**GRADE 12**

**ELECTRICITY AND MAGNETISM: ELECTRIC CIRCUITS**

**Current** is the **rate of flow of charge.** In symbols: I = 

The amount of **energy transferred per coulomb of charge** is called the **potential difference**.

In symbols: V = 

**Ohm’s Law:** The current (I) **through** a conductor is directly proportional to the potential difference (V) **across** it, provided the temperature remains constant.

In symbols: R = 

Remember: R =  the V must be **across** R and the I through R

Know your rules for components in series or parallel or even a combination of the two.

|  |  |
| --- | --- |
| **Series Circuits** | **Parallel Circuits** |
| A series circuit is simply a circuit that has only one pathway. There are no branches in the circuit, and hence the electricity can only travel in one route. | Parallel circuits are circuits which have more than one branch, or pathway which charges can travel through. |
| http://www.antonine-education.co.uk/physics_as/module_3/Topic_3/circ_1.gif | **http://www.antonine-education.co.uk/physics_as/module_3/Topic_3/circ_3.gif** |
| * VT = V1 + V2 + V3 * The total potential difference (voltage) across all resistors will add up to the potential difference (voltage) off the power source, e.g. a battery. | * Vtot = V1 = V2 = V3 * The potential difference (voltage) in parallel circuits is actually the same for each branch, and equal to the potential difference (voltage) of the power source when the switch is closed. |
| * IT = I1  = I2 = I3 * In a series circuit the current is the same at any particular point in the circuit. The current does not vary as it passes through each individual resistor. | * Itot = I1 + I2 + I3 * Current is divided between the various branches. The current in one branch will not be the same as in other branches (unless of course all the resistances are the same). The sum of the current in each individual branch will add up to give the total current of the circuit. |
| **OR R =**  *Rtotal = R1 + R2 + R3 + ....* | **OR R =** |

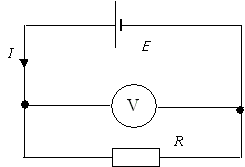
**Internal resistance**

A battery is said to produce an **emf** (electromotive force). EMF is a **potential difference (voltage)**.

Note that EMF is energy per unit charge (V), NOT a force, which can lead to confusion

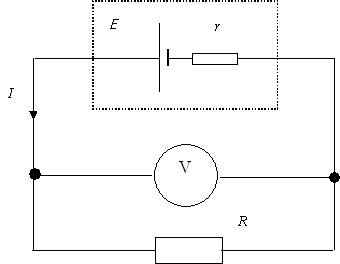
A good working definition of EMF is that it is the **open circuit terminal potential difference** (voltage) of the battery, i.e. **when there is no current in the external circuit**

Suppose we now add a load (component with resistance) as shown in the circuit diagram below.  We will assume the wires have **negligible** resistance.



This time we find that the terminal potential difference (voltage) drops from Ɛ to *V*. Since V is **less** than the EMF, it tells us that not all of the potential difference (voltage) is being transferred to the outside circuit. Some is lost due to the internal resistance of the battery causing the battery to become hot.

EMF = terminal voltage + lost voltage In symbols:  = Vterminal + Vlost



We can thus represent the circuit as in the accompanying circuit diagram.

We can now treat this as a simple series circuit and we know that the current, I, will be the same throughout the circuit.  We also know the potential difference (voltage)s in a series circuit add up to the battery potential difference (voltage).

Emf = V(external) + V(internal) In symbols: = IR +Ir = I(R + r)

Many learners panic at the sight of internal resistance problems. All you have to do is turn the cell with the internal resistance into a perfect battery in series with its internal resistor, and treat it as a simple series circuit.

**MULTIPLE CHOICE QUESTIONS**

1. Which ONE of the circuits below can be used to measure the current in a conductor **X** and the potential difference across its ends?

V

A

**X**

V

A

**X**

A B

A

**X**

V

C D

**X**

V

A

# A set of identical light bulbs are connected as shown in the circuit diagrams below. The internal resistance of the battery is negligible.

In which ONE of these circuits will the light bulbs glow the brightest?

A B

CD

1. The unit of measurement of THE RATE OF FLOW OF CHARGE in a conductor is …

A watt.

B volt.

C ampere.

D coulomb.

1. In the circuit represented below, the resistance of the variable resistor is decreased.

r

R



V

A

How would this decrease affect the readings on the voltmeter and ammeter?

|  |  |  |
| --- | --- | --- |
|  | **Voltmeter reading** | **Ammeter reading** |
| A | unchanged | unchanged |
| B | decreases | increases |
| C | decreases | unchanged |
| D | increases | increases |

1. In the circuit diagram below, the internal resistance of the battery and the resistance of the conducting wires are negligible. The emf of the battery is *E*.

*E*

**R**

V

**2R**

**S**

A

When switch **S** is closed, the reading on voltmeter V, in volts, is ...

A 0

B E

C E

D E

6. Which ONE of the following is the unit of measurement for the rate of flow of charge?

A watt

B coulomb

C volt

D ampere

1. The diagram below shows two light bulbs, **X** and **Y**, connected in series to a battery with negligible internal resistance.

**X**

**Y**

If bulb **X** glows brighter than bulb **Y**, then the …

A current through bulb **X** is smaller than that through bulb **Y**.

B resistance of bulb **X** is smaller than that of bulb **Y**.

C resistance of bulb **X** is greater than that of bulb **Y**.

D current through bulb **X** is greater than that through bulb **Y**.

**STRUCTURED QUESTIONS**

**QUESTION 1**

In the circuit represented below, two 60 Ω resistors connected in parallel are connected in series with a 25 Ω resistor. The battery has an emf of 12 V and an internal resistance of 1,5 Ω.

emf = 12 V

60 Ω

60 Ω

25 Ω

1,5 Ω

Calculate the:

1.1 Equivalent resistance of the parallel combination

1.2 Total current in the circuit

1.3 Potential difference across the parallel resistors

**QUESTION 2**

Learners conduct an investigation to determine the emf and internal resistance (*r*) of a battery. They set up a circuit as shown in the diagram below and measure the potential difference using the voltmeter for different currents in the circuit.

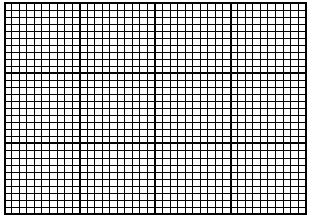
**A**

*r*

**V**

The results obtained are shown in the graph below.

Graph of potential difference versus current



0

0,5

0,5

1,0

1,5

Current (A)

1,0

0

Potential difference (V)

2.1 Use the graph to determine the emf of the battery.

2.2 Calculate the gradient of the graph.

2.3 Which physical quantity is represented by the magnitude of the gradient of the graph?

2.4 How does the voltmeter reading change as the ammeter reading increases? Write down INCREASES, DECREASES or REMAINS THE SAME. Use the formula emf = IR + Ir to explain the answer.

**QUESTION 3**

# The headlamp and two IDENTICAL tail lamps of a scooter are connected in parallel to a battery with unknown internal resistance as shown in the simplified circuit diagram below. The headlamp has a resistance of 2,4 Ω and is controlled by switch S1. The tail lamps are controlled by switch S2. The resistance of the connecting wires may be ignored.

The graph alongside shows the potential difference across the terminals of the battery before and after switch **S1** is closed (whilst switch **S2** is open). Switch **S1** is closed at time t1.

•

•

S1

*r*

2,4 Ω

tail lamp 1

S2

•

•

tail lamp 2

V

potential difference (volts)

time (s)

12

9,6

0

t1

3.1 Use the graph to determine the emf of the battery.

3.2 WITH ONLY SWITCH **S1** CLOSED, calculate the following:

3.2.1 Current through the headlamp

3.2.2 Internal resistance, *r*, of the battery

BOTH SWITCHES **S1** AND **S2** ARE NOW CLOSED. The battery delivers a current of 6 A during this period.

3.3 Calculate the resistance of each tail lamp.

3.4 How will the reading on the voltmeter be affected if the headlamp burns out? (Both switches **S1** and **S2** are still closed.)

Write down only INCREASES, DECREASES or REMAINS THE SAME. Give an explanation.

**QUESTION 4**

The headlights of a car are connected in parallel to a 12 V battery, as shown in the simplified circuit diagram below. The internal resistance of the battery is 0,1 Ω and each headlight has a resistance of 1,4 Ω. The starter motor is connected in parallel with the headlights and controlled by the ignition switch, **S2**. The resistance of the connecting wires may be ignored.

•

•

# Starter motor

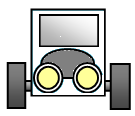
S1

emf = 12 V

0,1 Ω

1,4 Ω

1,4 Ω



S2

•

•

4.1 State Ohm's law in words.

4.2 With only switch **S1** closed, calculate the following:

4.2.1 Effective resistance of the two headlights

4.2.2 Potential difference across the two headlights

4.2.3 Power dissipated by one of the headlights

Ignition switch **S2** is now closed (whilst **S1** is also closed) for a short time and the starter motor, with VERY LOW RESISTANCE, rotates.

4.3 How will the brightness of the headlights be affected while switch **S2** is closed? Write down INCREASES, DECREASES or REMAINS THE SAME. Fully explain how you arrived at the answer.

# QUESTION 5

Three resistors, R1, R2 and R3, are connected to a battery, as shown in the circuit diagram below. The internal resistance of the battery is 0,3 Ω. The resistance of R2 and R3 is equal. The resistance of R1 is half that of R2. When both switches are open, the voltmeter across the battery reads 9 V.

9 V

r

A

R2 = 2R

0,3 Ω

S2

S1

N

P

Q

R1 = R

R3  = 2R

V1

5.1 What is the value of the emf of the battery? Give a reason for your answer.

5.2 When **only switch S1 is closed**, the reading on the ammeter is 3 A. Calculate the resistance of R1.

Both switches **S1** and **S2** are now closed.

5.3 How will the resistance of the circuit change? Write down only INCREASES, DECREASES or REMAINS THE SAME.

5.4 A conducting wire of negligible resistance is connected between points **Q** and **N**. What effect will this have on the 'lost volts'? Explain the answer.

**QUESTION 6**

Learners investigate the conducting ability of two metal wires **P** and **Q**, made of different materials. They connect ONE wire at a time in a circuit as shown below.

A

Wire

V

The potential difference across each wire is increased in equal increments, and the resulting current through these wires is measured. Using the measurements, the learners obtained the following sketch graphs for each of the wires.

Wire **Q**

Wire **P**

Current (A)

Potential difference (V)

6.1 Name TWO variables that the learners would have controlled in each of the experiments.

6.2 Which one (**P** or **Q**) is the better conductor? Explain your answer.

# QUESTION 7

A circuit is connected as shown below. The resistance of *R*, which is connected in parallel with the 10 Ω resistor, is unknown. With switch S closed, the reading on voltmeter V decreases from 45 V to 43,5 V. The internal resistance of the battery is 0,5 Ω.

0,5 Ω

S

12 Ω

*R*

10 Ω

•

•

7.1 Calculate the reading on ammeter A. Show ALL your calculations.

7.2 Determine the resistance of resistor *R*.

7.3 How will the reading on voltmeter V change if resistor *R* burns out? Give a reason for your answer.

**QUESTION 8**

Learners use Ohm's law to determine which ONE of two resistors **A** and **B** has the greater resistance. For each resistor, they measure the current through the resistor for different potential differences across its ends. The graph below shows the results obtained in their investigation.

**A**

**B**

potential difference (V)

current (A)

The learners are supplied with the following apparatus:

6 V battery

Voltmeter

Ammeter

Rheostat

Resistors **A** and **B**

Conducting wires

8.1 Draw a circuit diagram to show how the learners must use the above apparatus to obtain each of the graphs shown above.

8.2 Write down ONE variable that must be kept constant during this investigation.

8.3 Which ONE of **A** or **B** has the higher resistance? Give an explanation for the answer.

**QUESTION 9**

In the circuit diagram below, the battery has an emf of 12 V and an internal resistance of 0,8 Ω. The resistance of the ammeter and connecting wires may be ignored.

0,8 Ω

12 V

2 Ω

4 Ω

8 Ω

8 Ω

A

V

Calculate the:

9.1 Effective resistance of the circuit

9.2 Reading on the ammeter

9.3 Reading on the voltmeter

# QUESTION 10

The battery in the circuit below has an emf of 12 V and an internal resistance of 0,2 Ω. The resistance of the connecting wires can be ignored.

15 Ω

9 Ω

8 Ω

2 Ω

0,2 Ω

12 V

I

I

V

10.1 Calculate the current, I, that flows through the battery.

10.2 How will the reading on the voltmeter be affected if the 9 Ω resistor is removed and replaced with a conducting wire of negligible resistance? Explain your answer.

**QUESTION 11**

The circuit diagram below shows a battery, with an internal resistance *r*, connected to three resistors, **M**, **N**, and Y. The resistance of **N** is 2 Ω and the reading on voltmeter V is 14 V. The reading on ammeter A**1** is 2 A and the reading on ammeter A**2** is 1 A. (The resistance of the ammeters and the connecting wires may be ignored.)

1 A

2 A

14 V

Y

*r*

M

N

V

A**1**

A**2**

11.1 State Ohm's law in words.

11.2 How does the resistance of **M** compare with that of **N**? Explain how you arrived at the answer.

11.3 If the emf of the battery is 17 V, calculate the internal resistance of the battery.

11.4 Calculate the potential difference across resistor **N**.

11.5 Calculate the resistance of **Y**.