

Exercise walk-through

9.2

Potential difference and power

A-Level Physics

Sheet 9.2 – what you need to know

You must be able to:

- define **potential difference** and the volt, and use $V = \frac{W}{Q}$
- use $P = VI$, $P = I^2R$ and $P = \frac{V^2}{R}$, whichever fits the data
- find the energy transferred, $W = Pt = VIt$
- compare the power in components in series and in parallel

What the exam asks

“Define electric potential difference across a component.”

[1]

“State and explain which resistor dissipates more power.” **[3]**

Practise on exercise sheet 9.2, then try the real exam questions on past-paper sheet 9.2.

Potential difference and e.m.f.

Voltage is energy transferred per unit charge, measured in **volts** :

$$V = \frac{W}{Q}, \quad [V] = V = \text{J C}^{-1}.$$

e.m.f.

energy given **to** the charge
by the source

p.d.

energy given **up** to a component

Electrical power

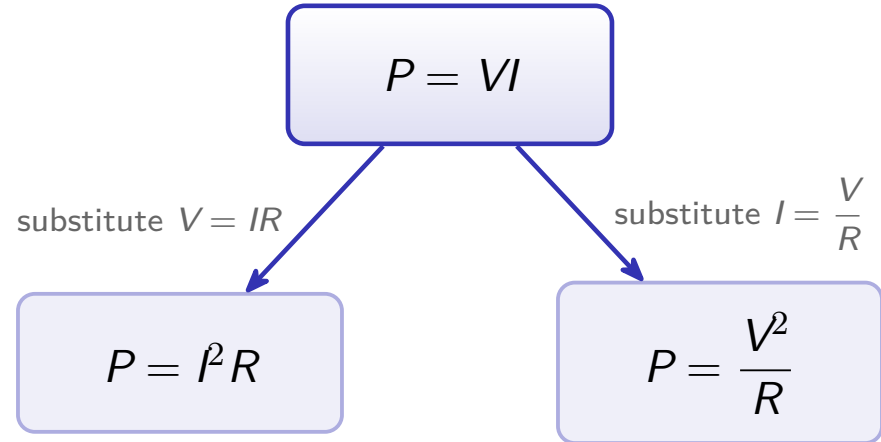
$$P = VI = I^2 R = \frac{V^2}{R}.$$

Pick the form for the quantities you know.

Kettle “2.4 kW, 240 V”

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

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



Which resistor takes more power?

In parallel across 12 V: the same p.d.

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

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

Same V : the **smaller** resistance takes more.

In series at 0.40 A: the same current

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

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

Same I : the **larger** resistance takes more.

Two words the definitions turn on

E.m.f.

The **electromotive force** (e.m.f.) of a source is the energy given **per unit charge by the source**; potential difference is the energy *delivered* per unit charge to a component.

Potential divider

Put a thermistor or LDR in a **potential divider** and the output voltage changes with temperature or light – the standard sensing circuit.

In parallel

Two resistors in **parallel** across the same **voltage** : the *smaller* resistance takes more power, since $P = V^2 / R$.

E.m.f. and p.d. share a unit and a symbol but not a meaning. Say “per unit charge” in both definitions, and name which way the energy goes.

Exercises 2.1·2.2

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]



Exercises 2.1·2.2

2.1 Define **potential difference**.

[1]

potential difference

2.1

- the energy transferred per unit charge passing through a component
-

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

[2]



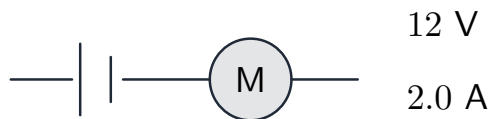
2.2

- $V = 6.0 \text{ V}$ and $Q = 25 \text{ C}$ are known; from $V = \frac{W}{Q}$, rearrange for W

$$W = VQ = 6.0 \text{ V} \times 25 \text{ C} = \mathbf{150 \text{ J}}$$

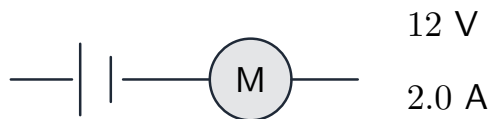
Exercise 2.3

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



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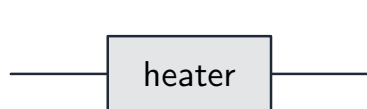
2.3

- V and I are known, so use $P = VI$

$$P = VI = 12 \text{ V} \times 2.0 \text{ A} = \mathbf{24 \text{ W}}$$

Exercise 2.4

2.4 A heater of resistance $48\ \Omega$ is connected to a $240\ \text{V}$ supply. Calculate its power. [2]

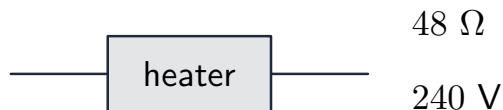


$48\ \Omega$

$240\ \text{V}$

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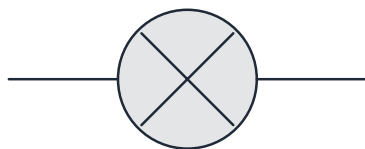
2.4

- $V = 240\ \text{V}$ and $R = 48\ \Omega$ are known and I is not, so use $P = \frac{V^2}{R}$

$$P = \frac{V^2}{R} = \frac{(240\ \text{V})^2}{48\ \Omega} = \mathbf{1200\ \text{W}}$$

Exercise 2.5

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

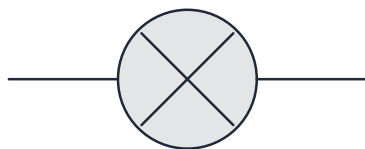


60 W

5.0 min

Exercise 2.5

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



60 W

5.0 min

2.5

- $P = 60 \text{ W}$ and $t = 5.0 \text{ min} = 300 \text{ s}$; power is energy per unit time, so $W = Pt$

$$W = Pt = 60 \text{ W} \times 300 \text{ s} = \mathbf{1.8 \times 10^4 \text{ J}}$$

Exercise 3.1

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]

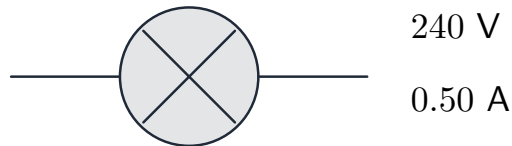
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A 0.50 W

B 120 W

C 240 W

D 480 W

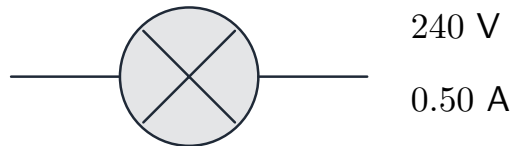


Exercise 3.1

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



3.1 B

- V and I are known, so use $P = VI$

$$P = VI = 240 \text{ V} \times 0.50 \text{ A} = 120 \text{ W}$$

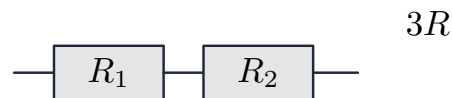
- **D** divides instead of multiplying

Exercise 3.2

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



Exercise 3.2

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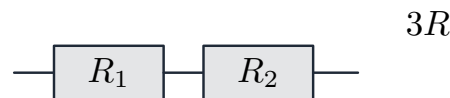
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A $\frac{1}{9}$

B $\frac{1}{3}$

C 3

D 9



3.2 C

- in series the current I is the same in both, so compare them with $P = I^2 R$

$$\frac{P_{3R}}{P_R} = \frac{I^2(3R)}{I^2 R} = \mathbf{3}$$

- **B** uses V^2/R , which needs the same p.d.

Exercise 3.3 (a)

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

(a) **Define** the volt.

[1]

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

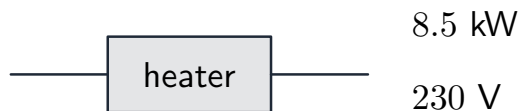
(a) one joule per coulomb: the p.d. when one joule is transferred per coulomb of charge

Exercise 3.3 (b)

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

(b) Calculate the current in the shower.

[2]

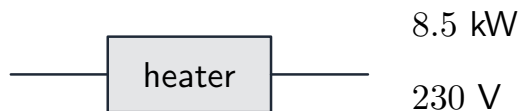


Exercise 3.3 (b)

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

(b) Calculate the current in the shower.

[2]



(b) $P = 8.5 \text{ kW} = 8500 \text{ W}$ and $V = 230 \text{ V}$; use $P = VI$ and rearrange for I

$$I = \frac{P}{V} = \frac{8500 \text{ W}}{230 \text{ V}} = \mathbf{37 \text{ A}}$$

Exercise 3.3 (c)

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

(c) Calculate the resistance of its heating element.

[2]

Exercise 3.3 (c)

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

(c) Calculate the resistance of its heating element.

[2]

(c) P and V are known, so use $P = \frac{V^2}{R}$ and rearrange for R

$$R = \frac{V^2}{P} = \frac{(230 \text{ V})^2}{8500 \text{ W}} = \mathbf{6.2 \, \Omega}$$

Exercise 3.3 (d)

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

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

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

(d) $t = 6.0 \text{ min} = 360 \text{ s}$; current is the rate of flow of charge, so $Q = It$

$$Q = It = 37 \text{ A} \times 360 \text{ s} = \mathbf{1.3 \times 10^4 \text{ C}}$$

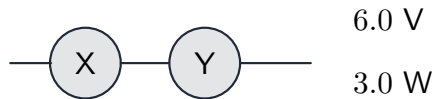
- power is energy per unit time, so $W = Pt$

$$W = Pt = 8500 \text{ W} \times 360 \text{ s} = \mathbf{3.1 \times 10^6 \text{ J}}$$

Exercise 3.4 (a)

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".

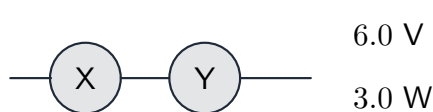
(a) Calculate the resistance of each lamp at its rated p.d. [2]



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



(a) each lamp's rated P and V are known, so use $P = \frac{V^2}{R}$ and rearrange for R

$$R_X = \frac{V^2}{P_X} = \frac{(6.0 \text{ V})^2}{3.0 \text{ W}} = \mathbf{12 \, \Omega}$$

$$R_Y = \frac{V^2}{P_Y} = \frac{(6.0 \text{ V})^2}{12 \text{ W}} = \mathbf{3.0 \, \Omega}$$

Exercise 3.4 (b)

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".

(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]

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(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]

(b) in series both lamps carry the same current, $I = 0.25$ A, so use $P = I^2 R$

$$P_X = I^2 R_X = (0.25 \text{ A})^2 \times 12 \Omega = \mathbf{0.75 \text{ W}}$$

$$P_Y = I^2 R_Y = (0.25 \text{ A})^2 \times 3.0 \Omega = \mathbf{0.19 \text{ W}}$$

- X takes more power, so X is brighter

Exercise 3.4 (c)

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".

(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]

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(c) in parallel both have the same p.d., and $P = \frac{V^2}{R}$, so the smaller resistance, Y, takes more power

- in series both have the same current, and $P = I^2 R$, so the larger resistance, X, takes more