9th Class

Running Notes

GRAVITATION

INTRODUCTION

According to Newton's first law of motion, the planets and satellites can move in circular orbits only if some force is acting on them. The mystery of the motion of all these heavenly bodies (i.e. planets and satellites) in nearly circular orbits was resolved by Issac Newton when he observed that an apple fell from a tree towards the earth. Thereafter, he proposed that all particles or objects in the universe attract each other in the same manner as the earth attracted the apple.

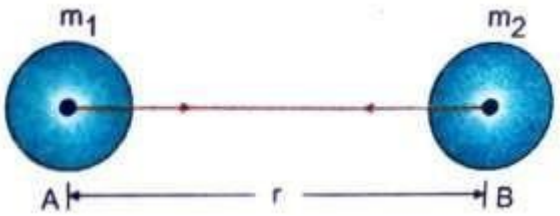
The force of attraction between any two particles in the universe is called ***gravitation or gravitational force.***

UNIVERSAL LAW OF GRAVITATION OR NEWTON'S LAW OF GRAVITATION

According to this law, the force of attraction between two particles or bodies is directly proportional to the product of their masses and inversely proportional to the square of the distance between these particles or bodies.

Relation between gravitational force between two bodies and the distance between them.

Consider two bodies A and B having masses m_1 and m_2 respectively.Let the distance between these bodies be r.



According to the law of gravitation, the force of attraction (F) or force of gravitation between these bodies is directly proportional to (1) product of masses of bodies

and (i) inversely proportional to square of distance between bodies.

$$\rightarrow F \propto m_1 \times m_2$$

$$\rightarrow F \propto \frac{1}{r^2}$$

$$\rightarrow F \propto \frac{m_1 \times m_2}{r^2}$$

$$F = \frac{Gm_1m_2}{r^2}$$

Where G is constant and is known as universal gravitational constant.Value of G = 6.667×10^{-11} Nm^2/kg^2.

IMPORTANCE OF UNIVERSAL LAW OF GRAVITATION

The gravitational force plays an important role in nature.

All the planets revolve around the sun due to the gravitational force between the sun and the planets. The force required by a planet to move around the sun in elliptical path (known as centripetal force) is provided by the gravitational force of attraction between the planet and the sun. Thus, gravitational force is responsible for the existence of the solar system.

(i) Tides in oceans are formed due to the gravitational force between the moon and the water in oceans. Let us see how ocean tides take place. The moon exerts large gravitational force on the earth. The distance between the moon and the water in ocean is less than the distance between the moon and the earth. So, the moon pulls oceanwater with large force than the moon pulls the earth .Therefore, the water in ocean is raised towards the side of the moon. As a result of this, high ocean tide is caused.

(ii) Gravitational force between a planet and its satellite (i.e., moon) decides whether a planet has a moon or not. Since the gravitational force of the planets like mercury and venus is very small, therefore, these planets do not have any satellite or moon.

(iii) Artificial and natural satellites revolve around the earth due to the gravitational force between the earth and the satellite. The gravitational force between the earth and the satellite provides a necessary centripetal force to the satellite to move in a circular path around the earth.

(iv) The atmosphere (envelope of gases) of the earth is possible due to gravitational force of the earth.

(v) Rainfall and snowfall is possible only due to gravitational force of the earth.

(vi) We stay on the earth due to the gravitational force between the earth and us.

FREE FALL

Any object dropped from some height always falls coward, the earth. If a feather and a stone are dropped from the top of, the, it is observed that feather falls onto the ground much later than the stone. So, it was thought that objects of different mass 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.

EXPERIMENTAL VERIFICATION

This fact was verified experimentally by Robert Boyle just after the death of Galileo. Robert Boyle used his newly invented vacuum pump to evacuate the air from a long jar containing a

lead bullet and a feather. Then he inverted the jar and found that both the bullet and the feather reached the bottom of the jar at the same time.

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

If the air resistance is neglected or not taken into account, then the only force acting on the falling body is the force of gravitation of the earth. This force of gravitation of the earth is constant and hence produces a constant acceleration in the body. Since this acceleration is produced by the gravitational force of the earth and hence known as *acceleration due to gravitational force of earth or acceleration due to gravity.*

Definition of 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.

Definition of Free Fall

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 constant acceleration equal to acceleration due to gravity (g).

EXPRESSION FOR THE ACCELERATION DUE TO GRAVITY

Consider a body of mass m near the surface of the earth. The force acting on the body is the gravitational force of the earth. The magnitude of the gravitational force acting on the body due to the earth is given by

$$F = \frac{GMm}{R^2} \text{ ..... (1)}$$

where, M = mass of the earth and R = radius of the earth

[Here, height of the body from the surface of the earth is neglected as compared to the radius of the earth because R = 6400 km is very large.]

This gravitational force (F) produces acceleration equal to 'g' in the body of mass m. So according to Newton's second law of motion,

$$F = mg \text{ .....(2)}$$

Equating eqns. (1) and (2), we have

$$mg = \frac{GMm}{R^2}$$

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

which is the expression for the acceleration due to gravity.

Equation shows that acceleration due to gravity does not depend on the mass of the object or body. Thus, all objects hollow or solid, big or small should fall at the same rate.

Value of g is 9.8 m/s^2.

MASS

Mass of a body is defined as the quantity of matter contained in the body. Since mass of a body is a measure of inertia of the body, so mass is also known as inertial mass.

UNIT OF MASS

SI unit of mass is kilogram (kg).

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 places. 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.
7. Masses of objects or bodies are added algebraically.

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 an acceleration due to gravity (g).

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

$$\mathbf{F = ma = m \times g = mg}$$

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

$$\mathbf{Weight,\ W = mg}$$

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).Spring balance measures the weight of an object.

THRUST

When a body is placed on a surface, the weight of the body acts downward and the force exerted by the body on the surface is equal to the weight of the body.

The total force exerted by the body perpendicular to the surface is known as thrust.

PRESSURE

Pressure is defined as the force acting perpendicular on unit area of the surface.If

F = Force acting perpendicular to the surface = Thrust

A = Area of the surface on which force acts.

Then, $Pressure = \frac{Force}{Area} or\ P = \frac{F}{A}$

S.I. Unit of Pressure is Pascal (Pa).

Consequences of Pressure

(Explanation of everyday observations on the basis of pressure)

1. **Railway tracks are laid on large sized wooden or iron sleepers.**

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 produced. This prevents the sinking of the ground under the weight of the train.

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

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.

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

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. On the other hand, sand under the feet of camel does not sink much due to small pressure. Hence camel can walk and run easily on the sandy surface.

4. A sharp needle pierces the skin easily but not a blunt needle although the force applied on both the needles is same.

The area under the pointed end of the sharp needle is very small as compared to the area under the pointed end of the blunt needle. So pressure exerted by the sharp needle is much more than the pressure exerted by the blunt needle. Hence a sharp needle pierces the skin easily than the blunt needle.

5. **It is painful to hold a heavy bag having strap made of a strong and thin string.**

When we hold a heavy bag having strap made of a strong and thin string, then the area under the strap is small.Hence, large pressure is exerted by the strap on our fingers or shoulder. Due to this large pressure, the strap tends to cut the skin and hence pain is caused.

PRESSURE IN FLUIDS

Fluid: A substance which can flow under the action of external force is called fluid. Since liquids and gases can flow, so they are known as fluids.

Fluids i.e. liquids and gases enclosed in containers exert pressure in all directions on the walls of the container.

Pascal's Law

A great French physicist and mathematician, Blaise Pascal gave a law regarding the pressure exerted by a fluid enclosed in a container. According to this law:

"Pressure applied to an enclosed fluid is transmitted undiminished to every portion of the fluid and the walls of the containing vessel."

DEFINITION OF UPTHRUST OR BUOYANT FORCE

The upward force exerted by a liquid on a body which is immersed in the liquid is known as the upthrust or buoyant force.

Factors on which upthrust or buoyant force depends

(i) the size or volume of the body immersed in a liquid, and

(ii) the density of the liquid in which the body is immersed.

Buoyancy: The tendency of an object to float in a liquid or the power of liquid to make an object float in it is called buoyancy.

WHY OBJECTS FLOAT OR SINK WHEN PLACED ON THE SURFACE OF WATER?

Object floats on the liquid if density of the object is less than the density of the liquid. An object sinks in the liquid if the density of the object is greater than the density of the liquid.

ARCHIMEDES' PRINCIPLE

When a body is immersed partially or completely in a fluid (liquid or gas), it experiences an upthrust or buoyant force which is equal to the weight of the fluid displaced by the body. The weight of the body decreases due to the buoyant force acting on the body, when immersed in a fluid.

Upthrust or buoyant force = weight of fluid displaced by a body = weight of body in air - weight of body in fluid.

APPLICATIONS OF ARCHIMEDES' PRINCIPLE

Archimedes' principle is used to design: (i) the ships and submarines (ii) the hydrometers to find the densities of liquids (iii) the lactometers to test the purity of milk.

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