Simple Revision Notes

Physics I – Measurement · Grade 12 first term (competency levels 1.1 – 1.5)

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1. Physics and the scientific method (syllabus 1.1 · question bank section A)

The idea

Physics studies energy, matter in relation to energy, and how energy changes form – from fundamental particles to the whole Universe. It drives technology in transport, communication, energy, medicine and space exploration.
Scientific method: **observe** → **question** → **hypothesis** → **experiment** → **analyse** → **conclude**. Variables: **independent** (you change it), **dependent** (you measure it), **controlled** (kept constant).

Worked example

Pendulum investigation.
Independent: length of string. Dependent: period.
Controlled: mass of bob, amplitude, location (g).
Conclusion only from repeated, recorded data.

Common mistake

Changing two variables at once – then you cannot tell which one caused the change.

2. Physical quantities and SI units (syllabus 1.2 · question bank section B)

The idea

7 base quantities and units: mass kg, length m, time s, current A, temperature K, luminous intensity cd, amount of substance mol. Supplementary: plane angle rad, solid angle sr. Everything else is derived (N = kg m s^{-2}, J = kg m^2 s^{-2}, W = kg m^2 s^{-3}, Pa = kg m^{-1} s^{-2}).
Prefixes: p 10^{-12}, n 10^{-9}, μ 10^{-6}, m 10^{-3}, c 10^{-2}, d 10^{-1}, k 10^{3}, M 10^{6}, G 10^{9}, T 10^{12}.
Rules: prefix with no space (mm); multiplied units with a space (N m). Some quantities have no unit (relative density, refractive index).

Worked example

Convert 13.6 g cm^{-3} to kg m^{-3}.
1 g = 10^{-3} kg, 1 cm^3 = 10^{-6} m^3
13.6 × 10^{-3} / 10^{-6} = 13.6 × 10^{3} = 1.36 × 10^{4} kg m^{-3}
Check: water 1 g cm^{-3} = 1000 kg m^{-3}, mercury is 13.6 times that ✓

Common mistake

Squared and cubed prefixes: 1 mm^2 = 10^{-6} m^2 (not 10^{-3}), 1 cm^3 = 10^{-6} m^3. Also '5 ms^{-1}' means 5 per millisecond – write 5 m s^{-1}.

3. Significant figures and scientific notation (syllabus 1.2 · question bank section C)

The idea

Significant figures: all non-zero digits; zeros between them; trailing zeros after a decimal point. Leading zeros are **not** significant.
× and ÷: answer has as many s.f. as the least precise value. + and −: answer has as many decimal places as the least precise value.
Scientific notation: a × 10^{n} with 1 ≤ a < 10.

Worked example

Area of 3.42 cm × 2.5 cm.
3.42 × 2.5 = 8.55
Least s.f. = 2 (from 2.5)
Answer 8.6 cm²

Common mistake

Dropping a meaningful trailing zero: 2.10 cm (vernier, 0.01 cm) is not the same as 2.1 cm.

4. Dimensions (syllabus 1.3 · question bank section D)

The idea

Write quantities in M, L, T: velocity LT^{-1}, acceleration LT^{-2}, force MLT^{-2}, momentum/impulse MLT^{-1}, work/energy/torque ML^2T^{-2}, power ML^2T^{-3}, pressure $ML^{-1}T^{-2}$, density ML^{-3}.
Uses: (1) check an equation – each term same dimensions; (2) find units of a constant; (3) derive a relation $y = k\,a^x\,b^y\,c^z$ by equating powers of M, L, T.
Limits: cannot find dimensionless constants or relations with added terms; angles and ratios have no dimensions.

Worked example

$T = k\,m^x\,l^y\,g^z$
$T^1 = M^x\,L^y\,(LT^{-2})^z$
M: $x = 0$; L: $y + z = 0$; T: $-2z = 1$
$z = -\frac{1}{2}$, $y = \frac{1}{2}$ → $T = k\sqrt{(l/g)}$
Check: $\sqrt{(m / m\,s^{-2})} = s$ ✓

Common mistake

Thinking 'dimensionally correct ⇒ correct'. Also: inside sin( ), exp( ) the argument must be dimensionless (so ω in sin ωt has unit s^{-1}).

5. Errors in measurement (syllabus 1.4 · question bank section E)

The idea

Systematic error: shifts every reading the same way (zero error, slow clock) – remove by correction, not averaging. **Random error**: readings scatter both ways – reduce by repeating and averaging.
Fractional error = least count ÷ reading; percentage = × 100 %. A larger reading with the same instrument gives a smaller percentage error.
Precise = readings close together; accurate = close to the true value.

Worked example

Timing 20 oscillations: 32.4 s (least count 0.2 s).
% error = 0.2/32.4 × 100 = 0.62 %
One oscillation 1.6 s: 0.2/1.6 × 100 = 12.5 %
So time many oscillations.

Common mistake

Comparing instruments by least count alone. Compare percentage errors: 50.0 cm on a metre rule (0.2 %) beats 3.00 cm on a vernier (0.33 %).

6. Metre ruler and choosing the right instrument (syllabus 1.4 · question bank section F)

The idea

Metre ruler: least count 1 mm; read with the eye perpendicular (no parallax); start from a clear mark if the end is worn.
Choosing: metre rule (> 10 cm), vernier caliper (1–15 cm; inner, outer, depth), micrometer (< 2.5 cm, thin wires, sheets), spherometer (curvature), travelling microscope (tiny lengths, no contact), electronic balance (small masses), stopwatch (time – many cycles).

Worked example

Thickness of one sheet of paper with a metre rule:
Measure a stack of 500 sheets = 4.8 cm
One sheet = 4.8/500 = 0.0096 cm = 0.096 mm
% error = 0.1/4.8 = 2.1 %

Common mistake

Choosing a vernier for a 0.3 mm wire – error 33 %. Use a micrometer (3 %).

7. Vernier caliper (syllabus 1.4 · question bank section G)

The idea

Least count = 1 MSD − 1 VSD. If n VSD = (n − 1) MSD: LC = MSD/n (e.g. 1 mm/20 = 0.05 mm). Extended vernier n VSD = (2n − 1) MSD: LC = 2 MSD − 1 VSD.
Reading = main scale reading just before vernier zero + (coinciding division × LC).
Zero error: vernier zero right of main zero → **positive** = +k × LC; left → **negative** = −(n − k) × LC.
Corrected = observed − zero error. Outer jaws: external sizes; inner jaws: internal diameter; depth bar: depth.

Worked example

n = 20, MSD = 1 mm, zero error: vernier zero left, 18th coincides.
LC = 1/20 = 0.05 mm
Zero error = −(20 − 18) × 0.05 = −0.10 mm
Reading 54 mm + 13 div = 54.65 mm
Corrected = 54.65 − (−0.10) = 54.75 mm

Common mistake

(1) Adding a positive zero error. (2) For a negative error using k × LC instead of (n − k) × LC. (3) In a **difference** of two readings (wall thickness = (D − d)/2) the zero error cancels.

8. Micrometer screw gauge (syllabus 1.4 · question bank section H)

The idea

Pitch = distance moved per full turn. **LC = pitch ÷ circular divisions** (0.5/50 = 0.01 mm).
Reading = sleeve reading (include the 0.5 mm mark if it is visible) + circular division on the reference line × LC.
Zero error: circular zero below the reference line → positive (+k × LC); above → negative (−(N − k) × LC). Use the ratchet for equal pressure; turn one way to avoid backlash; measure wires in two perpendicular directions at several places.

Worked example

Pitch 0.5 mm, 50 div. Sleeve shows 6.5 mm, circular 37, zero error +0.03 mm.
Observed = 6.5 + 37 × 0.01 = 6.87 mm
Corrected = 6.87 − 0.03 = 6.84 mm

Common mistake

Missing the half-millimetre mark: 5.5 + 0.02 = 5.52 mm, not 5.02 mm.

9. Spherometer (syllabus 1.4 · question bank section I)

The idea

Three fixed legs at the corners of an equilateral triangle (side l) and a central micrometer screw. h = reading on curved surface − reading on plane glass (convex) or the reverse (concave).
$R = l^2/6h + h/2$ (or $R = a^2/2h + h/2$ with $a = l/\sqrt{3}$, the centre-to-leg distance). Find l by pressing on paper and averaging the three sides. The central tip just touches when the instrument begins to rock / tip meets its image.

Worked example

Concave mirror: plane 2.36 mm, mirror 1.86 mm
h = 0.50 mm = 0.050 cm; l = 4.50 cm
$R = 20.25/(6 \times 0.050) + 0.025 = 67.5$ cm

Common mistake

Mixing units – put l and h both in cm. And remember $R \propto 1/h$, so a small error in h gives a big error in R.

10. Travelling microscope (syllabus 1.4 · question bank section J)

The idea

A microscope with cross-wires that slides on vertical and horizontal scales with verniers (LC often 0.01 mm). Used for small lengths without touching (capillary bore, rubber tube walls). Focus the eyepiece on the cross-wires first (no parallax); move in one direction only (no backlash); take horizontal and vertical diameters.

Worked example

Capillary: horizontal readings 3.452 and 3.506 cm → 0.054 cm; vertical 6.215 and 6.161 cm → 0.054 cm.
Mean diameter 0.054 cm; radius 0.027 cm.

Common mistake

Reversing the direction of the screw between two readings – backlash error.

11. Balances, stopwatches and the digital multimeter (syllabus 1.4 · question bank section K)

The idea

Balances measure **mass**. Triple/four beam: add the rider readings. Electronic: use 'tare' to zero with a container. Digital stopwatch reads 0.01 s but human reaction (~0.2 s) dominates → time many cycles. Digital multimeter: ammeter in series, voltmeter in parallel; choose a range above the expected value; resolution = place value of the last digit.

Worked example

Four-beam balance: 100 g + 20 g + 5 g + 0.6 g = 125.6 g.

Common mistake

Quoting a single hand-timed swing to 0.01 s – the digits are not meaningful.

12. Scalars and vectors (syllabus 1.5 · question bank section L)

The idea

Vector: magnitude + direction (displacement, velocity, force, momentum). Scalar: magnitude only (mass, time, energy, work).

Add tip-to-tail (triangle, polygon) or parallelogram: $\mathbf{R^2 = P^2 + Q^2 + 2PQ\cos\theta}$, $\tan\alpha = Q\sin\theta/(P + Q\cos\theta)$. Range $|P - Q| \le R \le P + Q$.

Resolve: $F_x = F\cos\theta$, $F_y = F\sin\theta$; add components, then $R = \sqrt{(\Sigma F_x^2 + \Sigma F_y^2)}$.

Worked example

4 N and 6 N at 60°.

$R^2 = 16 + 36 + 2(4)(6)(0.5) = 76 \rightarrow R = 8.7$ N

$\tan\alpha = 6(0.866)/(4 + 3) = 0.742 \rightarrow \alpha \approx 37°$ from the 4 N force.

Common mistake

A − B means A + (−B): reverse B before adding. $\Delta v = v_{final} - v_{initial}$, not the difference in speeds.