Figure 9.3 The gravitational field around a point (or spherical) mass is radial.
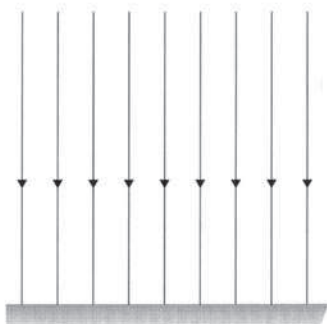

Figure 9.4 The gravitational field above a flat mass is uniform.

Example questions

Q5

Two stars have the same density but star A has double the radius of star B. Determine the ratio of the gravitational field strength at the surface of each star.

Answer

The volume of star A is 8 times that of star B since the radius of A is double. Hence the mass of A is 8 times that of B. Thus

$$\frac{g_A}{g_B} = \frac{GM_A/R_A^2}{GM_B/R_B^2}$$

$$= \frac{M_A}{M_B}\frac{R_B^2}{R_A^2}$$

$$= 8 \times \frac{1}{4}$$

$$= 2$$

Q6

Show that the gravitational field strength at the surface of a planet of density ρ has a magnitude given by $g = \frac{4G\pi\rho R}{3}$.

Answer

We have

$$g = \frac{GM}{R^2}$$

Since

$$M = \rho\frac{4\pi R^3}{3}$$

it follows that

$$g = \frac{G4\pi\rho R^3}{3R^2}$$

$$= \frac{4G\pi\rho R}{3}$$

Questions

1 What is the gravitational force between:
   (a) the earth and the moon;
   (b) the sun and Jupiter;
   (c) a proton and an electron separated by 10^{-10} m?
   (Use the data in Appendices 1 and 3.)

2 A mass m is placed at the centre of a thin, hollow, spherical shell of mass M and radius R (see Figure 9.5a).
   (a) What gravitational force does the mass m experience?
   (b) What gravitational force does m exert on M?
   (c) A second mass m is now placed a distance of $2R$ from the centre of the shell (see Figure 9.5b). What gravitational force does the mass inside the shell experience?
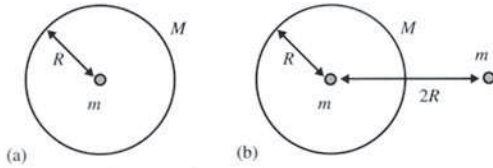   (d) What is the gravitational force experienced by the mass outside the shell?

Figure 9.5 For question 2.

3 Stars A and B have the same mass and the radius of star A is 9 times larger than the radius of star B. Calculate the ratio of the gravitational field strength on star A to that on star B.

4 Planet A has a mass that is twice as large as the mass of planet B and a radius that is twice as large as the radius of planet B. Calculate the ratio of the gravitational field strength on planet A to that on planet B.

5 Stars A and B have the same density and star A is 27 times more massive than star B. Calculate the ratio of the gravitational field strength on star A to that on star B.

6 A star explodes and loses half its mass. Its radius becomes half as large. Find the new gravitational field strength on the surface of the star in terms of the original one.

7 The mass of the moon is about 81 times less than that of the earth. At what fraction of the distance from the earth to the moon is the gravitational field strength zero? (Take into account the earth and the moon only.)

8 Point P is halfway between the centres of two equal spherical masses that are separated by a distance of 2×10^9 m (see Figure 9.6). What is the gravitational field strength at:
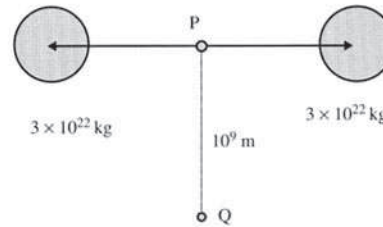(a) point P;
(b) point Q?

Figure 9.6 For question 8.

9 Consider two masses. There is a point somewhere on the line joining the masses where the gravitational field strength is zero, as shown in Figure 9.7. Therefore, if a third mass is placed at that point, the net force on the mass will be zero. If the mass is slightly displaced away from the equilibrium position to the left, will the net force on the mass be directed to the left or the right?
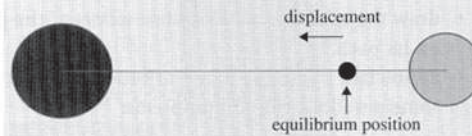

Figure 9.7 For question 9.