Consideration in Real Circuits

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Learning Outcome

I highly recommend you to finish this checklist to determine whether you've achieved the learning objectives.

- ☐ explain the effects of *internal resistance* on *terminal p.d.* and power output of a source of e.m.f.
- ☐ describe experiments to decide the e.m.f. and internal resistance of a source or battery
- ☐ explain the use of *potential divider*[1] circuits
- ☐ solve problems involving the potentiometeras a means of comparing voltage

[1] def:

Leadin

When a battery is short, huge currents will flow from the postive terminal to negative terminal, causing heating of battery. And such accumulation may even lead to explosion. Check the video. Why we should treat battery so seriously?

Figure 1: when a battery is short, chemical energy is transformed into heat immediately

Internal Resistance

But how large is the current when the battery is short, could it be infinite ampere flowing in the battery? The answer is obviously NO!, because realistic battery have its **internal resistance**

definition

The definition of the internal resistance is:

Summary

The resistance resistance inherent in the source itself

Some energy is transferred into thermal energy as work is done in driving charges through the source itself. In order to distinguish the internal resistance with the "external resistance", the symbol for internal resistance is r.

terminal p.d.

With the concept internal resistance, we can explain the phenomenon that when the battery is connected to single component like resistor, lamp or motor as shown in Fig.2

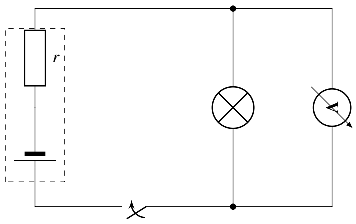


Figure 2: The voltmeter measures the p.d. across the component

Task

Using Kirchhoff's Second Law, explain why the p.d. is less than the e.m.f. of the battery in Fig.2.

Because the existance of internal resistance, the potential difference that can be consumed by the electric components are to be **less than** the e.m.f. of the battery. Such potential difference can also been measured by connecting the voltmeter to the terminals of the battery, hence, it is called the *terminal p.d.* (voltage)

Experiment

By adjusting the resistors connected in the circuit, the terminal p.d. and the current in the circuit will change in ____________________ (same/opposite) direction.

Task

Draw a circuit diagram to show the experiment setup.

Record the terminal p.d. and current respectively in the diagram below:

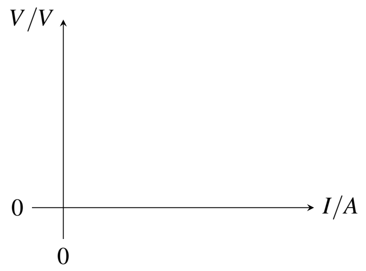


Figure 3: The result graph of determining the $\mathscr{E}$ of a battery

According to the Kirchhoff's second law:

$$\mathscr{E} = I \cdot r + V$$

by rearranging the formula, making V as y and I as x, you will arrive at:

Summary

$$V = -r \cdot \boxed{} + \boxed{}$$
$$y = k \cdot x + b$$

Task

According to the relationship between terminal voltage and current, state what does y-intercept and the gradient represent.

Here are some

Summary

- terminal p.d. depends on the external resistance
- the maximum currents occurs when the battery is short
- the intercept is ____________ of the battery
- the graident of V-I function is the _______________ of the battery

Potential Divider

The Fig.4 shows a potential divider circuits which can provide continous voltage output by connecting in parallel.

Task

Find the expression of the output voltage V_{out} in terms of V_{in}, R_1, R_2

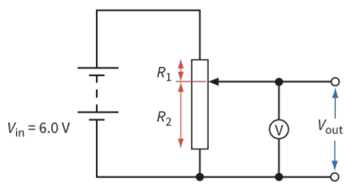


Figure 4: a potential divider

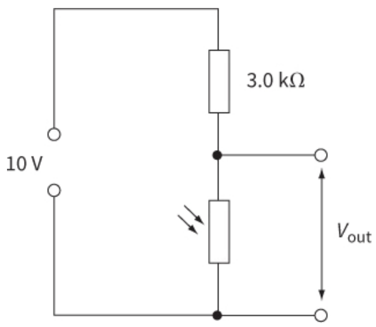
Sensors

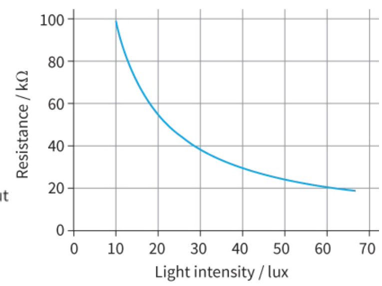
According to KVL $\mathscr{E} = Ir + IR$, by measuring the current(or voltage), the external resistance can be calculated, and if some other factors, like the temperature, pressure, light, etc., may change the external resistance then the factor may be inferred from the resistance. Such device can be called *sensors* or *transducer*[2].

[2] def:

LDR as sensor

The resistance of LDR will vary with the change of light intensity, the circuit diagram and the variation of resistance with light are shown below:





Thermistor as sensor

The resistance of NTC will vary with the change of temperature

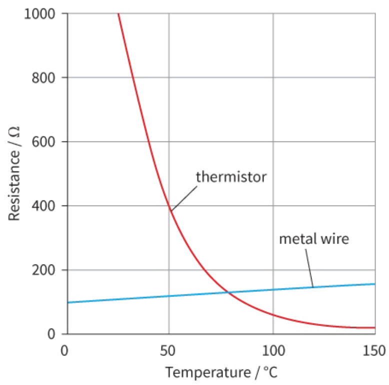


Figure 5: The variation of resistance of NTC thermistor with temperature

Potentiometer

Potentiometer applies generally same ciruit and rationale as the potential divider, the purpose of such device is to measure the unkown e.m.f. of a cell or battery with a driver cell with known e.m.f.

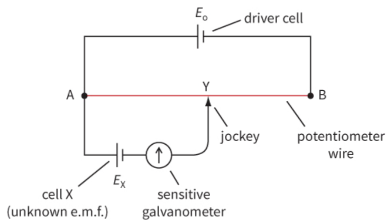


Figure 6: a potentiometer circuit setup

Summary

To find the e.m.f. of cell X, the reading of the galvanometer should be zero, such method is called *null method* State what condition should be satisfied when the galvanometer has a reading of 0 μA.