PARMAR SSC

GRAVITATION AND WORK DONE

Lecture - 3



BY PARMAR SIR

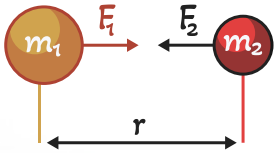
UNIVERSAL LAW OF GRAVITATION

- Newton put forward the universal law of gravitation in 1687 and used it to explain the observed motions of the planets and moons.

Newton's Law of Universal Gravitation

It states that "Every particle attracts every other particle in the universe with force directly proportional to the product of their masses and inversely proportional to the square of the distance between them".

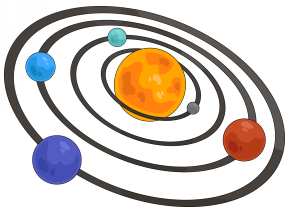
$F \propto m_1.m_2 \Rightarrow F \propto \frac{1}{r^2} \Rightarrow F = \frac{Gm_1 m_2}{r^2}$



$F_1 = F_2 = G\frac{m_1 \times m_2}{r^2}$

- F is the gravitational force between bodies, m_1 and m_2 are the masses of the bodies, r is the distance between the centres of two bodies, G is the universal gravitational constant.
- The value of G is found to be $G = 6.673 \times 10^{-11}\ N\ m^2/kg^2$ (Discovered experimentally by Henry Cavendish in 1798).
- The gravitational force is both a non-contact force (acting at a distance) and a conservative force (work done is independent of path and work done in a closed path is zero).

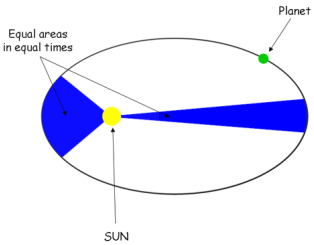
Kepler's Planetary Laws (1609)



First Law: Law of Orbit

- It states that "Planets move in elliptical orbits with the Sun as a focus".

Second Law: Law of Area



- It states that "The line joining the planet and the Sun sweep out equal areas in equal interval of time".

Third Law: Law of Time Period

- It states that "The square of the time period of revolution of a planet around the Sun is directly proportional to the cube of its mean distance from the Sun".

$$T^2 \propto r^3$$

Mass Vs Weight

Mass	Weight
The mass of a body is the amount of matter present in it	The weight of a body is the force with which the earth attracts it
It has magnitude but not direction (scalar quantity)	It has both magnitude and direction (vector quantity)
It does not change from place to place	It changes from place to place (W = m × g)
It can never be zero	It is zero at the center of earth
Its S.I. Unit is kilogram	Its S.I. Unit is Newton

Variation in the gravity

1. The gravity is more at the poles than at the equator.
2. The gravity decreases with altitude.
3. The gravity on the moon is 1/6th of Earth's gravity.

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

$$m \times g = \frac{GMm}{R^2}$$

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

$$g = 9.8\ m/s^2$$

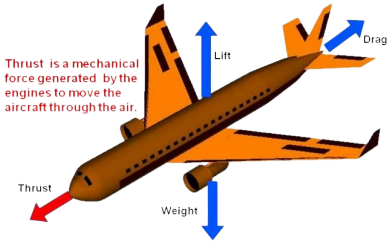
M = Mass of the Earth
R = Radius of the Earth
G = Universal Gravitational Constant
g = Acceleration due to gravity

"g" represents the acceleration that an object experiences due to the Earth's gravity (or the gravity of any celestial body).

- Gravity gets weaker as you move farther from Earth's center. This is because gravity is inversely proportional to the square of the distance between the centers of two objects.
- When we go higher, the distance increases → gravity decreases.
- As we move deeper into the Earth, only the Earth's mass beneath us contributes to the gravitational pull. The mass above us has no effect → gravity also decreases.
- So, gravity is strongest at the surface and weaker both above and below it.

THRUST

- Thrust is a force, or push, that acts on a surface in a direction perpendicular (normal) to that surface. It is measured in Newtons (N).
- E.g. Thrust is generated by the engines of the aircraft through some kind of propulsion system.



PRESSURE

- Pressure is the force (or thrust) acting per unit area. S.I. unit is pascal (Pa).

$$\text{Pressure} = \frac{\text{Thrust / Force}}{\text{Area}}$$

$$P = Kgm / s^2m^2 \text{ Or } 1\ Pa = N / m^2$$

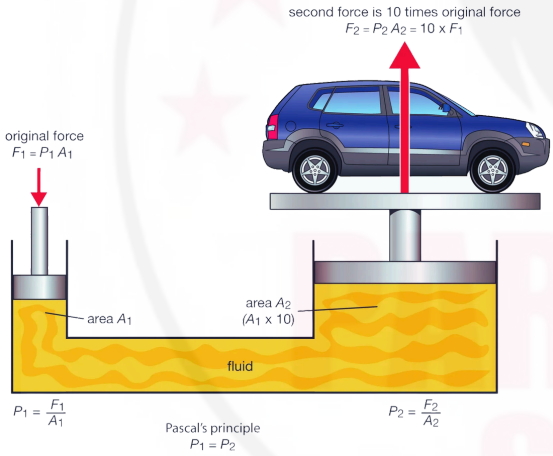
Pascal's Law

- Pascal's law (also Pascal's principle or the principle of transmission of fluid-pressure) is a principle given by Blaise Pascal that states that "A pressure change at any point in a confined incompressible fluid is transmitted throughout the fluid such that the same change occurs everywhere".
- It was given in 1653 and published in 1663.

$$1\ atm = 1.013 \times 10^5\ Pa$$

$$1\ atm = 1.01325\ bar$$

$$1\ N = 10^5\ Dyne$$



$$P_1 = \frac{F_1}{A_1} \qquad P_2 = \frac{F_2}{A_2}$$

$$P_1 = P_2$$

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

Archimedes' Principle

- Archimedes' principle states that "The upward buoyant force that is exerted on a body immersed in a fluid whether fully or partially is equal to the weight of the fluid that the body displaces".

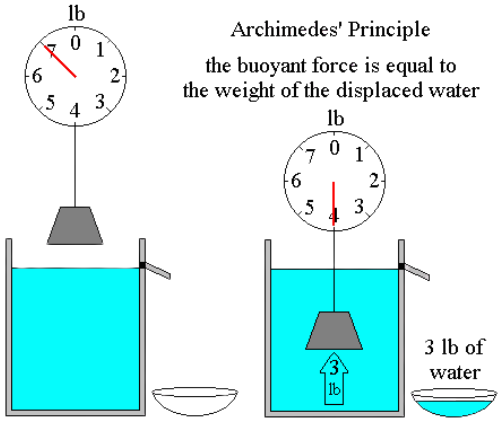
$$F_\beta = \rho g V$$

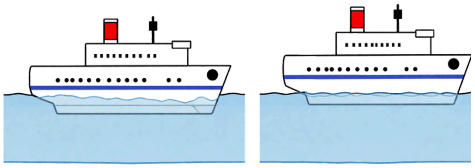
F_β = Buoyant force

ρ = Fluid density

g = Acceleration due to gravity

V = Fluid volume





Fresh water
(less dense)

Salty water
(more dense)

- **E.g.** A ship will float higher in saltwater than in freshwater because the denser saltwater exerts a greater buoyant force, requiring the ship to displace less volume of water to remain afloat. The same principle applies to a person swimming, who will feel lighter and easier to float in saltwater.

Relative Density

- Relative density is the ratio of the density of a substance to the density of a reference substance (usually water for liquids and solids).

$$Relative\ Density = \frac{Density\ of\ a\ Substance}{Density\ of\ Water}$$

$$Density = \frac{Mass}{Volume}$$

S.I. unit of density is Kg/m^3.
Relative Density has no S.I. unit.

Substance	Density, g/mL
Hydrogen (gas)	9
Carbon dioxide (gas)	19
Cork	21
Oak wood	71
Ethyl alcohol	79
Water	100
Magnesium	174
Table salt	216
Sand	232
Aluminum	270
Iron	786
Copper	892
Lead	1,134
Mercury	1,359
Gold	193

Work and Energy

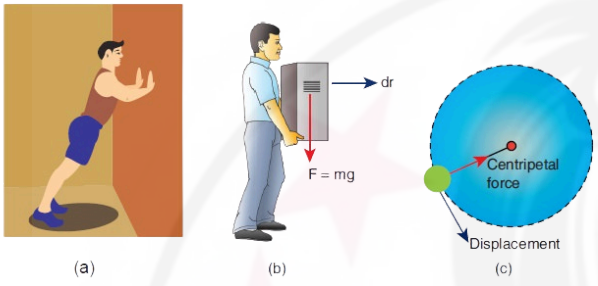
Work

- "Work" is defined as the energy transferred by a force that causes an object to move a certain distance in the direction of the force.
- The S.I. unit is Joule (J) which is equivalent to Newton-meter (N m).

Work Done = Force × Displacement
Work Done = FS cos θ

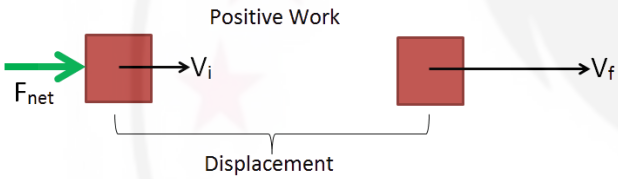


Work done is a scalar quantity.
The S.I. unit of energy is Joule.
It is named after English physicist James Prescott Joule.

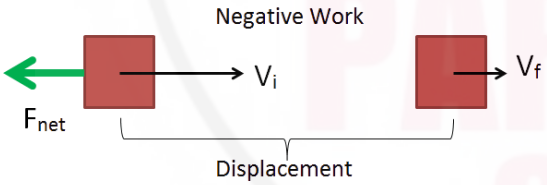


Different cases of zero work done

- Work done is zero, when force and displacement are perpendicular (angle = 90°).
- Work done is zero when there is no displacement.



Work done is positive when force and displacement have same direction (are parallel to each other).



Work done is negative when force and displacement are in opposite directions (anti-parallel, angle 180°).

Energy

- Energy is defined as the capacity to do work, or the ability to cause change, in any exist in potential, kinetic, thermal, electrical, chemical, nuclear, or other various forms.
- S.I. unit of energy is Joule (J).
- Biggest source of energy is the Sun.

Forms of Energy

Kinetic Energy

- Kinetic energy refers to the energy possessed by an object due to its motion.

$$K.E. = \frac{1}{2} mv^2$$

m = Mass
V = Velocity

Relationship between K.E. and Linear Momentum (p)

$$K.E. = \frac{1}{2} mV^2 \times \frac{m}{m}$$

$$= \frac{(mV)^2}{2m} \qquad \boxed{p = mV}$$

$$K.E. = \frac{p^2}{2m}$$

When Momentum is Doubled

If momentum (p) doubles, the kinetic energy (K.E.) becomes 4 times.

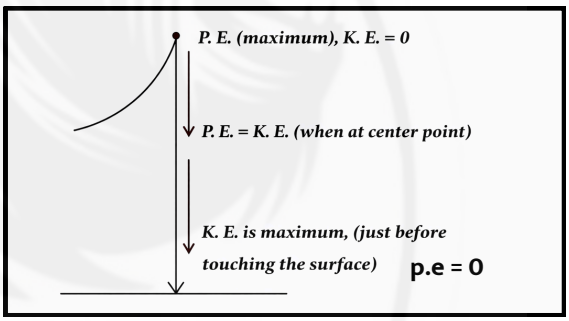
$$K.E. = \frac{(2p)^2}{2m} = \frac{4p^2}{2m}$$

Potential Energy

- Potential energy (P.E.) is stored energy that an object has because of its position or state, ready to be released and do work. E.g. Gravitational P.E.
- The concept of a dam is fundamentally based on potential energy (P.E.), where the stored water at a height possesses potential energy that can be converted into kinetic energy (motion) and used in turbines to generate electricity or for other purposes.

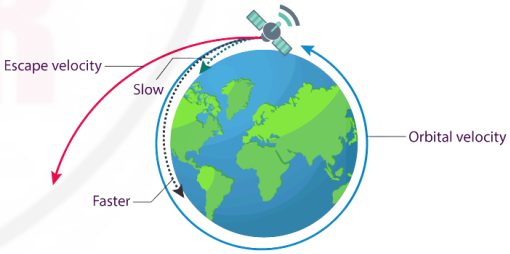
P.E = mgh

m = Mass of the body
g = Acceleration due to gravity
h = Height



Escape Velocity

- The velocity needed for a body to escape from a gravitational centre of attraction without undergoing any further acceleration. E.g. Imagine throwing a ball upwards, if you throw it lightly, it comes back down due to gravity; however, if you throw it with a high enough velocity, it will escape Earth's gravity and never return.
- Escape velocity is approx. 11.2 km/s.



Law of Conservation

- The law of conservation of energy states that "Energy can neither be created nor be destroyed. Although, it may be transformed from one form to another".
- The 1st Law of Thermodynamics is based on this concept.

Dynamo

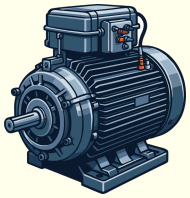


It converts mechanical energy into electrical energy.

Generator



It converts mechanical energy into electrical energy.



Motor

It converts electrical energy into mechanical energy.



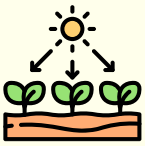
Microphone

It converts sound energy into electrical energy.



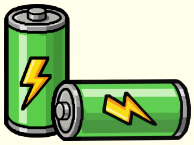
Loudspeaker

It converts electrical energy into sound energy.



Photosynthesis

Process by which plants, algae, and some bacteria convert light energy (primarily from sunlight) into chemical energy in the form of sugars, using carbon dioxide and water, and releasing oxygen as a byproduct.



Battery

It converts chemical energy into electrical energy.



Bulb

It converts electrical energy primarily into light energy and heat energy. Bulb filament is made of Tungsten (W).

Bernoulli's Principle

- Bernoulli's principle is a key concept in fluid dynamics. It states that "In a streamline flow of incompressible, non-viscous fluid, the sum of pressure energy, kinetic energy, and potential energy per unit volume remains constant".

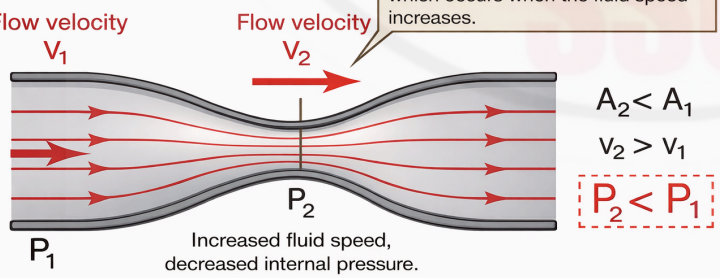
Pressure energy + Kinetic energy + Potential energy = Constant

Energy per unit volume before = Energy per unit volume after

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$$

Pressure Energy | Kinetic Energy per unit volume | Potential Energy per unit volume

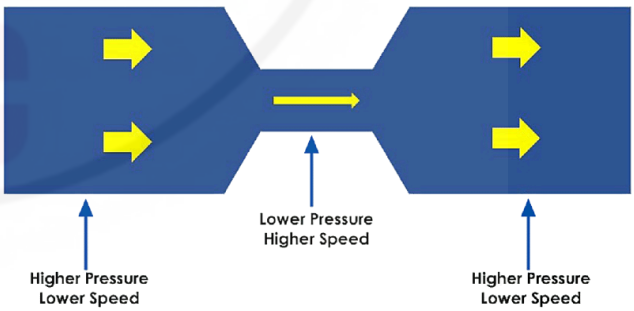
The often cited example of the Bernoulli Equation or "Bernoulli Effect" is the reduction in pressure which occurs when the fluid speed increases.



$A_2 < A_1$

$V_2 > V_1$

$P_2 < P_1$



law of thermodynamics

Zeroth Law of Thermodynamics

- It states that "If body A in thermal equilibrium with B, and B is in thermal equilibrium with C, then A is also in thermal equilibrium with C".
- Zeroth law was given by Ralph H. Fowler in 1931.

First Law of Thermodynamics

- It states that "Energy can neither be created nor be destroyed only converted from one form to another".
- It is the law of conservation of energy applied to heat.

$$Q = \Delta U + W$$

Q = Heat added to the system
ΔU = Change in internal energy
W = Work done by the system

Second Law of Thermodynamics

- Heat cannot flow from a colder body to a hotter body on its own.
- It introduces the concept of entropy (disorder).
- **E.g.** Heat engine can't be 100% percent efficient, refrigerator requires external work to transfer heat from cold to hot.

Third Law of Thermodynamics

- As temperature approaches absolute zero (0 K), the entropy of a perfect crystal becomes zero.

Entropy, the measure of a system's thermal energy per unit temperature that is unavailable for doing useful work.

POWER

- Power is the rate at which work is done or the rate at which energy is transferred from one place to another or transformed from one type to another.
- The S.I unit of power is Watt (W).

$$Power = \frac{Work}{Time}$$

$$Power = Force \times Velocity$$

$$P = FV$$

A watt (W) is a unit of power, specifically defined as one joule of energy transferred or converted per second (1 J/s).

HORSE POWER

- Horsepower (hp) is a unit of measurement of power, or the rate at which work is done, often used to describe the output of engines or motors.

1 hp = 746 W

1 hp = 0.746 kW

1 kW = 1000 W



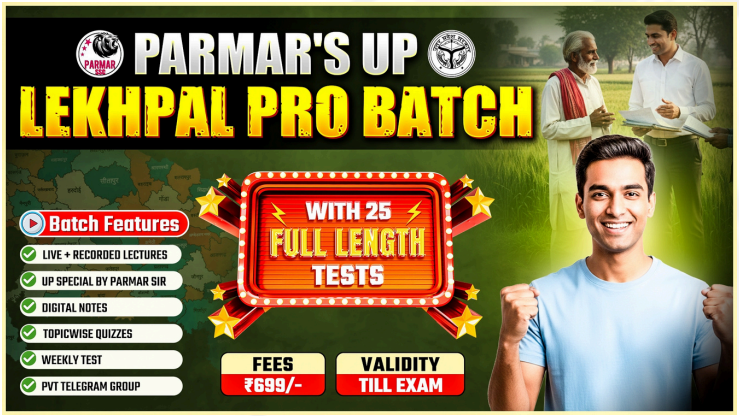
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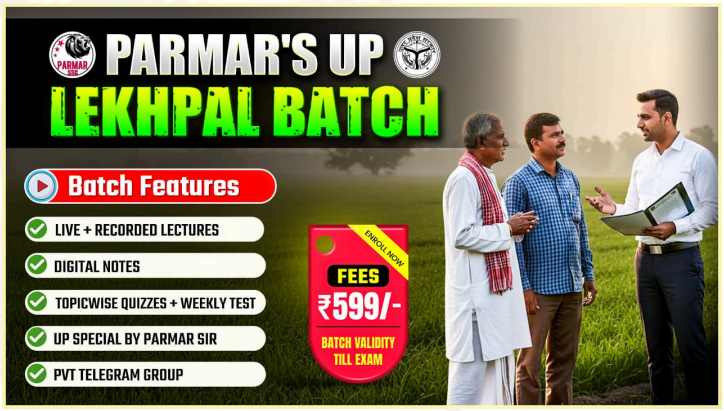
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