Physics Sensei – Study Guides

Master Physics from White Belt to Black Belt

Units, Conversions, and Dimensional Analysis – White to Black Belt Mastery

Intro Quote or Motto

"A measurement without units is like a punch without aim — it has no real meaning."

Key Concept (White Belt Level)

Units give meaning to numbers, conversions change units without changing value, and dimensional analysis checks if equations make physical sense. In this guide, report final answers to 3 significant figures (3SF).

Core Principles

1. SI base units: meter (m), kilogram (kg), second (s), ampere (A), kelvin (K), mole (mol), candela (cd).

2. Derived units (examples): newton (N = kg·m/s²), joule (J = N·m), watt (W = J/s), pascal (Pa = N/m²).

3. Prefixes: milli (m, 10^{-3}), micro (μ, 10^{-6}), kilo (k, 10^{3}), mega (M, 10^{6}), giga (G, 10^{9}).

4. Factor–label method: multiply by "conversion factors" equal to 1 so units cancel cleanly.

5. Dimensional analysis: both sides of every equation must match in dimensions (e.g., [M], [L], [T]).

Common Mistakes and Pitfalls

- Mixing unit systems without converting (e.g., m with km).
- Dropping units during steps; always carry them through and cancel visibly.
- Rounding too early—keep guard digits until the final result (then 3SF).
- Using formulas that are not dimensionally consistent.

Sensei's Shortcuts

- Write units on every line; let them guide each operation.
- Convert prefixes first (km → m) before other calculations.
- If dimensions don't match, fix the algebra before plugging numbers.
- Do a quick magnitude check: does the result look reasonable?

Worked Example – Step by Step (White Belt)

Problem

Convert 65.0 km/h to m/s, and convert 2.50 h to seconds. Show 3SF.

Solution

Speed: 65.0 km/h × (1000 m / 1 km) × (1 h / 3600 s) = 18.1 m/s.
Time: 2.50 h × (3600 s / 1 h) = 9.00×10^3 s.

Final Answer: 18.1 m/s; 9.00×10^3 s.

Practice Drill

A) Convert 3.60 km/min to m/s.
B) Convert 45.0 m/s to km/h.
C) Convert 3.50 g/cm³ to kg/m³.

Answers

A) 60.0 m/s
B) 162 km/h
C) 3.50×10^3 kg/m³

Yellow Belt Extension – Deeper Skills

Example: Dimensional check of $s = u\,t + 0.5\,a\,t^2$

$u\,t \Rightarrow (L \cdot T^{-1}) \cdot T = L$; $a\,t^2 \Rightarrow (L \cdot T^{-2}) \cdot T^2 = L$; sum gives L, matching s (length).

Example: Pendulum period depends on length L and gravity g.

Assume T ∝ L^α g^β. [T] = [L]^α [L·T^−2]^β = L^{α+β} T^{−2β}. Match exponents: −2β = 1 ⇒ β = −1/2; α + β = 0 ⇒ α = 1/2 ⇒ T ∝ √(L/g).

Black Belt Mastery – Exam Strategy and Challenge

Challenge

1) A cyclist rides at 27.8 m/s. Convert to mph.
2) A pressure reading is 1.02×10^5 Pa. Convert to kPa and to atm (1 atm = 1.013×10^5 Pa).
3) Someone claims power = force × distance. Use dimensions to accept or reject this.

Sensei Strategy Notes

- Chain factors for part 1 (m→km→mi, s→h).
- For part 2, Pa → kPa (÷1000) and compare to atm.
- Power should be force × velocity (check dimensions).

Sensei's Final Words

"Units are your stance, conversions your footwork, and dimensional analysis your guard. Master them, and every calculation lands clean."