CIE A Level Physics

Your notes

9.2 Potential Difference & Power

Contents

Potential Difference

Your notes

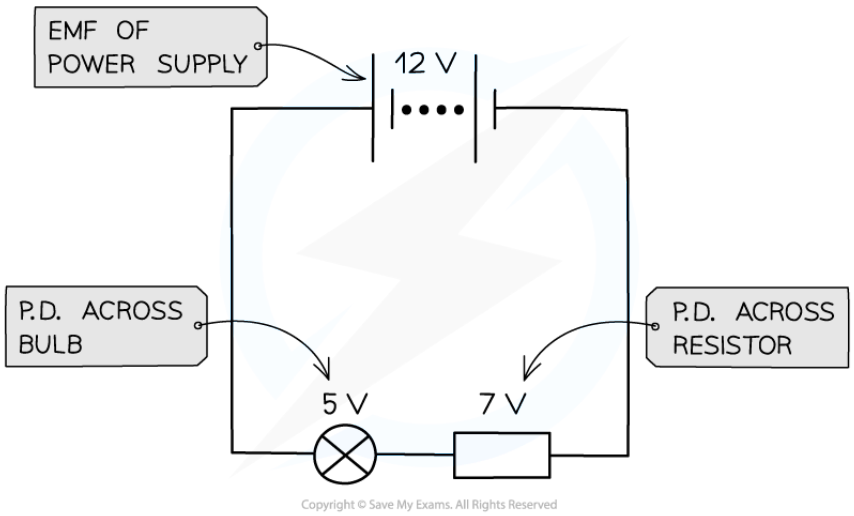
Defining potential difference

- A cell makes one end of the circuit positive and the other negative. This sets up a **potential difference** (p.d.) across the circuit
- The potential difference across a component in a circuit is defined as:

The energy transferred per unit charge flowing from one point to another

- Potential difference (sometimes called voltage) is measured in **volts (V)**. One volt is the same as one **joule per coulomb (J C^{-1})**
  - If a bulb has a potential difference of 3 V, every coulomb of charge passing through the bulb will transfer 3 J of energy to the bulb
- The potential difference of a power supply connected in **series** is always **shared** between the components in the circuit

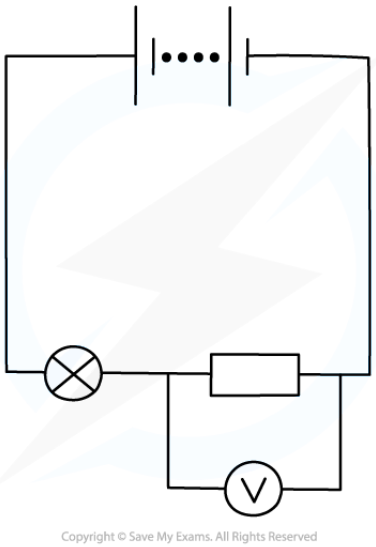
Potential difference in a series circuit



The potential difference is the voltage across each component in a circuit

- Potential difference is measured using a **voltmeter**
- A **voltmeter** is always set up in **parallel** so that it can measure the difference in electrical potential on each side of the component
  - This is a measure of how much energy has been transferred to the component

Potential difference in a parallel circuit



Potential difference can be measured by connecting a voltmeter in parallel between two points in a circuit.

Your notes

Calculating potential difference

Your notes

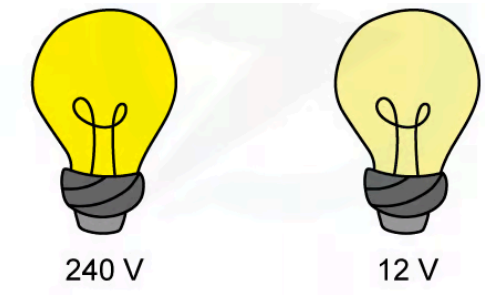
- The potential difference is defined as the **energy transferred per unit charge**
- Another measure of energy transfer is **work done**
- Therefore, potential difference can also be defined as the **work done per unit charge**

$$V = \frac{W}{Q}$$

- V = potential difference (V)
- W = work done (J)
- Q = charge (C)

Worked example

A lamp is connected to a 240 V mains supply and another to a 12 V car battery. Both lamps have the same current, yet the 240 V lamp glows more brightly.



Explain in terms of energy transfer why the 240 V lamp is brighter than the 12 V lamp.

ANSWER:

- Both lamps have the same current, which means charge flows at the same rate in both
- The 240 V lamp has a potential difference 20 times greater than the 12 V lamp
- Potential difference is the energy transferred (work done) per unit charge
- This means the energy transferred by each coulomb of charge to the 240 V lamp is 20 times greater than for the 12 V lamp
- This makes the 240 V lamp shine much brighter than the 12 V lamp

Examiner Tip

Think of potential difference as being the **energy per coulomb** of charge transferred between two points in a circuit

Electrical Power


Your notes

Calculating electrical power

- Power is defined as the **rate of doing work**
- Potential difference is the **work done per unit charge**
- Current is the **rate of flow of charge**
- Therefore, the power dissipated (delivered) by an electrical device is defined as:

$$P = IV$$

- Where:
  - P = power, measured in W
  - I = current, measured in A
  - V = potential difference, measured in V
- Resistance is given by the equation:

$$R = \frac{V}{I} \Rightarrow V = IR \Rightarrow I = \frac{V}{R}$$

- Where:
  - R = resistance, measured in Ω
  - V = potential difference, measured in V
  - I = current, measured in A
- The expression for potential difference can be substituted into the power equation to give:

$$P = IV = I(IR)$$

$$P = I^2R$$

- Or the expression for current can be substituted into the power equation to give:

$$P = IV = \left(\frac{V}{R}\right)V$$

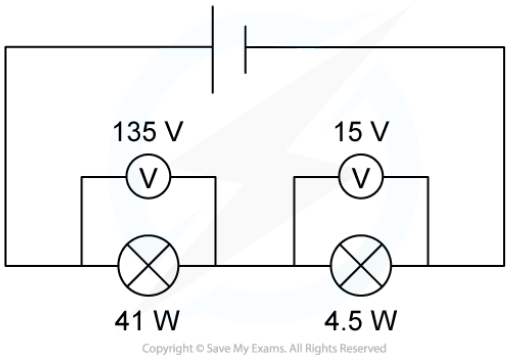
$$P = \frac{V^2}{R}$$

- This shows that for a given resistance, if the current or potential difference were doubled, the power would be four times greater

Your notes

Worked example

Two lamps are connected in series to a 150 V power supply.



Which statement most accurately describes what happens?

A. Both lamps light normally

B. The 15 V lamp blows

C. Only the 41 W lamp lights

D. Both lamps light at less than their normal brightness

ANSWER: A

Step 1: State the power equation

$$P = IV$$

Step 2: Rearrange for *I*

$$I = \frac{\mathrm{P}}{\mathrm{V}}$$

Step 3: Substitute in values to calculate

- For the 41W lamp:

$$I = \frac{41\mathrm{W}}{135\mathrm{V}} = 0.3\ \mathrm{A}$$

- For the 4.5W lamp:

$$I = \frac{4.5\mathrm{W}}{15\mathrm{V}} = 0.3\ \mathrm{A}$$

- For both to operate at their normal brightness, a current of 0.3 A is required

- Since the lamps are connected in series, the same current would flow through both
- Therefore, the lamps will light at their normal brightness
- This is option **A**

Examiner Tip

You can use the mnemonic "Twinkle Twinkle Little Star, Power equals *I* squared *R*" to remember whether to multiply or divide by resistance in the power equations. Which equation to use will depend on whether the value of current or voltage has been given in the question.

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