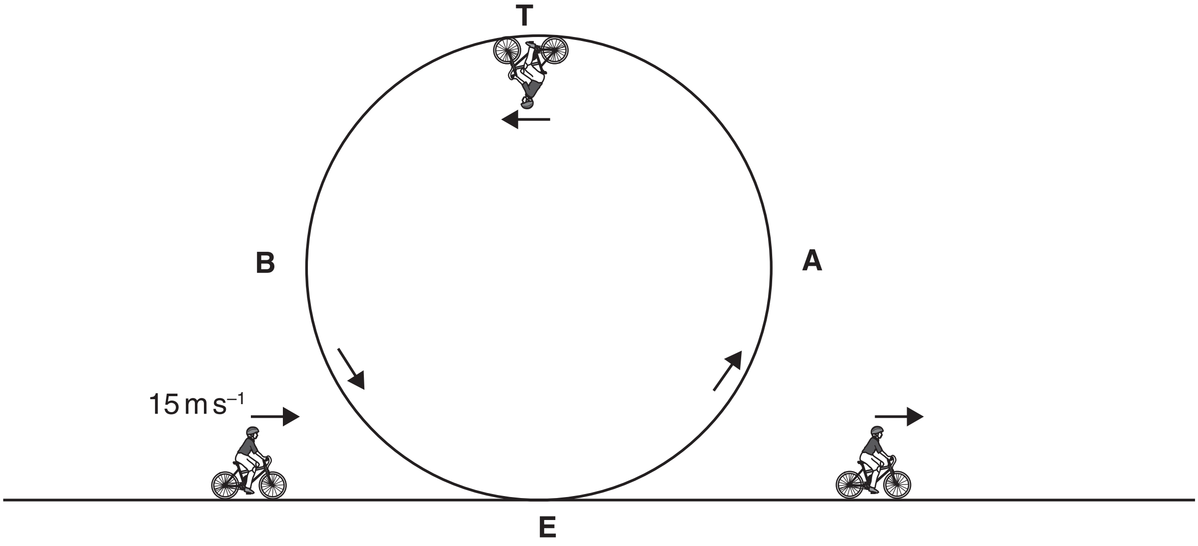

Fig. 6.3

In order to calculate the maximum diameter of loop in which the cyclist can safely execute the manoeuvre, the student makes the following assumptions

- the cyclist stops pedalling once he enters the loop at **E**
- the normal reaction of the runway on the tyre just becomes zero at the top of the loop **T**
- therefore the centripetal force at the top **T** is provided by the force of gravity only
- air resistance and runway friction can be ignored.

As a result, the student calculates the diameter of the track to be 9.17 m.

(i) Show that the speed of the cyclist at the top **T** of the loop should be $6.7\,m\,s^{-1}$.

[3]

(ii) The total mass of the cyclist and bike is 86 kg. Calculate

1 the kinetic energy of the cyclist at the top **T**

kinetic energy = ... J [2]

2 the gravitational potential energy of the cyclist at the top **T**. Take the gravitational potential energy at **E** to be zero.

potential energy = ... J [2]

(iii) Show that the sum of the kinetic and potential energies at the top **T** of the loop is equal to the kinetic energy of the cyclist as he enters the loop at **E**.

[2]

(iv) The cyclist suggests that removing the top half or semicircle of the loop from **A** to **B** would allow him to fly in a semi-circular arc through the air and thus make a more spectacular stunt. How should the student respond to this suggestion? Explain your reasoning.

....

....

....

.... [2]

[Total: 20]

END OF QUESTION PAPER

PLEASE DO NOT WRITE ON THIS PAGE