Gravitational Fields Supplementary Questions

Study Guide 21

Part 1 - Gravitational Force

1. Calculate the size of the gravitational force of attraction of a sphere of 10 kg acting on a sphere of mass 2.0 kg, when their centres are 200 mm apart.

2. Calculate the gravitational force of attraction between two bodies, each of mass 15 kg, placed 1.2 m apart.

3. Two asteroids of mass 1.00×10^{12} kg and 5.00×10^{12} kg are floating in space. The force of attraction between them is 10.0 N. How far apart are their centres of mass?

4. A woman of mass 65.0 kg stands on the Earth's surface. Calculate, to 3 significant figures, the pull of the Earth on her using:
   i) Newton's Law of Gravitation (with the accompanying data about the Earth);
   ii) the value of g = 9.81 m/s^2.

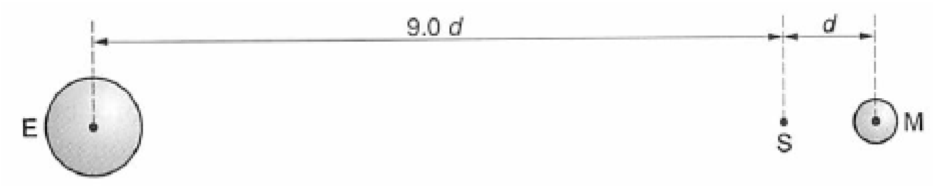
5. Calculate the gravitational force of attraction due to the Earth on:
   i) a satellite of mass 80 kg at a distance of 8.0×10^6 m from the Earth's centre;
   ii) a geosynchronous satellite of mass 100 kg at a distance of 4.2×10^7 m from the Earth's centre;
   iii) the Moon, which has a mass of 7.3×10^{22} kg and whose centre is 3.8×10^8 m from the Earth's.

6. An astronaut stands on the surface of the Moon. He is carrying a life-support pack of mass 55 kg. The mass of the Moon is 7.3×10^{22} kg and its radius is 1.6×10^6 m.
   Determine the force acting on the astronaut due to the life-support pack.

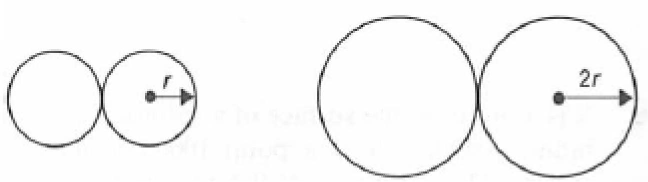
7*. Two small spheres of mass 4.0 kg and M kg are placed 80 cm apart. If the gravitational force is zero at a point 20 cm from the 4 kg mass along the line between the two masses, calculate the value of M.

8*. The mass of the Earth is 6.0×10^{24} kg and that of the Moon is 7.4×10^{22} kg. If the distance between their centres is 3.8×10^8 m, calculate the point on the line joining their centres where there is no net gravitational force.

9*. The diagram below shows a space vehicle S at a point between the Earth and the Moon at which the gravitational force of attraction due to the Earth is equal in magnitude to the gravitational force of attraction due to the Moon. Such a position is called a neutral point. By equating the forces using Newton's Law of Gravitation, express the mass of the Earth m_E as a multiple of the mass of the Moon m_M.



10*. Two identical lead spheres of radius r are in contact and attract each other with a gravitational force F. What would be the gravitational force of attraction between two similar lead spheres of radius r, as a multiple of F?



11*. Two stationary particles of mass M_1 and M_2 are a distance d apart. A third particle experiences no gravitational force if it lies on the line joining M_1 and M_2 at a distance D from M_1. Determine D as a function of d, M_1 and M_2.

Part 2 - Gravitational Field Strength

1. The Apollo 11 space capsule was placed in a parking orbit of radius 6.56 x 10^6 m around the Earth before moving on towards the Moon. Calculate the value of the Earth's gravitational field strength at this radius.

2. The Apollo 11 spacecraft was orbiting the Moon at a speed of 1.65 km/s before the first lunar module landed. The mass of the Moon is 7.34 x 10^{22} kg.
   i) Determine the radius of the spacecraft's orbit around the Moon.
   ii) If the Moon has a mean radius of 1.64 x 10^6 m, how far above the Moon's surface was the spacecraft orbiting?

3. The gravitational field strength on the surface of the Moon is 1.7 N/kg. Assuming that the Moon is a uniform sphere of radius 1.7 x 10^6 m, calculate:
   i) the mass of the Moon;
   ii) the gravitational field strength 1.0 x 10^6 m above its surface.

4. A neutron star has a mass of 2.0 x 10^{30} kg and a diameter of 20 km. Calculate:
   i) the mean density of the star;
   ii) the gravitational field strength at the surface of the star.

5. How far above the Earth's surface in terms of its radius, R, would you have to go for your weight to be:
   i) one quarter of what it is on the surface;
   ii) half of what it is on the surface.

6*. X is a point on the surface of a spherical planet of radius 2000 km. Y is a point 1000 km above he surface. Determine the ratio g_X / g_Y of the accelerations of free fall measured at X and Y.

7*. A spherical planet has radius R and uniform density ρ. Determine an expression for the acceleration due to free fall at the surface of the planet.

8*. The acceleration due to gravity at the Earth's surface is 9.8 m/s^2. Calculate the acceleration due to gravity on the surface of a planet which has:
   i) the same mass and twice the density;
   ii) the same density and twice the radius;
   iii) the same mass and twice the radius.

Part 3 - Orbital Motion

1. A geosynchronous satellite moves in a circle of radius 4.2×10^7 m every 24 hours. Determine:
   i) the strength of the gravitational field at the satellite's orbit;
   ii) the centripetal acceleration of a satellite moving in an orbit of radius 2.1×10^7 m;
   iii) the speed of this inner satellite;
   iv) the orbital period of this inner satellite.

2. An astronaut is moving in a circular orbit 350 km above the Earth's surface. Determine:
   i) the strength of Earth's gravitational field at this height;
   ii) the speed of the astronaut in this orbit;
   iii) how long it takes the astronaut to circle the Earth.

3. Galileo is often credited with the early discovery of four of Jupiter's many moons. The moons orbiting Jupiter follow the same laws of motion as the planets orbiting the sun. One of the moons is called Io; its distance from Jupiter's centre is 4.2 units and it orbits Jupiter in 1.8 Earth-days. Another moon is called Ganymede; it is 10.7 units from Jupiter's centre. Determine the orbital time period for Ganymede.

4. Suppose a small planet is discovered that is 14 times as far from the sun as the Earth's distance is from the Sun. Use Kepler's third law to predict the orbital period of such a planet.

5. The asteroid belt between Mars and Jupiter has a mean radius from the Sun of 2.6 astronomical units. How long does it take for an asteroid in the belt to orbit the Sun?

6. A spy satellite is located one Earth radius above the surface of the Earth. How long does it take the satellite to orbit the Earth once?

7. Mars has two moons, Phobos and Deimos (Fear and Panic, the companions of Mars, the Roman God of War). Deimos has a period of 30 hours 18 minutes and a mean distance from the centre of Mars of 2.3×10^4 km. If the period of Phobos is 7 hours 39 minutes, what mean distance is it from the centre of Mars?

8*. Using the details from the previous question as well as the fact that at an altitude of 100 km above the Martian surface the gravitational field strength is 3.32 N/kg, what would be the time period of a Martian satellite which orbited Mars at a mean altitude of 100 km.

9*. The period of the Moon's rotation is the same as its orbital period, 27.3 days. At what height above the Moon's surface should a satellite be placed if it is to be in a lunastationary orbit?

Answers - Gravitational Fields Supplementary Questions

Part 1

1. 3.34×10^{-8} N
2. 1.04×10^{-8} N
3. 5.77×10^{6} m
4. i) 635 N ii) 638 N
5. i) 500 N ii) 22.7 N iii) 2.02×10^{20} N
6. 105 N

7*. 9 kg

8*. 3.38×10^{8} m (from the Earth)

9*. $M_E = 81\ M_M$

10*. 16 F

11*. $D = \dfrac{d}{1+\sqrt{\dfrac{M_2}{M_1}}}$

Part 2

1. $9.30\ \text{m/s}^2$
2. i) 1.80×10^{6} m ii) 1.60×10^{5} m
3. i) 7.37×10^{22} kg ii) 0.674 N/kg
4. i) $4.77 \times 10^{17}\ \text{kg/m}^3$ ii) 1.33×10^{12} N/kg
5. i) R above surface ii) $\left(\sqrt{2}-1\right)$R above surface

6*. 9/4

7*. $\dfrac{4}{3}\pi G\rho R$

8*. i) $15.6\ \text{m/s}^2$ ii) $19.6\ \text{m/s}^2$ iii) $2.45\ \text{m/s}^2$

Part 3

1. i) $0.227\ \text{m/s}^2$ ii) $0.907\ \text{m/s}^2$ iii) 4370 m/s iv) 30200 s
2. i) $8.78\ \text{m/s}^2$ ii) 7700 m/s iii) 5510 s
3. 7.32 days
4. 52.4 years
5. 4.19 years
6. 14,400 seconds
7. 9.19×10^{6} m

8*. 6440 s

9*. 8.66×10^{7} m