OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS A

2825/05

Telecommunications

Monday **27 JUNE 2005** Afternoon 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.
- 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	14	
2	14	
3	13	
4	17	
5	12	
6	20	
TOTAL	90	

This question paper consists of 19 printed pages and 1 blank page.

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

[Turn over

Answer **all** the questions.

1 Fig. 1.1 shows a portable radio receiver approximately equidistant from three different radio stations, each broadcasting different programmes on the AM medium wave network.

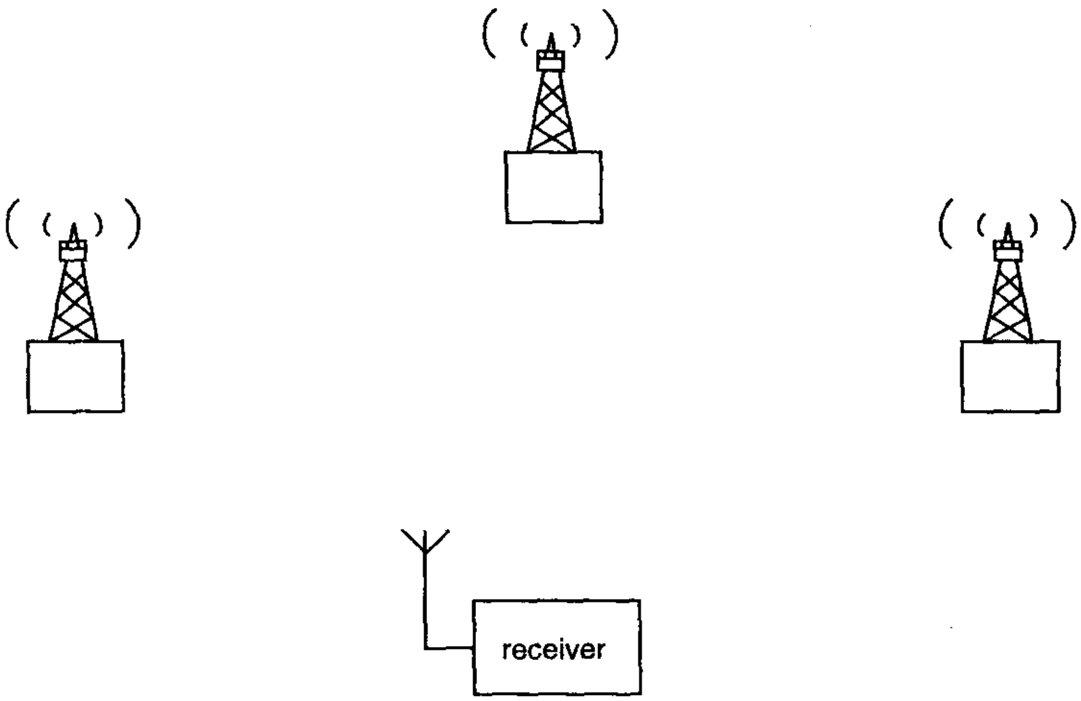

Fig. 1.1

(a) State a typical carrier frequency that one of the transmitters could use.

.... Hz [1]

(b) Show by means of a suitable calculation that it is impractical for the portable radio to use a dipole aerial.

[2]

(c) State **two** reasons why the aerial of the receiver cannot simply be connected directly to a moving-coil loudspeaker.

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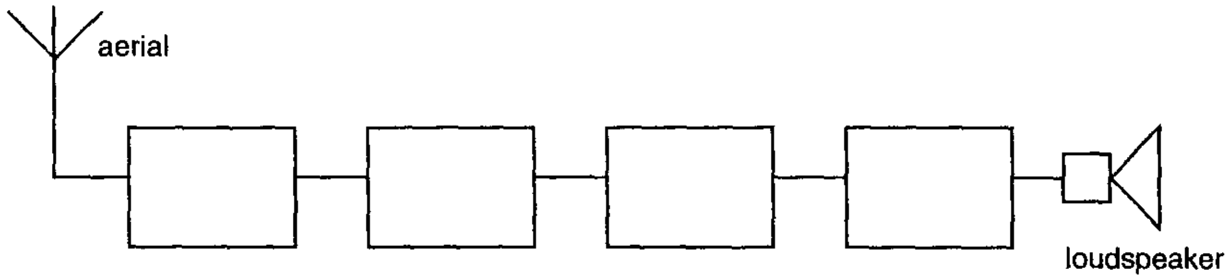
....[2]

For Examiner's Use

(d) (i) Complete the block diagram, below, of an AM radio receiver.



[4]

(ii) Explain the function of each block in the diagram.

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....[5]

[Total: 14]

2 Fig. 2.1 shows a circuit with a light-dependent resistor (LDR) and an op-amp operating from ±15 V power supplies. As the light intensity at the LDR changes, a light-emitting diode (LED) may change its state of ON or OFF.

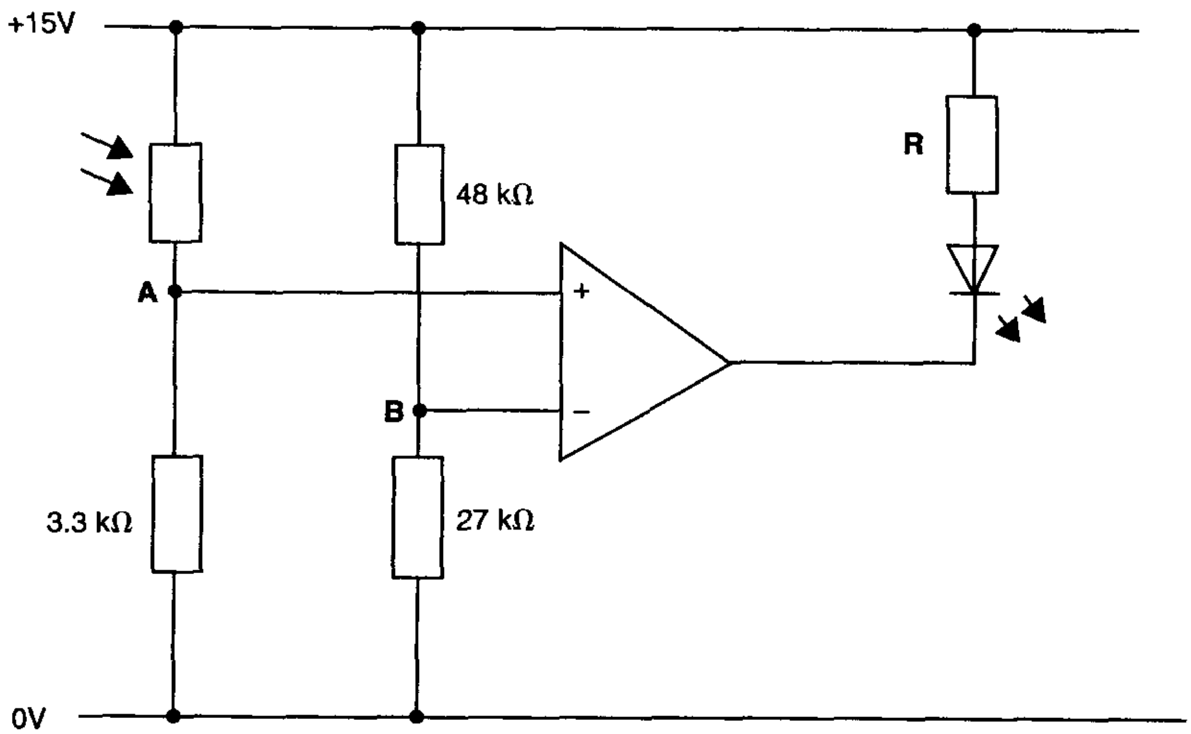


Fig. 2.1

(a) The op-amp in this circuit is being used to compare the fixed voltage V_B at **B**, with the variable voltage V_A at **A**. Explain how the output of the op-amp changes as V_A changes.

....

....

....[2]

(b) Draw a circle around the component which senses light. [1]

(c) Calculate the voltage at **B**.

V_B = ... V [2]

For Examiner's Use

(d) In a certain light condition, the LDR has a resistance of 6.2 kΩ. What will be the output voltage of the op-amp and corresponding state of the LED?

op-amp output = ... V

LED .... [3]

(e) Explain how the brightness of the LED changes as the lighting conditions change from darkness (LDR resistance ≈ 1 MΩ) to brightness (LDR resistance ≈ 100 Ω).

....

....

....

....[3]

(f) Calculate a suitable value for the resistor **R** to limit the LED current to a maximum value of 5 mA.

resistor **R** = ... Ω [3]

[Total: 14]

3 Fig. 3.1 shows a system for time-division multiplexing (TDM) the digitised samples of three different analogue signal voltages on to a single transmission line.

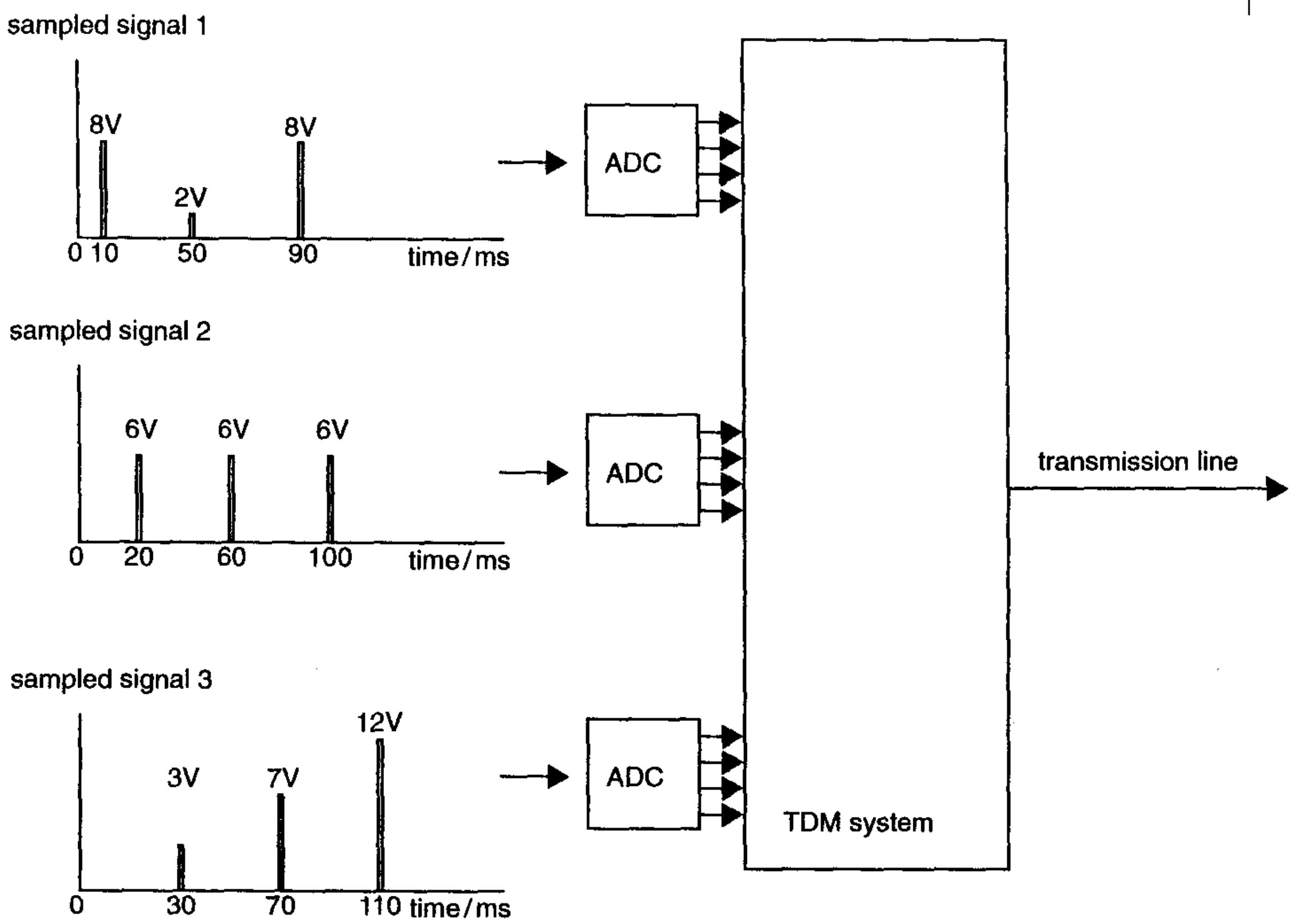
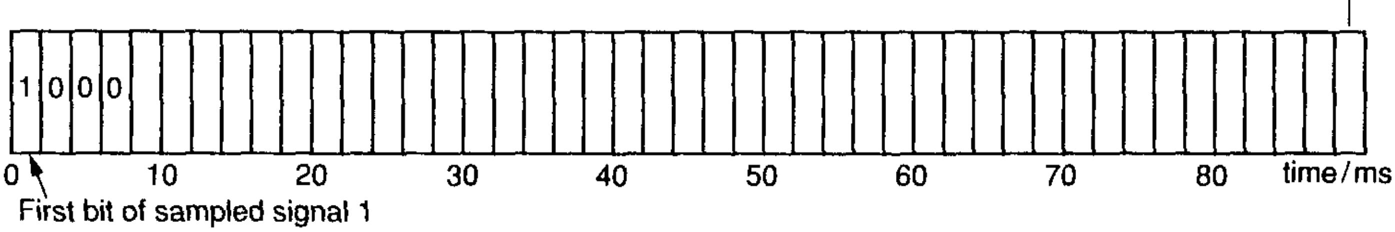


Fig. 3.1

(a) All three analogue signals are each sampled at a frequency of 25 Hz. Show that the time between the samples of each signal is 40 ms.

[1]

(b) Each of the sample voltages shown in Fig. 3.1 is converted to a 4-bit binary signal by three analogue-to-digital converters (ADC). The TDM system makes each bit last for 2 ms. Complete Fig. 3.2 to represent the variation with time of the 1s and 0s of the digital signal in the transmission line over a period of 90 ms. The first processed digital signal is already shown. Indicate the most significant bit of each 4-bit word.



[5]

Fig. 3.2

(c) The system in Fig. 3.1 shows three signals being sampled and multiplexed. Calculate the **maximum** number of analogue signals, sampled and digitised in the same way, that could share the transmission line.

maximum number = ... [2]

(d) State the maximum frequency of analogue signal, sampled in the same way, which could be recovered at the other end of the transmission line. Explain how you arrived at your answer.

maximum frequency = ... Hz

....

....[2]

(e) State **three** different changes which could be made to the system of Fig. 3.1, each of which would cause the maximum number of analogue signals sharing the line to be increased.

1. ....

....

2. ....

....

3. ....

....[3]

[Total: 13]

4 (a) During the 1980s, glass fibres began to replace coaxial cable in the telecommunications industry. This was because of two technical advances. Firstly, very high purity glasses became available. Secondly, methods of making fibres with cores and claddings of different refractive indices were developed.

- Explain why the two technical advances mentioned enabled the development of the modern optic fibre.
- State and explain **three** advantages of optic fibre over coaxial cable.

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....[10]

For Examiner's Use

(b) It is found that a 38 mW signal, input to a type of optic fibre, can be transmitted through a maximum uninterrupted distance of 80 km.
The noise power in the receiver is 6.3 μW.
The signal-to-noise ratio at the receiver must be kept above 25 dB.
The refractive index of the fibre is 1.5.

Calculate

(i) the lowest signal power that can be allowed to arrive at the receiver

lowest signal power = ... W [2]

(ii) the characteristic attenuation per kilometre of the fibre and give a suitable unit for your answer

attenuation per kilometre = ... unit .... [3]

(iii) the shortest time taken for a light pulse to travel along the fibre.

time = ... μs [2]

[Total: 17]

5 When recording music in a studio, the audio analogue signal is converted to a digital signal.

(a) Explain what is meant by

(i) *audio*

....

(ii) *analogue*

....

....

(iii) *digital*.

....

....
[3]

(b) The recording studio makes a compact disc (CD) by sampling the audio signal at 44.1 kHz. Each sample consists of a 16-bit left and a 16-bit right stereo channel. Typically, the CD stores an hour of recorded music. For such a CD, calculate

(i) the total number of bits stored

total number of bits = ... [2]

(ii) the rate at which bits are received during playback.

bit rate = ... s^{-1} [1]

(c) State **two** advantages of converting original analogue information into digital form.

1. ....

....

2. ....

.... [2]

(d) A type of computer keyboard can produce 120 different alphanumeric characters (i.e. letters, numbers and symbols).

(i) Show that each character requires 7 bits to define it uniquely.

[1]

(ii) Estimate the number of bits required to store a typical page of text from a novel.

number of bits per page = ... [2]

(iii) Use your answers to **(b)(i)** and **(d)(ii)** to estimate the number of pages of text which could be stored on a CD if used to store data rather than music.

number of pages = ... [1]

[Total: 12]

6 The London Eye, Fig. 6.1, is the largest observation wheel ever built. It has 32 egg-shaped capsules attached to the outside of the rim of the wheel. Each capsule holds up to 25 passengers and completes one revolution in 30 minutes.

The wheel of diameter 122 m, is driven by a drive system based on tyres gripping the edge of the wheel rim. 16 rubber tyres each supply a tangential force of 12.5 kN to the rim. The tyres are pressed against the rim by hydraulic cylinders.

The design engineers used computer simulations to predict all of the stresses on the structure. These programs modelled the effect of metal fatigue as well as wind and temperature changes over the whole structure. All of the 80 cables between the rim of the wheel and the hub (centre) remain under tension as the wheel rotates. The system acts like a large bicycle wheel suspended in the air.

As the wheel rotates, the tension in each cable changes. The wheel and support as a whole has a natural frequency of oscillation and it is important that the combination is not set in oscillation by the wind.

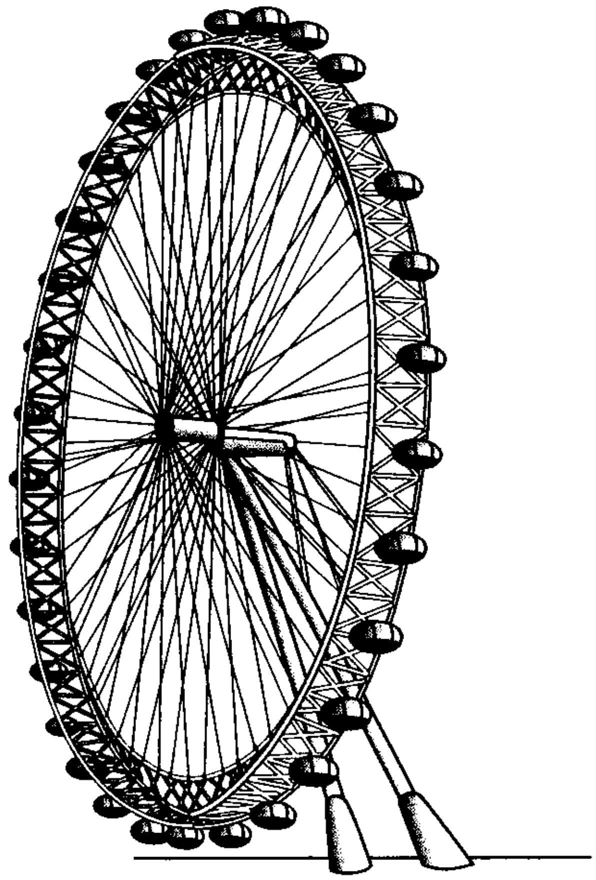

Fig. 6.1

For Examiner's Use

(a) (i) Calculate the linear speed of the wheel rim when it is turning normally.

speed = ... $m\,s^{-1}$ [2]

(ii) Calculate the total force exerted by the drive system.

force = ... N [1]

(iii) Calculate the work done in moving the wheel through one revolution.

work done = ... J [2]

[Turn over

For Examiner's Use

(iv) Calculate the useful power needed for the wheel to turn at the rate of one revolution every 30 minutes.

power = ... W [2]

(v) The wheel turns at a constant speed. Energy is converted as a result of

- friction in the bearings
- friction between the tyres and the rim
- electrical energy supplied to the motor.

Apply the conservation of energy for the rotating wheel and discuss which of the above produces useful work in rotating the London Eye.

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.... [5]

(b) The London Eye behaves like a large bicycle wheel suspended in the air. Fig. 6.2(i) shows the front wheel and fork of a stationary bicycle wheel which is in contact with the ground. Fig. 6.2(ii) shows the front wheel and fork of the same bicycle when lifted off the ground.

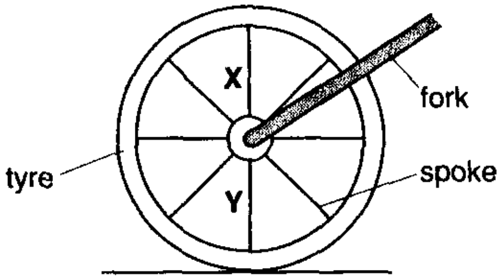

Fig. 6.2(i)

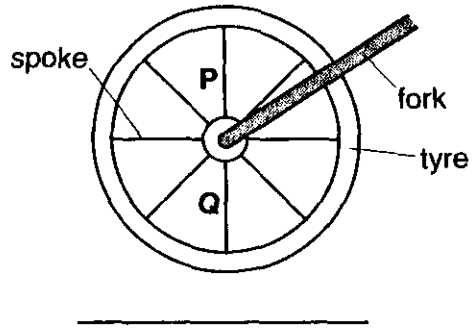

Fig. 6.2(ii)

Assume all spokes are always in tension.
Compare, giving a reason in each case, the magnitude of

(i) the tension in the spokes **X** and **Y**

....

....

(ii) the tension in the spokes **P** and **Q**.

....

....
[2]

(c) This question is concerned with the effect of the wind on the London Eye.

(i) In a storm the wind may exert a horizontal force of 1800 kN on the wheel support, causing it to deflect horizontally by 90 cm. Calculate a value for the spring constant k of the wheel support.

k = ... N m^{-1} [2]

For Examiner's Use

(ii) The natural frequency f of oscillation of the wheel is given by the equation

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

where m is the mass of the system.
Calculate the fundamental natural frequency f of oscillation of the wheel support when m is 9.5×10^5 kg.

f = ... Hz [2]

(iii) The wind may cause fluctuations at the frequency calculated in **(c)(ii)**. What problem might this cause and how may this problem be overcome?

....

....

....
[2]

[Total: 20]

END OF QUESTION PAPER

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