9.2 Potential difference and electrical power

Name: _____ Class: _____ Date: _____ **Total: 25 marks**

KEY WORDS potential difference • power • energy • charge • resistance

Objective

Answer exam questions on **potential difference** and **electrical power** : p.d. as energy transferred per unit charge, and the three power equations with the energy transferred in a time. Syllabus 9.2, learning outcomes 1 to 3.

You must be able to:

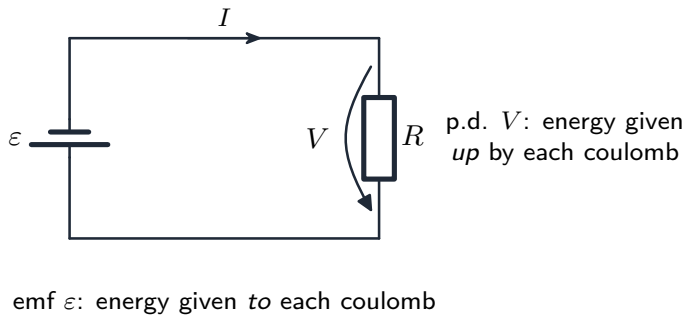
- define potential difference and the volt, and use $V = \frac{W}{Q}$
- use $P = VI$, $P = I^2R$ and $P = \frac{V^2}{R}$, choosing the form that fits the data
- find the energy transferred, $W = Pt = VIt$
- compare the power in components on the same supply or carrying the same current

1 Key knowledge and worked examples

■ **Key knowledge: potential difference and power**

Idea	Rule
potential difference (1 mark)	the energy transferred (from electrical to other forms) **per unit charge** passing through a component, $V = \frac{W}{Q}$
the volt	one joule per coulomb: 1 V = 1 J C^{-1}
power	$P = VI = I^2R = \frac{V^2}{R}$, from $P = \frac{W}{t}$ and $W = VQ = VIt$
energy in a time	$W = Pt = VIt$

The same...	Use	So
p.d. (components in parallel, or one supply)	$P = \frac{V^2}{R}$	the **smaller** resistance takes **more** power
current (components in series)	$P = I^2R$	the **larger** resistance takes **more** power



Worked example: energy per charge

A charge of 15 C passes through a lamp, and 180 J is transferred to thermal energy and light.

1. **P.d.** – W and Q are known, and p.d. is the energy transferred per unit charge, $V = \frac{W}{Q}$:

$$V = \frac{W}{Q} = \frac{180 \text{ J}}{15 \text{ C}} = 12 \text{ V}$$

Worked example: a kettle

A kettle is marked "2.4 kW, 240 V": $P = 2400$ W at $V = 240$ V.

1. **Current** – P and V are known, so use $P = VI$ and rearrange for I:

$$I = \frac{P}{V} = \frac{2400 \text{ W}}{240 \text{ V}} = 10 \text{ A}$$

2. **Resistance** – again P and V are known, so use $P = \frac{V^2}{R}$ and rearrange for R:

$$R = \frac{V^2}{P} = \frac{(240 \text{ V})^2}{2400 \text{ W}} = 24\ \Omega$$

3. **Energy in 3.0 minutes** – $t = 180$ s; power is energy per unit time, so $W = Pt$:

$$W = Pt = 2400 \text{ W} \times 180 \text{ s} = 4.3 \times 10^5 \text{ J}$$

■ **Worked example: which resistor takes more power?**

A 10 Ω and a 20 Ω resistor are used first in parallel across 12 V, then in series with a current of 0.40 A.

1. **In parallel** – both have the same p.d., $V = 12$ V, so use $P = \dfrac{V^2}{R}$ for each; the **smaller** resistance takes more:

$$P_{10\,\Omega} = \frac{V^2}{R} = \frac{(12\text{ V})^2}{10\ \Omega} = 14.4\text{ W}$$

$$P_{20\,\Omega} = \frac{V^2}{R} = \frac{(12\text{ V})^2}{20\ \Omega} = 7.2\text{ W}$$

2. **In series** – both carry the same current, $I = 0.40$ A, so use $P = I^2R$ for each; the **larger** resistance takes more:

$$P_{10\,\Omega} = I^2R = (0.40\text{ A})^2 \times 10\ \Omega = 1.6\text{ W}$$

$$P_{20\,\Omega} = I^2R = (0.40\text{ A})^2 \times 20\ \Omega = 3.2\text{ W}$$

■ **Worked example: losses in a cable**

A cable of resistance 0.50 Ω carries 20 A to a heater.

1. **Power lost in the cable** – the current is known and the p.d. across the cable is not, so use $P = I^2R$:

$$P = I^2R = (20\text{ A})^2 \times 0.50\ \Omega = 200\text{ W}$$

2. **Halving the current** – R does not change, and $P = I^2R$, so $P \propto I^2$:

$$P_{\text{new}} = \left(\tfrac{1}{2}\right)^2 P = \tfrac{1}{4} \times 200\text{ W} = 50\text{ W}$$

2 Practice

Now apply the methods above.

2.1 Define **potential difference**. [1]

potential difference

2.2 A p.d. of 6.0 V is across a resistor. Calculate the energy transferred when 25 C passes through it. [2]

2.3 A 12 V supply drives a current of 2.0 A through a motor. Calculate the power supplied to the motor. [1]

12 V

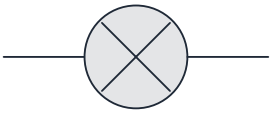
2.0 A

2.4 A heater of resistance 48 Ω is connected to a 240 V supply. Calculate its power. [2]

48 Ω

240 V

2.5 A 60 W lamp runs for 5.0 minutes. Calculate the energy transferred. [2]



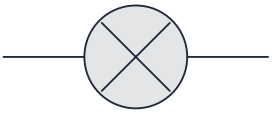
60 W

5.0 min

3 Exam-style questions

3.1 A lamp has a p.d. of 240 V across it and a current of 0.50 A in it. What is its power? [1]

☐ **A** 0.50 W
B 120 W
C 240 W
D 480 W



240 V

0.50 A

3.2 Two resistors, R and $3R$, are connected in series to a supply. What is $\frac{\text{power in } 3R}{\text{power in } R}$? [1]

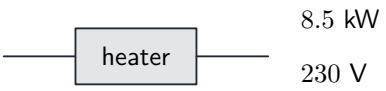
☐ **A** $\frac{1}{9}$
B $\frac{1}{3}$
C 3
D 9

$3R$

3.3 An electric shower is rated at 8.5 kW on a 230 V supply.

(a) **Define** the volt. [1]

(b) Calculate the current in the shower. [2]



8.5 kW

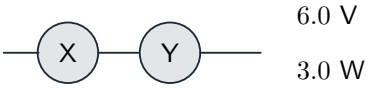
230 V

(c) Calculate the resistance of its heating element. [2]

(d) Calculate the charge that passes through the element in a 6.0-minute shower, and the energy transferred. [3]

3.4 A student compares two lamps. Lamp X is marked "6.0 V, 3.0 W" and lamp Y "6.0 V, 12 W".

(a) Calculate the resistance of each lamp at its rated p.d. [2]



(b) The lamps are connected in series to a supply so that the current is 0.25 A. Assume the resistances do not change. Calculate the power in each lamp, and state which is brighter. [3]

(c) Explain why the answer to (b) is the reverse of what happens when both lamps are connected in parallel to a 6.0 V supply. [2]