

Checking units, uncertainties and vector components

Physics grades 11-12 (A Level · IB · Class 11-12) · Worksheet answers

Each answer shows the formula, the substitution and the result in bold. Intermediate values are rounded only at the end, so a small difference in the last digit is acceptable. Compare your method as well as your numbers.

Level: Physics grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** A Level 1, IB A

Problem 1 Base units

1. $F = ma$, so $N = \text{kg} \times \text{m s}^{-2} = \mathbf{kg\ m\ s^{-2}}$.
2. $J = N\ m = \text{kg m s}^{-2} \times \text{m} = \mathbf{kg\ m^2\ s^{-2}}$.
3. $W = J\ s^{-1} = \text{kg m}^2 \text{s}^{-2} \times \text{s}^{-1} = \mathbf{kg\ m^2\ s^{-3}}$.

Problem 2 Prefix conversions

1. $4.5\ \text{mm} = 4.5 \times 10^{-3}\ \text{m} = \mathbf{0.0045\ m}$.
2. $72 \div 3.6 = \mathbf{20\ m/s}$.
3. $0.25\ \text{g/cm}^3 = 0.25 \times 1000\ \text{kg/m}^3 = \mathbf{250\ kg/m^3}$.
4. $1.2\ \text{GW} = \mathbf{1.2 \times 10^9\ W}$.

Problem 3 Scalar or vector

1. Scalar. 2. Vector. 3. Scalar. 4. Vector. 5. Scalar. **Speed, kinetic energy and time are scalars; displacement and force are vectors.**

Problem 4 Percentage of one reading

1. $0.1 \div 24.3 \times 100 = \mathbf{0.41\ \%}$.
2. $0.2 \div 1.6 \times 100 = \mathbf{12.5\ \%}$, so about 13 %.

Problem 5 Components of a pull

1. $F_x = 120 \cos 40^\circ = 120 \times 0.766 = \mathbf{91.9\ N}$.
2. $F_y = 120 \sin 40^\circ = 120 \times 0.643 = \mathbf{77.1\ N}$.

Problem 6 Spot the wrong equation

1. v and u are in m s^{-1} . $a\ t^2$ is $(\text{m s}^{-2})(\text{s}^2) = \text{m}$.
2. A term in m cannot be added to terms in m s^{-1} , so the equation is not homogeneous. **It is**

dimensionally wrong (the correct term is at).

Problem 7 Check $v^2 = u^2 + 2as$

1. v^2 and u^2 : $(\text{m s}^{-1})^2 = \text{m}^2 \text{s}^{-2}$. $2as$: $(\text{m s}^{-2})(\text{m}) = \text{m}^2 \text{s}^{-2}$.
2. All three terms match, so the equation is **homogeneous**.

Problem 8 Unit of a drag constant

1. $k = F \div v^2$.
2. Units: $\text{kg m s}^{-2} \div \text{m}^2 \text{s}^{-2} = \mathbf{kg\ m^{-1}}$.

Problem 9 Sum and difference

1. $15.2 + 8.7 = 23.9$ cm; uncertainty $0.1 + 0.1 = 0.2$ cm: **23.9 ± 0.2 cm**.
2. $15.2 - 8.7 = 6.5$ cm, uncertainty again 0.2 cm: **6.5 ± 0.2 cm**.
3. Sum: $0.2 \div 23.9 = 0.84\%$. Difference: $0.2 \div 6.5 = 3.1\%$. **The difference has the larger percentage uncertainty.**

Problem 10 Area of a garden

1. $0.5 \div 45.0 = 1.11\%$ and $0.5 \div 30.0 = 1.67\%$.
2. Area = $45.0 \times 30.0 = 1350$ m². Percentage uncertainty = $1.11 + 1.67 = 2.78\%$, so $0.0278 \times 1350 = 37.5$ m². **Area = 1350 ± 40 m²**.

Problem 11 Speed with uncertainty

1. $v = 100.0 \div 12.5 = 8.00$ m/s.
2. $0.5 \div 100.0 = 0.50\%$ and $0.1 \div 12.5 = 0.80\%$, total **1.3%** .
3. $0.013 \times 8.00 = 0.104$ m/s, so **$v = 8.0 \pm 0.1$ m/s**.

Problem 12 Volume of a sphere

1. $V = (4/3) \times \pi \times 2.50^3 = 4.189 \times 15.625 = \mathbf{65.4\ cm^3}$.
2. $0.05 \div 2.50 = \mathbf{2.0\%}$.
3. Power of 3: $3 \times 2.0 = 6.0\%$. $0.060 \times 65.4 = 3.9$ cm³. **$V = 65 \pm 4$ cm³**.

Problem 13 Perpendicular forces

1. $R = \sqrt{(8.0^2 + 6.0^2)} = \sqrt{100} = \mathbf{10.0\ N}$.
2. $\tan \theta = 6.0 \div 8.0 = 0.750$, so $\theta = \mathbf{36.9^\circ}$ from the 8.0 N force.

Problem 14 Suitcase handle

1. $55 \cos 28^\circ = 55 \times 0.883 = \mathbf{48.6\ N}$.

- $2. 55 \sin 28^\circ = 55 \times 0.469 = \mathbf{25.8 \text{ N}}$.
- The upward component of 25.8 N **lifts the suitcase slightly and reduces the push on the floor**.

Problem 15 Repeated timings

- Sum = 11.60 s, mean = $11.60 \div 5 = \mathbf{2.32 \text{ s}}$.
- Range = $2.35 - 2.29 = 0.06 \text{ s}$, so uncertainty = $\pm \mathbf{0.03 \text{ s}}$.
- $0.03 \div 2.32 = \mathbf{1.3 \%}$.

Problem 16 Finding g with a pendulum

- $g = 39.48 \times 0.840 \div 1.84^2 = 33.16 \div 3.386 = \mathbf{9.79 \text{ m/s}^2}$.
- L: $0.002 \div 0.840 = 0.24 \%$. T: $0.02 \div 1.84 = 1.09 \%$.
- T is squared, so $2 \times 1.09 = 2.17 \%$. Total = $0.24 + 2.17 = 2.41 \%$, and $0.0241 \times 9.79 = 0.24 \text{ m/s}^2$.
- $\mathbf{g = 9.8 \pm 0.2 \text{ m/s}^2}$.

Problem 17 Gradient uncertainty

- Best: $42 \div 10.0 = 4.2 \text{ m/s}$. Steepest: $(47 - 0.5) \div 10.0 = 4.65 \text{ m/s}$. Shallowest: $(38 + 0.5) \div 10.0 = 3.85 \text{ m/s}$.
- Uncertainty = $(4.65 - 3.85) \div 2 = \mathbf{0.40 \text{ m/s}}$.
- speed = $4.2 \pm 0.4 \text{ m/s}$** .

Problem 18 Two tugs on a barge

- $500 + 350 \cos 60^\circ = 500 + 175 = \mathbf{675 \text{ N}}$.
- $350 \sin 60^\circ = \mathbf{303 \text{ N}}$.
- $R = \sqrt{(675^2 + 303^2)} = \sqrt{(455\,625 + 91\,875)} = \sqrt{547\,500} = \mathbf{740 \text{ N}}$.
- $\tan \theta = 303 \div 675 = 0.449$, so $\theta = \mathbf{24.2^\circ \text{ north of east}}$.

Problem 19 Dimensional analysis

- F: kg m s^{-2} . m: kg. v: m s^{-1} . r: m.
- kg: $1 = a$. s: $-2 = -b$. m: $1 = b + c$.
- $a = 1$, $b = 2$, $c = 1 - 2 = -1$, so $\mathbf{F = k m v^2 \div r}$. Dimensions cannot give k itself.

Problem 20 Crossing a river

- $t = 90 \div 3.0 = \mathbf{30 \text{ s}}$.
- Drift = $1.2 \times 30 = \mathbf{36 \text{ m}}$.
- $v = \sqrt{(3.0^2 + 1.2^2)} = \sqrt{10.44} = \mathbf{3.2 \text{ m/s}}$.
- $\tan \theta = 1.2 \div 3.0 = 0.40$, so $\theta = \mathbf{21.8^\circ \text{ downstream}}$.