1.1 Quantities, units and measurement

Name: _____ Class: _____ Date: _____ **Total: 21 marks**

KEY WORDS charge • current • voltage • power • energy • passive sign convention • ammeter • voltmeter

Objective

Use the six electrical quantities with correct units and SI prefixes, apply the passive sign convention to decide who supplies and who absorbs, and describe how real meters are connected and what they can get wrong.

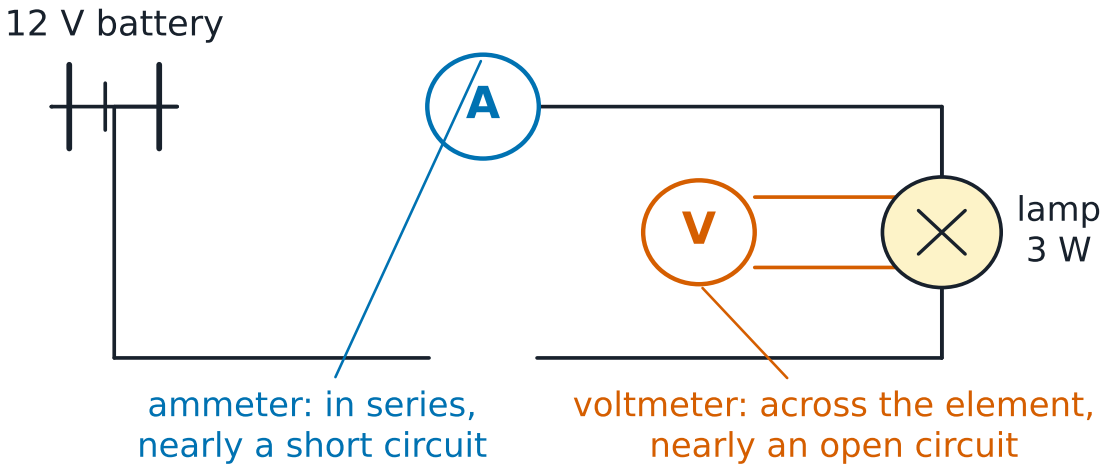
1 Key knowledge and worked examples

■ Six quantities as one chain

- **Charge** (coulombs, C) moves; its rate is **current** (amperes, A, with 1 A = 1 C/s). **Voltage** (volts, V) is energy per unit charge, always measured between two points, and **power** (watts, W) is energy per unit time (1 W = 1 J/s).
- **Energy** (joules, J) is power integrated over time. Electricity is sold in **kilowatt-hours**: 1 kW · h = 3.6 MJ.

$$q = \int i\,dt \qquad w = \int p\,dt$$

Where each meter goes



■ **Worked example: the sign convention settles supply and demand**

Pick a current direction through each element. If the arrow enters the `+` terminal, `p = vi` is the power **absorbed**.

A 12 V battery drives a lamp drawing 0.25 A. Lamp: $p = 12 \times 0.25 = 3W$ absorbed. Battery, same arrow drawn: the arrow enters its `-` terminal, so it absorbs `-3 W` – it supplies exactly what the lamp takes. Over 2 minutes the lamp takes $w = pt = 3 \times 120 = 360J$.

A negative absorbed power is a supplier; nothing more is needed to tell them apart.

■ **Worked example: prefixes and a real energy budget**

A phone battery is rated 3.7 V and 3000 mA · h. The stored charge is $3000mA \cdot h = 3A \times 3600s = 10800C$; energy is $3.7V \times 3A \cdot h = 11.1W \cdot h = 11.1 \times 3600 \approx 4.0 \times 10^4 J$. An 18 W fast charger, ideally, refills it in $11.1/18 \approx 0.62h$ – about 37 minutes.

An **ammeter** is wired in series and must be nearly a short circuit; a **voltmeter** sits across the element and must be nearly an open circuit. A multimeter set to amps and placed across a battery is a mistake: its low resistance makes a near short, and the large current can damage the meter, the battery or both.

2 Practice

2.1 A torch lamp carries 0.5 A for 40 s. Calculate the charge that passed, and the number of elementary charges it represents (use e = 1.6×10^{-19} C). [3]

2.2 A 2.2 kW kettle runs for 3 minutes. Calculate the energy in J and in kW · h, and state what a 13 A plug rating implies about its current relative to the plug. [4]

2.3 An element has its current arrow entering the + terminal. The measurements are $v = 5V$ and $i = -2A$. Calculate the absorbed power, state whether the element supplies or absorbs, and give the magnitude of its energy transfer in 10 s. [3]

3 Exam-style questions

3.1 A power bank is labelled 3.7 V and 20 000 mA · h. Convert the rating to amp-hours, then calculate the stored energy in W · h and in joules. The bank drives a 10 W tablet charger at 90% conversion efficiency; estimate the full-discharge time in hours, stating one assumption your estimate makes. [6]

3.2 A student wants the current in a resistor and connects the multimeter (set to amps) in parallel with it, across a 9 V supply of internal resistance 0.5 Ω. The meter's amps range behaves like a 0.1 Ω resistor.

Explain, with a calculation, why this wiring is dangerous rather than merely wrong, and state the two correct placements for measuring the resistor's current and its voltage. [5]