X PHYSICS SHORT NOTES

2. Work, Energy & Power

A) WORK, ENERGY & POWER, THEIR MEASUREMENTS AND UNITS.

- **Work**:
  - **Definition:** Work is said to be done only when the force applied on a body produces displacement of the body.

  - **Factors affecting amount of work done**:
    - The magnitude of the applied force – **Directly Proportional.**
    - The displacement produced by the applied force – **Directly Proportional.**
    - The angle of inclination – **Directly Proportional**.

  - **Conditions for the work done by the force to be zero**:
    - It produces no displacement. (S = 0) OR
    - It produces displacement of a body which is normal to the direction of applied force. [$\theta = 90^o$].

  - **Units of work**:
    - SI unit is **joule**. (J)
    - 1 joule = 1 newton $\times$ 1 meter.
    - **Definition: 1 joule of work** is said to be done when a force of 1 newton displaces a body through a distance of 1 meter in the same direction.
    - 1 kJ = 10^3 J, 1 MJ = 10^6 J and 1GJ = 10^9 J.
    - M.K.S. unit:
      - Force = kg m s^{-2}.
      - Work = kg m^2 s^{-2}.
    - C.G.S unit of work is erg.
    - 1 erg = 1 dyne $\times$ 1 cm.
    - **Definition: 1 erg of work** is said to be done when a force of 1 dyne displaces a body through a distance of 1 cm in the same direction.
    - 1 joule = 1 N $\times$ 1 m. [1 N = 10^5 dyne and 1 m = 10^2 cm]
    - 1 joule = 10^5 dyne $\times$ 10^2 cm.
    - 1 joule = 10^7 dyne $\times$ cm.
    - 1 joule = 10^7 erg.

- **Energy:**
  - **Definition:** The energy of a body is its capacity to do work.

  - **Units of energy: (Same as work.)**
    - SI unit of energy is joule.
    - C.G.S unit of energy is erg.
    - 1 J = 10^7 erg.

  - **Other units of energy:**
    - **Watt hour:** One watt hour is the energy spent / work done by a source of power 1 W in 1 h.
    - **Kilowatt hour:** One kilowatt hour is the energy spent / work done by a source of power 1 kW in 1 h.
    - **Calorie:** 1 calorie is the heat energy required in raising the temperature of 1 g of water from 14.5°C to 15.5°C.
    - **Electron volt:** 1 eV is the energy gained by an electron when it accelerates through a potential difference of 1 volt.

  - **Conversion all of units of energy/work:**
    - 1 watt hour (Wh) = 1 watt × 1 hour
      = $1\ J\ s^{-1} \times 3600\ s$
      = 3600 J
      = 3.6 kJ
    - 1 kilowatt hour (kWh) = 1 kilowatt × 1 hour
      = $1000\ J\ s^{-1} \times 3600\ s$
      = 3.6×10^6 J
      = 3.6 MJ
    - 1 eV = Charge on an electron × 1 volt
      = 1.6×10^{-19} coulomb × 1 volt
      = $1.6 \times 10^{-}$ joule
  - **List of all conversions:**
    - 1 watt hour (Wh) = 3600 J = 3.6 kJ.
    - 1 kilowatt hour (kWh) = 3.6×10^6 J = 3.6 MJ.
    - 1 J = 0.24 calorie.
    - 1 calorie = 4.18 J.
    - 1 kilocalorie = 4180 J = 1000 calories.
    - 1 eV = 1.6×10^{-19}J.

- **Power:**
  - **Definition:** The rate of doing work is called power.
  - Power = $\frac{work\ done}{time\ taken}$; P = $\frac{W}{t}$
  - Power = Force × Average speed
  - P = Fv. (if displacement is in straight line)
  - P = Fv cos θ. (if displacement is at an angle.)

  - **Factors affecting power spent by a source:**
    - The amount of work done by the source – **Directly Proportional.**
    - The time taken by the source to do the said work – **Inversely Proportional.**

  - **Units of power:**
    - S.I. unit of power is watt.
    - 1 watt = 1 J s^{-1}.
    - **Definition:** If 1 joule of work is done in 1 second, the power spent is said to be 1 watt.
    - **Definition:** Horse power is a unit of power, largely used in mechanical engineering.

    - M.K.S unit: kg m^2 s^{-3}.
    - C.G.S unit: erg per second (erg s^{-1}).
    - 1 W = 1 Js^{-1} = 10^7 erg s^{-1}.
    - 1 H.P = 746 W = 0.746 kW.
    - Other units of power:
      - 1 kilowatt (1 kW) = 1000W = 10^3 W.
      - 1 megawatt (1 MW) = 1000,000 W = 10^6 W.
      - 1 gigawatt (1 GW) = 1000,000,000 W = 10^9 W.
      - 1 milli watt (1 mW) = 10^{-3}W.
      - 1 micro watt (1 μW) = 10^{-6}W

B) DIFFERENT FORMS OF ENERGY.

- **Mechanical energy and different forms of mechanical energy:** The energy possessed by a body due to its state of rest or motion is called the mechanical energy.

- **Potential Energy (mgh):** The energy possessed by a body at rest by virtue of its specific position or changed configuration is called the potential energy.
  - **Gravitational potential energy:** The potential energy possessed by a body due to its position relative to the center of earth is called its gravitational potential energy.
  - **Elastic potential energy:** The potential energy possessed by a body in the deformed state due to change in its configuration, is called the elastic potential energy.

- **Kinetic Energy: ($K = \frac{1}{2}mv^2$)** The energy possessed by a body by virtue of its state of motion is called the kinetic energy.

- **Conversion of one form of energy to the other form:**
  - Mechanical energy to electrical energy - dynamo.
  - Electrical energy to mechanical energy-electric motor; which is used in devices such as: electric fan, washing machine, mixer, grinder, industrial machine.
  - Electrical energy to heat energy-electric iron, heater, oven, toaster, geyser etc.
  - Heat energy to electrical energy-thermo couple.
  - Electrical energy to sound energy- loudspeaker, electric bell.
  - Sound energy to electrical energy- microphone.
  - Electrical energy to chemical energy- charging a battery.
  - Chemical energy to electrical energy- electric cell.
  - Chemical energy to light energy- lighted candle, kerosene lamp.
  - Light energy to chemical energy- photosynthesis.
  - Electrical energy to light energy- electric bulb.
  - Light energy to electrical energy- photoelectric cell, solar cells.
  - Heat energy to mechanical energy-steam engine (chemical to heat to mechanical).
  - Chemical energy to heat energy- Burning of fuel such as wood, coal, biogas etc. Burning of firecrackers, lighting a matchstick.
  - Chemical energy to mechanical energy-in automobiles when in motion.
  - Electrical energy to magnetic energy- electromagnet.
  - Mechanical energy to heat energy- The potential energy stored in water at a height changes to kinetic energy in falling waters. On reaching the ground, this kinetic energy changes to heat energy due to which the temperature of water rises. Similarly, the moving parts of a machine get heated due to friction, thus changing mechanical into heat energy.

- **Note**:
  - When mechanical energy changes to any form of energy, the potential energy first changes to kinetic energy and then the kinetic energy changes to the other forms.
  - Energy converted to undesirable form or is lost to the environment during the desired transformation from one form to the other is called the **degraded energy**.
  - The conversion of energy to the undesirable/non-useful form is called the **dissipation of energy**.

C) CONSERVATION OF ENERGY

- **Principle of conservation of energy**:
  - **Statement**: Energy can neither be created nor destroyed, it only changes from one form to another.

- **Conservation of mechanical energy (Fundamental Principle of nature)**:
  - **Statement**: According to the law of conservation of mechanical energy, whenever there is an interchange between the potential energy and the kinetic energy, the total mechanical energy remains constant.
  - K + U = constant, when there are no frictional forces.

  - **Table showing the U and K of a body**:

Motion.	Height above the ground.	Kinetic energy K.	Potential energy U.	Total energy E = K + U.
Downward motion. (i.e., free fall)	h (highest point A). $\frac{1}{2}h$ (middle point B). 0 (ground C).	0 $\frac{1}{2}$ mgh. mgh.	mgh. $\frac{1}{2}$ mgh. 0	mgh mgh mgh
Upward motion.	0 (ground C) $\frac{1}{2}h$(middle pt B). h (highest pt A)	Mgh $\frac{1}{2}$ mgh 0	0 $\frac{1}{2}$ mgh Mgh	mgh mgh mgh

  - **Note**: The conservation of mechanical energy is strictly valid in vacuum, where friction due to air is absent, although the law of conservation of total energy of all kinds is always true.

- **Application of principle of conservation of energy to a simple pendulum**:
  - **A swinging the bob has**:
    - Maximum Potential energy at extreme position B or C.
    - Kinetic energy at resting position A is maximum.
    - At an intermediate position (between A and B or between A and C), the bob has both the kinetic energy and potential energy, and the sum of both the energies (i.e., total mechanical energy) remains constant throughout the swing.
    - This is strictly true in vacuum where there is no friction due to air.

- **Differences:**
  - **Work and power:**

Work	Power
Work is said to be done only when the force applied on a body makes the body move. (i.e., there is a displacement of the body).	Power of a source is the rate of doing work by it.
Work done does not depend on time.	Power spent depends on the time in which work is done.
SI unit of work is joule (J).	SI unit of power is watt (W).

  - **Energy and power:**

Energy	Power
Energy of a body is its capacity to do the work.	Power of a source is the energy spent by it in 1 s.
Energy spent does not depend on time	Power spent depends on the time in which energy is spent.
S.I. unit of energy – joule (J).	S.I. unit of power – watt (W).

  - **Watt and watt hour:**

Watt	Watt hour
It is the unit of power.	It is the unit of energy.

  - **Kinetic energy and potential energy:**

Kinetic Energy	Potential Energy
The energy possessed by a body by virtue of its state of motion is called the kinetic energy.	**The energy possessed by a body by virtue of its specific position (or changed configuration) is called the potential energy.**
$K = \frac{1}{2}mv^2$	**U = mgh**

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FORMULAE:

1. **W = F × S (horizontal motion)**
2. **W = F × S cos θ (angular motion)**
3. **F = Weight = mg**
4. **F = ma**
5. **W = FS (Horizontal) = mgh (Vertical)**
6. **Energy = Work**
7. **P = $\frac{W}{t}$**
8. **P = Fv**
9. **P = Fv (cos θ)**
10. **V = u ± at**
11. **S = $\frac{1}{2}$(u + v)t = ut ± $\frac{1}{2}$ at^2**
12. **v^2 = u^2 ± 2aS**
13. **F = ma**
14. **U = mgh**
15. **p = m v**
16. **W = U = K**
17. **W = FS**
18. **K = $\frac{1}{2}$ mv^2**
19. **K = $\frac{p^2}{2m}$**
20. **p = $\sqrt{2mK}$**
21. **Gain in U = mg ($h_2 - h_1$)**
22. **Loss in U = mg ($h_1 - h_2$)**
23. **Δ K = $\frac{1}{2}$ m ($v_2 - u_2$)**
24. W = mgh
25. U = mgh
26. Δ in P.E. = mg ($h_2 – h_1$)
27. K.E. = $\frac{1}{2}$ mv^2
28. Δ In K.E. = $\frac{1}{2}$ (mv^2 – mu^2)