OXFORD CAMBRIDGE AND RSA EXAMINATIONS
Advanced GCE

PHYSICS B (Advancing Physics) **2863/01**
Rise and Fall of the Clockwork Universe

Tuesday **23 JANUARY 2001** Afternoon 1 hour 10 minutes

Candidates answer on the question paper.
Additional materials:
Data, Formulae and Relationships Booklet
Electronic calculator

TIME 1 hour 10 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 on the question paper.
- Read each question carefully and make sure you know what you have to do before starting your answer.
- Show clearly the working in all calculations, and round answers to only a justifiable number of significant figures.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets [ ] at the end of each question or part question.
- The values of standard physical constants are given in the Data, Formulae and Relationships Booklet. Any additional data required are given in the appropriate question.
- You are advised to spend about 20 minutes on Section A and 50 minutes on Section B. You will be awarded marks for the quality of written communication in Section B.

Section A

1 A 4000 μF capacitor has a potential difference of 20 V across it.

(a) Calculate the charge on the capacitor.

charge = ……………… C

(b) Calculate the energy stored on the capacitor.

energy = …………………… J [4]

2 A sealed vessel contains 0.42 mol of nitrogen (N_2) molecules.

The molar mass of nitrogen is 0.028 kg mol^{-1}

(a) Calculate the mass of nitrogen in the vessel.

mass = ……………………….. kg

The gas is kept at a temperature of 300 K in a sealed vessel of volume 4.2×10^{-3} m^3.
It behaves like an ideal gas in these conditions.

(b) Show that the pressure in this gas is 2.5×10^5 Pa.

[3]

3 A mass of 0.80 kg of water is heated using a 1500 W heater.

The specific thermal capacity of water is 4200 J kg^{-1} K^{-1}.

Calculate the initial rate of temperature change of the water.

rate of temperature change = ………………………… Ks^{-1} [2]

4 A tuning fork oscillates with simple harmonic motion described by the equation: $x = 0.00150 \cos(2770t)$ with time t in seconds.

(a) Calculate the frequency of the fork.

frequency = ……………………… Hz

(b) When the fork is held above the neck of a half-full milk bottle the sound gets louder. This increase in loudness is not heard when a fork of different frequency is brought to the neck of the same bottle. Explain these observations.

[4]

5 A fireworks rocket rises vertically upwards. It has an initial mass of 80 grams.

(a) Calculate the initial weight of the rocket.

weight = ………………….. N

The rocket ejects 9.0 grams of fuel each second at a velocity of 240 m s^{-1}.

(b) Show that the initial thrust on the rocket is 2.2 N.

(c) Calculate the initial acceleration of the rocket.

acceleration =………………………….. ms^{-2}
[5]

6 Fig. 6.1 shows the variation in gravitational field strength around Ceres, the largest known asteroid.

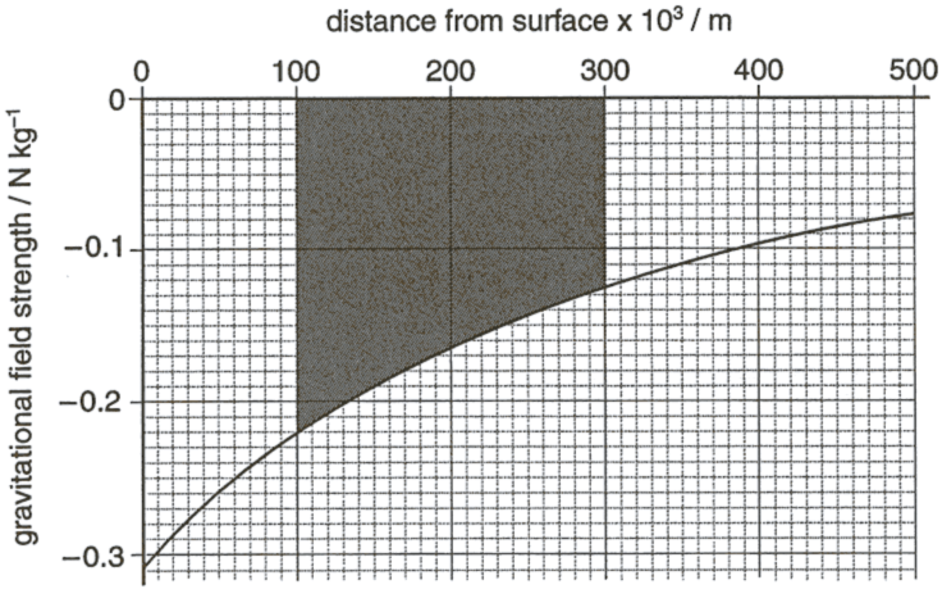

Fig.6.1

Explain what the shaded area on Fig. 6.1 represents.

[2]

Section B

Four marks in this section are awarded for quality of communication.

7 This question is about a telecommunications satellite.

(a) The satellite is placed at a height of 36000 km above the surface of the Earth at the equator. At this height the time to make a complete orbit is exactly one day (= 8.64×10^4 s).

(i) The radius of the Earth is 6400 km. State the separation between the centre of the Earth and the satellite.

separation = ………………………. km

(ii) Show that the satellite is travelling at approximately 3100ms^{-1}.

[4]

(b) (i) Calculate the centripetal force on the satellite.

Mass of satellite = 700 kg.

centripetal force = ………………………. N

(ii) The centripetal force is provided by the Earth's gravitational pull on the satellite. Use this fact to derive an expression for the mass of the Earth, M_E in terms of:
G, the gravitational force constant
r, the radius of orbit of the satellite
v, the speed of the satellite in its orbit.

M_E = ………………………………

[5]

(c) Explain why satellites used to transmit television signals directly into the home are put into this special orbit.

[3]

8 This question is about the oscillation of a trolley between two springs as shown in Fig. 8.1.

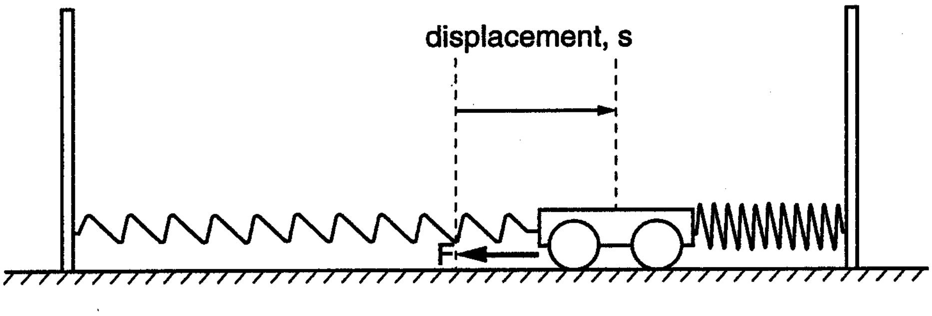

Fig. 8.1

Figure 8.2 shows the relationship between force on the trolley and displacement of the trolley from its equilibrium position.

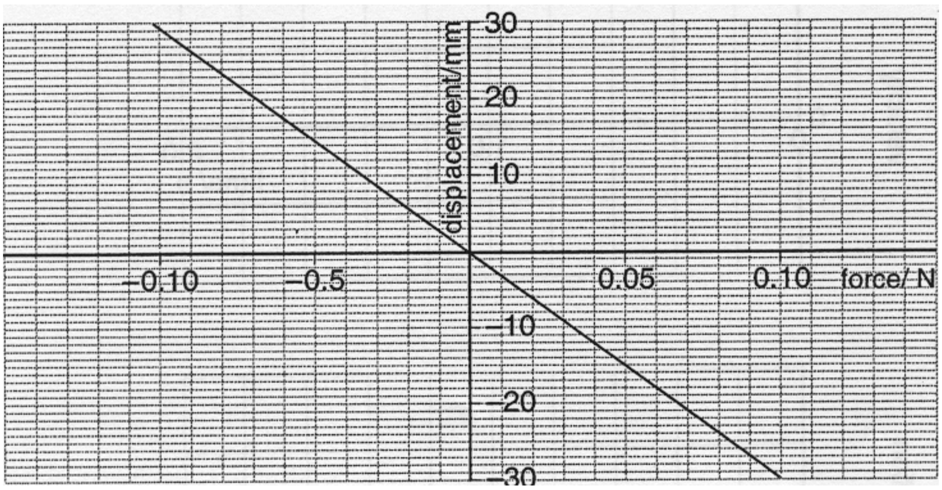

Fig. 8.2

(a) Use Fig. 8.2 to explain why the trolley will oscillate with simple harmonic motion.

[3]

(b) Fig. 8.3 shows a displacement-time graph of the trolley over two oscillations. On the axes below draw curves to show how (i) the velocity of the trolley and (ii) the acceleration of the trolley vary over two oscillations.

(i)

(ii)

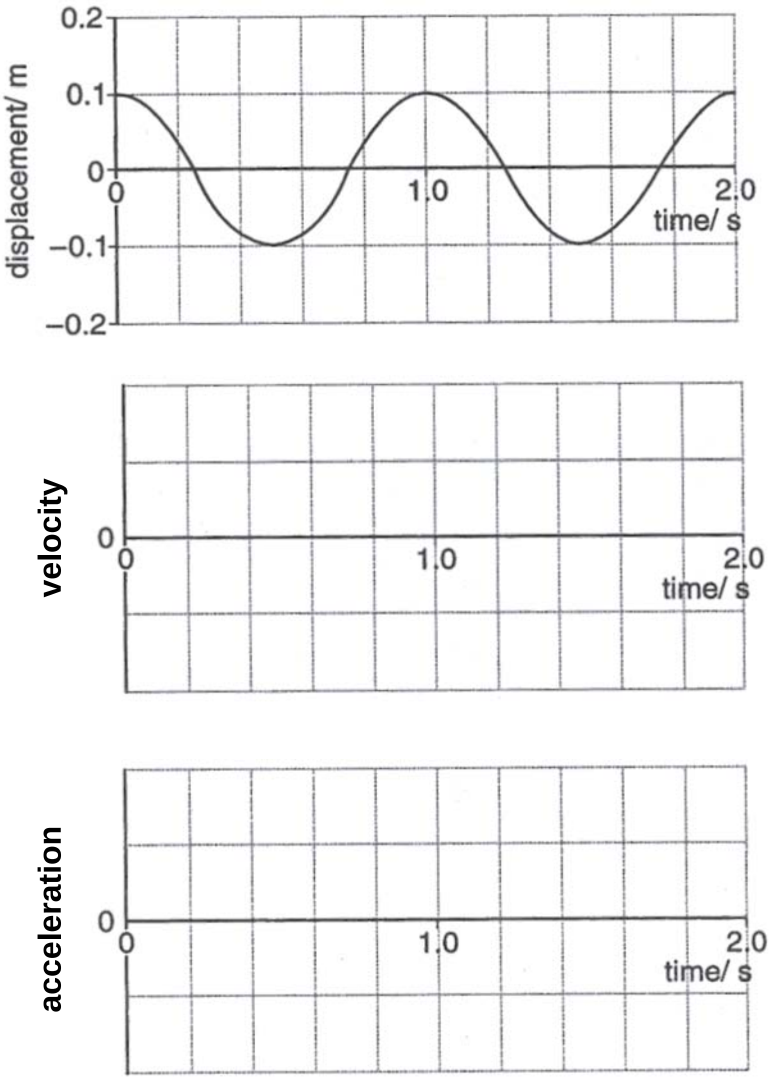

Fig. 8.3

[4]

(c) It has been suggested that the oscillations of masses tethered to springs could be used to measure mass in 'weightless' or low-gravity situations. Explain how this measurement could be made and suggest one limitation such a system might have. Use equations in your explanation where appropriate.

[4]

9 This question is about the behaviour of gases at different temperatures.

(a) Describe how the kinetic theory of gases explains the pressure an ideal gas exerts on the walls of its container.

[3]

(b) At room temperature, 288 K, an ideal gas in a cylinder is at a pressure of 5.00×10^5 Pa.

Show that the average energy of a molecule of the gas under these circumstances is about 4×10^{-21} J.

[2]

(c) A small proportion of the molecules making up a particular gas are 'dissociated' or split into two or more pieces. The energy E needed to dissociate a molecule is much greater than the average energy of a molecule at room temperature. The fraction of molecules which have energy larger than E is given by the Boltzmann factor, $e^{-E/kT}$.

Calculate the proportion of molecules which are dissociated in the gas at 288K when $E = 3.4 \times 10^{-20}$ J.

(d) Fig.9.1 shows how the Boltzmann factor, $e^{-E/kT}$ *varies* with temperature T, in kelvin.

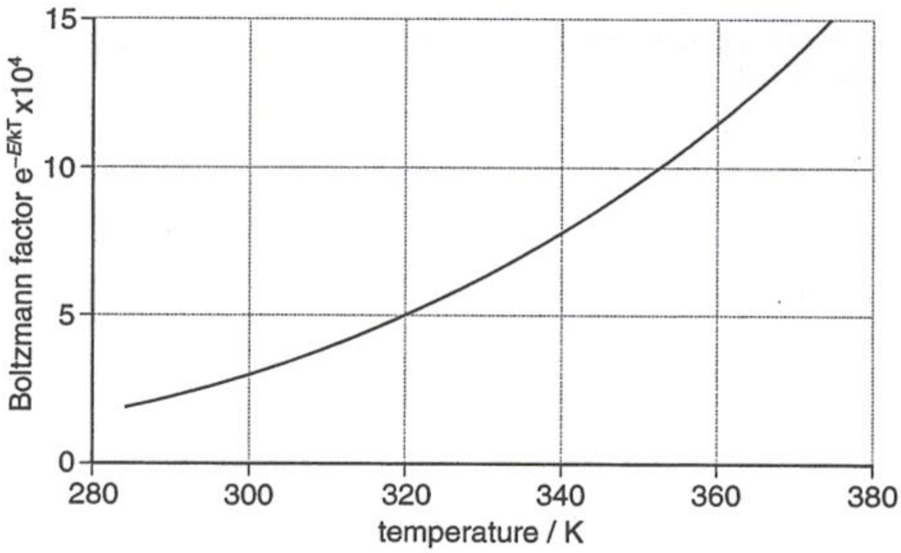

Fig. 9.1

(i) Use the graph to describe how the Boltzmann factor, $e^{-E/kT}$, varies with T over the range shown.

(ii) By approximately what factor does the proportion of dissociated molecules increase when there is a modest increase in temperature of the gas from 300 K to 360 K?

[5]

10 This question is about evidence of a 'hot big bang' origin of the Universe.

(a) Fig. 10.1 shows how the speed of recession of galaxies, *v,* is related to distance, *d,* from the Earth.

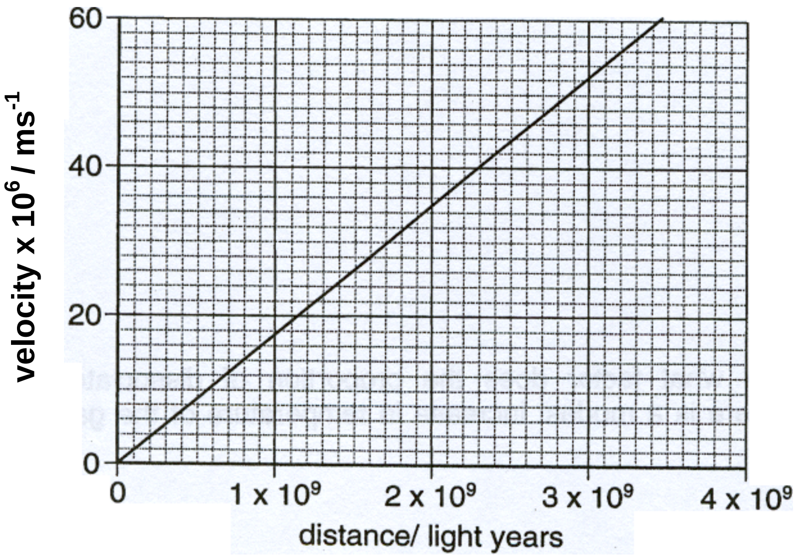

Fig 10.1

Use the graph to determine a value for the Hubble constant, H_0, where v = H_0 *d*

1 *light year* = 9.5×10^{15}m

Ho= ……………………….. units= ………………

[3]

The recession of the galaxies was first observed by the astronomer Edwin Hubble in 1925. Since that time the strongest evidence for a hot big bang has come from observations of cosmological red shift and the cosmological microwave background.

(b) (i) Describe how the cosmological red shift is observed and explain how it supports the big bang model.

(ii) The cosmological microwave background has been described as 'the biggest red-shift known'. It is detectable in all directions. Explain why the microwave background gives evidence of events further back in time than any other red shift observations.

[7]

Quality of Written Communication [4]