

BELLTES ACADEMY

Mechanics Calculations Reference Guide

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Introduction to Mechanics

Mechanics is the branch of physical science dealing with the energy and forces that influence objects in motion or at rest. This reference guide outlines core equations, practical examples, and physical analogies to build intuitive problem-solving skills.

1. Kinematics (Equations of Motion)

Kinematics describes the motion of objects without looking at the underlying forces causing that motion. These calculations apply perfectly to uniform (constant) acceleration.

Velocity-Time Relation

$$v_f = v_i + a\Delta t$$

Variables: v_f = final velocity (m/s), v_i = initial velocity (m/s), a = acceleration (m/s^2), Δt = time elapsed (s).

Analogy: Think of a car joining a highway. Your final speedometer reading depends on your entry speed plus how hard and how long you pressed down on the gas pedal.

Example: A motorbike starts from rest ($v_i = 0 \text{ m/s}$) and accelerates at 4 m/s^2 for 5 seconds. Find its final velocity:

$$v_f = 0 + (4 \times 5) = \mathbf{20 \text{ m/s}}.$$

Displacement-Time Relation

$$\Delta x = v_i \Delta t + \frac{1}{2}a(\Delta t)^2$$

Variables: Δx = displacement (m).

Analogy: Imagine throwing a ball forward down a long hallway. The total distance it travels depends partly on how hard you threw it initially, combined with how much gravity or a booster accelerates it over time.

Example: A car travelling at 10 m/s accelerates steadily at 2 m/s^2 for 3 seconds. Find the distance covered:

$$\Delta x = (10 \times 3) + 0.5 \times 2 \times (3)^2 = 30 + 9 = \mathbf{39 \text{ meters}}.$$

2. Dynamics & Forces

Dynamics bridges the gap between the motion of an object and the forces acting upon it.

Newton's Second Law of Motion

$$F_{\text{net}} = m \cdot a$$

Variables: F_{net} = net force acting on the system (Newtons, N), m = mass (kg), a = acceleration (m/s^2).

Analogy: Pushing a heavy grocery cart vs. a light plastic laundry basket. To make them speed up at exactly the same rate, you have to push the heavy cart with significantly more muscle effort.

Example: A toy crate with a mass of 15 kg is pushed, causing it to accelerate at 3 m/s^2 . Calculate the net force applied:

$$F_{\text{net}} = 15 \text{ kg} \times 3 \text{ m/s}^2 = \mathbf{45 \text{ N}}.$$

Frictional Force

$$f_k = \mu_k \cdot N$$

Variables: f_k = kinetic friction force (N), μ_k = coefficient of kinetic friction (dimensionless constant), N = normal force (N).

Analogy: Dragging a heavy box across slick ice vs. a coarse concrete pavement. The rougher the microscopic interlocking ridges between surfaces, the higher the coefficient (μ_k), making it much harder to keep the box sliding.

Example: A wooden block exerts a normal force of 50 N on a table surface. If the friction coefficient μ_k is 0.3, find the dragging friction:

$$f_k = 0.3 \times 50 \text{ N} = \mathbf{15 \text{ N}}.$$

3. Momentum and Impulse

Momentum measures an object's resistance to stopping, describing its mass in motion.

Linear Momentum

$$p = m \cdot v$$

Variables: p = linear momentum ($\text{kg} \cdot \text{m/s}$), m = mass (kg), v = velocity (m/s).

Analogy: A slow-moving heavy train vs. a fast-moving bullet. Both are exceptionally hard to stop, one because of its immense, towering mass, and the other because of its extreme velocity.

Example: A rugby player weighing 90 kg runs down the field at a velocity of 6 m/s. Calculate his momentum:

$$p = 90 \text{ kg} \times 6 \text{ m/s} = \mathbf{540 \text{ kg}\cdot\text{m/s}}.$$

Impulse-Momentum Theorem

$$\mathbf{J = F_{net} \cdot \Delta t = \Delta p}$$

Variables: J = impulse (N·s or kg·m/s), Δp = change in momentum.

Analogy: Why cars have built-in crumple zones and soft airbags. By stretching out the duration of the crash impact (Δt), the dangerous net structural force (F_{net}) felt by the passengers drops dramatically.

Example: A soccer coach kicks a stationary ball, applying an average force of 200 N for exactly 0.05 seconds. Find the momentum transferred to the ball:

$$J = 200 \text{ N} \times 0.05 \text{ s} = \mathbf{10 \text{ kg}\cdot\text{m/s}}.$$