

# Mechanics Terms: Kinematics, Dynamics, Energy

A clean guide to how the words and equations connect

**Main idea:** these topics are not separate chapters. They are three languages for the same motion event.

Dynamics explains why  $a$  exists → Kinematics uses  $a$  to describe motion

Energy skips time by tracking work and energy transfer

## The Three Languages

Topic	Question it answers	Main quantities
<b>Kinematics</b>	What is the motion? How far, how fast, how long?	$s, u, v, a, t$
<b>Dynamics</b>	Why did the motion change? What forces caused the acceleration?	$\sum F, m, a$ , weight, normal force, friction, tension
<b>Energy</b>	Where did the ability to move come from or go?	$KE, GPE, W$ , energy dissipated, power

## The core chain

force → acceleration → change in velocity → motion

$$\sum F = ma \quad \text{then} \quad v = u + at \quad \text{or} \quad v^2 = u^2 + 2as$$

**Translation:** dynamics usually gives you acceleration. Kinematics then uses acceleration to find velocity, displacement, or time.

## Kinematics Terms: Motion Description

Kinematics describes motion without explaining the cause. It is the “what happened?” view.

### SUVAT variables

$s$  = displacement  
 $u$  = initial velocity  
 $v$  = final velocity  
 $a$  = acceleration  
 $t$  = time

Term	Meaning	Common trap
<b>Distance</b>	Total path length travelled. Scalar.	Always positive; no direction.
<b>Displacement, <math>s</math></b>	Change in position. Vector.	Can be negative depending on chosen direction.
<b>Speed</b>	Rate of change of distance. Scalar.	Speed has no direction.
<b>Velocity, <math>u</math> or <math>v</math></b>	Rate of change of displacement. Vector.	Direction matters; sign matters.
<b>Acceleration, <math>a</math></b>	Rate of change of velocity.	Acceleration can be negative if velocity is decreasing in chosen positive direction.
<b>Time, <math>t</math></b>	Duration of motion.	SUVAT assumes constant acceleration.

## Key equations

$$v = u + at$$

$$s = ut + \frac{1}{2}at^2$$

$$v^2 = u^2 + 2as$$

Use kinematics when the question gives or asks for time, displacement, velocity, or constant acceleration.

## Dynamics Terms: Force Explanation

Dynamics explains why motion changes. It is the “what caused the acceleration?” view.

$$\sum F = ma$$

**Resultant force causes acceleration.** If  $\sum F = 0$ , then  $a = 0$ : the object is either stationary or moving at constant velocity.

Term	Meaning	Link to motion
<b>Force, <math>F</math></b>	A push or pull.	A resultant force causes acceleration.
<b>Resultant force, <math>\sum F</math></b>	Net force after adding forces with signs/directions.	Determines $a$ through $\sum F = ma$ .
<b>Mass, <math>m</math></b>	Resistance to acceleration.	Larger $m$ means same force gives smaller $a$ .
<b>Weight, <math>mg</math></b>	Gravitational force on mass.	Acts downward. Near Earth, $g \approx 9.81 \text{ m s}^{-2}$ .
<b>Normal contact force, <math>N</math></b>	Support force from a surface.	Perpendicular to the surface.
<b>Friction, <math>f</math></b>	Contact force opposing sliding or attempted sliding.	Reduces acceleration; dissipates mechanical energy.
<b>Tension, <math>T</math></b>	Pulling force in a string or rope.	Often connects motion of two objects.

## How dynamics connects to kinematics

$$\text{forces} \xrightarrow{\sum F=ma} a \xrightarrow{\text{SUVAT}} s, v, t$$

Example: if a trolley is pulled, first use dynamics to find  $a$ . Then use kinematics to find how far it travels or how fast it becomes.

## Energy Terms: Transfer Explanation

Energy explains motion by tracking stores and transfers. It is the “where did the motion energy come from or go?” view.

$$KE = \frac{1}{2}mv^2, \quad GPE = mgh, \quad W = Fs \cos \theta$$

$$W_{\text{net}} = \Delta KE$$

Term	Meaning	Link to motion
<b>Kinetic energy, <math>KE</math></b>	Energy due to motion.	Depends on speed: $KE = \frac{1}{2}mv^2$ .
<b>Gravitational potential energy, <math>GPE</math></b>	Energy due to height in a gravitational field.	Falling converts $GPE$ into $KE$ if no losses.
<b>Work done, <math>W</math></b>	Energy transferred by a force acting through a distance.	$W = Fs \cos \theta$ . Force over distance changes energy.
<b>Power, <math>P</math></b>	Rate of energy transfer.	$P = W/t$ or $P = E/t$ .
<b>Dissipated energy</b>	Energy transferred to surroundings, usually thermal/internal energy.	Often caused by friction or air resistance.
<b>Conservation of energy</b>	Energy is not created or destroyed.	It changes form or is transferred.

Use energy when time is not needed and the question talks about height, speed, work done, frictional loss, or energy conservation.

## The Most Important Equation Link

This is the bridge between the chapters.

Start with the kinematics equation:

$$v^2 = u^2 + 2as$$

Rearrange:

$$v^2 - u^2 = 2as$$

Multiply by  $\frac{1}{2}m$ :

$$\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = mas$$

From dynamics,  $F = ma$ , so  $mas = Fs$ :

$$Fs = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$$

Therefore:

$$W = \Delta KE$$

**Meaning:** work-energy is not random. It is force and motion rewritten with time removed. Instead of tracking acceleration over time, you track force over distance.

## Same Symbol, Different Role

Symbol	In kinematics	In dynamics	In energy
$a$	A motion variable used in SUVAT.	Caused by resultant force: $a = \sum F/m$ .	Usually hidden; energy methods often skip $a$ .
$v$	Final velocity.	Acceleration changes velocity.	Appears in $KE = \frac{1}{2}mv^2$ .
$s$	Displacement.	Direction chosen affects force signs.	Distance along force direction in $W = Fs \cos \theta$ .
$m$	Usually not needed.	Resistance to acceleration in $F = ma$ .	Appears in $KE$ and $GPE$ .
$f$	Not a SUVAT variable.	Friction is a force opposing motion.	Friction does negative work; energy is dissipated.

## Worked Example: Block Sliding Down a Rough Slope

Same block. Same motion. Three languages.

**Kinematics view:** describe motion using  $u, v, a, s, t$ .

$$v^2 = u^2 + 2as$$

This tells you speed after travelling a distance, if you know acceleration.

**Dynamics view:** draw forces: weight  $mg$ , normal force  $N$ , friction  $f$ . Resolve forces along the slope.

$$\sum F = ma$$

This finds the acceleration down the slope.

**Energy view:** gravitational potential energy decreases. Kinetic energy increases. Friction dissipates some energy.

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

This finds speed without needing time.

## How to Choose the Method

Question gives/asks about	Usually use	Why
Time, displacement, initial/final velocity, constant acceleration	Kinematics	SUVAT directly connects $s, u, v, a, t$ .
Forces, mass, tension, friction, normal force, acceleration	Dynamics	Forces determine acceleration through $\sum F = ma$ .
Height, speed, work done, energy loss, conservation of energy	Energy	Energy connects height, work, and speed without needing time.

**Common mistake:** choosing a formula because it looks familiar. Instead, ask: what does the question give me? Time suggests kinematics. Forces suggest dynamics. Height/work/energy loss suggests energy.

## One-Line Summary

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**Dynamics gives acceleration. Kinematics uses acceleration. Energy skips time by tracking work and energy transfer.**