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CHAPTER NOTES

Work Energy and Power Class 11 Notes | CBSE Physics Chapter 5

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CHAPTER SUMMARY

Work, Energy and Power links the force you apply to the motion it produces, defining work as force times displacement and introducing kinetic and potential energy. It builds up to the work-energy theorem, the conservation of mechanical energy, power as the rate of doing work, and the analysis ...

... see more

CHAPTER NOTES

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Key Concepts

1. Work Done by a Constant Force

Work is done when a force acting on a body produces a displacement in its direction. It is a scalar quantity equal to the dot product of force and displacement.

W = F·s = Fs cos θ, where θ is the angle between the force and the displacement.

- **SI unit:** joule (J); 1 J = 1 N·m. **Dimensions:** $[ML^2T^{-2}]$.
- **Positive work** (θ < 90°): force aids motion, e.g. a falling body's weight.
- **Negative work** (θ > 90°): force opposes motion, e.g. friction.
- **Zero work** (θ = 90°): force is perpendicular to displacement, e.g. centripetal force, or carrying a bag horizontally.

2. Work Done by a Variable Force

When the force changes with position, we add up the work over tiny displacements where the force is nearly constant. This sum becomes an integral.

W = ∫ F dx (from x_1 to x_2)

Graphically, the work done by a variable force equals the **area under the force–displacement (F–x) graph**.

[DIAGRAM: A force–displacement graph; the shaded area between the curve and the x-axis from x_1 to x_2 represents the work done.]

3. Kinetic Energy

Kinetic energy (KE) is the energy a body possesses by virtue of its motion. It equals the work needed to bring the body from rest to its current speed.

KE = ½mv²

- **SI unit:** joule (J); it is a scalar and always positive.

- Relation with momentum: **$KE = p^2/2m$** and **$p = \sqrt{(2m \cdot KE)}$**.
- If momentum is constant, a lighter body has more kinetic energy.

4. Work-Energy Theorem

The **work-energy theorem** states that the net work done by all forces on a body equals the change in its kinetic energy.

$W_{net} = \Delta KE = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

- It holds for constant and variable forces alike.
- Positive net work speeds the body up; negative net work slows it down.
- This single equation replaces messy force-and-acceleration calculations in many problems.

5. Potential Energy

Potential energy (PE) is the energy stored in a body by virtue of its position or configuration. It is defined only for conservative forces.

Gravitational Potential Energy

Near the Earth's surface, lifting a mass m through a height h stores energy:

$U = mgh$

The reference level (where $U = 0$) is chosen for convenience, usually the ground.

Elastic (Spring) Potential Energy

A spring obeying Hooke's law (restoring force $F = -kx$) stores energy when stretched or compressed by x:

$U = \frac{1}{2}kx^2$

This U is the area under the $F = kx$ line — a triangle of area $\frac{1}{2}kx^2$.

6. Conservative and Non-Conservative Forces

A **conservative force** does work that depends only on the start and end positions, not the path taken; the work done in a closed loop is zero. Potential energy can be defined for it.

A **non-conservative force** does path-dependent work, so no potential energy can be defined; mechanical energy is lost (usually as heat).

Conservative	Non-Conservative
Gravity, spring force, electrostatic force	Friction, air resistance, viscous drag
Work in a closed loop = 0	Work in a closed loop ≠ 0
PE can be defined; $F = -dU/dx$	PE cannot be defined

Force from potential energy: for a conservative force, **$F = -dU/dx$** — the force points towards decreasing potential energy.

7. Conservation of Mechanical Energy

If only conservative forces act on a body, its total **mechanical energy** (KE + PE) stays constant throughout the motion.

$E = KE + PE = \frac{1}{2}mv^2 + mgh = \text{constant}$

Freely Falling Body

As a body of mass m falls from height H, PE converts to KE while the total stays mgH. At the bottom, all of it is kinetic: $\frac{1}{2}mv^2 = mgH$, giving the familiar $v = \sqrt{(2gH)}$.

[DIAGRAM: A ball falling from height H — at the top all energy is PE (mgH), midway it is half PE half KE, at the ground all KE ($\frac{1}{2}mv^2$); the total bar stays the same height.]

When friction acts: mechanical energy is not conserved; the lost energy equals the work done against friction: $W_{friction} = E_{initial} - E_{final}$.

8. Power

Power is the rate at which work is done, or equivalently the rate at which energy is transferred.

$P = W/t$ (average power) and **$P = dW/dt = F \cdot v$** (instantaneous power)

- **SI unit:** watt (W); 1 W = 1 J/s. It is a scalar.
- Commercial unit of energy: 1 kWh = 3.6×10^6 J (one "unit" of electricity).
- 1 horsepower (hp) = 746 W.

9. Collisions

A **collision** is a brief, strong interaction between bodies in which momentum is exchanged. **Linear momentum is conserved in every collision** (no net external force during the impact). Kinetic energy may or may not be conserved.

Type	Momentum	Kinetic Energy	Example
Elastic	Conserved	Conserved	Collision of two smooth billiard balls; atomic collisions
Inelastic	Conserved	Not conserved	A ball hitting clay; most everyday collisions
Perfectly inelastic	Conserved	Maximum loss	Bodies stick and move together; bullet embeds in block

Elastic Collision in One Dimension

For two masses m_1 (velocity u_1) and m_2 (velocity u_2), solving conservation of momentum and kinetic energy together gives:

$$v_1 = [(m_1 - m_2)u_1 + 2m_2u_2] / (m_1 + m_2)$$

$$v_2 = [(m_2 - m_1)u_2 + 2m_1u_1] / (m_1 + m_2)$$

- **Equal masses ($m_1 = m_2$):** the bodies simply exchange velocities.
- **Heavy hits light at rest:** heavy body continues, light body shoots off at $\approx 2u_1$.
- **Light hits heavy at rest:** light body rebounds with nearly the same speed.

Perfectly Inelastic Collision in One Dimension

The bodies stick and move with a common velocity v:

$$v = (m_1u_1 + m_2u_2) / (m_1 + m_2)$$

Kinetic energy lost = $\frac{1}{2} \cdot [m_1m_2/(m_1 + m_2)] \cdot (u_1 - u_2)^2$ — this is the maximum possible loss.

Collision in Two Dimensions (Oblique)

When the bodies do not move along the same line after impact, momentum is conserved separately along two perpendicular axes:

- **Along x:** $m_1u_1 = m_1v_1 \cos\theta_1 + m_2v_2 \cos\theta_2$
- **Along y:** $0 = m_1v_1 \sin\theta_1 - m_2v_2 \sin\theta_2$

For an elastic 2-D collision, kinetic energy conservation gives a third equation.

10. Coefficient of Restitution

The **coefficient of restitution (e)** measures how elastic a collision is. It is the ratio of the relative velocity of separation to the relative velocity of approach.

$$e = (v_2 - v_1) / (u_1 - u_2)$$

- **e = 1:** perfectly elastic collision (KE conserved).
- **e = 0:** perfectly inelastic collision (bodies stick).
- **0 < e < 1:** real, partially inelastic collision.

For a ball dropped from height h_1 and rebounding to height h_2: **$e = \sqrt{(h_2/h_1)}$**.

Read the rest of the chapter →

Flash Cards: Work, Energy and Power

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What is Work?

A force does work only when it moves something along its line of action.

$$W = \vec{F} \cdot \vec{d} = F\, d \cos\theta$$

Scalar; SI unit joule (J), 1 J = 1 N·m, dimensions [M L^2 T^{-2}].

- ✓ θ < 90° → +ve work; θ = 90° → zero; θ > 90° → −ve work
- ✓ Zero-work traps: coolie carrying load horizontally, string tension in circular motion
- ✓ Variable force: W = ∫ F dx = area under the F–x graph

Core energy 2/9

Kinetic Energy

Kinetic energy is the energy a body has because it is moving.

$$K = \tfrac{1}{2} m v^2 = p^2 / 2m$$

Always ≥ 0; scalar; unit joule. Here p = mv is momentum.

- ✓ Double the speed → KE becomes 4× (v^2 dependence)
- ✓ Double KE → momentum rises by √2
- ✓ Energy carried only by motion, never negative

Key theorem

Work-Energy

The net work of all fo kinetic energy.

$$W\_net = \Delta K =$$

Holds for constant & va conserv

- ✓ Constant speed motion) → net w
- ✓ Stopping distan μ g), so d ∝ v^2
- ✓ A shortcut: com of tracking force

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Q1 NEET 2021

Water falls from a height of 60 m at the rate of 15 kg/s to operate a turbine. The losses due to frictional force are 10% of the input energy. How much power is generated by the turbine? (g = 10 m/s²)

- A 10.2 kW
- B 8.1 kW
- C 12.3 kW
- D 7.0 kW

Q2 NEET 2020

The energy required to break one bond in DNA is 10^{-20} J. This value in eV is nearly

- A 0.2
- B 0.06

C 0.006

D 6

Q3 NEET 2020

A particle is released from height S from the surface of the Earth. At a certain height its kinetic energy is three times its potential energy. The height from the surface of the earth and the speed of the particle at that instant are respectively

A S/4, 3gS/2

B S/4, $\sqrt{(3gS/2)}$

C S/2, $\sqrt{(3gS/2)}$

D S/4, $\sqrt{(3gS)}$

Q4 NEET 2020

A point mass m is moved in a vertical circle of radius r with the help of a string. The velocity of the mass is $\sqrt{(7gr)}$ at the lowest point. The tension in the string at the lowest point is

A 6mg

B 7mg

C 8mg

D mg

Q5 NEET 2019

A force F = 20 + 10y acts on a particle in y-direction, where F is in newton and y in meter. Work done by this force to move the particle from y = 0 to y = 1 m is

A 5 J

B 25 J

C 20 J

D 30 J

Q6 NEET 2019

An object of mass 500 g, initially at rest, is acted upon by a variable force whose X component varies with X in the manner shown. The velocities of the object at points X = 8 m and X = 12 m would be the respective values of (nearly)

A 18 m/s and 24.4 m/s

B 23 m/s and 24.4 m/s

C 23 m/s and 20.6 m/s

D 18 m/s and 20.6 m/s

Q7 NEET 2019

An object flying in air with velocity $(20\hat{i} + 25\hat{j} - 12\hat{k})$ suddenly breaks in two pieces whose masses are in the ratio 1 : 5. The smaller mass flies off with a velocity $(100\hat{i} + 35\hat{j} + 8\hat{k})$. The velocity of the larger piece will be

A $4\hat{i} + 23\hat{j} - 8\hat{k}$

B $-100\hat{i} - 35\hat{j} - 8\hat{k}$

C $20\hat{i} + 15\hat{j} - 80\hat{k}$

D $-20\hat{i} - 15\hat{j} - 80\hat{k}$

Q8 NEET 2018

A particle moves from a point $(-2\hat{i} + 5\hat{j})$ to $(4\hat{j} + 3\hat{k})$ when a force of $(4\hat{i} + 3\hat{j})$ N is applied. How much work has been done by the force?

A 8 J

B 11 J

C 5 J

D 2 J

Q9 NEET 2016

A particle of mass 10 g moves along a circle of radius 6.4 cm with a constant tangential acceleration. What is the magnitude of this acceleration if the kinetic energy of the particle becomes equal to 8×10^{-4} J by the end of the second revolution after the beginning of the motion?

A 0.15 m/s^2

B 0.18 m/s^2

C 0.2 m/s^2

D 0.1 m/s^2

Q10 NEET 2012

The potential energy of a particle in a force field is $U = A/r^2 - B/r$, where A and B are positive constants and r is the distance of particle from the centre of the field. For stable equilibrium, the distance of the particle is

A B/2A

B 2A/B

C A/B

D B/A

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Frequently Asked Questions

What is work in physics and when is it zero?

Work is the product of force and the displacement along the line of that force, given by W = F d cos theta. It is zero when the force is perpendicular to the displacement (theta = 90 degrees), such as the tension in a string during circular motion or a coolie carrying a load horizontally.

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What does the work-energy theorem state?

The work-energy theorem says the net work done by all forces on a body equals the change in its kinetic energy, W_net = half m v squared minus half m u squared. It holds for both constant and variable forces and for conservative and non-conservative forces.

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What is the difference between conservative and non-conservative forces?

For a conservative force like gravity or a spring force, the work done depends only on the start and end points and is zero around any closed loop, so the energy can be stored as potential energy. Non-conservative forces like friction and air drag depend on the path and dissipate energy as heat and...

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How are elastic and inelastic collisions different?

In every collision linear momentum is conserved, but kinetic energy is conserved only in an elastic collision (coefficient of restitution e = 1). In an inelastic collision some kinetic energy is lost to heat, sound and deformation, and in a perfectly inelastic collision (e = 0) the bodies stick and move...

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Is Work, Energy and Power important for NEET?

Yes, it is a high-weightage Class 11 mechanics chapter that NEET questions regularly, often combining kinetic energy, the work-energy theorem, conservation of mechanical energy and collisions. Mastering its formulas, including P = F v for power and v = root 2gh for a free drop, helps you solve problems...

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