PHOTON ACADEMY

Topic A.1

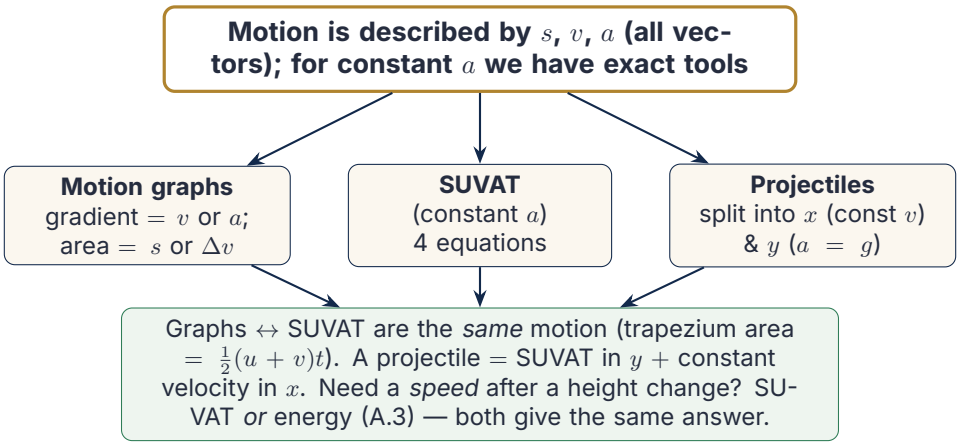
KINEMATICS

Every Formula, Trick & Trap on a Page
& IB-Style Quick Reference

Topics Covered	Exam Relevance
Scalars, Vectors & Motion Graphs	P1 & P2 (with & without GDC)
SUVAT — Uniform Acceleration	Foundation for all mechanics
Measuring Motion & Free-Fall	Free-fall g experiment (Paper 3)
Projectile Motion (2-D)	"Speed at apex" & cliff traps
Fluid Resistance & Terminal Velocity	Air resistance — qualitative

The Big Picture — How A.1 Fits Together

A.1 (SL/HL)



§1 — Scalars, Vectors & Definitions

A.1 (SL/HL)

Scalar quantities:
Distance, speed, time, mass, energy

Vector quantities:
Displacement, velocity, acceleration, force

Displacement: $\vec{s} = \vec{r}_f - \vec{r}_i$
Change in position (vector, can be −ve)

Distance: total path length (always ≥ 0)

Quantity	Definition	Instantaneous form
Velocity	$\bar{v} = \Delta s/\Delta t$	$v = ds/dt$ = gradient of s-t
Acceleration	$\bar{a} = \Delta v/\Delta t$	$a = dv/dt$ = gradient of v-t

TRICK Average speed $\neq |\bar{v}|$ if object reverses. Average speed = total distance ÷ time.

TRAP If an object reverses, |displacement| < distance. Do not confuse them in SUVAT.

§2 — SUVAT Equations (Uniform Acceleration)

A.1 (SL/HL)

$$v = u + at$$
$$s = \tfrac{1}{2}(u+v)t$$
$$s = ut + \tfrac{1}{2}at^2$$
$$v^2 = u^2 + 2as$$

s = displacement (m)
u = initial velocity (m/s)
v = final velocity (m/s)
a = acceleration (m/s^2)
t = time (s)

Variables:

Don't know	Use
s	$v = u + at$
v	$s = ut + \frac{1}{2}at^2$
u	$v^2 = u^2 + 2as$
a	$s = \frac{1}{2}(u+v)t$
t	$v^2 = u^2 + 2as$

TRAP SUVAT requires **constant** a. If a varies, use calculus or graph area.

TRICK For free fall upward positive: $a = -9.81\,\text{m/s}^2$. At max height $v = 0$ only momentarily.

TRICK **Displacement two ways:** area under the v–t line (trapezium $\frac{1}{2}(u+v)t$) = SUVAT $s = \frac{1}{2}(u+v)t$ — same number.

TRICK **Speed after a height change, two ways:** SUVAT $v^2 = u^2 + 2as$ *or* energy $\frac{1}{2}mv^2 = \frac{1}{2}mu^2 - mgs$. Identical (energy, A.3, is quickest when time doesn't matter).

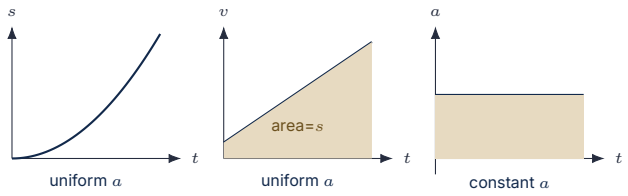
FROM THE PHOTON QUESTION BANK

List u, v, a, t, s with "?" for the unknown, then pick the equation *missing* the variable you don't want. SUVAT only for *constant* a; free-fall $a = g$ (mind the sign).

§3 — Motion Graphs

A.1 (SL/HL)

Graph	Gradient	Area under
s-t	v	—
v-t	a	s (displacement)
a-t	—	Δv



NOTE A curved s-t graph means non-uniform velocity. Tangent at a point gives instantaneous v.

TRICK To find displacement from v-t: count squares (estimate) or split into triangles + rectangles.

FROM THE PHOTON QUESTION BANK

Gradient of s–$t = v$, of v–$t = a$; area under v–t = displacement, under a–$t = \Delta v$. Average speed $\neq$ |average velocity| unless straight-line motion.

§4 — Projectile Motion (No Air Resistance)

A.1 (SL/HL)

Horizontal (constant v):

$v_x = u\cos\theta$

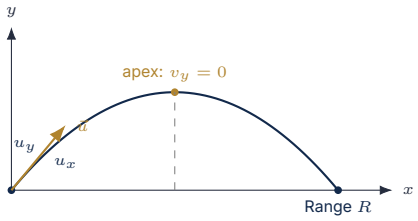
$x = u\cos\theta \cdot t$

Vertical (constant $a = g$ down):

$v_y = u\sin\theta - gt$

$y = u\sin\theta \cdot t - \frac{1}{2}gt^2$

Time to apex:	$t_{\text{apex}} = u\sin\theta/g$
Max height:	$H = u^2\sin^2\theta/(2g)$
Total flight time:	$T = 2u\sin\theta/g$
Range (same height):	$R = u^2\sin 2\theta/g$
Max range:	$\theta = 45°$; equal ranges for θ and $(90° - \theta)$



TRAP Do NOT use range formula if launch height $\neq$ landing height. Resolve into components instead.

TRICK At apex: $v_x = u\cos\theta$ (unchanged), $v_y = 0$. Speed at apex $= u\cos\theta$.

TRICK **Velocity two ways:** *solve* in components ($v_x = u\cos\theta$ constant, $v_y = u\sin\theta - gt$), then *quote* the resultant $v = \sqrt{v_x^2 + v_y^2}$ at angle $\tan\phi = v_y/v_x$.

TRAP The equation of trajectory is **NOT required** in IB — don't waste time deriving it in exams.

FROM THE PHOTON QUESTION BANK

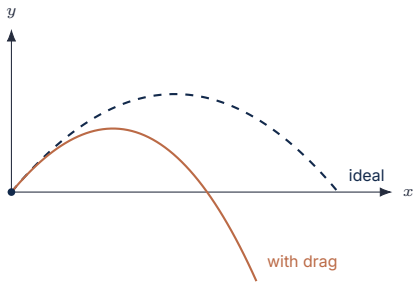
Decompose into independent components — the top-tested A1 skill: horizontal v constant, vertical $a = g$; time from the vertical, range from the horizontal. A dropped ball and a horizontally-fired ball land *together*.

§5 — Fluid Resistance Effects

A.1 (SL/HL)

With air resistance compared to ideal:
- Range **decreases**
- Max height **decreases**
- Time of flight **decreases**
- Trajectory **NOT symmetric** (steeper descent)
- Landing speed **less than** launch speed
- Drag opposes **velocity direction** (changes throughout flight)

Terminal speed: drag $= mg$; acceleration $= 0$.



NOTE IB only requires qualitative description. Do NOT apply SUVAT when air resistance is present.