Unit 1 · Physical Quantities

ANSWER KEY · FOR TEACHERS

Full marks 35

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Key words

K · 4

1. physical quantity
2. fundamental
3. derived
4. mole
5. candela
6. accuracy
7. precision
8. homogeneity

Each carries 0.5 mark.

2 True or false

U · 3

i. ✓ **True**

ii. ✗ **False**: A light year is a unit of distance, the distance light travels in one year: its dimensions are [L].

iii. ✗ **False**: Both are [M L T^{-1}]: impulse is force × time, which equals a change in momentum.

iv. ✓ **True**

v. ✗ **False**: A steady error like this spoils the accuracy of every reading by the same amount; averaging can't reveal or remove it.

vi. ✓ **True**

Each carries 0.5 mark.

3 Multiple choice

i. **b.** [M L^{-1} T^{-2}] — K · 1

Pressure = force ÷ area = [M L T^{-2}] ÷ [L^2] = [M L^{-1} T^{-2}].

ii. **b.** work and torque — U · 1

Work = force × displacement and torque = force × perpendicular distance: both [M L^2 T^{-2}].

iii. **b.** 6.44 — A · 1

The first digit dropped is exactly 5 (only a zero after it), so the digit before it goes up because it is odd: 3 → 4.

iv. **c.** 3.1 m^2 — A · 1

2.5 × 1.25 = 3.125 m^2. In a product, keep the fewest significant figures of the inputs: two (2.5), so 3.1 m^2.

v. **c.** 2% — A · 1

$A = \pi r^2$, so $\Delta A/A = 2\,\Delta r/r = 2 \times 1\% = 2\%$ (π is exact).

4 Short answers

a. MARKING SCHEME — U · 2

✓ Prapti's 5.2 g is right.

✓ The balance reads to 0.1 g; 5.20 g claims a precision (0.01 g) it can't give.

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b. MARKING SCHEME K · 2

- ✓ Any one, e.g. it can't give the value of a dimensionless constant (the 2π in a pendulum's period).
- ✓ Any second, e.g. it can't derive a relation with sin, log or exponential functions; it can't tell a scalar from a vector; it can't tell two quantities with the same dimensions apart; it can't handle more than three quantities in mechanics, or a sum of terms.

c. MARKING SCHEME U · 2

- ✓ A constant of nature doesn't change, while an object can (gain or lose mass, be damaged).
- ✓ Any laboratory anywhere can realize the unit from the constant; the object is in one place only.

d. MARKING SCHEME A · 3

- ✓ The conversion formula with the powers −1, 3 and −2.
- ✓ 1 kg = 1000 g and 1 m = 100 cm put in.
- ✓ G = 6.67×10^{-8} dyn cm^2 g^{-2}.

5 Long answer

ANSWER A · 4

Let $v = k\,\lambda^a\,\rho^b g^c$, with k a pure number.
$[LT^{-1}] = [L]^a\,[ML^{-3}]^b\,[LT^{-2}]^c = [M^b L^{a-3b+c} T^{-2c}]$
M: b = 0. T: $-2c = -1$, so c = ½. L: a − 3b + c = 1, so a = ½.
So $v = k\sqrt{g\lambda}$: longer waves travel faster.
Since b = 0, the speed doesn't depend on the density: waves of the same wavelength on a denser liquid travel at the same speed.

MARKING SCHEME

- ✓ Assumes v = k λ^a ρ^b g^c and writes the dimensions of each.
- ✓ Equates the powers of M, L and T.
- ✓ Solves: a = ½, b = 0, c = ½, so v = k$\sqrt{(g\lambda)}$.
- ✓ The density doesn't matter (b = 0): the same speed on a denser liquid.

6 Numerical problems

a. ANSWER A · 4

V = 2.00 × 2.50 × 2.00 = 10.0 cm^3, so ρ = 25.0 ÷ 10.0 = 2.50 g/cm^3.
Relative uncertainties add for a product and a quotient:
$\frac{\Delta\rho}{\rho} = \frac{0.1}{25.0} + \frac{0.01}{2.00} + \frac{0.01}{2.50} + \frac{0.01}{2.00} = 0.004 + 0.005 + 0.004 + 0.005 = 0.018$, that is **1.8%**.
$\Delta\rho = 0.018 \times 2.50 = 0.045$ g/cm^3, so ρ = **(2.50 ± 0.05) g/cm^3**.

MARKING SCHEME

- ✓ V = 10.0 cm^3 and ρ = 2.50 g/cm^3.
- ✓ Relative uncertainties added (mass and all three sides).
- ✓ 0.018, or 1.8%.
- ✓ ρ = (2.50 ± 0.05) g/cm^3.

b. ANSWER A · 3

T = 36.4 ÷ 20 = 1.82 s; ΔT = 0.2 ÷ 20 = 0.01 s. So T = **(1.82 ± 0.01) s**.
One swing: 0.2 s in about 1.82 s, 0.2 ÷ 1.82 ≈ **11%**, against 0.01 ÷ 1.82 ≈ 0.5% for twenty.

MARKING SCHEME

- ✓ T = 1.82 s.
- ✓ ΔT = 0.2 ÷ 20 = 0.01 s.
- ✓ About 11% for a single swing.

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7 Think

ANSWER HA · 3

No. A pound-force second and a newton second are both units of impulse, [M L T^{-1}]: the same dimensions. Every equation was dimensionally correct; only the numbers were 4.45 times too small. Dimensions can tell one kind of quantity from another, but not one unit of the same quantity from another, so only checking the units themselves would have caught it.

MARKING SCHEME

- ✓ No, it would not have been caught.
- ✓ Both units are units of impulse, with the same dimensions [M L T^{-1}].
- ✓ Dimensions can't tell two units of the same quantity apart; only the number (by 4.45 times) was wrong.

8 Activity: The thickness of a coin

(not marked)

WHAT STUDENTS SHOULD FIND

Each height is read to about 0.5 mm, whatever the stack, so the uncertainty in one coin is 0.5 mm divided by the number of coins: ± 0.5, 0.1, 0.05 and 0.025 mm. A single coin, about 1.5 mm thick, is uncertain by a third; the stack of 20 pins one coin down to a few hundredths of a millimeter. The 20-coin stack is the most precise, as with the pages of a book or the twenty swings of a pendulum.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	7	8	17	3	**35**

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