# Simple Revision Notes

Physics II – Mechanics · Grade 12 first term (competency levels 2.1 – 2.5)

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# 1. Relative motion (parallel paths) (syllabus 2.1 · question bank section A)

**The idea**

Velocity of A relative to B: $\mathbf{v_{AB} = v_A - v_B}$ (choose one direction as positive). Same direction → subtract speeds; opposite → add. (Syllabus: parallel paths only.) Overtaking/passing time = total length to cover ÷ relative speed.

**Worked example**

Trains 100 m and 150 m, 20 and 30 m s⁻¹.
Opposite: 250/(20 + 30) = 5 s
Same direction: 250/(30 − 20) = 25 s; faster train covers 30 × 25 = 750 m over the ground.

**Common mistake**

Forgetting to convert km h⁻¹ to m s⁻¹ (÷ 3.6), and forgetting that passing 'completely' needs the sum of both lengths.

# 2. Graphs of motion (syllabus 2.1 · question bank section B)

**The idea**

s–t: gradient = velocity. v–t: gradient = acceleration; **area = displacement** (area below the axis is negative). Straight v–t line = uniform acceleration; s–t of uniform acceleration is a parabola.

**Worked example**

v: 0 → 20 m s⁻¹ in 10 s, steady 20 s, 0 in 8 s.
Area = 100 + 400 + 80 = 580 m
Average speed = 580/38 = 15.3 m s⁻¹

**Common mistake**

Distance vs displacement: for v from +10 to −10 m s⁻¹ in 4 s, displacement 0 but distance 20 m.

# 3. Equations of motion (line, vertical, incline) (syllabus 2.1 · question bank section C)

**The idea**

Constant acceleration: $v = u + at$, $s = \frac{1}{2}(u + v)t$, $s = ut + \frac{1}{2}at^2$, $v^2 = u^2 + 2as$. Vertical: $a = -g$ (up positive). Smooth incline: $a = g\sin\theta$ along the plane. Distance in the nth second: $s_n = u + a(n - \frac{1}{2})$.

**Worked example**

Stone thrown up at 15 m s⁻¹ from a 20 m tower.
$-20 = 15t - 5t^2 \rightarrow t^2 - 3t - 4 = 0$
t = 4 s (reject −1)
v = 15 − 40 = −25 m s⁻¹

**Common mistake**

An object released from a moving balloon/lift starts with the balloon's velocity, not from rest.

## 4. Projectile motion (syllabus 2.1 · question bank section D)

**The idea**

Split into horizontal (constant $u_x = u\cos\theta$) and vertical ($u_y = u\sin\theta$, $a = -g$). Time from the vertical motion; range from $x = u_x t$. $H = u^2\sin^2\theta/2g$, $T = 2u\sin\theta/g$, $R = u^2\sin2\theta/g$ (level ground). Max range at 45°; $\theta$ and $90° - \theta$ give the same range.

**Worked example**

Thrown horizontally at 20 m s$^{-1}$ from 45 m.
$45 = 5t^2 \rightarrow t = 3$ s; $x = 60$ m
$v_y = 30 \rightarrow v = \sqrt{(400 + 900)} = 36$ m s$^{-1}$, 56° below horizontal

**Common mistake**

At the top the velocity is $u\cos\theta$, not zero. Air resistance is ignored unless stated.

## 5. Resultant of forces (syllabus 2.2 · question bank section E)

**The idea**

Resultant = single force with the same effect. Two forces: parallelogram law $R^2 = P^2 + Q^2 + 2PQ\cos\theta$. Many forces: resolve and add components, or draw a polygon. Three forces in equilibrium form a closed triangle, so each must be ≤ the sum of the other two.

**Worked example**

Parallelogram-of-forces experiment: 6 N and 8 N strings at 90° hold W.
$W = \sqrt{(36 + 64)} = 10$ N
8 N string makes $\tan^{-1}(6/8) = 37°$ with the vertical.

**Common mistake**

Mixing up the resultant (same effect) with the equilibrant (equal and opposite to it).

## 6. Moments, couples and parallel forces (syllabus 2.2 · question bank section F)

**The idea**

Moment = F × **perpendicular** distance (N m). Couple: two equal, opposite, parallel forces – moment F × d about any point, zero resultant force, causes rotation only; balanced only by another couple. Two parallel like forces P, Q: resultant P + Q, acting where $Px = Q(d - x)$.

**Worked example**

20 N at 30° to a 0.5 m spanner:
perpendicular distance = $0.5\sin30° = 0.25$ m
moment = $20 \times 0.25 = 5$ N m

**Common mistake**

Using the distance along the spanner (giving 10 N m) instead of the perpendicular distance.

## 7. Centre of gravity and centre of mass (syllabus 2.2 · question bank section G)

**The idea**

Centre of gravity: point where the whole weight acts. $\bar{x} = \Sigma mx/\Sigma m$. Uniform rod: midpoint; triangle: medians meet (⅓ height); ring: centre (outside the material). Cut-outs: treat as negative mass. Irregular lamina: hang from two points with a plumb line – lines cross at G. Force through the centre of mass → translation only; otherwise also rotation. Internal forces cannot move the centre of mass.

**Worked example**

Disc radius R, hole radius R/2 centred R/2 from O.
Hole mass = ¼ of disc
$\frac{3}{4}\bar{x} = -\frac{1}{4}(R/2) \rightarrow \bar{x} = -R/6$ (away from the hole)

**Common mistake**

Forgetting that the cut part's mass is proportional to its **area** ($r^2$ for a circle).

## 8. Inertia and Newton's laws (syllabus 2.3 · question bank section H)

**The idea**

1st law: no net force → no change in velocity (inertia; mass measures inertia). Valid in inertial frames. 2nd law: $F = \Delta p/\Delta t \rightarrow F = ma$ (1 N gives 1 kg 1 m $s^{-2}$). 3rd law: forces in pairs, equal and opposite, on **different** bodies, same type. Always draw a free-body diagram for one body at a time.

**Worked example**

Lift moving down and slowing at 2 m $s^{-2}$ (acceleration is upward):
$R - mg = ma$
$R = 60(10 + 2) = 720$ N

**Common mistake**

Calling the normal reaction the 'reaction' to weight – the pair of the Earth's pull on a book is the book's pull on the Earth.

## 9. Momentum, impulse and conservation of momentum (syllabus 2.3 · question bank section I)

**The idea**

Momentum $p = mv$ (kg m $s^{-1}$ = N s). Impulse = $Ft = \Delta p$ = area under an F–t graph. Longer contact time → smaller force for the same Δp (catching, crumple zones, bending knees). With no external force, total momentum is conserved (collisions, explosions, recoil).

**Worked example**

Ball 0.2 kg, 10 m $s^{-1}$ in, 8 m $s^{-1}$ out, 0.05 s.
$\Delta p = 0.2(8 - (-10)) = 3.6$ N s
$F = 3.6/0.05 = 72$ N

**Common mistake**

Ignoring direction: a rebound changes momentum by m(v + u), not m(v − u).

## 10. Friction and self-adjusting forces (syllabus 2.3 · question bank section J)

**The idea**

Static friction is **self-adjusting**: equals the applied force up to the limit $F_{max} = \mu_s R$. Once sliding, $F = \mu_k R$ ($\mu_k < \mu_s$). Friction does not depend on contact area. On an incline about to slip: $\mu_s = \tan\theta$. Other self-adjusting forces: tension, thrust, normal reaction.

**Worked example**

5 kg box, $\mu_s = 0.40$, $\mu_k = 0.25$.

Push 15 N: limit 20 N → at rest, friction 15 N

Push 25 N: moves, friction 12.5 N, $a = 12.5/5 = 2.5$ m s$^{-2}$

**Common mistake**

Writing friction = μR when the body is not moving.

## 11. Applying Newton's laws: connected bodies (syllabus 2.3 · question bank section K)

**The idea**

Connected bodies: one string → same tension throughout (light string, smooth pulley) and same acceleration. Method: free-body diagram for each body, F = ma for each, solve together. Whole-system shortcut: a = (net external force)/(total mass).

**Worked example**

3 kg on rough table (μ 0.2), 2 kg hanging.

2 kg: $20 - T = 2a$; 3 kg: $T - 6 = 3a$

$14 = 5a$ → $a = 2.8$ m s$^{-2}$, $T = 14.4$ N

**Common mistake**

Using the whole system to find tension – tension is internal; use one body.

## 12. Equilibrium (syllabus 2.4 · question bank section L)

**The idea**

Equilibrium: ΣF = 0 and Σmoments = 0 about **any** point. Principle of moments: clockwise = anticlockwise. Three non-parallel forces in equilibrium are concurrent and form a closed triangle (triangle of forces); more → polygon. Stable / unstable / neutral; lower G and wider base → more stable; topples when the vertical through G leaves the base.

**Worked example**

Ladder 5 m, 200 N, foot 3 m out, smooth wall.

Moments about foot: $4S = 200 \times 1.5$ → $S = 75$ N

$R = 200$ N, $F = 75$ N, $\mu_{min} = 0.375$

**Common mistake**

Taking moments about a point where an unknown force acts is good – it removes that force. Forgetting the weight of the beam/ladder itself is the common error.

# 13. Work, energy and power (syllabus 2.5 · question bank section M)

**The idea**

Work $W = Fs\cos\theta$ (J). $KE = \frac{1}{2}mv^2$; $PE = mgh$; elastic $PE = \frac{1}{2}kx^2$. Work–energy principle: net work = $\Delta KE$. Conservation of mechanical energy when only gravity/springs do work; otherwise energy lost = work against friction. Power $P = W/t = Fv$; efficiency = useful output/input × 100 %.

**Worked example**

Car: 30 kW, top speed 30 m s$^{-1}$ → resistance = 30 000/30 = 1000 N.
At 20 m s$^{-1}$: F = 30 000/20 = 1500 N
a = (1500 − 1000)/1000 = 0.5 m s$^{-2}$

**Common mistake**

$KE = p^2/2m$: equal momenta → the lighter body has more KE.

# 14. Collisions and explosions (syllabus 2.5 · question bank section N)

**The idea**

Momentum is conserved in **every** collision/explosion (no external force). Elastic: KE also conserved. Inelastic: KE lost (heat, sound, deformation); perfectly inelastic: bodies stick. Explosions: KE is created from stored energy; total momentum stays the same (often zero).

**Worked example**

Bullet 0.02 kg at 300 m s$^{-1}$ into 1.98 kg block.
Momentum: 6 = 2.00v → v = 3.0 m s$^{-1}$
Then energy: $h = v^2/2g$ = 0.45 m
KE lost = 900 − 9 = 891 J

**Common mistake**

Using energy conservation across the impact. Momentum for the impact, energy afterwards.