HOLY FAITH PRESENTATION SCHOOL

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Term-II ***(Cass 8th – Physics)***

GRAVITATION AND FLOTATION

GRAVITATION

INTRODUCTION: Historical background

Observation of stars, planets and their motion has been the subject of attention since earlier times. The earliest recorded model for planetary motion proposed by ***Ptolemy*** about 2000 years ago was '***geocentric' mode*** in which all celestial objects, stars, the sun and the planets, all revolved around the earth in circular orbits.

However more elegant model '***heliocentric'*** model was already mentioned by ***Aryabhatta***, according to which sun was at the centre around which planets revolved.

A thousand years later, ***Nicolas Copernicus*** proposed a definitive model in which planets moved around sun in circular orbits. Galileo supported his theory.

It was around the same time, a nobleman from Denmark ***Tycho Brahe*** spent his entire life time recording observations of planets with naked eye. He compiled data and this data was analysed later by ***Johannes Kepler*** and he extracted three laws form. This data, called ***Kepler's laws of planetary motion***. These laws were known to ***Newton*** and he came up with a ***universal law of Gravitation.***

Universal law of Gravitation

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

The direction of the force is along the line joining the two masses.

If m_1 and m_2 are the masses of two bodies separated by a distance d and F is the force of attraction between them, then

$$F \quad \alpha \quad m_1 m_2 / d^2$$

$$F = G m_1 m_2 / d^2$$

Where G is a constant of proportionality and known as the constant of universal gravitation and equal to 6.67×10^{-11} Nm^2 / kg^2

If $m_1 = m_2 = 1kg$ and $d = 1m$, then $G = F$

I.e. Universal gravitational constant is the force of attraction (in Newton) between two bodies of mass 1(kg) each lying 1(m) distance apart.

Characteristics of Gravitational force :-

1. Gravitational force between two bodies or object does not need any contact between them. It means, gravitational force is action at a distance.

2. Gravitational force between two bodies varies inversely proportional to the square of the distance between them. Hence, gravitational force is an inverse square force.

3. The gravitational forces between two bodies or objects form an action-reaction pair. If object A attract object B with a force F_1 and the object

B attracts object A with a force F_2, then

$$F_1 = F_2$$

Do you know?

1. The value of $G = 6.67 \times 10^{-11}$ $N\, m^2 kg$

2. The value of G is same throughout the universe and hence G is known as universal gravitational constant.

3. Value of G was determined in laboratory by Sir Henry Cavendish.

4. Since the value of G is very small, so the gravitational force is a very weak force.

5. Gravity: The gravitational force between a body and the earth is called gravity.

IMPORTANCE OF THE UNIVERSAL LAW OF GRAVITATION

The Universal law of gravitation given by Newton has explained successfully several phenomena. For example:

1. The gravitational force of attraction of the Earth is responsible for binding all terrestrial objects on the Earth.

2. The gravitational force of the Earth is responsible for holding the atmosphere around the Earth.

3. The gravitational force of the Earth is also responsible for the rain fall and snowfall on the Earth.

4. The flow of water in rivers is also due to gravitational force of the Earth on water.

5. The moon revolves around the Earth on account of gravitational 'pull of the Earth on the Moon.

Even all artificial satellites revolve around the Earth on account of gravitational pull of the Earth on the satellites.

6. Tides in oceans are formed due to the gravitational force between the moon and the water in oceans.

KEPLER'S LAWS OF PLANETARY MOTION

Johannes Kepler was a 16th century astronomer who established three laws which govern the motion of planets (around the sun). These are known as Kepler's laws of planetary motion. The same laws also describe the motion of satellites (like the moon) around the planets (like the earth). The Kepler's laws of planetary motion are given below.

1. Kepler's first law : The planets move in elliptical orbits around the sun,with the sun at one of the two foci of the elliptical orbit. This law is called ***law of orbits.***

2. Kepler's second law: Each planet revolves around the sun in such a way that the line joining the planet to the sun sweeps over equal areas in equal intervals of time. This is called ***law of areas.***

3. Kepler's third law: The cube of the mean distance of a planet from the sun is directly proportional to the square of time it takes to move around the sun. This is also called ***law of periods.*** The law can be express edas:

$$T^2 \alpha \quad R^3$$

Or, $$T^2 / R^3 = \text{constant}$$

Newton's third law of motion and gravitation

The Newton's third law of motion also holds good for the force of gravitation. This means that when earth exerts a force of attraction on an object, then the object also exerts an equal force on the earth, in the opposite direction.

According to Newton's second law,

Force = Mass × Acceleration

$F = ma$

or $a = F/m$

The mass of earth is very large and acceleration produced in the earth very small and cannot be detected with even the most accurate instrument available to us.

Free fall;

Any object dropped from some height always falls towards the earth. If a feather and a stone are dropped from the top of a tower, it is observed that feather falls onto the ground much later than the stone. So, it was thought that object of different masses dropped from same height take different times to reach the ground.

However, Galileo dropped three iron balls of different masses simultaneously from the top of the tower of Pisa and found that all the three balls reached the earth's surface at the same time.

Galileo explained that the feather suffered much air resistance during fall because of its large surface area. Due to this opposing force, feather takes longer time to reach the ground than the stone. He further explained that if air resistance is eliminated, both feather and the stone will reach the ground simultaneously.

Conclusion :- Galileo concluded that the bodies of different masses dropped simultaneously from the same height hit the ground at the same time, if air resistance is neglected.

Definition of freefall:

The falling body on which only force of gravitation of the earth acts is known as freely falling body and such fall of a body is known as free fall. A freely falling body has acceleration equal to acceleration due to gravity.

Acceleration due to gravity :-

The acceleration with which a body falls towards the earth due to earth's gravitational pull is known as acceleration due to gravity. It is denoted by 'g'.

Thus, all bodies irrespective of their masses fall down with constant acceleration.

Determination of value of g

When a body of mass m is dropped from a certain distance R from the centre of earth of mass M, then the force exerted by the earth on the body is

$F = GMm/R^2$.....................(i)

Let this force produces an acceleration a in mass m.

$F = ma$ or $F=mg$ ......(ii)

From (i) and (ii),

$$g = GM / R^2$$

For bodies falling near the surface of earth, this acceleration is called acceleration due to gravity and is represented by g with value 9.8

Do you know ?

1. The acceleration due to gravity of a planet depends on its mass and its radius. Its value is high if mass is large and radius is small.

2. The value of g at the surface of earth is 9.8 m/s^2 on an average.

3. The value of g decreases with height.

4. The value of g decreases with depth.

5. The value of g is more at poles and less at equator.

6. The value of g is zero at the centre of the earth.

7. The value of acceleration due to gravity is minimum at planet mercury and maximum at planet Jupiter.

8. Acceleration due to gravity is independent of mass shape size etc of falling body i.e. there will be equal acceleration in a light and heavy falling body.

MASS

The amount of matter contained in a body is called its mass

Or the measure of the quantity of matter in a body is called its mass.

The mass of a body is a scalar quantity. It is independent of surroundings and the position of the body. It is a constant quantity for a given body.

Mass is measured in kilograms (kg) in SI system.

Characteristics of mass of a body:-

1. Mass of a body is proportional to the quantity of matter contained in it.

2. Mass of a body does not depend on the shape, size and the state of the body.

3. Mass of a body remains the same at all place. This means, the mass of a body will be same throughout the universe. This is because the quantity of matter contained in the body does not change throughout the universe.

4. Mass of a body does not change in the presence of other bodies near it.

5. Mass of a body is a scalar quantity.

6. Mass of a body can be measured with the help of a beam balance.

Weight

The force with which a body is attracted by the earth is known as the weight of the body. When the earth attracts a body with a gravitational force, the body accelerates towards the earth with acceleration due to gravity (g).

Thus, the force with which body of mass m is attracted by the earth is given by

$F = ma = m \times g = mg$

This force is known as the weight of the body. Weight of a body is denoted by W.

Weight, $W = mg$

Weight has both magnitude and direction. Hence weight is a vector quantity.

Unit of Weight:-

SI unit of weight is same as that of the force i.e., newton (N).

Variation in the weight of a body

Weight of the body is given by

W = mg

So the weight of a body depends upon (i) the mass of the body and (ii) value of acceleration due to gravity.

The mass of a body remains the same throughout the universe, but the value of 'g' is different places. Hence the weight of a body is different at different place.

1. The value of 'g' is more at poles and less at the equator. Therefore, weight of a body is more at the poles and less at the equator. In other words, a body weighs more at the poles and less at the equator.

2. The value of 'g' on the surfaces of different planets of the solar system is different; therefore, the weight of a body is different on the different planets.

3. The value of 'g' decreases with height from the surface of the earth. Therefore, the weight of a body also decreases with height from the surface of the earth. That is why; the weight of a man is less on the peak of Mount Everest than the weight of the man at Delhi.

4. The value of 'g' decreases with depth from the surface of the earth. Therefore, the weight of a body decreases with depth from the surface of the earth.

5. The value of 'g' at the centre of the earth is zero, hence weight (= mg) of the body is zero at the centre of the earth.

FLOTATION

Thrust and pressure

Thrust: Force acting normally on a surface is called the thrust.

Thrust is a vector quantity and is measured in the unit of force, i.e., newton (N).

Pressure: The thrust acting on unit area of the surface is called the pressure.

Pressure is directly proportional to the force.

Pressure in inversely proportional to the area.

For the examples :

Ex. A sharp knife cuts easily than a blunt knife by applying the same force.

Ex. A sharp needle pressed against our skin pierces it. But a blunt object with a wider contact area does not affect the skin when pressed against it with the same force.

Some interesting aspects of pressure

1. The foundation of a building or a dam has a large surface area so that the pressure exerted by it on the ground is less. This is done to prevent the sinking of the building or the dam into the ground.

2. The tyres of a bus or a truck have larger width than those of a car. Further, the number of tyres of heavy vehicles is more than four. This is done to enable the tyres to carry more weight and to prevent sinking into ground.

3. A sleeping mattress is so designed that when you lie on it, a large area of your body comes in its contact. This reduces the pressure on the body and sleeping becomes comfortable.

4. Railway track are laid on large sized wooden or iron sleepers.

We know, Pressure =F/A

The weight (i.e., thrust) of the train is spread over a large area of the sleepers. Therefore, the pressure acting on the ground under the sleepers is reduced. This prevents the sinking of the ground under the weight of the train.

5. A sharp knife is more effective in cutting the objects than a blunt knife.

The pressure exerted =F/A

The area under the sharp knife is less than the area under the blunt knife. Hence, the pressure exerted by the sharp knife is more than the pressure exerted by the blunt knife on an object. Therefore, the sharp knife penetrates easily into the object than the blunt knife when same force is applied in both the cases. Hence, a sharp knife cuts the objects easily than a blunt knife.

6. A camel walks easily on the sandy surface than a man inspite of the fact that a camel is much heavier than aman.

This is because the area of camel's feet is large as compared to the area of man's feet. So the pressure exerted by camel on the sandy surface is very small as compared to the pressure exerted by man. Due to large pressure, sand under the feet of a man yields (i.e. sink) and hence he cannot walk easily on the sandy surface.

<u>Units of Pressure</u>. The SI unit of pressure is called pascal (Pa) in honour of Blaise Pascal.

I Pa = 1 N/m

One Pascal is defined as the pressure exerted on a surface area of 1 m by a thrust of 1 N (acting normally on it).

DENSITY

Density of a substance is defined as its mass per unit volume.

Density (d) = M/V

Unit of density: - Since mass (M) is measured in kilogram (kg) and the volume (V) is measured in metre (m), the unit of density is kg/m^3. In cgs system, the unit of density is $g/\ cm^3$.

These units are related as: $1\ g/\ cm^3 = 1000\ kg/m^3$.

RELATIVE DENSITY

Relative density (R.D.) of a substance is the ratio of the density of the substance to the density of water at 4°C.

Thus, Relative density = density of substance / density of water

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

PRESSURE IN FLUIDS

A substance which can flow is called a fluid. All liquids and gases are thus fluids. We know that a solid exerts pressure on a surface due to its weight. Similarly, a fluid exerts pressure on the container in which it is contained due to its weight. However, unlike a solid, a fluid exerts pressure in all directions.

A fluid contained in a vessel exerts pressure at all points of the vessel and in all directions.

All the streams of water reach almost the same distance in the air.

PASCAL'S LAW

In an enclosed fluid, if pressure is changed in any part of the fluid, then this change of pressure is transmitted undiminished to all the other parts of the fluid.

BUOYANCY

When a body is partially or wholly immersed in a liquid, an upward force acts on it which is called up thrust or buoyant force. The property of the liquids responsible for this force is called buoyancy.

Buoyancy is a familiar phenomenon: a body immersed in water seems to weigh less than when it is in air. When the body is less dense than the fluid, then it floats.

It is a common experience that when a piece of cork is placed in water it floats with two-fifth of its volume inside water. If the cork piece is pushed into water and released it comes to the surface as if it has been pushed by someone from inside due to the buoyant force exerted by fluid.

Factor on which buoyancy depends :-

Up thrust depends upon the following two factors:

(a) The volume of the body submerged in the fluid. :- It is found that greater the volume of a body greater is the up thrust it experience when inside a fluid.

(b) The density of fluid in which the body is immersed: - It is also found that greater the density of the fluid greater is the up thrust it applies on the body.

Note:

(1) When $W < U$, the body floats : In this case the body will rise above the surface on the liquid to the extent that the weight of the liquid displaced by its immersed part equals the weight of the body. Then the body will float with only a part of it immersed in the liquid. In this case $Vrg < Vsg$ or $r < s$. Thus if a cork, which has a density less than that of water will rise in water till a portion of it is above water. Similarly a ship floats in water since its density is less than the density of water.

(2) When $W > U$, the body sinks :- If r and s present the densities of the body and the fluid respectively and V the volume of the body (which is also the volume of the fluid displaced) then $Vrg > Vsg$ or $r > s$ i.e., the body sinks in the fluid in case its density is greater than the density of the fluid. An iron nail has greater density than water, therefore it sinks in water.

(3) When $W = U$: - The resultant force acting on the body when fully immersed in the fluid is zero. The body is at rest anywhere within the fluid. The apparent weight of the body is zero for all such positions.

Thus, we find that a body will float when its weight is equal to the weight U of the fluid displaced i.e. the up thrust.

ARCHIMEDES PRINCIPLE

Archimedes principle states that :-

"Anybody completely or partially submerged in a fluid is buoyant up by a force equal to the weight of the fluid displaced by the liquid".

In other words: - "When a body is partially or completely immersed in a fluid, the fluid exerts an upward force on the body equal to the weight of the fluid displaced by the body.

Experimental verification of Archimedes principle :-

Consider a container C filled with water upto the level from where pipe P extends out. The other end of pipe P opens to a small container C placed on a weighing balance which measure 00.00 [after the placement of the container C. A block B hangs on a spring balance S which shows a reading of 7 kg.

(a) If we partially immerse the block in water we observe some water flows out from C to C through P. The weighing machine shows a reading 1 kg and the loss of reading in spring balance is 7 _ 6 = 1kg. This means that weight of water displaced by the block is equal to loss in weight of block.

(b) Now we completely immerse the block in water, we observe that the weight of water displaced by the block is 5 kg and the reading in spring balance is 2 kg. The loss of weight of block is 7 _ 2 = 5 kg. Again we reach the same conclusion that weight of water displaced by the block is equal to the loss in weight of block.

(c) What happens when the block is further immersed? No more water will be displaced by the block and therefore reading shown by weighing machine and spring balance remains unchanged.

Why the spring balance shows a loss in weight of the block when Fig. A block of 7 kg hanging on a the block is immersed in water? This is because of buoyant force on spring balance acting vertically upwards. The loss in weight is equal to the buoyant force.

Note: A body placed in a gaseous medium is also acted by the up thrust equal to the weight of the gas displaced.

The above facts has been summarised in Archimedes principle which states that the upward force acting on a solid body which is partially or completely immersed in a fluid, is equal to the weight of the fluid displaced.

This upward force is called buoyant force or up thrust.

<u>Applications of Archimedes Principle</u>

1. in designing ships and submarines.

2. Lactometer is based on the Archimedes principle. It is used to determine the purity of a sample of milk.

3. Hydrometer is also based on the Archimedes principle. It is used to determine the density of liquids.

(a) Ships:

Although it is made of iron and steel which are materials denser than water a ship floats in water. This is due to the fact that a floating ship displaces a weight of water equal to its own weight including that of the cargo. The volume of the ship is much larger than the volume of the material with which it is made. Since the empty space in the ship contains air therefore its average density is less than the density of water. Thus a ship floats with a small section under water.

A ship has to move in waters of different seas which have different densities. As a result it sinks more in water with less density than in water with more density. Therefore ships are marked with white lines on its sides called load lines of plimsoll marks. The load lines (called the Plimsoll mark) on the side of a ship of a ship show how low in the water it can lie and still be safely and legally loaded under different conditions.

(b) Submarines :

A submarine, figure sinks by taking water into its buoyancy tanks. Once submerged, the up thrust is unchanged but the weight of the submarine increases with the inflow of water and it sinks faster. To surface, compressed air is used to blow the water out of the tanks.

Each submarine is provided with ballast tanks. If the submarine has to submerge these tanks are filled with water. This makes the average density of the submarine greater than that of water as a result it sinks. When the submarine has to be surfaced, compressed air is blown into these tanks to expel the water.
Again the average density of the submarine becomes less than that of water, hence it floats.

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