Laboratory Manual

Physics 2

Dr. Andrea Bourke

Experiments:
- Snell's Law – Refractive Index
- Electric Circuits – Ohm's Law, Resistors in Series and in Parallel

For each experiment write a detailed report under the following headings.
1. Name
2. Date
3. Title
4. Aim
5. Theory
6. Apparatus (List and labelled diagram)
7. Experimental methodology
8. Results and Analysis
    (i) Table of Results
    (ii) Graph
    (iii)Analysis of graph
9. Discussion
    (i) Error Analysis
    (ii) Sources of error - list and discussion
    (iii)Discussion of results
10. Conclusion

Lab Report

Here are some headings and pointers for writing your lab reports:

Name:

Date:

~~**Lab partner:**~~

Title of the experiment:

Aims of the experiment: To investigate the relationship between...... using…

Theory section

Min. full page on theory section - definitions, derivations, equations, background research, applications

e.g. motion parameters, equations of motion, derivations, laws of motion, free fall, simple harmonic motion, oscillation, waves,

Theoretical values quoted

Materials/apparatus used: (list)

Diagram of apparatus: (LABELLED!) photo/schematic/picture (reference if required)

Procedure

Do not copy directly from the lab manual. Summarise in your own words. Short/bullet-points/list.

Results:

Table of results: properly labelled - parameter name, symbol, unit

Graph: Title of graph (e.g. Graph of height, s (m) versus time^2 t^2 (s^2) for ball dropping from rest using free-fall apparatus)

Axis labelled (e.g. height, s (m)) and properly scaled

Only **pencil** should be used for plotting graphs.

Analysis:

Analysis of slope

If the graph is linear, draw the BEST FIT STRAIGHT LINE (do not just join the dots!). (This is easiest to do using a long transparent ruler). Do not try to force it to go through the origin.

The best fit line then represents **all of your data**. From this best fit line you calculate the slope of the line. This slope represents all of your data. The slope should be calculated from two (new) points that lie on your best fit line (not just points from your data)

Step by step calculations for the slope of the line should be shown clearly. Don't forget to include the units for your slope

The equation of a straight line $y = mx + c$ should be matched with the theoretical equation for the graph you have drawn (e.g. Ohm's Law $V=RI$ - if voltage is plotted on the y axis and current is plotted on the x axis then the slope of the line represents the resistance of the circuit)

Calculations of parameters from the slope of the graph.

Error Analysis

Calculation of % error in results.

Dimensional Analysis - Are the equations dimensionally consistent?

Discussion of results

Comment on magnitude of %error. What are the sources of the error? Is this %error realistic/acceptable? What could be done to reduce error in results?

Discuss the shape of the graph. What is the relationship between the parameters?

What does the straight line graph tells us about the relationship between the parameters?

Why plot t^2 instead of t? Comment on the shape of these graphs. What is different?

Does the line go through the origin? Why? What is the intercept of the graph? What does the intercept represent?

Discussion of theory and real world applications

Conclusion:

Summary

Refraction – Snell's Law

Aim: to investigate the relationship between the angle of incidence and the angle of refraction for a regular transparent block and hence calculate its refractive index.

Introductory Theory

Refraction of light refers to the change in direction of a light ray as it passes from one medium to another

Snell's Law states that when light travels from air to another transparent medium, $\frac{\sin(i)}{\sin(r)}$ is constant known as the refractive index of the transparent medium and is denoted by η where *i* is the angle of incidence in air and *r* is the angle of refraction in the transparent medium.

Refraction through a glass/perspex block

When a ray of light enters a glass block at an angle other than the normal, it changes speed, wavelength and direction. In going from a less dense medium (air) to a more dense medium (e.g. glass), light bends towards the normal. This means that $i > r$ (the angle *i* is greater than the angle *r*). In going from a more dense to a less dense medium (glass to air), light bends away from the normal. The change in angle of the light ray is the same when it enters and leaves the glass.
If the incident ray had continued without changing direction, then the emergent ray would be parallel to it.
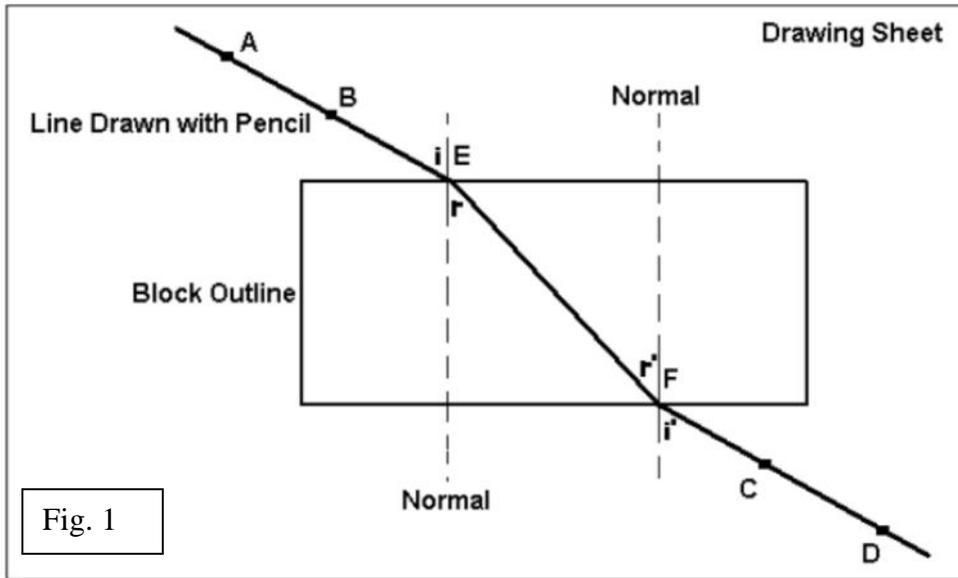
Apparatus (non-virtual laboratory experiment)

- Drawing board,
- Drawing sheet,
- Thumb Tacks,
- Locating Pins,
- Transparent Block,
- Protractor

Procedure (non-virtual laboratory experiment)

1. Pin the drawing sheet to the board with thumb tacks.
2. Mark the outline of the block on the paper.
3. At a point such as E (see Fig 1) draw a ray with an angle of incidence of, for example, *i* =60° (Note: this corresponds to making an angle of 60° with the *normal*).
4. Trace the path of the ray of light through the block by marking the ray with pins A and B; Look through the block and locate the emerging ray by placing pins C and D in line with A and B.
5. Remove the block and join D to C and extend the line to touch the block outline.
6. Draw the normal at F. This defines the angles *i, r, r', i'*.
7. Measure and record each of the four angles for this ray of light.
8. Repeat the process for a number of angles of incidences e.g. angles of 0°, 10°, 20°, 30°, 40°, 50°, 60°, 70°, 80°, 90° with the normal.
9. Draw a graph of *i* versus *r* and comment on the graph.
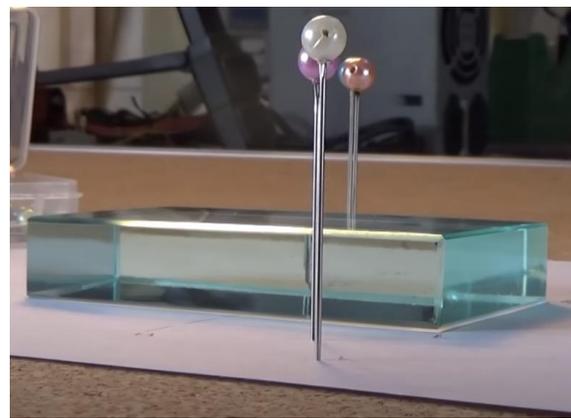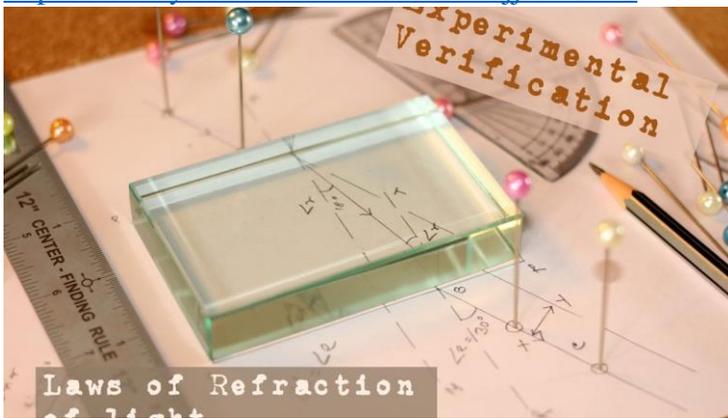10. Draw a graph of sin i versus sin r.

11. The relationship should now be self evident. Write down the equation for the relationship between i and r, and using the slope of your graph of sin(*i*) versus sin(*r*) determine a value for the refractive index of the transparent material

12. Compare your results to theory. Determine the percentage difference between your experimentally determined value and the theoretical value for the refractive index of the transparent material.

13. Write a detailed report as per guidelines.

Fig. 1

YouTube video link of experiment carried out in a laboratory:
https://www.youtube.com/watch?v=1RcGHJUMgDQ
https://www.youtube.com/watch?v=CdjjDsb5Fz8

Ohm's Law

Aim:
   (i)   To investigate the relationship between current flowing through a resistive circuit and the voltage drop across a resistive circuit.
   (ii) To verify Ohm's Law.
   (iii) To determine the value of a resistor.

Apparatus
- Resistor
- D.C. Power Supply
- Digital ammeter
- Digital voltmeter

Theory

Current, I – this is the rate of flow of charge in a circuit. It is measured in amps (A).
Voltage, V, can be thought of as electrical pressure – the higher the electrical pressure, the faster the charge flows in the circuit, the higher the current. The potential difference across an element of the circuit is a measure of the difference in electrical pressure across the element. Both voltage and potential difference are measured in volts (V).
For some circuit elements, such as resistors, current and potential difference are directly related to each other i.e.

$$V \propto I$$

We can convert this into an equation by introducing a constant, R, which is called resistance and is related to the opposition to charge flow through the circuit element. The SI unit of resistance is the ohm, Ω.

$$V = IR$$

This equation can be rearranged to give Ohm's law which states that the current, I, through a conductor is given by

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

where
V = potential difference across the resistor (V)
I = current through the resistor (A)

R = resistance of resistor to current flow (Ω)

Power
When current flows in a resistor, the current loses energy to the resistor and the resistor will tend to heat up. This is the basis of all electrical heaters. The power developed in a resistor (i.e. the heat released per second) is given by

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

where
P = power developed in the resistor (W)

Multimeters
The measurement of current and voltage will be carried out using Digital MultiMeters (DMM). The connection points are shown below - note that some DMMs have a single connection for current i.e. there are only 3 connection points on the DMM - A/mA, COM and V.
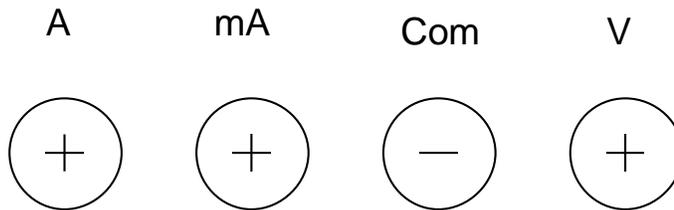

Fig 1

Note that in any measurement using a DMM, there are only ever two connections to the DMM and one of these must be to the COM (common) connection. In order to get accurate readings from the DMM, follow these simple rules.

- To take a reading using the DMM, rotate the control knob round to the section marked V, A or Ω as appropriate.
- Use the scale which will give the most precise value. For example, a reading on the 200 mA scale may give a reading of 0.2. If you rotate the control on to the 2 mA scale, the reading becomes 0.241 mA which is more precise. By the way, the values on each scale represent the maximum possible reading for that control position. For example, when set to 20 mA, the DMM will only be able to read currents that are less than 20 mA in magnitude. If the current is greater than this you will get a flashing blank display which means that you need to move to a higher scale.
- When you have a reading, you will want to know what unit it has been measured in. Basically the unit of the display is the same as that indicated on the scale. So if you are measuring on the 2 V scale, all readings on the display will be in volts but if you are measuring on the 200 mV scale, all readings on the display will be in millivolts.
- Check whether the circuit is ac or dc. Different models of DMM deal with this problem in different ways. Some models have a button in the top corner of the DMM with which you can select whether you are measuring ac or dc. In others there are separate scales for ac and dc measurements of both I and V. Note ac can be indicated by a ~ and dc by an = sign.

Ammeter- An ammeter is a current measuring device which has a small resistance (ideally zero). It is inserted in a circuit as part of the circuit loop through which all of the current flows i.e. **in series**. When using a DMM, the positive of the battery should be connected to either the A or mA connection depending on the size of

current to be measured. Initially it is best to connect to the A, you can always reconnect to mA if the current in the circuit turns out to be small. The COM (common) connector is then connected to the resistor which in turn is connected to the negative of the power supply.

Voltmeter - A voltmeter has an extremely high resistance of the order of 10 MΩ - ideally it should be infinite. The voltmeter should not be connected as part of the current loop. It should be connected across a circuit element such as the resistor in Fig 2 i.e. **in parallel**. To use a DMM as a voltmeter the high potential side of the resistor (i.e. the side of the resistor connected to the positive of the power supply) should be connected to the V/Ω connection and the low potential side of resistor to the COM connection.

Resistance -The resistance of a resistor can be measured directly using a DMM. Simply remove the resistor from the circuit, connect one end to the V/Ω connection and the other to the COM. Then select an appropriate resistance scale (marked with Ω) using the control knob.

Experimental Procedure
1. Using the ohmmeter setting on the multimetre, measure the resistance of the resistor (directly) and record in a suitable table.
   a. Connect two leads into the dmm to the common and Ω terminals
   b. Turn the dial of the meter to the resistance setting (start at the 2 kΩ setting and adjust as necessary)
   c. Place the other end of the leads across the resistor, the resistance value will appear on the display.

2. You are required to set up a circuit using one resistor R which is connected in series with a power supply. Draw this circuit diagram (clearly labelled).
3. Modify the circuit diagram to show how the voltage drop across the resistor and the current flowing through the resistor can be measured.
4. Set up your circuit as shown in your diagram.
5. Do NOT switch on power supply until the circuit has been fully checked by the laboratory demonstrator. **Note**: Be careful to ensure that the ammeter is connected in series and voltmeter is connected in parallel (or 'across') the circuit element under investigation.
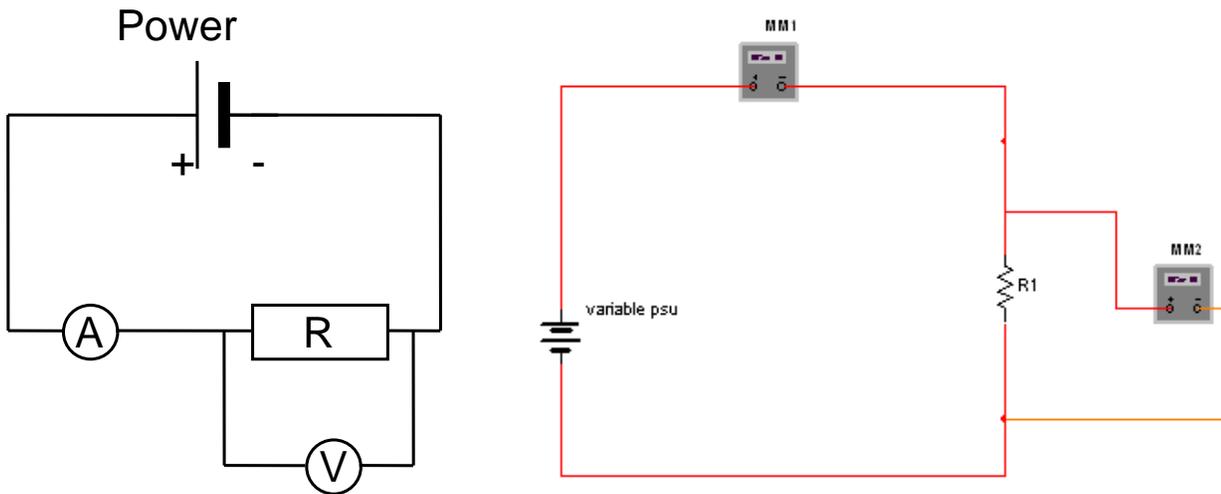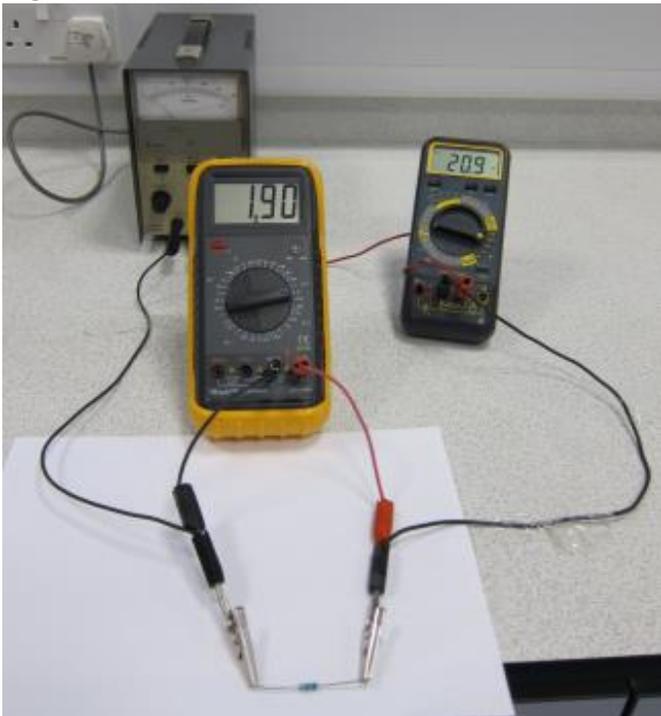
Fig. 2

6. By varying the power supply voltage you will obtain a range of current and voltage measurements. Vary the supply voltage such that the potential difference across the resistor changes from 0 V to 9 V in steps of 1 V, measuring the current each time. For each applied voltage, record the current flowing through the resistors and the voltage drop across the resistor from the DMMs. Take your readings from the DMMs NOT from the power supply. Record the results in a suitable table with appropriate headings and units.

7. Plot a suitable graph of the voltage drop V across the resistor versus the current I flowing through the resistor. (Clearly labelled). Remember to plot your graph using the appropriate SI unit for each quantity.

8. From your graph determine the resistance of the resistor by matching your results with theory. (Hint: use the slope)

9. Compare your determined value of resistance (from graph) with the measured value of resistance (from ohmmeter in step 1) by determining the percentage error.

10. For the highest voltage used in your experiment determine the power developed in the resistor.

11. Write a detailed report as per guidelines.

Resistors in Series & Parallel

Aim:
- (i)   To investigate the relationship between current flowing through a resistive circuit and the voltage drop across a resistive circuit.
- (ii) To verify Ohm's Law.
- (iii) To determine the value of a resistor.
- (iv) To verify the equations for resistors connected in series and in parallel

Apparatus
- Resistors
- D.C. Power Supply
- Digital multimeters (ammeters/voltmeters/ohmmeters)

Experimental Procedure - Series Circuit.
The procedure is very similar to that for the Ohm's Law experiment.
1. Measure the resistance of each resistor (directly) and record in a suitable table. (Use an ohmmeter)
2. You are required to set up a circuit using two resistors: R_1 and R_2 connected in series. This combination is connected in series with a power supply. Draw this circuit diagram (clearly labelled).
3. Modify the circuit diagram to show how the voltage drop across each resistor and the current flowing through each resistor can be measured.
4. Set up your circuit as shown in your diagram.
5. Do NOT switch on power supply until the circuit has been fully checked by the laboratory demonstrator. **Note**: Be careful to ensure that the ammeter is connected in series and voltmeter is connected in parallel (or 'across') the circuit element under investigation
6. By varying the power supply voltage you will obtain a range of current and voltage measurements. Vary the supply voltage such that the potential difference across the combination of resistors in series changes from 0 V to 9 V in steps of 1 V, measuring the current each time. For each applied voltage from the power supply, record the current flowing through the resistors, the voltage drop across each resistor, the voltage drop across the combination of resistors, and the applied voltage across the circuit. Take your readings from the DMMs NOT from the power supply. Record the results in a suitable table with appropriate headings and units.
7. Plot suitable graphs of the voltage drop V across each of the resistance combinations versus the current I flowing through the corresponding resistance combination. (Clearly labelled). Remember to plot your graph using the appropriate SI unit for each quantity.

8. From your graph determine the resistance of each resistor by matching your results with theory.
9. Compare your determined value of resistance (from graph) with the measured value of resistance (from ohmmeter in step 1) by determining the percentage error. Repeat this for each individual resistor and the combination connected in series. i.e. determine R_1, R_2, R_S
10. Explain how the graph can be used to verify the equation for the equivalent resistance of two resistors in series.
11. For the highest voltage used in your experiment determine the power developed in each resistor. Remember to use the data that corresponds to each resistor in question.
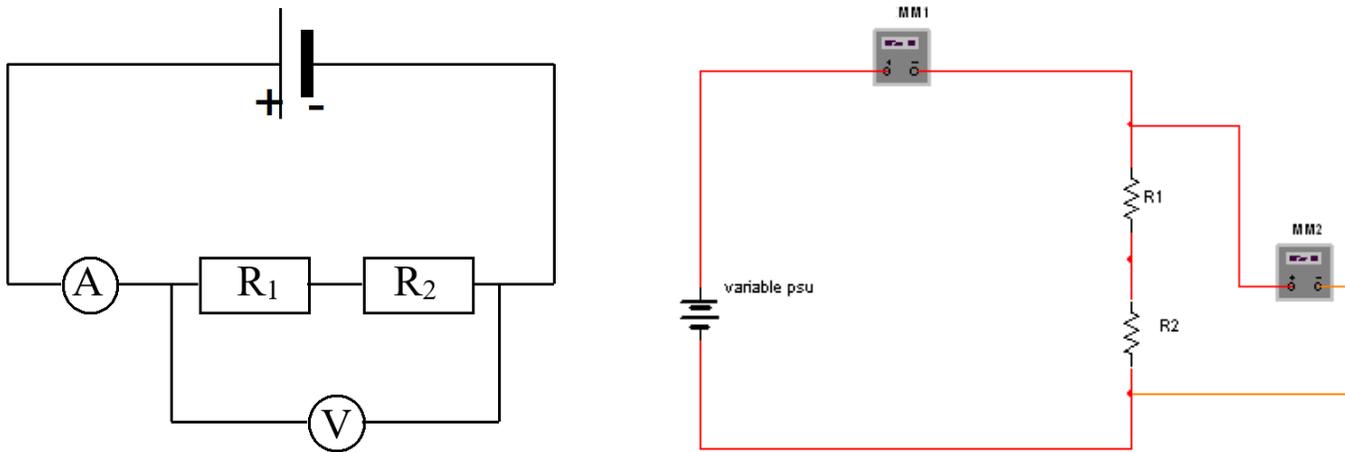12. Write a detailed report as per guidelines.

Fig 3

Experimental Procedure – Electrical Networks
1. Measure the value of each of the three resistors R_1, R_2, and R_3 using the digital multimeter.
2. Set up the series circuit shown in Fig 4.
3. Set the emf, E, of the power supply to 9 V.
4. Measure the total current (I_T) and the current flowing through each resistor.(I_1, I_2, and I_3)
5. Measure the emf of the battery (V_T), and potential difference across each of the three resistors.(V_1, V_2, and V_3)
6. Determine the current flowing through each resistor, using Ohm's Law.
7. Use appropriate equations to verify your results by calculation.
8. Draw up a table of your experimental vs calculated results for each circuit.
9. Repeat procedure for circuit shown in Fig. 5 and in Fig. 6
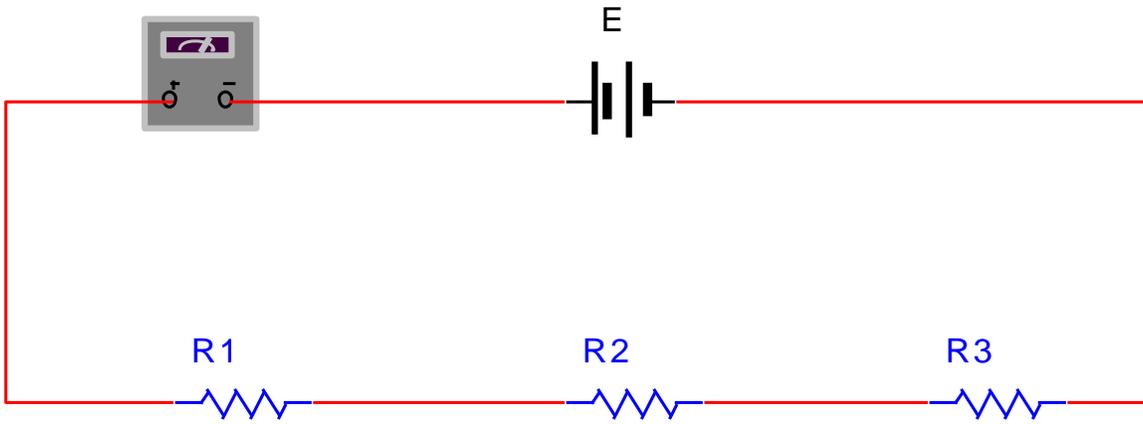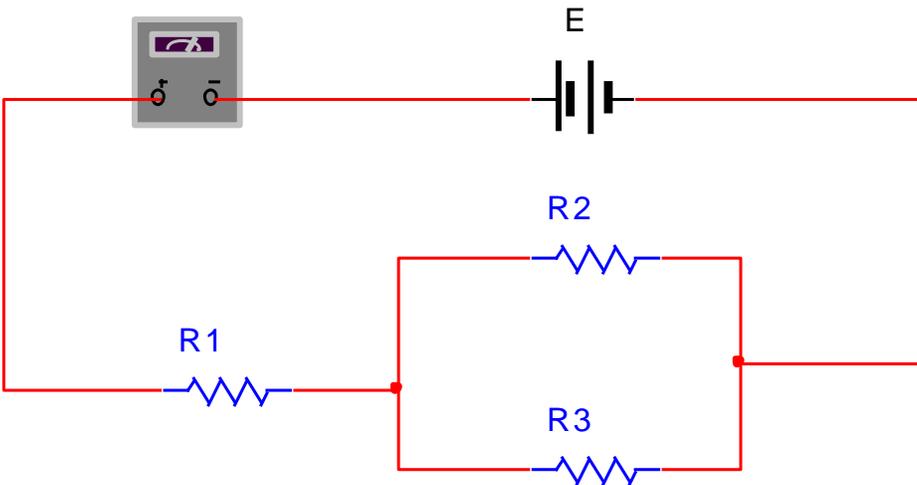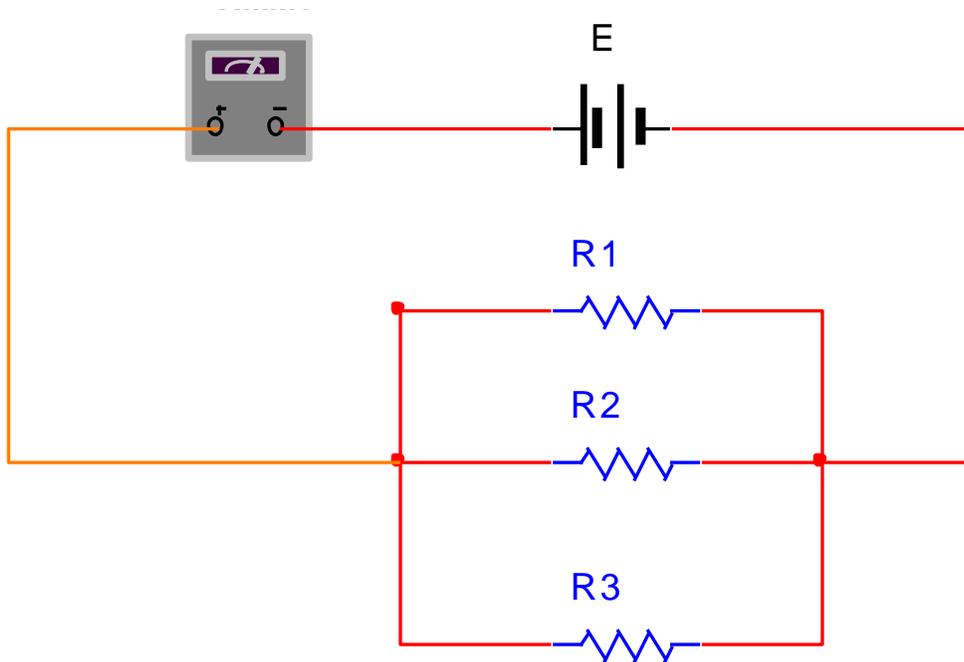
Fig. 4. Three resistors in series

Fig. 5

Figure 6. Three resistors in parallel