# UNIT 5

# GRAVITATION

ClassNotes

**Q1. Who gave the idea of gravity?**

**Ans:** The first man who came up with the idea of gravity was Isaac Newton. It was an evening of 1665 when he was trying to solve the mystery why planets revolve around the Sun. Suddenly an apple fell from the tree under which he was sitting. The idea of gravity flashed in his mind. He discovered not only the cause of falling apple but also the cause that makes the planets to revolve around the Sun and the moon around the Earth. This unit deals with the concepts related to gravitation.

**Q2. What is meant by the force of gravitation?**

**Ans: The force of gravitation:**

There exists a force due to which everybody of the universe attracts every other body. This force is called the force of gravitation.

**Q3. Explain Newton's law of gravitation?**

**Ans:** See Q # 5.9 from Exercise.

**Q4. Explain that the gravitational forces are consistent with Newton's third law of motion?**

**Ans: Law of gravitation and Newton's third law of motion:**

It is to be noted that mass $m_1$ attracts $m_2$ towards it with a force F while mass $m_2$ attracts $m_1$ towards it with a force of the same magnitude F but in the opposite direction. If the force acting on $m_1$ is considered as action then the force acting on $m_2$ will be the reaction. The action and reaction due to force of

gravitation are equal in magnitude but opposite in direction. This is in consistence with Newton's third law of motion which states, to every action there is always an equal but opposite reaction.

**Q5. Explain gravitational field as an example of field of force?**

**Ans: Gravitational field:**




The field in a region space in which a particle would experience a gravitational force is called gravitational field.

It is assumed that a gravitational field exists all around the Earth due to the gravitational force of attraction of the Earth.

The weight of a body is due to the gravitational force with which the Earth attracts a body. 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 acting on the body whether the body is in contact with the Earth or not. Such a force is called the **field force**. It is assumed that a **gravitational field** exists all around the Earth. This field I directed towards the center of the Earth.

**Q6. 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 gravitational field strength of the Earth. It is 10 N $kg^{-1}$ near the surface of the Earth.

The gravitational field becomes weaker and weaker as we go farther and farther away from the Earth. At any place its value is equal to the value of g at that point.

**Q7. How the mass of the Earth can be determined?**

**Ans:** See Q # 5.10 from Exercise.

**Q8. Why does the value of g vary from place to place? Explain how the value of g varies with altitude.**

**Ans:** See Q # 5.13 from Exercise.

**Q9. Explain the variation of 'g' with altitude.**

**OR**

**What is the effect of the following on the gravitational acceleration?**

**a. Mass of a freely falling body.**

**b. Distance of freely falling body from the center of the Earth.**

**c. Is there any difference between the values of g at the equator and at the poles? Explain.**

**Ans: (a)** Since $g = G M_e / R^2$ ..... (i)

Equation (i) shows that the value of g does not depend upon mass of the body. This means that light and heavy bodies should fall toward the center of the Earth with the same acceleration.

**(b)** The value of g varies inversely as the square of the distance i.e. $g \alpha 1 / R^2$ if the distance from the center of the earth is increased then the

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Equation (i) shows that the value of g does not depend upon mass of the body. This means that light and heavy bodies should fall toward the center of the Earth with the same acceleration.

**(b)** The value of g varies inversely as the square of the distance i.e. $g \alpha 1 / R^2$ if the distance from the center of the earth is increased then the

value of g will decrease. That is why the value of g at hills (Murree) is less than its value of the sea shore (Karachi).

**(c)** Earth is not a perfect sphere. It is flattened at the poles for this reason the value of g at the pole is more than at the equator. Because polar radius is less than equatorial radius. ($g \alpha 1 / R^2$)

## MINI EXERCISE

**1. Does an apple attract the Earth towards it?**

**Ans:** Yes, according to the law of gravitation an apple attracts Earth towards it but its attraction is very small and cannot be felt.

**2. With what force an apple weighing 1N attracts the Earth?**

**Ans:** The force of attraction is equal to the weight of the object. So, an apple weighing 1N attracts the Earth with 1N force.

**3. Does the weight of an apple increase, decrease or remain when taken to the top of a mountain?**

**Ans:** The value of g varies inversely as the square of the distance i.e. $g \alpha 1/ R^2$

Therefore, the weight of an apple decreases when taken to the top of a mountain due to less gravity of Earth.

## DO YOU KNOW?

Value of g on the surface of a celestial object depends on its mass and its radius. The radius of g on some of the objects is given below:

| Object | g($ms^{-2}$) |
|---|---|
| Sun | 274.2 |
| Mercury | 3.7 |
| Venus | 8.87 |
| Moon | 1.62 |
| Mars | 3.73 |
| Jupiter | 25.94 |

**Q10. What are artificial satellites?**

**Ans:** See Q # 5.14 from Exercise.

**Q11. What are geostationary satellites also write their uses.**

**Ans:** Geostationary satellites whose velocity relative to Earth is zero. These satellites remain stationary with respect to the Earth at a height of about 42300 km from the surface of Earth. These are used for global TV transmissions and for other telecommunication purposes.

As Earth also completes its one rotation about its axis in 24 hours, hence, these communication satellites appear to be stationary with respect to Earth. It is due to this reason that the orbit of such a satellite is called geostationary orbit.

Dish antennas sending and receiving the signals from them have fixed direction depending upon their location on the Earth.

**Uses of geostationary satellites:**

Such satellites are useful for the following purposes.

**(i)** Worldwide communication **(ii)** Weather observations

**(iii)** Navigation **(iv)** Other military uses

**Note:** Three geostationary satellites can cover the whole earth.

## DO YOU KNOW?

**Geostationary satellite:**

The height of a geostationary satellite is about 42,300 km from the surface of the Earth. Its velocity with respect to Earth is zero.

## DO YOU KNOW?

**Global Positioning System (GPS):**

Global Positioning System (GPS) is a satellite navigation system. It helps us to find the exact position of an object anywhere on the land, on the sea or in the air. GPS consists of 24 Earth satellites. These satellites revolve around the Earth twice a day with a speed of 3.87 $kms^{-1}$.

**Q12. How Newton's law of gravitation helps in understanding the motion of satellites? On what factors the orbital speed of a satellite depends?**

**OR**

**Derive the formula for the orbital speed of an artificial satellite?**

**Ans:** See Q # 5.15 from Exercise.

## DO YOU KNOW?

Moon is nearly 3, 80, 000 km away from the Earth. It completes its one revolution around the Earth in 27.3 days.

## SUMMARY

1. Newton's law of universal gravitation: Newton's law of universal gravitation states that everybody in the universe attracts every other body with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centers.
2. The Earth attracts a body with a force equal to its weight.
3. Gravitational force of attraction of the Earth: It is assumed that a gravitational field exists all around the Earth due to the gravitational force of attraction of Earth.
4. Gravitational field strength of the Earth: In the gravitational field of the Earth, the gravitational force per unit mass is called the gravitational field strength of the Earth. It is 10 N $kg^{-1}$ near the surface of the Earth.
5. Acceleration $\boldsymbol{g} = \mathbf{G}\frac{\mathbf{Me}}{\mathbf{R2}}$
6. Mass of Earth $\boldsymbol{Me} = \frac{\mathbf{R2\,g}}{\mathbf{G}}$
7. $g$ at an altitude h = $G\frac{\boldsymbol{M}}{\boldsymbol{(R+h)2}}$
8. **Satellite**: An object that revolves around the planet is called a satellite.
9. The moon revolves around the Earth so moon is a natural satellite of the Earth.
10. **Artificial Satellites**: Scientist have sent many objects into space. Some pf these objects revolve around the Earth. These are called artificial satellites.
11. Orbital velocity $v_o = \sqrt{g_h}(R+h)$