A Guide to Electric Circuits

Teaching Approach

In this series we continue with what was learnt in Grade 10. We therefore first revise the work covered in Grade 10. This includes the difference between series and parallel circuits, and how this influences the current and potential difference.

Next, we establish the relationship between potential difference and current in a circuit. We show this experimentally and use graphs and mathematics to establish Ohm's Law. We also need to distinguish between ohmic and non-ohmic conductors and give differences between these.

In order to cement the learners understanding of all of the above and especially Ohm's Law we need to ensure that the students can answer questions based on circuit diagrams, solving for current, potential difference and resistance in various parts of the circuit.

Next, we introduce the concept of energy usage across various parts of the circuit. Students need to understand that there is a conversion from chemical energy stored in the battery, to other forms of energy such as mechanical, sound, light and heat energy.

We introduced the concept of power as a measure of the rate at which energy is converted. The following equations are introduced and derived;

- P = E/t
- W = VQ
- Q = It
- And therefore W = VIt
- P = VI
- $P = I^2R$
- $P = V^2/R$

We investigate how power is dissipated across series and parallel circuits. Students need to understand how to use these equations to solve problems involving energy and power in circuit diagrams.

Finally, the cost of energy and power is discussed. The unit, kilowatt-hour is introduced and we need to make sure that the students understand how the cost of electricity is calculated. It is important that students gain a grasp of which appliances use more electricity than others, and also how to save electricity and why this is important.

Video Summaries

Some videos have a 'PAUSE' moment, at which point the teacher or learner can choose to pause the video and try to answer the question posed or calculate the answer to the problem under discussion. Once the video starts again, the answer to the question or the right answer to the calculation is given

Mindset suggests a number of ways to use the video lessons. These include:

- Watch or show a lesson as an introduction to a lesson
- Watch or show a lesson after a lesson, as a summary or as a way of adding in some interesting real-life applications or practical aspects
- Design a worksheet or set of questions about one video lesson. Then ask learners to watch a video related to the lesson and to complete the worksheet or questions, either in groups or individually
- Worksheets and questions based on video lessons can be used as short assessments or exercises
- Ask learners to watch a particular video lesson for homework (in the school library or on the website, depending on how the material is available) as preparation for the next day's lesson; if desired, learners can be given specific questions to answer in preparation for the next day's lesson

1. Grade 10 Revision

This lesson serves to recap the following Grade 10 principles:

- What makes an object positively or negatively charged
- Principle of conservation of charge
- Charge quantisation

2. Ohm's Law

In this lesson we experimentally investigate the relationship between current and potential difference across an ohmic resistor. We analyse the results both mathematically as well as graphically, and Ohm's Law is concluded

3. Non-Ohmic Resistors

In this lesson we experimentally investigate the relationship between current and potential difference across light bulbs. We analyse the results both mathematically as well as graphically.

4. Ohm's Law Calculations

In this video we address circuit problems and use Ohm's Law as well as our knowledge of how resistance is calculated in series and parallel to solve these problems.

5. Electrical Energy and Power

In this lesson the concept of energy conversion is introduced. We cover the conversion of chemical energy (stored inside the batteries) to other forms of energy such as mechanical (to move fans), heat (heaters) and light (light bulbs).

6. Power in Series Circuits

In this video we experimentally investigate how power is dissipated as we add more light bulbs in a series circuit. We learn that the more light bulbs we add in series, the dimmer they become.

7. Power in Parallel Circuits

In this lesson we experimentally investigate how power is dissipated as we add more light bulbs in a parallel circuit. To be thorough, we measure the current in both the main circuit as well as in each branch.

8. Energy and Power Calculations

We work through an example where we use our combined knowledge of Ohm's Law, resistance in series and parallel, and energy and power to solve circuit diagram problems.

9. Paying for Electricity

We discuss the cost of electrical energy. The kilowatt-hour unit is introduced. Calculations using the kilowatt-hour to calculate the cost of electrical energy are done. We also look at the power consumption of various household appliances.

Resource Material

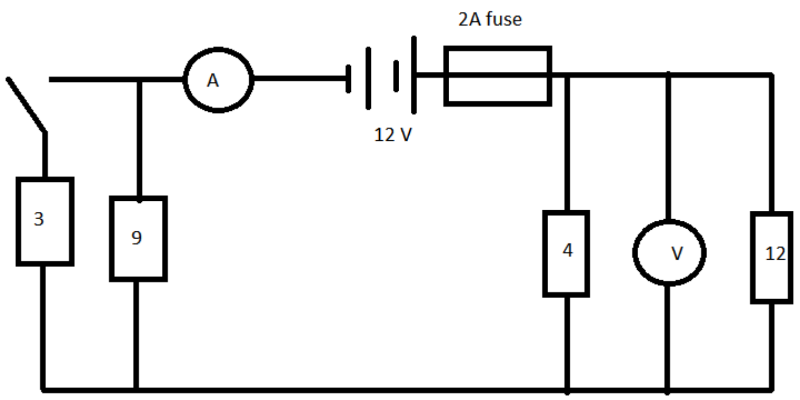
1. Grade 10 Revision	http://www.physicsclassroom.com/Class/circuits/u9l2c.cfm	A lesson on electric circuits.
	http://science.howstuffworks.com/what-is-voltage.htm	This page defines voltage.
	http://physics.bu.edu/py106/notes/Circuits.html	Notes on series and parallel circuits.
	http://www.facstaff.bucknell.edu/mastascu/elessonsHTML/Resist/Resist2.html	A lesson on combinations of resistors.
2. Ohm's Law	http://hyperphysics.phy-astr.gsu.edu/hbase/electric/ohmlaw.html	This page looks at Ohm's law.
	http://phet.colorado.edu/en/simulation/ohms-law	Fun, interactive, research-based simulations of Ohm's law.
	http://www.hamuniverse.com/ohmslaw.html	This page explains Ohm's law basics.
3. Non-ohmic Resistors	http://physics.nayland.school.nz/VisualPhysics/NZ-physics%20HTML/14_Electronics/chapter14a.html	This page looks at ohmic and non-ohmic conductors.
	http://au.answers.yahoo.com/question/index?qid=20110831223619AAKM3km	Here we look at what makes a resistor non-ohmic
	http://answers.yahoo.com/question/index?qid=20090427032506AAQtKzQ	The difference between ohmic and non ohmic conductors
4. Ohm's Law Calculations	http://www.csgnetwork.com/ohmslaw.html	This site provides students with assistance, direction and information on ohm's law calculations

	http://www.rapidtables.com/electric/ohms-law.htm	A resource on ohm's law.
	http://sunburst.usd.edu/~schieber/psyc770/resistors/ohms4beginner.html	This page defines ohm's law and looks at how and where it can be applied.
	http://www.wisc-online.com/Objects/ViewObject.aspx?ID=dce11904	Ohm's law practice problems.
5. Electrical Energy and Power	http://inst.eecs.berkeley.edu/~ee42/sp01/LectNotes/Lect6.PDF	Lecture notes on power and energy in electric circuits.
	http://www.launc.tased.edu.au/online/sciences/PhysSci/done/electric/power/Power.htm	This page looks at power and energy in circuits.
	http://www.education.leeds.ac.uk/assets/files/research/cssme/ns-tu/voltage_energy_power_in_electric_circuits.pdf	A learner resource on voltage, energy and power in electric circuits.
	http://www.engineeringtoolbox.com/electrical-formulas-d_455.html	The most common used electric formulas- Ohms Law and combinations.
	http://electronicsclub.info/power.htm	A resource on power and energy.
6. Power in Series Circuits	http://www.tpub.com/neets/book1/chapter3/1-13.htm	Power in series circuits.
	http://answers.yahoo.com/question/index?qid=20090527180032AANKyj9	How to find power in a series circuit.
	http://wiki.answers.com/Q/Is_the_power_dissipated_in_a_series_circuit_is_equal_to_the_sum_of_the_power_dissipated_by_each_resistances_in_the_circuit	This page looks at whether the power dissipated in a series circuit is equal to the sum of the power dissipated by each resistance in the circuit.
7. Power in Parallel Circuits	http://www.allaboutcircuits.com/vol_1/chpt_5/5.html	Power calculations.

	http://www.tpub.com/neets/book1/chapter3/1-27.htm	Power in a parallel circuit.
	http://www.instructables.com/id/Chapter-4-Parallel-Circuits/step10/Power-Dissipation-in-a-Parallel-Circuit/	This page looks at power dissipation in a parallel circuit.
8. Energy and Power Calculations	http://www.wilsonware.com/electronics/parallel_circuits.htm	A course on parallel circuits.
	http://answers.yahoo.com/question/index?qid=20110320130537AASvzeq	This site looks at how to calculate power in a parallel and series circuit.
	http://www.wisc-online.com/objects/viewobject.aspx?id=dce2202	Power calculations in a series/parallel circuit.
9. Paying for Electricity	http://www.wisc-online.com/objects/viewobject.aspx?id=dce2202	Power calculations in a series/parallel circuit.
	http://www.energylens.com/articles/kw-and-kwh	An explanation of kW and kWh.
	http://michaelbluejay.com/electricity/cost.html	This page explains a kilowatt-hour.
	http://www.apxsolar.com/downloads/5common_appliance_Wattages_.pdf	A list of common appliances, their wattage and an estimate of operating costs.
	http://energy.gov/energysaver/articles/estimating-appliance-and-home-electronic-energy-use	This page estimates appliance and home electric energy use.

Task

Question 1



The switch is open.

1.1 Calculate the resistance in the parallel network.
1.2 Calculate the reading on the ammeter.
1.3 Calculate the reading on the voltmeter
1.4 Calculate the amount of heat released by the 12Ω resistor in 5 minutes.
1.5 Calculate the current in the 4Ω resistor.

The switch is now closed.

1.6 Calculate the current in the circuit.
1.7 Explain what will happen to the 2A fuse using the concept of power.

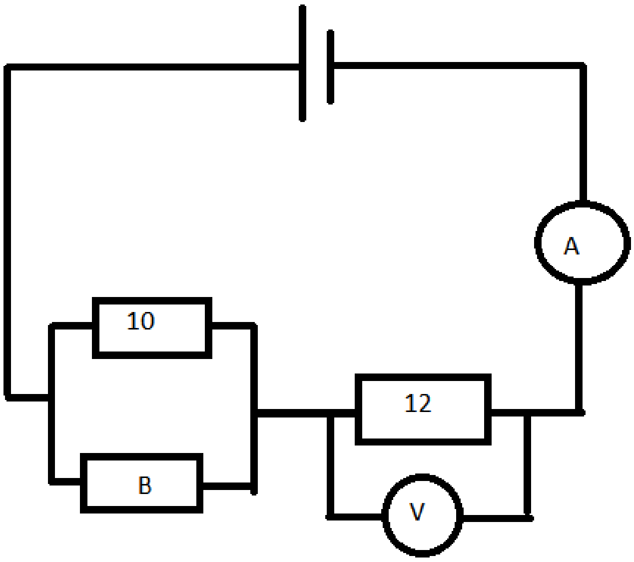
Question 2

A 960 W heater and a 192 W television are connected in parallel to a 240 V household power socket. A circuit breaker is a device which breaks the current if a certain current is reached. This is to stop fires caused by overheated wires in a house. The circuit breaker in this house is set to trip at 5 A.

2.1 Calculate the current flowing in each appliance.
2.2 Calculate the resistance of the heater.
2.3 Will the circuit breaker trip. Explain using a calculation.
2.4 Will the circuit breaker trip if an iron marked 1000 W is connected in parallel to this set? Justify your answer with a calculation.

Question 3

Consider the circuit below. The cell is marked 6 V, and the reading on the voltmeter is 4,57 V.



3.1 Calculate the reading on A.
3.2 Hence, or otherwise, calculate the resistance of B.

Question 4

It takes $4{,}05 \times 10^5$ J to boil 1250 ml of water.

4.1 How long will it take to boil this water if you use a kettle marked 2500 W?
4.2 If the cost of electricity is R1,78 per kWh, calculate how much it will cost to heat this water.

Task Answers

Question 1

1.1

$$\frac{1}{R_p} = \frac{1}{r_1} + \frac{1}{r_2} = \frac{1}{4} + \frac{1}{12} = \frac{3+1}{12} = \frac{4}{12} = \frac{1}{3}$$

$\therefore R_p = 3\Omega$

1.2

$I = \frac{12}{12} = 1$ A

1.3

V = IR = 1 X 3 = 3V

1.4

$W = \frac{V^2 t}{R} = \frac{3^2 \times 5 \times 60}{12} = 225\ \text{J}$

1.5 $R = \frac{V}{I}$

$\therefore I = \frac{V}{R}$

$I = \frac{3}{4} = 0,75$ A

The switch is now closed.

1.6

$$\frac{1}{R_p} = \frac{1}{r_1} + \frac{1}{r_2} = \frac{1}{3} + \frac{1}{9} = \frac{3+1}{9} = \frac{4}{9}$$

$\therefore R_p = 2,25\ \Omega$

$$I = \frac{V}{R} = \frac{12}{5,25} = 2,29\ A$$

1.7 The power allowed in the circuit is P = VI = 12 x 2 = 24 W.
When the switch is closed the power drawn by the circuit is P = VI = 12(2,29) = 27,5 W
Therefore the fuse will melt (or blow).

Question 2

2.1 Heater: P = VI ; 960 = 240 X I; I = 4 A
TV: P = VI; 192 = 240 x I; I = 0,8 A

2.2
$P = V^2/R$; $960 = (240)^2/R$; R = 60 Ω

2.3 Total current = 4A + 0,8 A = 4,8 A. This is less than 5 A so no, circuit breaker will not trip.

2.4 Iron: P = VI; 1000 = 240/I; I = 4,2 A
Total current is now = 4,2 + 4 + 0,8 = 9 A. Since this is more than the 5 A it will trip.

Question 3

3.1 Consider the 12 Ω resistor: I = V/R; I = 4.57/12 = 0,38 A

3.2 Hence, or otherwise, calculate the resistance of B.

$V_{total} = V_{Parallel} + V_{12\Omega}$

$6 = V_{parallel} + 4,57$

Therefore, $V_{parallel} = 1,43$ V

Now consider the parallel set:

$R_p = V/I = 1,43/0,38 = 3,76\ \Omega$

But

$$\frac{1}{R_P} = \frac{1}{r_1} + \frac{1}{r_2}$$
$$\frac{1}{3.76} = \frac{1}{10} + \frac{1}{R_B}$$
$$\frac{1}{3.76} - \frac{1}{10} = \frac{2.67 - 1}{10} = \frac{1.67}{10} = \frac{1}{R_B}$$

$R_B = 6\ \Omega$

Question 4

4.1 t = W/P = 4.05 x 10^5/2500 = 162 s = 2 min 42 s.

4.2 P = 2,5 kW.
t = 162 s = 0,045 h.
The energy used to boil the water is then W = E = Pt = 2,5 x 0,045 = 0,1125 kWh
The cost of which is 0,1125 x R1,78 = R0,20 or 20 cents.

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