

CHAPTER 5.3 • WORK, ENERGY AND POWER

Work

The physics of force, displacement,
and the angle between them.

[Target: NEET / JEE Main]

What Counts as Work

In everyday language, studying for hours or steadily holding a heavy load requires "energy" and "work." In physics, the definition is strictly geometric and mechanical. Without motion and alignment, no physical work is done.

1. Applied Force (F)

- A net force must act on the object. A block moving uniformly on a frictionless table experiences no horizontal force. (If $F = 0$, $W = 0$).

2. Displacement (d)

- The object must change position. A weightlifter holding a 150 kg mass steadily for 30 seconds does zero work on the load. (If $d = 0$, $W = 0$).

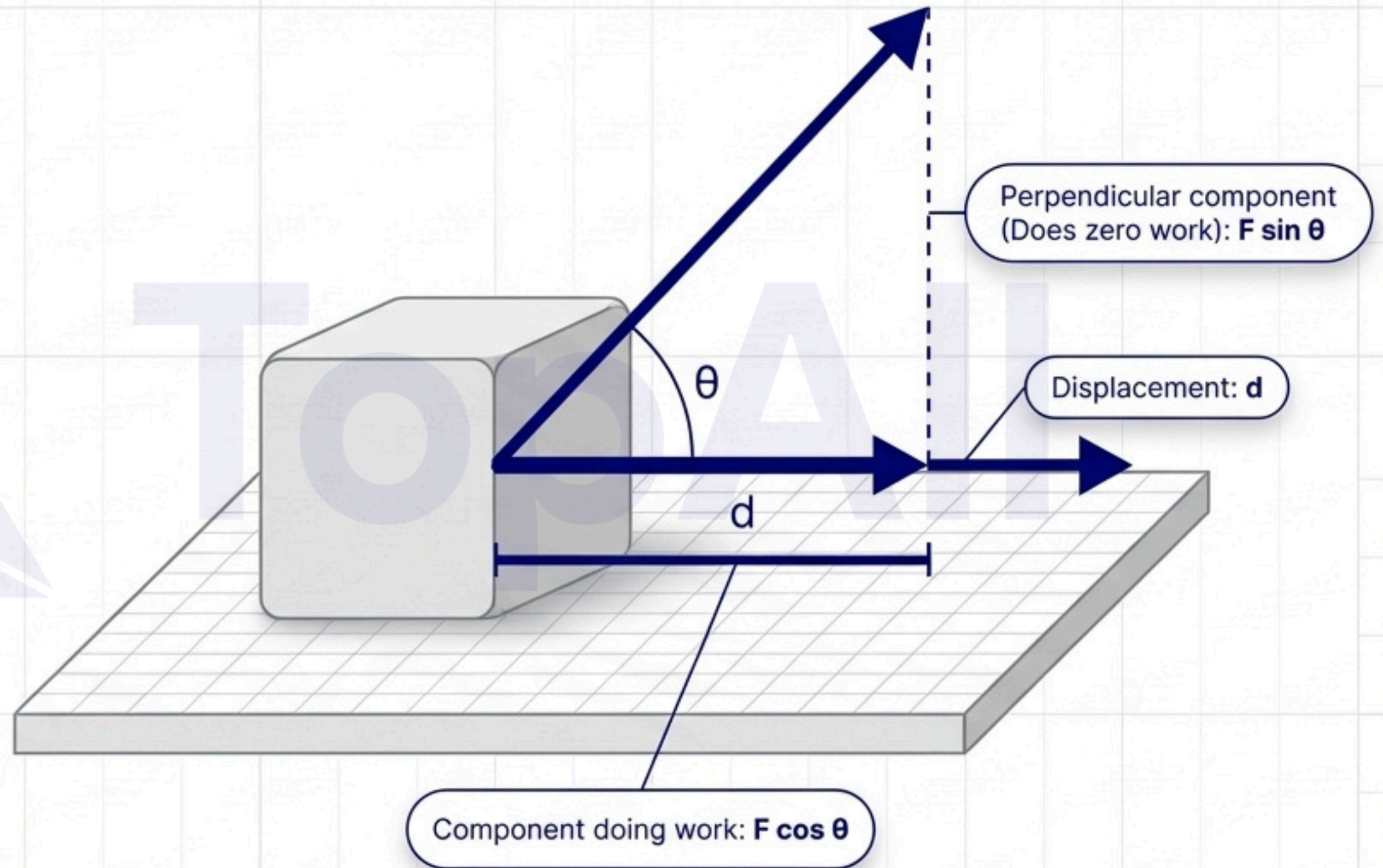
3. Component Alignment

- The force and displacement cannot be mutually perpendicular. (If $\theta = 90^\circ$, $W = 0$).

Force and Displacement at an Angle

The Core Concept

Work is not simply Force times Distance. It is the product of the displacement and the component of the force acting along the direction of that displacement.





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$$E=mc^2$$



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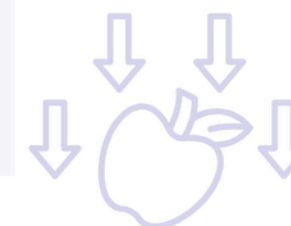
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The Mathematical Formalization

W: Work done (a Scalar quantity, despite being derived from vectors)

$\cos \theta$: The cosine of the angle between the F and d vectors

$$W = F \cdot d = Fd \cos \theta$$

F: Magnitude of Force

d: Magnitude of Displacement

Exam Data Card

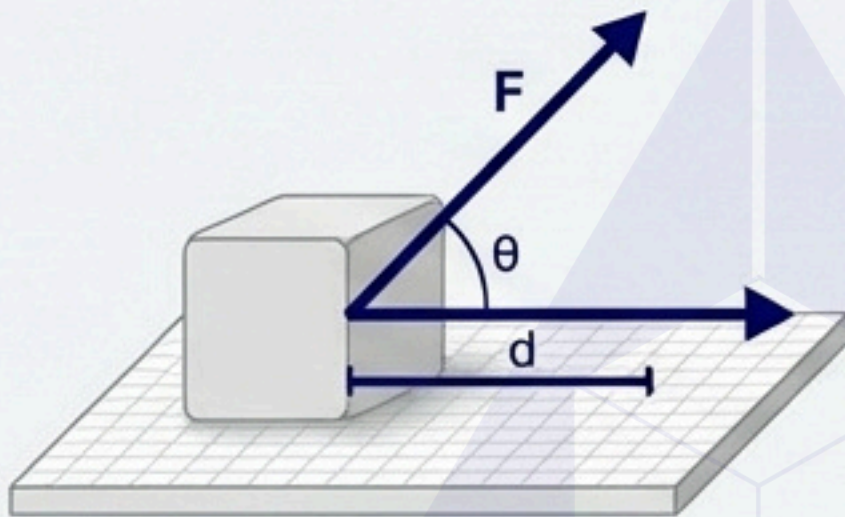
Unit: Joule (J) or N·m
(Named after James Prescott Joule)

Dimensions: $[ML^2T^{-2}]$

Math Note: Work is the scalar (dot) product of two vectors. It has magnitude but no direction.

Positive, Negative, and Zero Work

Positive Work

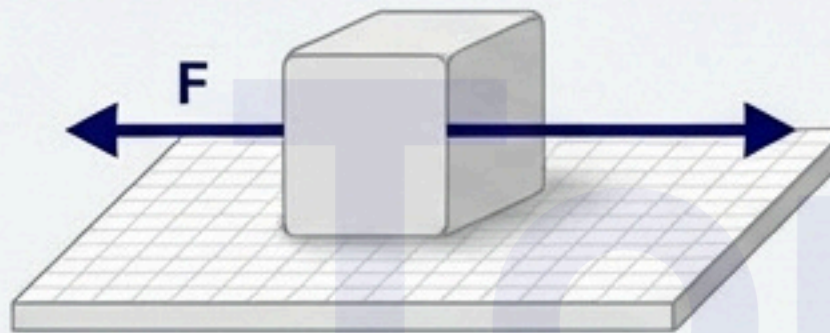


Math: $0^\circ \leq \theta < 90^\circ \rightarrow \cos \theta$ is positive.

Result: $W > 0$

Example: A falling raindrop (Gravity does positive work in the direction of motion).

Negative Work

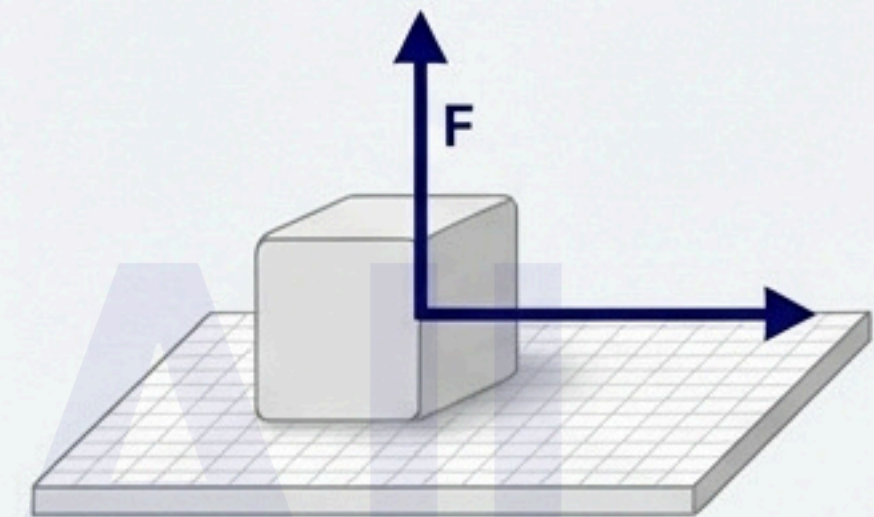


Math: $90^\circ < \theta \leq 180^\circ \rightarrow \cos \theta$ is negative.

Result: $W < 0$

Example: Frictional force opposing a sliding block ($\theta = 180^\circ$, $\cos 180^\circ = -1$).

Zero Work



Math: $\theta = 90^\circ \rightarrow \cos 90^\circ = 0$.

Result: $W = 0$

Example: The Earth's gravity acting on the moon in a perfectly circular orbit.

Key Takeaways

Exam Quick-Review

- Work is a scalar quantity derived from the dot product of two vectors: Applied Force and Displacement.
- Zero work occurs if displacement is zero, if net force is zero, or if the force and displacement are mutually perpendicular ($\theta = 90^\circ$).
- The sign of work depends entirely on the angle (θ): Positive (acute), Negative (obtuse/opposing), and Zero (perpendicular).
- Work shares the exact same dimensions as Energy: $[ML^2T^{-2}]$ and the SI Unit is the Joule (J).
- Although forces from body A to body B are equal and opposite (Newton's Third Law), the work done on A by B is not necessarily equal and opposite.



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