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GRAVITATION

All objects in the universe attract each other. This force of attraction between objects is called the **gravitational force**. Gravitation is a weak force unless large masses are involved.

Centripetal Force

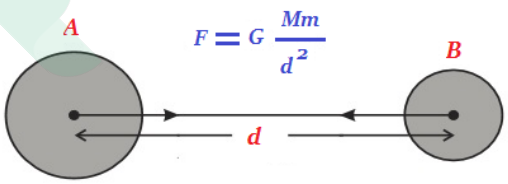
- The force that causes acceleration and keeps the body moving along the circular path is acting towards the Centre. This force is called the centripetal (Centre seeking) force.
- The motion of the moon around the earth is due to the centripetal force. If there were no such force the moon would pursue a uniform straight line motion.

Centrifugal Force

- The force that is felt by an object moving in a curved path that acts outwardly away from the center of rotation.
- Centrifugal force acts in a direction which is opposite to the direction of the centripetal force.
- Some of the applications of centrifugal force:
    - Banking of roads.
    - Washing machine dryer.
    - Cream separator.

Universal Law of Gravitation

- Every object in the universe attracts every other object with a force which is proportional to the product of their masses and inversely proportional to the square of the distance between them.



Gravitational force between two uniform objects

- **F** = force of attraction between two the objects 'A' & 'B'
- **M** = mass of 'A'
- **m** = mass of 'B'
- **d^2** = the square of the distance between 'A' & 'B'
- **G** = is the constant of proportionality and is known as the universal gravitation constant.
- The SI unit of G is **N m^2 kg^{-2}**. It is obtained by substituting the units of force, distance and mass (as given in the following equation –

$$G = \frac{Fd^2}{M \times m}$$

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- Henry Cavendish had calculated the value of **'G'** as **6.673×10^{-11} N m^2 kg^{-2}**.
- Henry Cavendish had used a sensitive balance to find the value of 'G.'
- The force exerted by the earth on the moon is 2.02 *10^20 N
- Newton's law of gravitation is called universal law of gravitation because it is applicable to all the bodies having mass whether the bodies are big or small or whether the bodies are terrestrial or celestial.

Importance of the Universal Law of Gravitation

- The force that binds us to the earth.
- The motion of the moon around the earth.
- The motion of planets around the Sun.
- The tides due to the moon and the Sun.

Acceleration Due to Gravity

- Whenever an object falls towards the earth acceleration is involved. This acceleration is due to the earth's gravitational force. Therefore, this acceleration is called the acceleration due to the gravitational force of the earth or acceleration due to gravity.

  $g = GM/R^2$

  G = 6.7 × 10–11 N m^2 kg^{-2},

  Mass of the earth M = 6×10^{24} kg

  Radius of the earth R = 6.4×10^6 m.

  From the equation we get g value

$$g = \frac{6.7 \times 10^{-11}\ Nm^2\ kg^{-2} \times 6 \times 10^{24}\ kg}{(6.4 \times 10^6\ m)^2}$$

- Value of acceleration due to gravity of the earth, g = 9.8 m/s^{-2}
- The earth is not a perfect sphere. The radius of the earth increases from the poles to the equator because value of g becomes greater at the poles than at the equator.
- Value of g decreases with the increase of height.
- Value of g decreases with depth and become zero at the center of the earth.
- Acceleration experienced by an object is independent of its mass. It means that all objects hollow or solid, big or small, should fall at the same rate.

Mass of the Earth

- Mass of the Earth M = g R^2 /G
- Substituting the known values of g, R and G, you can calculate the mass of the Earth as

  M = 5.97×10^{24} kg

Mass

- The Mass is a measure of the amount of matter in an object and it is a scalar quantity and its SI unit is kilograms.
- It remains the same whether the object is on the earth the moon or even in outer space.

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- The mass of an object is constant and does not change from place to place.

Weight

- The earth attracts every object with a certain force and this force depends on the mass (*m*) of the object and the acceleration due to the gravity (*g*).
- The weight of an object is the force with which it is attracted towards the earth

  W = m x g
- The SI unit of weight is the same as that of force that is newton (N) and weight is a vector quantity.
- Weight depends on its location because *g* depends on location.
- Acceleration due to gravity of the moon is less than the acceleration due to gravity of the earth because Weight of the object on the moon1/6th of its weight on the earth.
- The weight of an object is directly proportional to its mass ($W \propto m$).

Apparent Weight

- The weight that you feel to possess during up and down motion is not same as your actual weight. Apparent weight is the weight of the body acquired due to the action of gravity and other external forces acting on the body.
- Different possibilities of the apparent weight of the person that arise, depending on the motion of the lift:
  - Lift is moving upward with acceleration → Apparent weight is greater than the actual weight.
  - Lift is moving downward with acceleration → Apparent weight is lesser than the actual weight.
  - Lift is at rest → Apparent weight is equal to the actual weight.
  - Lift is falling down freely → Apparent weight is equal to zero.

Thrust and Pressure

- The force acting on an object perpendicular to the surface is called thrust.
- In SI units, the unit of thrust is newton (denoted as N).
- The force per unit area acting on an object concerned is called pressure. We can say thrust on a unit area is pressure.

  Pressure = Thrust /Area
- The unit of pressure is newton per square metre or newton metre^{-2} (denoted as Nm^{-2})
- 1 newton per square metre is called as 1 pascal.

Pressure in Fluids

- All liquids and gases are fluids.
- A solid exerts pressure on a surface due to its weight. Similarly, fluids have weight, and they also exert pressure on the base and walls of the container in which they are enclosed. Pressure exerted in any confined mass of fluid is transmitted undiminished in all directions.

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Buoyancy

- Buoyancy is the force exerted on an object that is wholly or partly immersed in a fluid.
- All objects experience a force of buoyancy when they are immersed in a fluid.
- The magnitude of this buoyant force depends on the density of the fluid.
- Salt water provides more buoyant force than fresh water, because, buoyant force depends as much on the density of fluids as on the volume displaced.

Archimedes' Principle

- **Archimedes principle states that 'a body immersed in a fluid experiences a vertical upward buoyant force equal to the weight of the fluid it displaces'.**
- Archimedes principle has many applications:
    - It is used in designing ships and submarines.
    - Lactometers which are used to determine the purity of a sample of milk.
    - Hydrometers used for determining density of liquids.

Relative Density

- The density of a substance is defined as mass of a unit volume. The unit of density is kilogram per metre cube.
- The density of a given sample of a substance can help us to determine its purity.
- Objects having density less than that of the liquid in which they are immersed float on the surface of the liquid.
- Density of the object is more than the density of the liquid in which it is immersed then it sinks in the liquid.
- The relative density of a substance is the ratio of its density to that of water

  Relative density = Density of a substance/Density of water

  Since the relative density is a ratio of similar quantities, it has no unit.

Pascal's Law

- Pascal's law states that an increase in pressure at any point inside a liquid at rest is transmitted equally and without any change, in all directions to every other point in the liquid.
- The applications of Pascal's law are:
    - In automobile service stations, the vehicles are lifted upward using the hydraulic lift which works as per Pascal's law.
    - Automobile brake system works according to Pascal's law.
    - The hydraulic press is used to compress the bundles of cotton or cloth so as to occupy less space.

Surface Tension

- Surface tension is the property of a liquid. The molecules of a liquid experience a force, which contracts the extent of their surface area as much as possible, so as to have the minimum value. The amount of force acting per unit length, on the surface of a liquid is defined as surface tension.

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- Its unit is Nm–1.
- Surface tension is the reason for many events we see in our daily life.
- In plants, water molecules rise up due to surface tension. Xylem tissues are very narrow vessels present in plants. Water molecules are absorbed by the roots and these vessels help the water to rise upward due to 'capillarity action', which is caused by the surface tension of water.
- During heavy storm, ships are damaged due surface tension of water. By pouring oil or soap powder into the sea, sailors reduce its impact.
- Water strider insect slides on the water surface easily due to the surface tension of water
- A falling drop of rain water acquires the spherical shape due to Surface Tension

Viscosity

- The frictional force acting between the successive layers of the liquid which acts in order to oppose the relative motion of the layer is known as viscous force. Such a property of a liquid is called viscosity.

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