CHAPTER 5: WORK, ENERGY & POWER

Work • Kinetic Energy • Potential Energy

1. Work Done by Constant Force

If the force makes an angle θ with the displacement, then

$$W = Fs\cos\theta$$

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In vector form,

$$\boxed{W = \vec{F}\cdot\vec{s}}$$

Where

- W = Work (Joule)
- F = Force (Newton)
- s = Displacement (metre)
- θ = Angle between Force and Displacement

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2. Special Cases

(i) θ = 0°

$$\boxed{W = Fs}$$

(ii) θ = 90°

$$\boldsymbol{W = 0}$$

(iii) θ = 180°

$$\boxed{\boldsymbol{W = -Fs}}$$

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3. SI Unit of Work

$$\boxed{1\,J = 1\,Nm}$$

4. Kinetic Energy

Definition

Energy possessed due to motion.

$$\boxed{KE = \frac{1}{2}mv^2}$$

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5. Relation between Work and Kinetic Energy

$$\boxed{W = \Delta KE}$$

This is known as the **Work-Energy Theorem**.

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6. Change in Kinetic Energy

$$\boxed{W = \frac{1}{2}m(v^2 - u^2)}$$

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7. Potential Energy

Gravitational Potential Energy

$$\boxed{PE = mgh}$$

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8. Change in Potential Energy

$$\boxed{\Delta PE = mg(h_2 - h_1)}$$

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9. Mechanical Energy

$$\boxed{E = KE + PE}$$

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10. Law of Conservation of Mechanical Energy

$$\boxed{KE + PE = \text{Constant}}$$

(Only when non-conservative forces are absent.)

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11. Conservative Force

Examples

- Gravitational Force
- Spring Force

For Conservative Force

$$\boxed{W = -\Delta PE}$$

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12. Non-Conservative Force

Examples

- Friction
- Air Resistance

Mechanical Energy is **not conserved**.

Power • Spring Energy • Variable Force • Energy Graphs

13. Power

Power = Rate of doing work

$$\boxed{P = \frac{W}{t}}$$

SI Unit

$$\boxed{1 Watt = 1 J/s}$$

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14. Average Power

The ratio of total work done to the total time taken is called average power.

$$\boxed{P_{av} = \frac{Total\ Work}{Total\ Time\ Taken}}$$

Average Power between the given time interval can also be calculated, if Power is a function of time or constant power as:

$$\boxed{P_{av} = \frac{\int_{t_1}^{t_2} p\,dt}{\int_{t_1}^{t_2} dt}}$$

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15. Instantaneous Power

$$\boxed{P = \vec{F} \cdot \vec{v}}$$

Special Case

If Force and Velocity are in same direction,

$$\boxed{P = Fv}$$

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16. Horse Power

$$\boxed{1 HP = 746 W}$$

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17. Spring Potential Energy

Using Hooke's Law

Spring Energy

$$F = -kx$$

$$\boxed{U = \frac{1}{2} k x^2}$$

where

- K = Spring Constant

- x = Extension/Compression

18. Variable Force

Work done by a variable force equals the **area under the Force–Displacement (F–x) graph**.

$$\boxed{W = \int F\,dx}$$

19. Spring Work

For a spring,

$$\boxed{W = \frac{1}{2}kx^2}$$

20. Mechanical Energy

$$\boxed{E = \frac{1}{2}mv^2 + mgh}$$

21. Conservation of Mechanical Energy

$$\boxed{\frac{1}{2}mv_1^2 + mgh_1 = \frac{1}{2}mv_2^2 + mgh_2}$$

22. Efficiency

$$\boxed{\eta = \frac{\text{Useful Output}}{\text{Input}} \times 100\%}$$

23. Energy Conversion

Gravitational PE → KE
Spring PE → KE
Electrical Energy → Mechanical Energy

24. Energy Graphs

Force–Displacement Graph

Area under graph = Work Done

Potential Energy–Position Graph

Slope of curve

$$\boxed{F = -\frac{dU}{dx}}$$

25. Equilibrium Position: Stable, Unstable & Neutral Positions

For Equilibrium Position,

$$\boxed{\boldsymbol{F = 0}}$$

For Stable Equilibrium Position,

$$\boxed{\boldsymbol{U\ should\ be\ Minimum}}$$

To find Minimum Position,

$$\boxed{\frac{d^2U}{dt^2} > 0}$$

Then, the point at which unstable equilibrium can be obtained by putting

$$\boxed{F = -\frac{dU}{dx} = 0}$$

For Unstable Equilibrium Position,

$$\boxed{\boldsymbol{U\ should\ be\ Maximum}}$$

And to find maximum position,

$$\boxed{\frac{d^2U}{dt^2} < 0}$$

Then, the point at which unstable equilibrium can be obtained by putting

$$\boxed{F = -\frac{dU}{dx} = 0}$$

Exam Tips

- If force and displacement are in same direction→ Work Positive
- If both are in opposite direction→ Work Negative
- If both are perpendicular → Work Zero
- **Area under F–x graph = Work Done**
- **Slope of U–x graph = Force**
- For conservative force only, mechanical energy is always conserved.
