RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS
Advanced GCE

PHYSICS A

2825/01

Cosmology

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 eight questions concern Cosmology. The last question concerns general physics.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	6	
2	13	
3	8	
4	10	
5	9	
6	6	
7	12	
8	6	
9	20	
TOTAL	**90**	

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

SP (NF/AR) S79683/4

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,	$= \sqrt{(1 - \frac{v^2}{c^2})}$
current,	$I = nAve$
nuclear radius,	$r = r_0 A^{1/3}$
sound intensity level,	$= 10 \lg\left(\dfrac{I}{I_0}\right)$

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For Examiner's Use

Answer **all** the questions.

1 Galileo was the first person to see the phases of a planet. The observations that he made over several weeks are represented in Fig. 1.1.

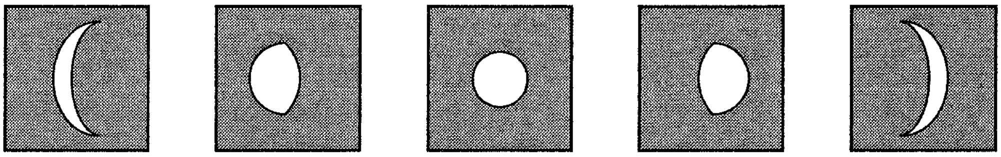

Fig. 1.1

(a) **(i)** State the name of the planet which Galileo was observing.

.... [1]

(ii) Explain why the size of the planet appeared to change.

....

.... [1]

(b) These observations and others led Galileo to support the Copernican model of the solar system.

(i) State **two** differences between the Copernican model of planetary motion and the previous model.

....

....

.... [2]

(ii) What other evidence led Galileo to believe that Copernicus' model of planetary motion was correct?

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.... [2]

[Total: 6]

For Examiner's Use

2 **(a)** State Kepler's laws of planetary motion.

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.... [3]

(b) Astronomers are searching for planets which orbit distant stars. The planets are not visible from the Earth. Their existence is revealed by the star's motion which causes a shift in the wavelength of the light it emits.
A large planet **P** is shown orbiting a star **S** in Fig. 2.1. Both the star and the planet rotate about their common centre of mass **C**.

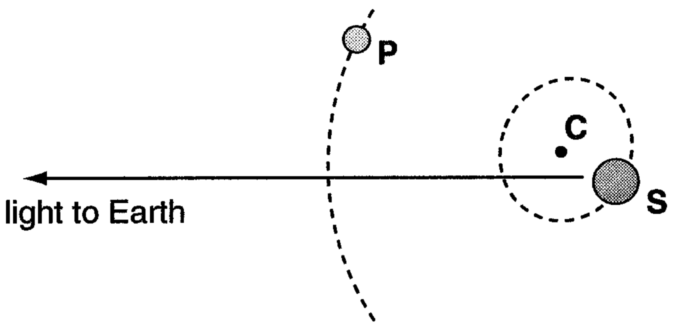


Fig. 2.1

When measured from a stationary source in the laboratory, a spectral line has a wavelength λ of 656.3 nm.
The light from star **S** is examined over a period of 74 hours. The change in wavelength $\Delta\lambda$ for the same spectral line is recorded. The velocity has been calculated and the data shown in Fig. 2.2.

time / h	$\Delta\lambda / 10^{-15}$ m	velocity / m s^{-1}
1	6.7	3.1
6	38.1	17.5
12	66.0	30.3
19	76.0	34.9
23	69.1	31.7
29	43.8	20.1
35	6.8	3.1
41	–32.2	–14.8
48	–66.0	–30.3
55	–76.0	–34.9
61	–62.5	–28.7
67	–32.2	–14.8
74		6.1

Fig. 2.2

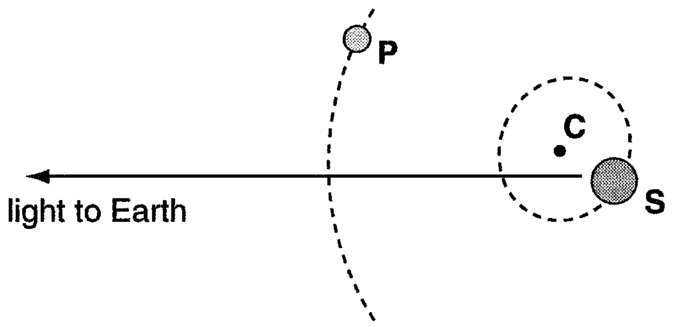
(i) Use the Doppler equation relating $\Delta\lambda$ with velocity v to calculate the change in wavelength for the final velocity of 6.1 m s^{-1}.

change in wavelength = ...m [3]

(ii) Plot a graph of the star's velocity against time using the grid in Fig. 2.3. The first seven points are already completed. The data required from Fig. 2.2 are repeated beneath the grid in Fig. 2.3. [2]

(iii) Draw a curve through all the points on the graph. [1]

(iv) On the diagram below, copy of Fig. 2.1, mark a point on the star's orbit that would correspond to a velocity of zero on the graph. Label this point **X**. [1]



Copy of Fig. 2.1

(v) Use your graph to estimate the time T for the planet to make one complete revolution around the star.

time ....h [1]

(vi) The mass M of the star is estimated to be 4×10^{30} kg. Calculate the radius of the planet's orbit using the relationship below.

$$r = \sqrt[3]{\frac{GMT^2}{4\pi^2}}$$

radius = ...m [2]

[Total: 13]

For Examiner's Use

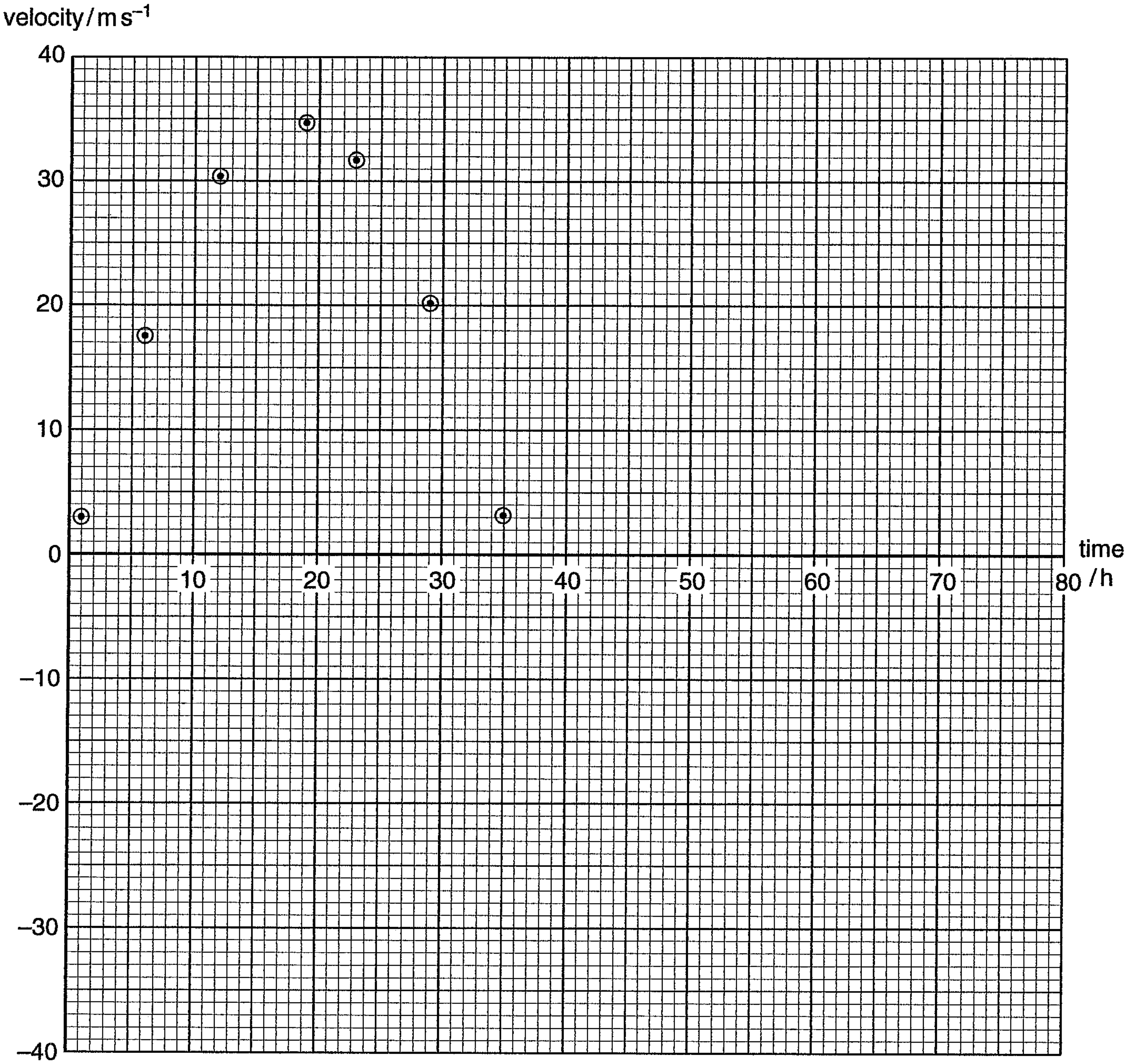


Fig. 2.3

time/h	velocity/ms^{-1}
41	–14.8
48	–30.3
55	–34.9
61	–28.7
67	–14.8
74	6.1

data from Fig. 2.2

[Turn over

For Examiner's Use

3 **(a)** Large distances in the Universe may be measured in parsecs. Explain what is meant by a *parsec*.

....

....

....[2]

(b) The apparent magnitude and absolute magnitude of three stars named Ceti, Diphda and Menka, are shown in Fig. 3.1

star	apparent magnitude	absolute magnitude
Ceti	3.50	5.71
Diphda	2.04	0.44
Menka	2.53	−0.47

Fig. 3.1

(i) Explain which of the stars appears brightest in the sky.

....

.... [2]

(ii) Explain what can be deduced about the relative sizes of Diphda and Menka, if the surface temperature of each is about the same.

....

.... [1]

(iii) Calculate the distance of Menka from the Earth.

distance = ...pc [3]

[Total: 8]

For Examiner's Use

4 **(a)** Explain how a main sequence star can develop into a supernova. Discuss what may remain after the explosion.

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.... [6]

(b) It is estimated that the Sun radiates energy at the rate of 3.8×10^{26} W and that a supernova explosion may produce 10^{44} J of energy.

(i) Calculate the rate at which mass is converted into energy within the Sun.

mass rate = ... $kg\,s^{-1}$ [2]

(ii) Calculate the time, in years, that it would take the Sun to produce the same amount of energy as that released in a supernova explosion. Assume 1 year to be 3.2×10^{7} s.

time = ... y [2]

[Total: 10]

[Turn over

For Examiner's Use

5 **(a)** What is the *Cosmological Principle*?

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....

.... [2]

(b) Describe the important properties of the cosmic microwave background radiation and how the standard model of the Universe explains these properties. Explain their significance as evidence for the past evolution of the Universe.

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.... [5]

(c) Why is our understanding of the very earliest moments of the Universe unreliable?

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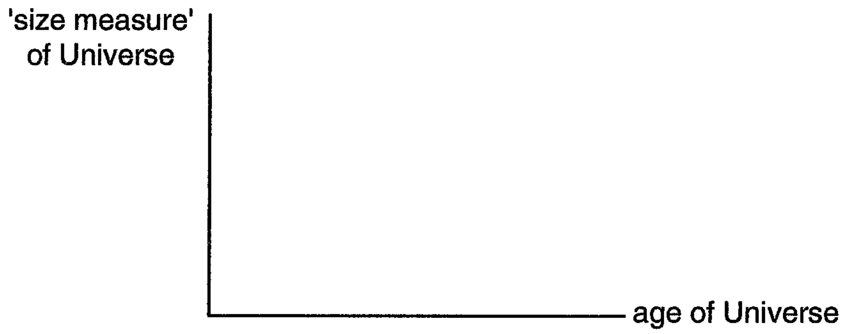
.... [2]

[Total: 9]

For Examiner's Use

6 (a) The future of the Universe may be *open, closed* or *flat.* Explain the meaning of the terms in italics, using a graph to illustrate your answer.



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.... [4]

(b) The mean density of the Universe, ρ_0, is thought to be approximately 1×10^{-26} kg m^{-3}. Calculate a value for the Hubble constant H_0.

H_0 = ...s^{-1} [2]

[Total: 6]

For Examiner's Use

7 **(a)** Describe a **thought** experiment which demonstrates time dilation within the special theory of relativity.

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.... [5]

(b) A circular particle accelerator is used to supply sub-atomic particles at a speed of $0.94c$. The particles are unstable and in the accelerator decay with a half-life of 1.0×10^{-5} s. The radius of this accelerator is 900 m.

(i) Show that the time taken for the particles to complete one revolution is 2.0×10^{-5} s.

[1]

(ii) What fraction of particles would remain undecayed after 2.0×10^{-5} s?

fraction remaining = ... [1]

(iii) What time has passed **in the laboratory** from the perspective of the particles during this time of 2.0×10^{-5} s?

time = ...s [3]

(iv) When the particles are stationary, their half-life is **not** 1.0×10^{-5} s. Without further calculation explain why this is so.

....

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.... [2]

[Total: 12]

8 **(a)** What is the *principle of equivalence*?

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.... [2]

(b) A spacecraft travels from Earth to the Moon carrying a very precise clock which is compared with an identical clock that was left behind.

Explain how the readings of the two clocks compare

(i) just after take-off

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....[2]

(ii) when the craft is on the Moon's surface.

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.... [2]

[Total: 6]

9 The London Eye, Fig. 9.1, 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.

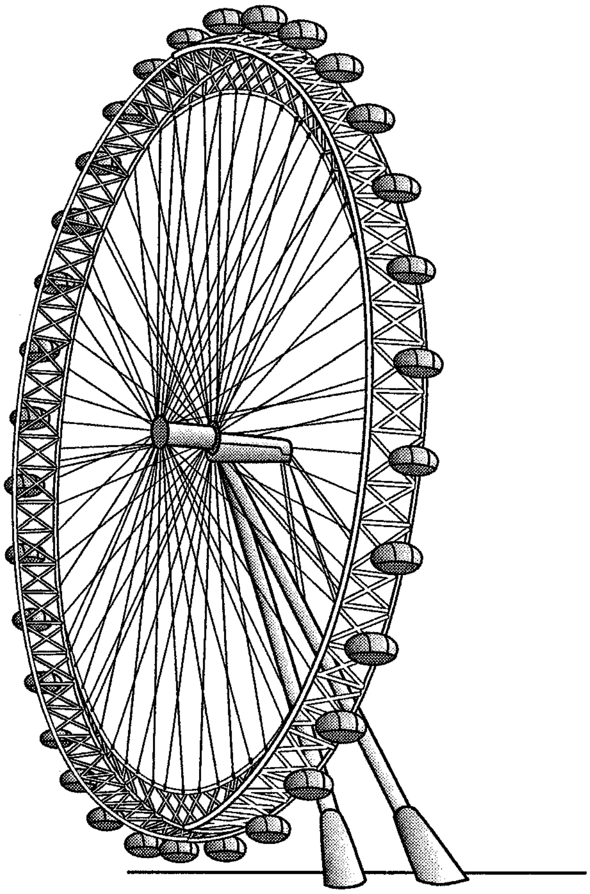

Fig. 9.1

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]

(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 to 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. 9.2(i) shows the front wheel and fork of a stationary bicycle wheel which is in contact with the ground. Fig. 9.2(ii) shows the front wheel and fork of the same bicycle when lifted off the ground.

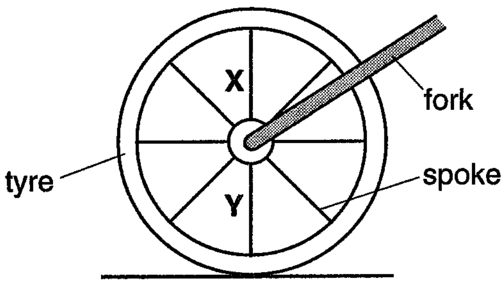

Fig. 9.2(i)

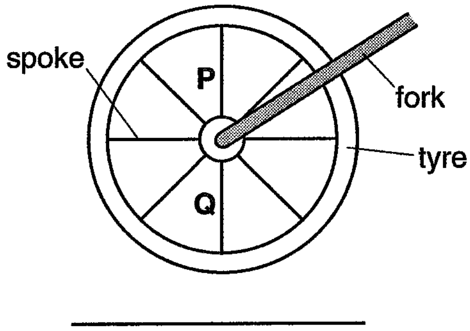

Fig. 9.2(ii)

Assume all the 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]

(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

Copyright Acknowledgements:

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