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4 The Earth has mass M and radius R, and a uniform density ρ.

(a) Using the definition of gravitational field strength g, show that the magnitude of gravitational field strength g and distance from the centre of the Earth r in terms of G, ρ and R is given by

$$g = \frac{4\pi \rho G R^3}{3r^2}$$

[2]

(b) The magnitude of the gravitational field strength g at a distance r inside the Earth is given by

$$g = \frac{4\pi \rho G r}{3}$$

On Fig. 4.1, sketch a graph showing the variation with distance r from the centre of the Earth of the gravitational field strength g. Values of g are not required.

Take the positive direction of g to be in the positive horizontal axis.

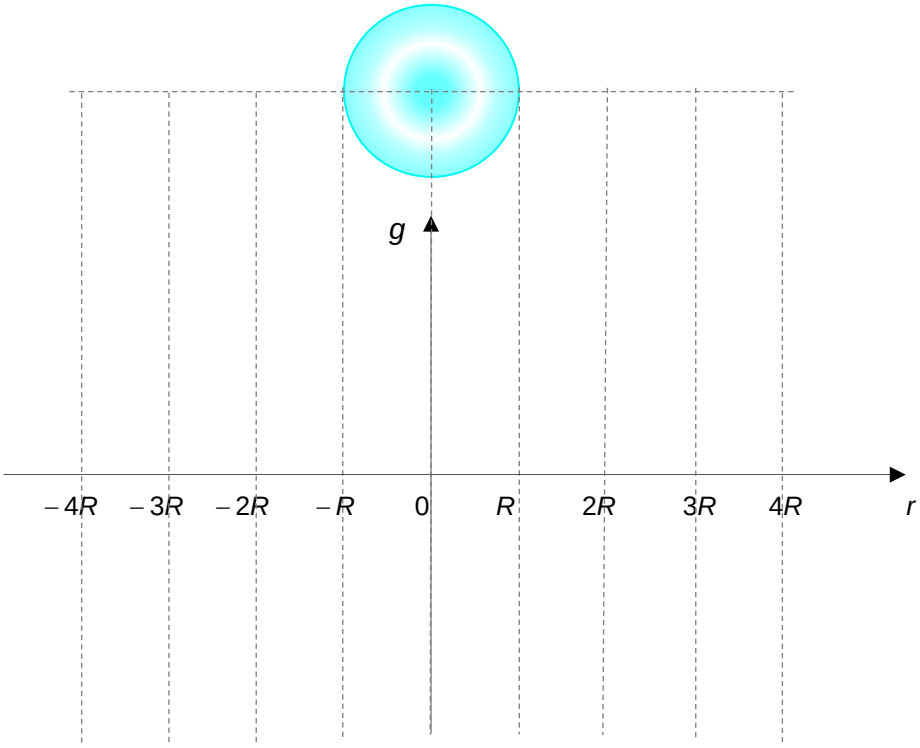

Fig. 4.1

[3]

[Turn over

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(c) Quito, Ecuador is the antipodal city of Singapore as it is situated at the other end of the straight line passing through the centre of the Earth. The two countries have built a very narrow frictionless tunnel through the centre of the Earth between Singapore and Quito as shown in Fig. 4.2.

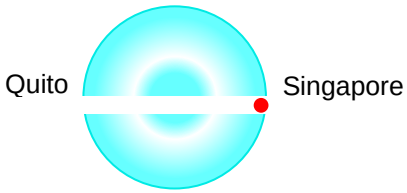

Fig. 4.2

(i) A parcel of medical supplies is released at the Singapore end of the tunnel. The Earth's gravitational field causes the parcel to oscillate with simple harmonic motion about the centre of the Earth with a period of T.

Derive an expression for T, in terms of G and ρ.

[2]

(ii) The density of the Earth ρ is 5.51 g cm^{-3}.

Hence, determine the time taken for a medical supply parcel from Singapore to arrive in Quito.

time taken = …….. s [2]

[Total: 9]