Cambridge AS & A Level · Mathematics 9709

Mathematics 9709 formulas and definitions: Mechanics

All 52 formulas, facts and definitions to learn, by syllabus topic. Formulas the exam gives you are left out.

Read online at **pastopic.com/cambridge/mathematics-9709/formulas**; each topic heading links to its full note.

© 2026 Pastopic. Free for personal study. Please share the link, not the file.

4 Mechanics

4.1 Forces and equilibrium

Weight $W = mg$, with $g = 10 \text{ m s}^{-2}$

Components of a force P at angle θ to a direction: $P\cos\theta$ along it, $P\sin\theta$ at right angles

On a slope at angle α: weight gives $mg\sin\alpha$ down the slope and $mg\cos\alpha$ into the slope

Resultant: $\sqrt{X^2 + Y^2}$ at angle $\tan^{-1}\dfrac{|Y|}{|X|}$ to the x-direction

Equilibrium: $\sum(\text{components}) = 0$ in each of two directions

Friction: $F \leqslant \mu R$; limiting friction $F = \mu R$

Limiting equilibrium on a slope with no other force along it: $\mu = \tan\alpha$

Newton's third law: action and reaction are equal in size and opposite in direction

$\tan\alpha = \frac{a}{b}$ gives $\sin\alpha = \dfrac{a}{\sqrt{a^2 + b^2}}$, $\cos\alpha = \dfrac{b}{\sqrt{a^2 + b^2}}$

4.2 Kinematics of motion in a straight line

$s = vt - \frac{1}{2}at^2$

The suvat formulae need **constant** acceleration

$v = \dfrac{ds}{dt}, \quad a = \dfrac{dv}{dt} = \dfrac{d^2s}{dt^2}$

$v = \displaystyle\int a\,dt, \quad s = \int v\,dt$ (find the constant each time)

Gradient of a displacement–time graph = velocity

Gradient of a velocity–time graph = acceleration; area under it = displacement

Greatest or least velocity: $a = 0$; instantaneous rest: $v = 0$

Average speed $= \dfrac{\text{total distance}}{\text{total time}}$

Free motion under gravity: $a = -g = -10$ m s^{-2} (upwards positive)

4.3 Momentum

Momentum $= mv$, in N s (or kg m s^{-1}); a vector, so its sign shows its direction

Conservation of momentum: $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

Coalescing: $m_1u_1 + m_2u_2 = (m_1 + m_2)v$

Kinetic energy $= \frac{1}{2}mv^2$, in J

KE lost in a collision $=$ total KE before $-$ total KE after

From momentum p and kinetic energy E: $u = \dfrac{2E}{p}$, $m = \dfrac{p}{u}$

Weight $= mg$, with $g = 10$ m s^{-2}

Newton's second law: resultant force $= ma$

Friction when sliding: $F = \mu R$ (on a horizontal floor $R = mg$, so the deceleration is μg)

Sliding freely on a smooth slope at angle α: acceleration $g \sin \alpha$ down the slope

Rough slope: $R = mg \cos \alpha$, $F = \mu R$; acceleration $g \sin \alpha - \mu g \cos \alpha$ sliding down, deceleration $g \sin \alpha + \mu g \cos \alpha$ sliding up

Total energy lost over a motion $=$ (PE $+$ KE at start) $-$ (PE $+$ KE at end) $=$ work against friction $+$ KE lost at impacts

Potential energy gained when rising h: mgh; falling h from rest on a smooth track gives $v^2 = 2gh$

Constant speed (no acceleration): distance $=$ speed $\times$ time

4.4 Newton’s laws of motion

Newton's second law: resultant force $= ma$

Weight $W = mg$, with $g = 10$ m s^{-2}

On a slope at angle α: weight gives $mg \sin \alpha$ down the slope and $mg \cos \alpha$ into it

Sliding friction: $F = \mu R$, against the direction of motion

Rough slope: $a = g \sin \alpha - \mu g \cos \alpha$ sliding down; $a = -(g \sin \alpha + \mu g \cos \alpha)$ sliding up, with no other force along it

Starts to slide or slides back only if $\mu < \tan \alpha$

Driving force $= \dfrac{P}{v}$, from power $P = Fv$

Constant speed (or greatest speed): resultant force $= 0$

Connected by a light inextensible string: same tension throughout, same size of acceleration
Newton's third law: equal and opposite forces on the two objects

4.5 Energy, work and power

Work done by a constant force: $W = Fd\cos\theta$, in J
Work done against a resistance F over a distance d: Fd
Kinetic energy: $\mathrm{KE} = \frac{1}{2}mv^2$
Gravitational potential energy: $\mathrm{PE} = mgh$ (h vertical); along a slope, $h = d\sin\alpha$
Work–energy: $\mathrm{KE}_1 + \mathrm{PE}_1 + \mathrm{WD\ by\ driving\ forces} = \mathrm{KE}_2 + \mathrm{PE}_2 + \mathrm{WD\ against\ resistances}$
Smooth, gravity only: $\mathrm{KE} + \mathrm{PE}$ is constant
Average power $= \dfrac{\text{work done}}{\text{time}}$; work done by an engine at constant power $= Pt$
$P = Fv$, so driving force $= \dfrac{P}{v}$
Vehicle uphill: $\dfrac{P}{v} - R - mg\sin\alpha = ma$; top speed when $a = 0$
Friction when sliding: $F = \mu R$