Chapter: 05

Gravitation

Exercise MCQs

1. **Earth's gravitational force of attraction vanishes at:**
   (A) 6400km (B) infinity (C) 42300km (D) 1000km

2. **Value of g increases with the:**
   (A) increases in the mass of the body (B) increase in altitude
   (C) decrease in altitude (D) none of the above

3. **The value of g at a height one Earth's radius above the surface of the Earth is:**
   (A) 2g (B) $\frac{1}{2}g$ (C) $\frac{1}{3}g$ (D) $\frac{1}{4}g$

4. **The value of g on moon's surface is $1.6ms^{-2}$. What will be the weight of a 100 kg body on the surface of the moon?**
   (A) 100N (B) 160N (C) 1000N (D) 1600N

5. **The altitude of geostationary orbits in which communication satellites are launched above the surface of the Earth is:**
   (A) 850km (B) 1000km (C) 6400km (D) 42,300km

6. **The orbital speed of a or orbit satellite is:**
   (A) Zero (B) $8ms^{-1}$ (C) $800ms^{-1}$ (D) $8000ms^{-1}$

Answer Key:

1	B	4	B
2	C	5	D
3	D	6	D

Short Questions

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1. **What is meant by the force of gravitation?**

Ans: Force of gravitation:

"The force due to which everybody of the universe attracts every other body is called force of gravitation".

Formula:

$$F = \frac{G\, m_1\, m_2}{r^2}$$

2. **What is a field force?**

Ans: Field force:

The force which is acting on the body by another body whether the body is in contact with other body or not. It is a non-contact force. The gravitational pull of the Earth acting on the body whether the body is in contact with the Earth or not.

3. **Do you attract the Earth or the Earth attracts you? Which one is attracting with a larger force? You or the Earth.**

Ans: **Yes,** Earth attracts us and in reaction we attract Earth as well. Both of these forces are equal in magnitude.

4. **How can you say that gravitational force is a field force?**

Ans: As gravitational force is a non-contact force. For example, the velocity of a body, thrown up, goes on decreasing while on return its velocity goes on increasing. This is due to the gravitational pull of the Earth's action on the body whether the body is in contact with the Earth or not. So, gravitational force is a field force.

5. **Why earlier scientists could not goes about the gravitational force?**

Ans: The earlier scientists could not guess about the gravitational force because they were not known about the concept of gravity. Concept of gravity was put forth by ISSAC NEWTON in 1665.

6. **Explain, what is meant by gravitational field strength.**

Ans: Gravitational field strength:

In the gravitational field of the earth, the gravitational force per unit mass is called the gravitational field strength of the earth.

Value:

At any place, its value is $10 Nkg^{-1}$

7. Explain the law of gravitation.

Ans: Law of gravitation:

The force of attraction between two objects is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

Formula:

$$F = \frac{G\, m_1\, m_2}{r^2}$$

The law of gravitation depends upon masses of objects and the distance between them.

- The greater the masses of objects, the greater will be force of gravitation.
- The greater the distance between objects, less will be the force of gravitation.

8. Why law of gravitation is important to us?

Ans: It is important to us because it helps us to understand why.

- Binds all terrestrial objects to earth.
- Keeps the atmosphere close to the earth.
- Keeps the moon revolving around the earth.
- The gravitational pull of the sun on the planet keeps them revolving around the sun.

9. How the mass of the earth can be determined?

Ans: The mass of the earth can be calculated with the help of the law of gravitation.

$$M_e = \frac{R^2 g}{G}$$

After calculation,

$$M_e = 6 \times 10^{24}\ \text{kg}$$

10. Why does the value of g vary from place to place?

Ans:

$$g_h = \frac{G\, M_e}{(R + h)^2}$$

The value of g is inversely proportional to the square of the radius of the earth. But it does not remain constant and decreases with altitude, that's why the value of g varies from place to place.

11. Can you determine the mass of our moon? If yes, then what do you need to know?

Ans: **Yes,** we can calculate the mass of our moon by using a formula.

$$M_m = \frac{R^2\,gm}{G}$$

Need to know:

- Value of radius of moon.
- Gravitational acceleration on the moon.
- Gravitational constant on moon.

12. Explain how the value of g varies with altitude.

Ans: The value of gravitational acceleration is determined by the following formula:

$$g_h = \frac{G\,M_e}{(R+h)^2}$$

So, g is inversely proportional to $(R+h)^2$. It means that with increasing altitude, the value of g decreases.

13. How Newton's law of gravitation help in understanding the motion of satellites?

Ans: A satellite requires centripetal force that keeps it to move around the earth. The gravitational force of attraction between the satellite and the earth provides the necessary centripetal force. This centripetal force is introduced by the Newton. So, in this way Newton's law of gravitation helps in understanding the motion of satellites.

14. What are artificial satellites?

Ans: **Artificial satellites:**

Scientists have sent many objects into space. Some of these objects revolve around the earth. These are called artificial satellites.

Example:

Geostationary satellites

15. Why communication satellites are stationed at geostationary orbits?

Ans: The satellites in the geometry orbits and remain all the time in front of the target part of the earth so that the direction of receiver is dish do not to be changed.

16. On what factors the orbital speed of a satellite depends?

Ans: The orbital speed of the satellite depends only on the height of satellites from the surface of the earth because both the gravitational acceleration of the earth and the radius of the earth are constants. It is clear from the given formula:

$$v_o = \sqrt{g_h (R + h)}$$

Important Formulas

- $g = \frac{G M_e}{R^2}$ or $M_e = \frac{g R^2}{G}$
- $g_h = \frac{G M_e}{(R + h)^2}$
- $F = \frac{G m_1 m_2}{r^2}$
- $v_o = \sqrt{g_h (R + h)}$

Important Values

- Gravitational constant = G = $6.67 \times 10^{-11} Nm^2kg^{-2}$
- Mass of earth = M_e = 6×10^{24}kg
- Radius of earth = R_e = 6.4×10^6m
- Orbital speed = v_o = $29000 kmh^{-1}$ ($8 kms^{-1}$)

Numerical

1. Find the gravitational force of attraction between two spheres each of mass 1000kg. The distance between the centers of the spheres is 0.5m.

Ans: Given data:

m_1 = 1000kg
m_2 = 1000kg
r = 0.5m
G = $6.67 \times 10^{-11} Nm^2kg^{-2}$

To Find:

F = ?

Solution:

$$F = \frac{G m_1 m_2}{r^2}$$

By putting the values, we have

$$F = \frac{6.67 \times 10^{-11} \times 1000 \times 1000}{(0.5)^2}$$

$$F = \frac{6.67 \times 10^{-5}}{0.25}$$

$$F = 26.68 \times 10^{-5}$$

$$F = 2.67 \times 10^{-4} N$$

Result:

Gravitational force of attraction between two spheres = F = 2.67×10^{-4}N

2. The gravitational force between two identical lead spheres kept at 1m apart is 0.006673N. Find their masses.

Ans: Given data:

$F = 0.006673N$

$r = 1m$

$G = 6.67 \times 10^{-11} Nm^2kg^{-2}$

To Find:

Mass of each lead spheres = $m = m_1 = m_2 = ?$

Solution:

From law of gravitation, we have

$$F = \frac{G m_1 m_2}{r^2}$$

As $m = m_1 = m_2$

$$F = \frac{G\ m \times m}{r^2}$$

$$F = \frac{G\ m^2}{r^2}$$

$$m^2 = \frac{F r^2}{G}$$

$$m^2 = \frac{0.006673 \times (1)^2}{6.67 \times 10^{-11}}$$

$$m^2 = 0.001000 \times 10^{11}$$

$$m^2 = 1.00 \times 10^8$$

$$m = 1.00 \times 10^4 kg$$

Result:

Mass of each lead spheres = $m = m_1 = m_2 = 1.00 \times 10^4$kg

3. Find the acceleration due to gravity on the surface of Mars. The mass of Mars is 6.42×10^{23}kg and its radius is 3370km.

Ans: Given data:

$$M = 6.42 \times 10^{23}\,\text{kg}$$
$$R = 3370\text{km} = 3370 \times 10^3\text{m} = 3.37 \times 10^6\text{m}$$
$$G = 6.67 \times 10^{-11}\,\text{Nm}^2\text{kg}^{-2}$$

To Find:

Gravitational acceleration = g = ?

Solution:

As we know that,

$$g = \frac{G\,M}{R^2}$$

By putting the values, we have

$$g = \frac{6.67 \times 10^{-11} \times 6.42 \times 10^{23}}{(3.37 \times 10^6)^2}$$

$$g = \frac{42.8214 \times 10^{12}}{11.3569 \times 10^{12}}$$

$$g = 3.77\ \text{ms}^{-2}$$

Result:

Gravitational acceleration = g = 3.77 ms^{-2}

4. The acceleration due to gravity on the surface of the moon is 1.62ms^{-2}. The radius of the moon is 1740km find the mass of the moon.

Ans: Given data:

$$g_m = 1.62\ \text{ms}^{-2}$$
$$R = 1740\text{km} = 1740 \times 10^3\text{m} = 1.74 \times 10^6\text{m}$$
$$G = 6.67 \times 10^{-11}\,\text{Nm}^2\text{kg}^{-2}$$

To Find:

Mass of the moon = M = ?

Solution:

As we know that,

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

$$M = \frac{R^2 g}{G}$$

By putting the values, we have

$$M = \frac{(1.74 \times 10^6)^2 \times 1.62}{6.67 \times 10^{-11}}$$

$$M = \frac{3.0276 \times 10^{12} \times 1.62}{6.67 \times 10^{-11}}$$

$$M = \frac{4.90 \times 10^{12}}{6.67 \times 10^{-11}}$$

$$M = 0.735 \times 10^{23}$$

$$M = 7.35 \times 10^{22}\ kg$$

Result:

Mass of the moon = M = 7.35×10^{22} kg

5. Calculate the value of g at a height of 3600km above the surface of the earth.

Ans: Given data:

Height above the surface of Earth = h = 3600km

Height above the surface of Earth = $3600 \times 10^3 m = 3.6 \times 10^6 m$

Gravitational constant = G = $6.67 \times 10^{-11} Nm^2kg^{-2}$

Mass of Earth = M = 6×10^{24} kg

To Find:

Gravitational acceleration = g = ?

Solution:

As we know that,

$$g = \frac{GM}{(R+h)^2}$$

By putting the values, we have

$$g = \frac{6.67 \times 10^{-11} \times 6 \times 10^{24}}{(6.4 \times 10^6 + 3.6 \times 10^6)^2}$$

$$g = \frac{40.02 \times 10^{13}}{(10 \times 10^6)^2}$$

$$g = \frac{40.02 \times 10^{13}}{1 \times 10^{14}}$$

$$g = 40.02 \times 10^{-1}$$

$$g = 4.002\ ms^{-2}$$

$$g = 4.0 ms^{-2}$$

Result:

Gravitational acceleration = g = 4.0ms^{-2}

6. Find the value of g due to earth at a geostationary satellite. The radius of the geostationary orbit is 48700km.

Ans: Given data:

Radius of geostationary satellite = R = 48700km

Radius of geostationary satellite = 48700×10^3m

Radius of geostationary satellite = 4.87×10^7m

Gravitational constant = G = $6.67 \times 10^{-11} Nm^2kg^{-2}$

Mass of Earth = M = 6×10^{24} kg

To Find:

Gravitational acceleration = g_h = ?

Solution:

As we know that,

$$g = \frac{G\ Me}{R^2}$$

By putting the values, we have

$$g = \frac{6.67 \times 10^{-11} \times 6 \times 10^{24}}{(4.87 \times 10^7)^2}$$

$$g = \frac{40.02 \times 10^{13}}{23.72 \times 10^{14}}$$

$$g = 1.68 \times 10^{-1}$$

$$g = 0.168\ ms^{-2}$$

$$g = 0.17 ms^{-2}$$

Result:

Gravitational acceleration = g_h = 0.17ms^{-2}

7. The value of g is 4ms^{-2} at a distance of 10000km from the centre of the earth. Find the mass of the earth.

Ans: Given data:

Radius from the center of Earth = R = 1000km

Radius from the center of Earth = 1000×10^3m = 1×10^7m

Gravitational acceleration = g = 4.0ms^{-2}

Gravitational constant = G = 6.67×10^{-11}Nm^{2}kg^{-2}

To Find:

Mass of Earth = M = ?

Solution:

As we know that,

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

$$M = \frac{R^2 g}{G}$$

By putting the values, we have

$$M = \frac{(1 \times 10^7)^2 \times 4}{6.67 \times 10^{-11}}$$

$$M = \frac{4 \times 10^{14}}{6.67 \times 10^{-11}}$$

$$M = 0.599 \times 10^{25}$$

$$M = 5.99 \times 10^{24}$$

$$M = 6 \times 10^{24}\text{ kg}$$

Result:

Mass of the Earth = M = 6×10^{24} kg

8. At what altitude the value of g would become one-fourth than on the surface of the earth?

Ans: Given data:

Gravitational acceleration = g = 10 m^{-2}

Gravitational acceleration at height = $g_h = \frac{g}{4} = \frac{10}{4}$ = 0.25 ms^{-2}

Radius of earth = $R_e = 6.4 \times 10^6$m

Mass of Earth = $M_e = 6 \times 10^{24}$ kg

Gravitational constant = $G = 6.67 \times 10^{-11} Nm^2kg^{-2}$

To Find:

$h = ?$

Solution:

As we know that,

$$g_h = \frac{G M_e}{(R+h)^2}$$

$$(R+h)^2 = \frac{G M_e}{g_h}$$

$$(6.4 \times 10^6 + h)^2 = \frac{6.67 \times 10^{-11} \times 6 \times 10^{24}}{0.25}$$

$$(6.4 \times 10^6 + h)^2 = \frac{40.02 \times 10^{13}}{0.25}$$

By taking square root on both sides, we have

$$6.4 \times 10^6 + h = \sqrt{\frac{40.02 \times 10^{13}}{0.25}}$$

$$h = \sqrt{\frac{40.02 \times 10^{13}}{0.25}} - 6.4 \times 10^6$$

$$h = \sqrt{17.79 \times 10^{13}} - 6.4 \times 10^6$$

$$h = \sqrt{177.9 \times 10^{12}} - 6.4 \times 10^6$$

$$h = 13.3 \times 10^6 - 6.4 \times 10^6$$

$h = 6.9 \times 10^6$ m (Approximately equal to the radius of Earth)

Result:

$h = 6.9 \times 10^6$ m (Approximately equal to the radius of Earth)

9. **A polar satellite is launched at 850km above earth. Find its orbital speed.**

Ans: Given data:

Height of satellite = h = 850 km = 850×10^3m = 0.85×10^6m

Radius of earth = $R_e = 6.4 \times 10^6$m

Mass of Earth = $M_e = 6 \times 10^{24}$ kg

Gravitational constant = $G = 6.67 \times 10^{-11} Nm^2kg^{-2}$

To Find:

Orbital Speed of Satellite = v_o = ?

Solution:

As we know that,

$$v_o = \sqrt{g_h (R + h)} \qquad \therefore g_h = \frac{G M_e}{(R+h)^2}$$

$$v_o = \sqrt{\left(\frac{G M_e}{(R+h)^2}\right)(R + h)}$$

$$v_o = \sqrt{\frac{G M_e}{(R+h)}}$$

$$v_o = \sqrt{\frac{6.67 \times 10^{-11} \times 6 \times 10^{24}}{6.4 \times 10^6 + 0.85 \times 10^6}}$$

$$v_o = \sqrt{\frac{40.02 \times 10^{24-11}}{7.25 \times 10^6}}$$

$$v_o = \sqrt{\frac{40.02 \times 10^{13}}{7.25 \times 10^6}}$$

$$v_o = \sqrt{5.52 \times 10^{13-6}}$$

$$v_o = \sqrt{5.52 \times 10^7}$$

$$v_o = \sqrt{55.2 \times 10^6}$$

$$v_o = 7.4296 \times 10^3$$

$$v_o = 7429.6 \text{ ms}^{-1}$$

Result:

Orbital Speed of Satellite = v_o = 7429.6 ms^{-1}

10. A communication, satellite is launched at 42000km above the earth. Find its orbital speed.

Ans: Given data:

Height of satellite = h = 42000 km

Height of satellite = 42000×10^3m = 4.2×10^7m

Radius of earth = R_e = 6.4×10^6m

Mass of Earth = M_e = 6×10^{24} kg

Gravitational constant = G = $6.67 \times 10^{-11} Nm^2kg^{-2}$

To Find:

Orbital Speed of Satellite = v_o = ?

Solution:

As we know that,

$$v_o = \sqrt{g_h (R + h)} \qquad \therefore g_h = \frac{G M_e}{(R+h)^2}$$

$$v_o = \sqrt{\left(\frac{G M_e}{(R+h)^2}\right)(R + h)}$$

$$v_o = \sqrt{\frac{G M_e}{(R+h)}}$$

$$v_o = \sqrt{\frac{6.67 \times 10^{-11} \times 6 \times 10^{24}}{6.4 \times 10^6 + 4.2 \times 10^7}}$$

$$v_o = \sqrt{\frac{40.02 \times 10^{24-11}}{4.84 \times 10^7}}$$

$$v_o = \sqrt{\frac{40.02 \times 10^{13}}{4.84 \times 10^7}}$$

$$v_o = \sqrt{8.26 \times 10^{13-7}}$$

$$v_o = \sqrt{8.26 \times 10^6}$$

$$v_o = 2.87 \times 10^3$$

$$v_o = 2870\ ms^{-1}$$

Result:

Orbital Speed of Satellite = v_o = 2870 ms^{-1}