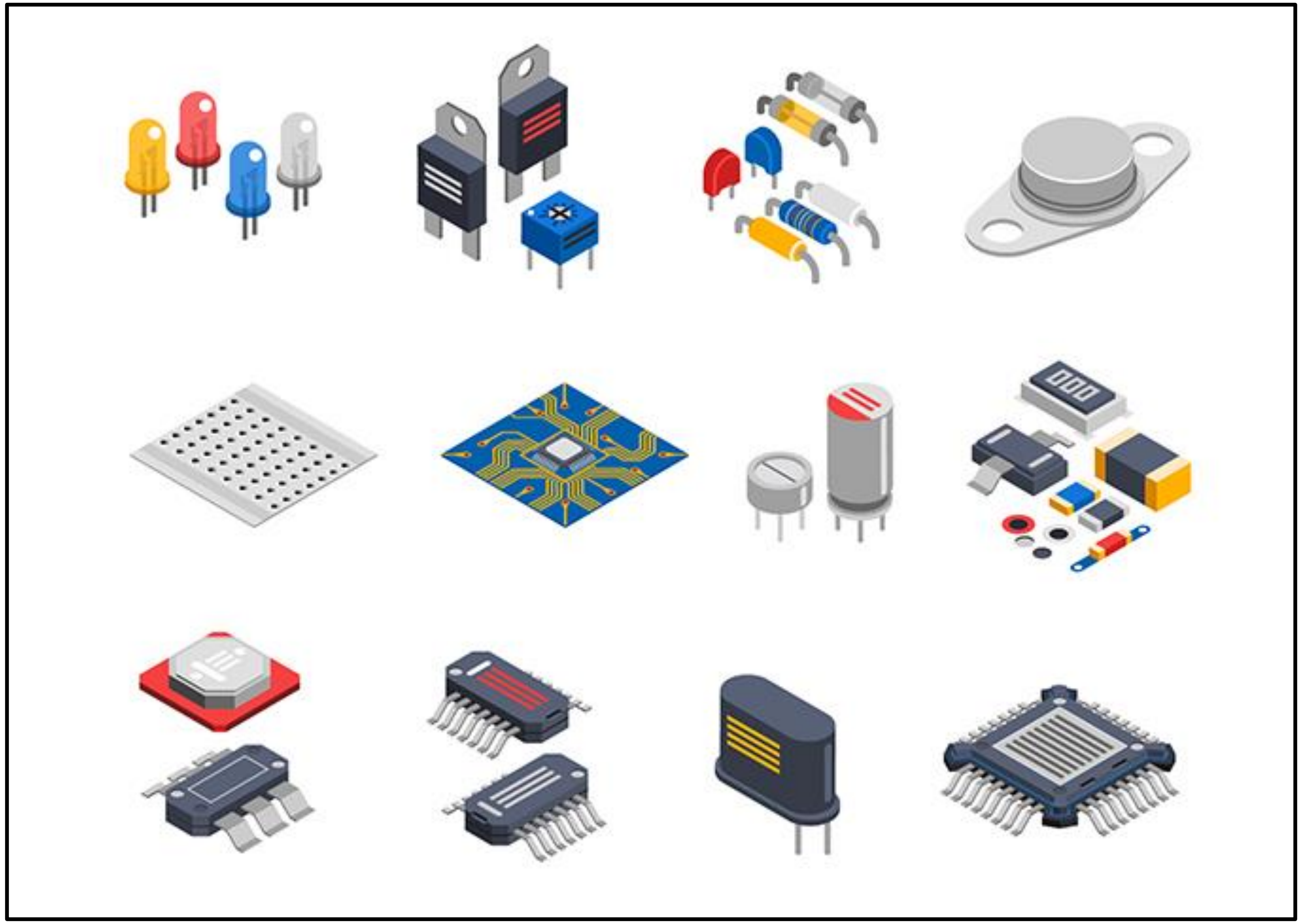
ELECTRIC CIRCUITS



Vera Guarrera - v.guarrera@bham.ac.uk

Account
Admin
Dashboard
Courses
Calendar
12
Inbox
History
Commons
PebblePad
Accessibil

2022/23

Home
Modules
Announcements
Assignments
Discussions
Grades
People
Quizzes
Panopto
Zoom
Pages
Collaborations
BigBlueButton
Syllabus
Outcomes
Files
Rubrics

View all pages

Published
Edit

Week 01 Materials

Week 01 lecture slides:

Week 01 typed notes: 01_Lecture_notes.pdf

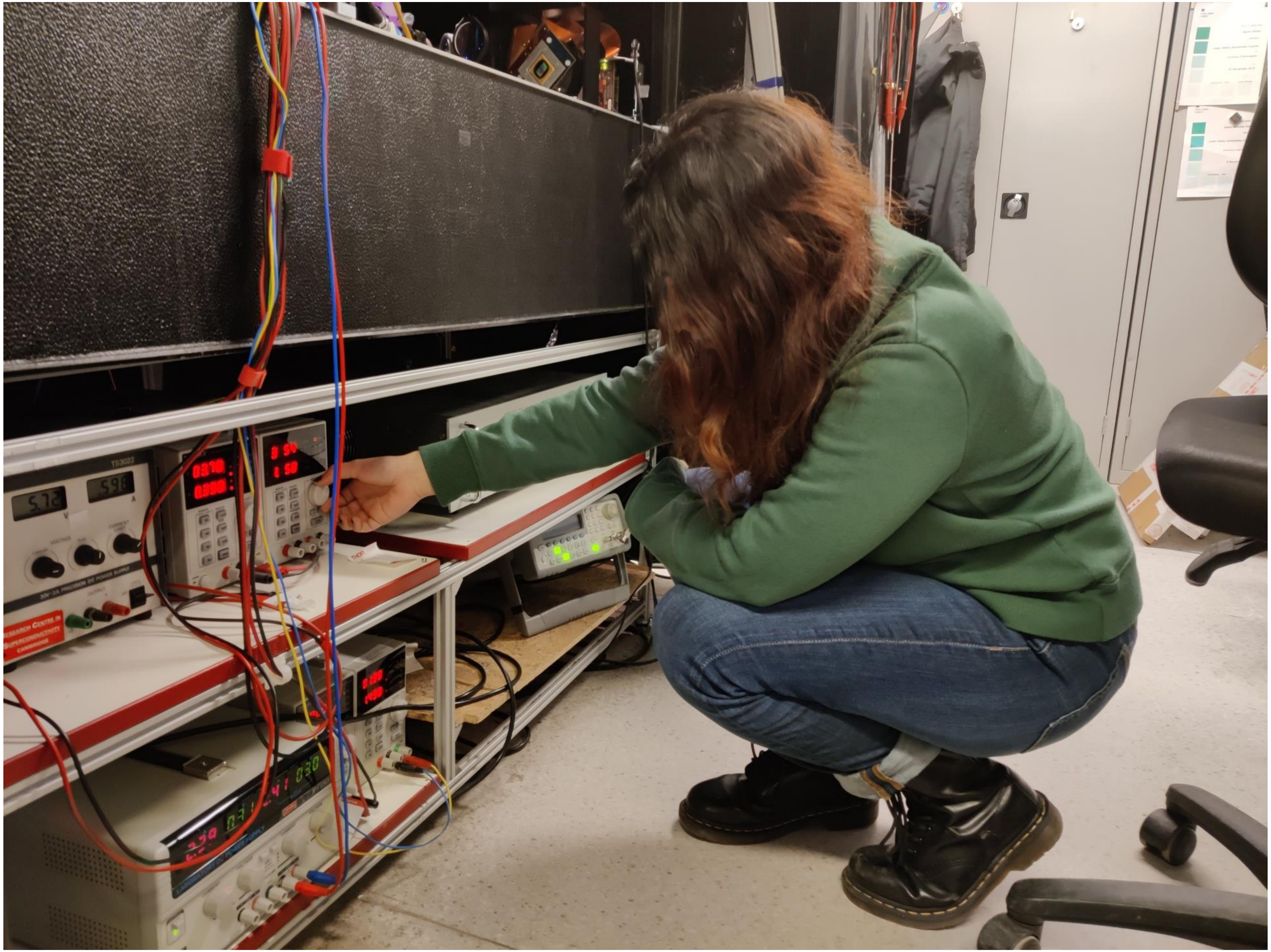
The Panopto recording of this weeks lecture can be seen **HERE**

Non-assessed problem sheets for this week: ec_na_week1_q.pdf and ec_na_week1_b.pdf

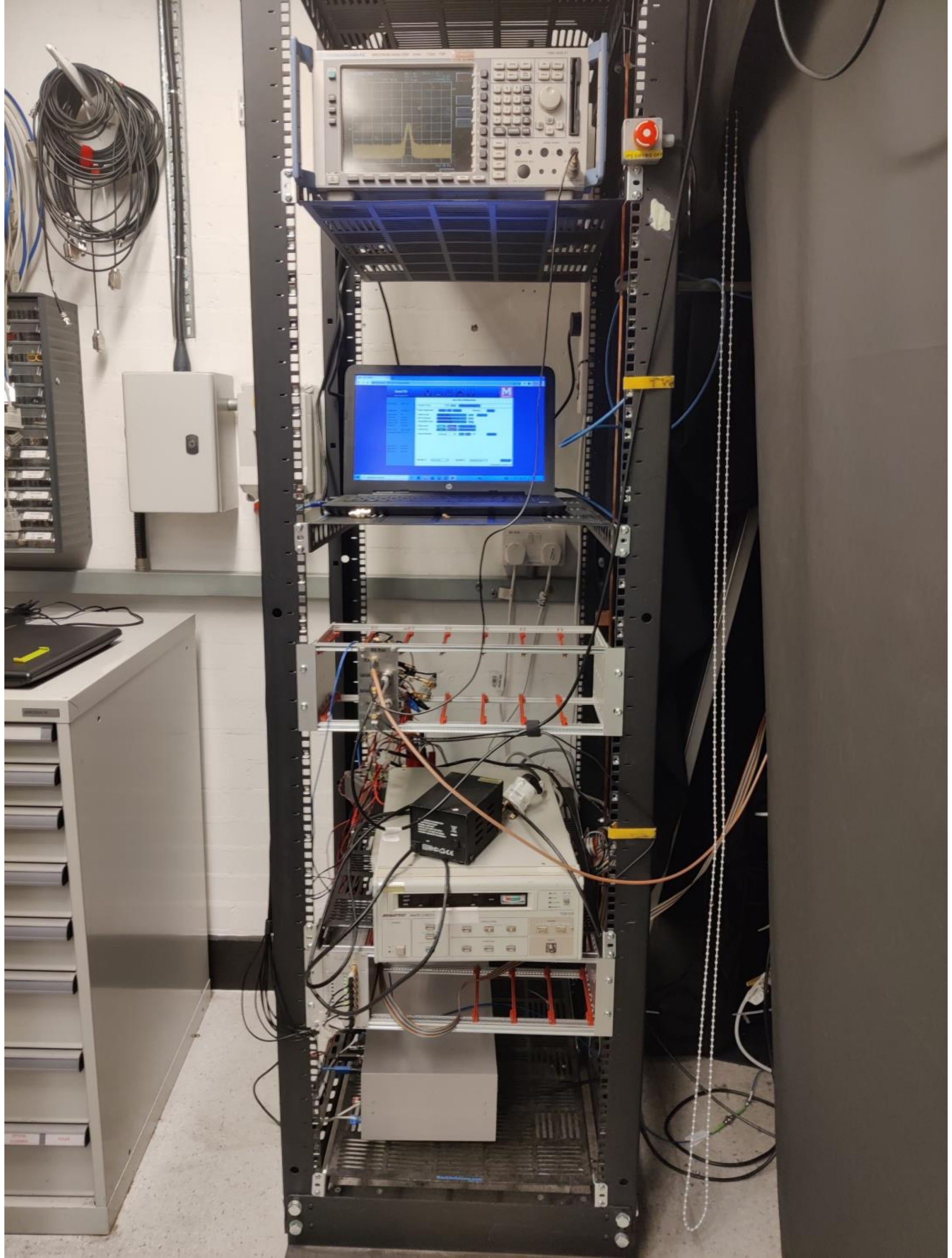
Solutions ec_na_week1_a-1.pdf , ec_na_week1_b_a-1.pdf

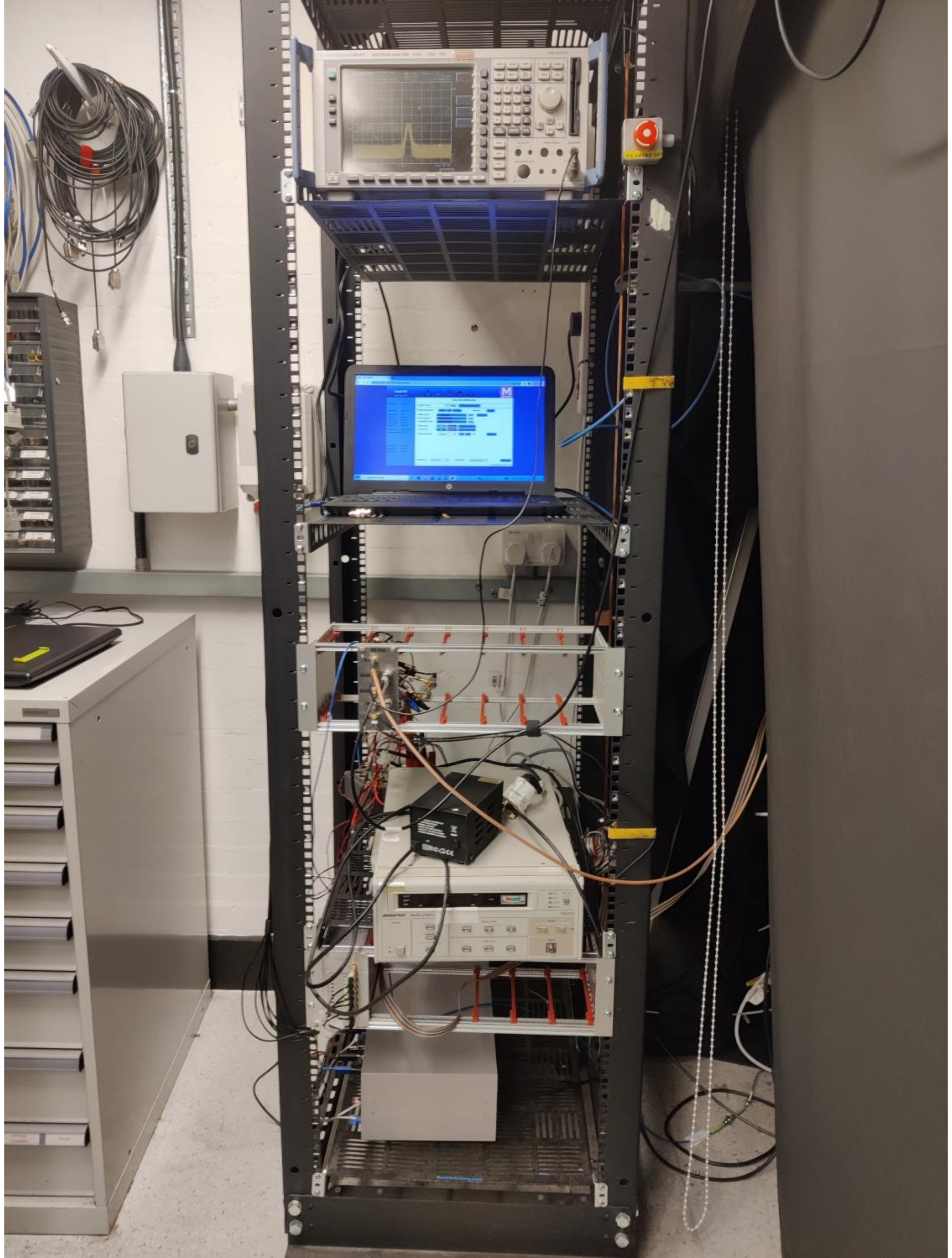
Previous
Next

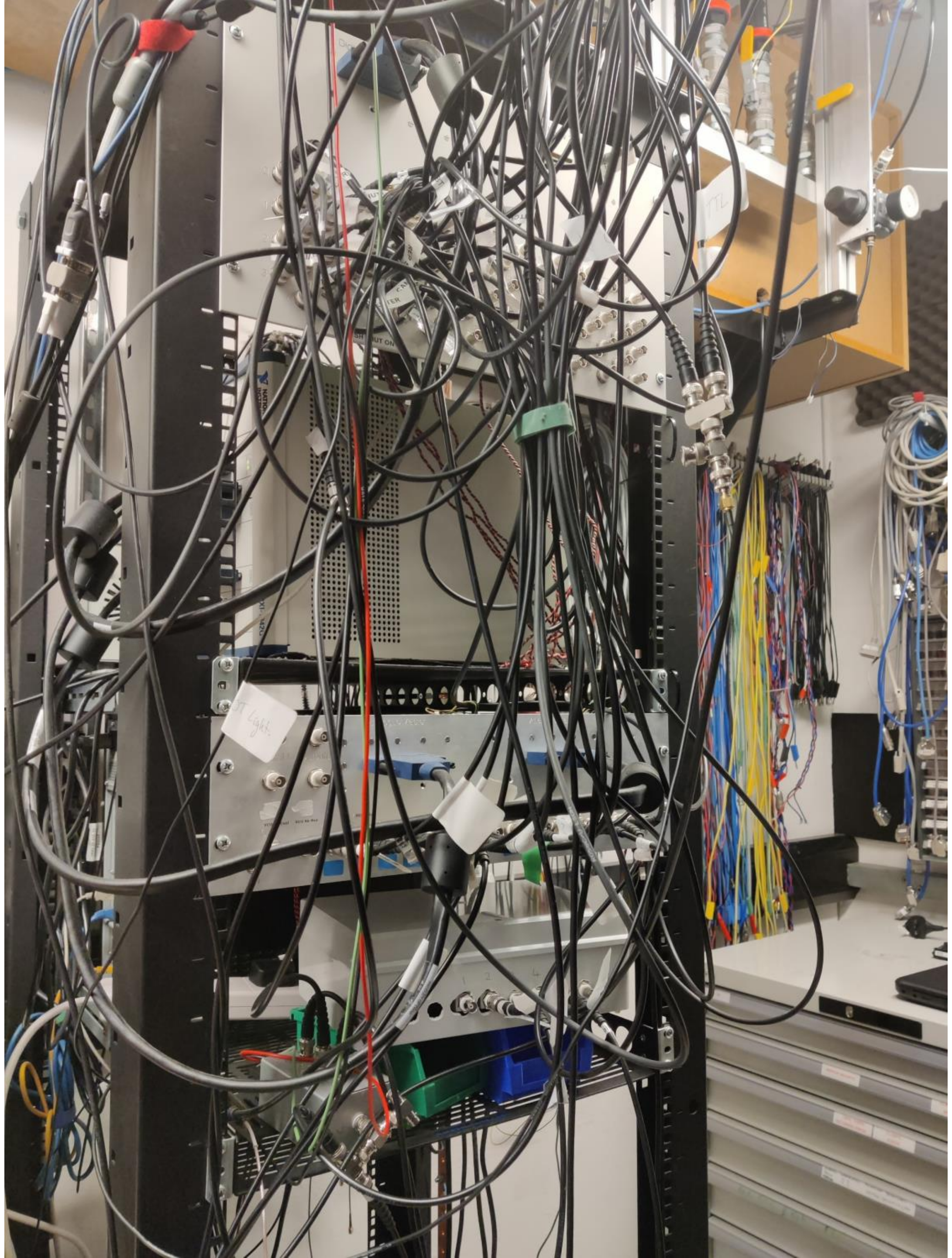
Photonic quantum computer: **Jiuzhang** (2020)



Phd student Symran
working in the
Quantum Systems group







Recommended textbooks

- **University Physics**
  Young and Freedman
  Suggestions for further reading will be given at the end of each lecture
- **Introduction to Electric Circuits**
  Ray Powell. Highly recommended! Main Library - short loan, (5 copies)
- **Physics for scientists and engineers (5th edition)**
  Paul A. Tipler and Gene Mosca
- **Electric Circuits (TK3226)**
  P. Silvester. School of Electrical Engineering Library, (9 copies)
- **Introductory Circuit Theory (TK3226)**
  J.K.Fidler and L. Ibbotson. Main Library - short loan, (2 copies)

- **The art of Electronics – *For advanced reading***
  P. Horowitz and W. Hill

Syllabus

- **Direct current (DC) circuit analysis** **(4 sessions)**
  Current, voltage, Ohm's law, Kirchhoff's law, Thevenin's theorem, Superposition theorem
- **Transient response** **(2 sessions)**
  Capacitors, inductors, RC and RL circuits, response to pulses
- **Alternating current (AC)**

- **Circuit analysis** **(4 sessions)**
  Phasors, complex impedance, RC and RL filters, LCR circuits, resonance, and Q factor.

Week 01: material covered

Units and definitions: current, voltage, power

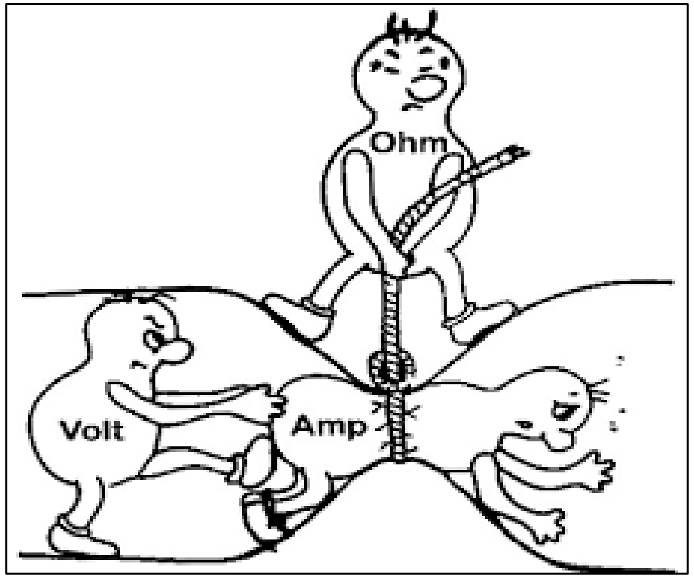
Resistance, Ohm's law

Dimensional analysis

Resistors in series and in parallel

Voltage divider and current splitter

Practical applications

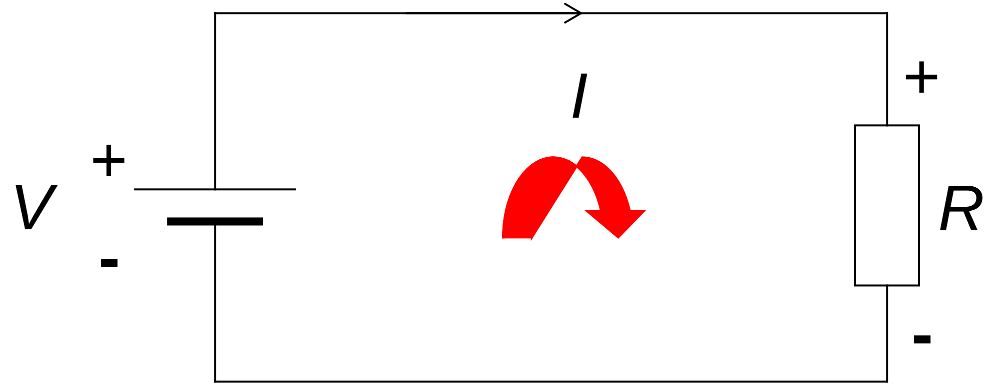


Definition

What is an Electrical Circuit?

A closed path around which an electrical current may flow.

Battery converts chemical energy into electrical potential energy.



Resistor only dissipates energy.

The terminal where the current enters a resistor is always at the higher electrical potential.

– Contains one or more active devices which deliver energy.

e.g. battery - or a source of Electromotive Force (EMF)

– Contains passive devices (e.g. resistors) which dissipate energy.

– Current is taken to flow from points of higher electrical potential to points of lower electrical potential.

– Conventional current flow is opposite to that of electrons.

Units

- **Charge (Coulomb, C)**

  The unit of electrical charge is the Coulomb. Charge is quantized, that is, it comes in discrete amounts. The charge of an electron is -1.602×10^{-19} C.

- **Current (Ampere, A)**

  Electric current is defined as the rate at which charge flows through a given point in a circuit: $\mathrm{I} = \frac{\Delta Q}{\Delta t}$

- **Potential Difference (Volt, V)**

  The work done when transferring charge from one point in a circuit to another: $\mathrm{V} = \frac{\Delta W}{\Delta Q}$

- **Resistance (Ohm, Ω), Ohm's law**

  The ratio of the voltage across a circuit element to the current flowing through it.

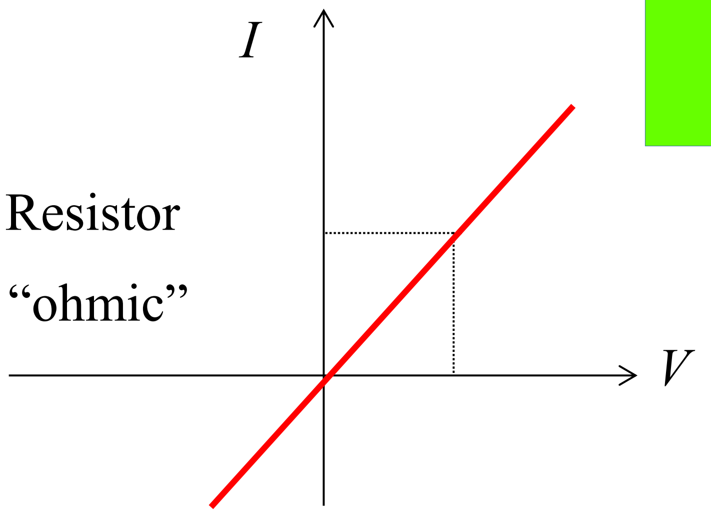
- **Power (Watt, W) is defined as the rate of doing work.**

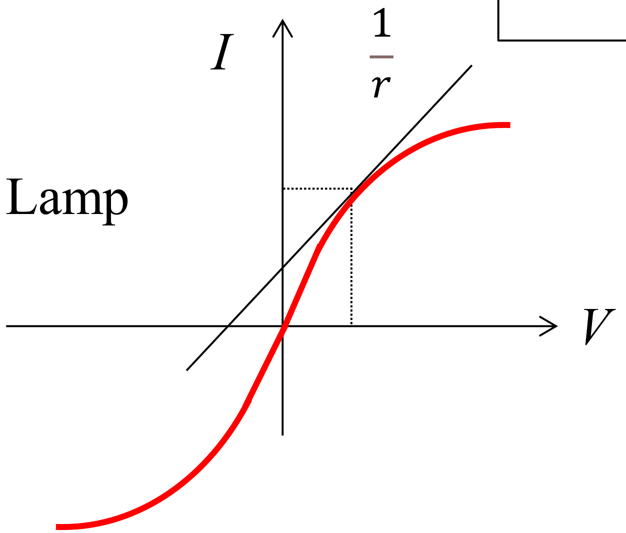
Resistance and Ohm's law

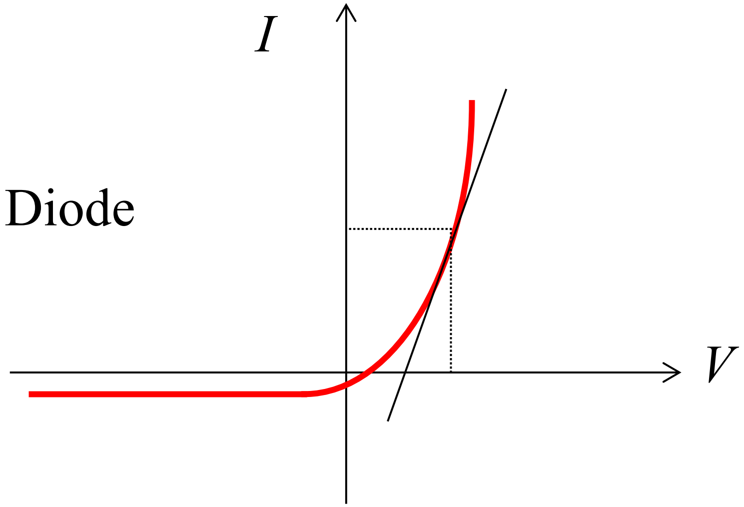
- I-V characteristics

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

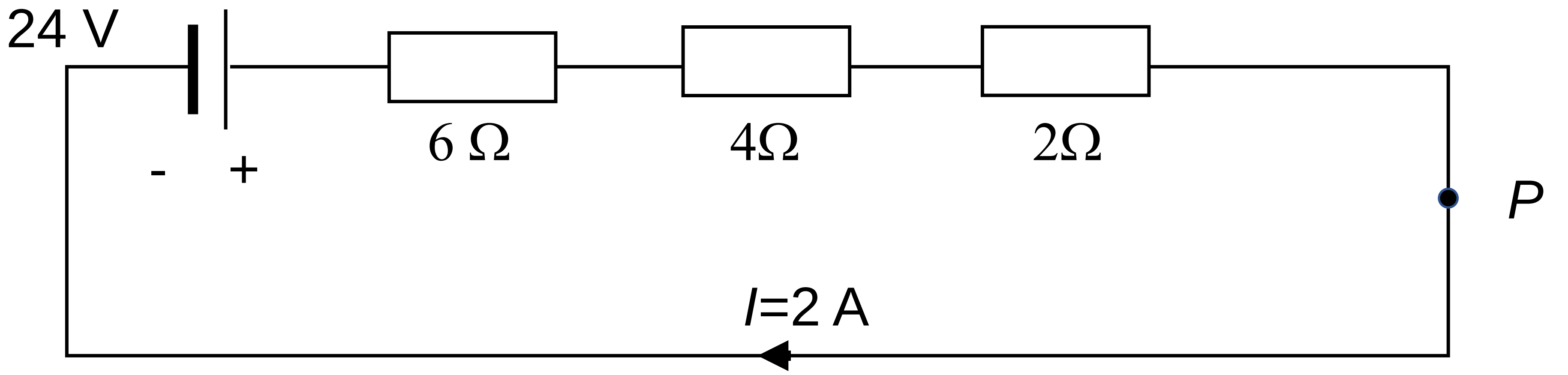
Dynamic resistance $\boxed{r = \frac{dV}{dI}}$

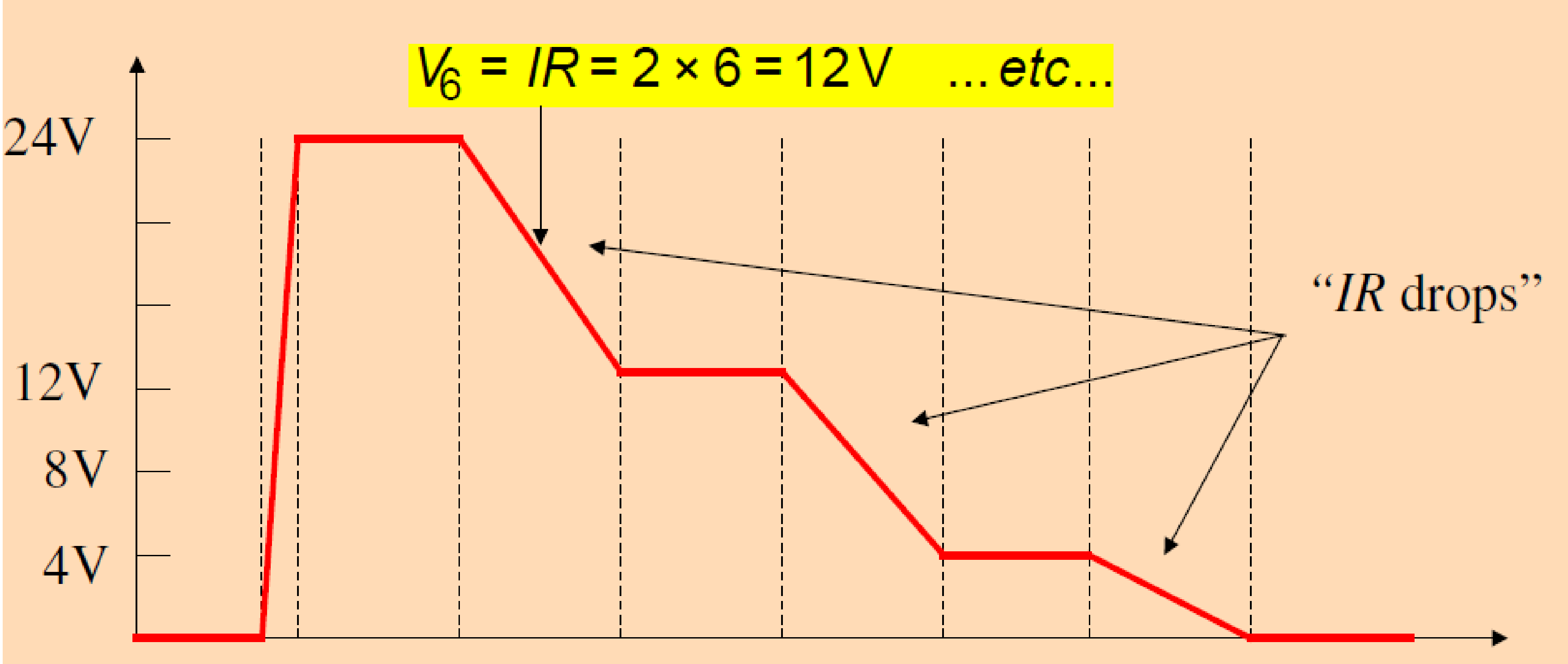




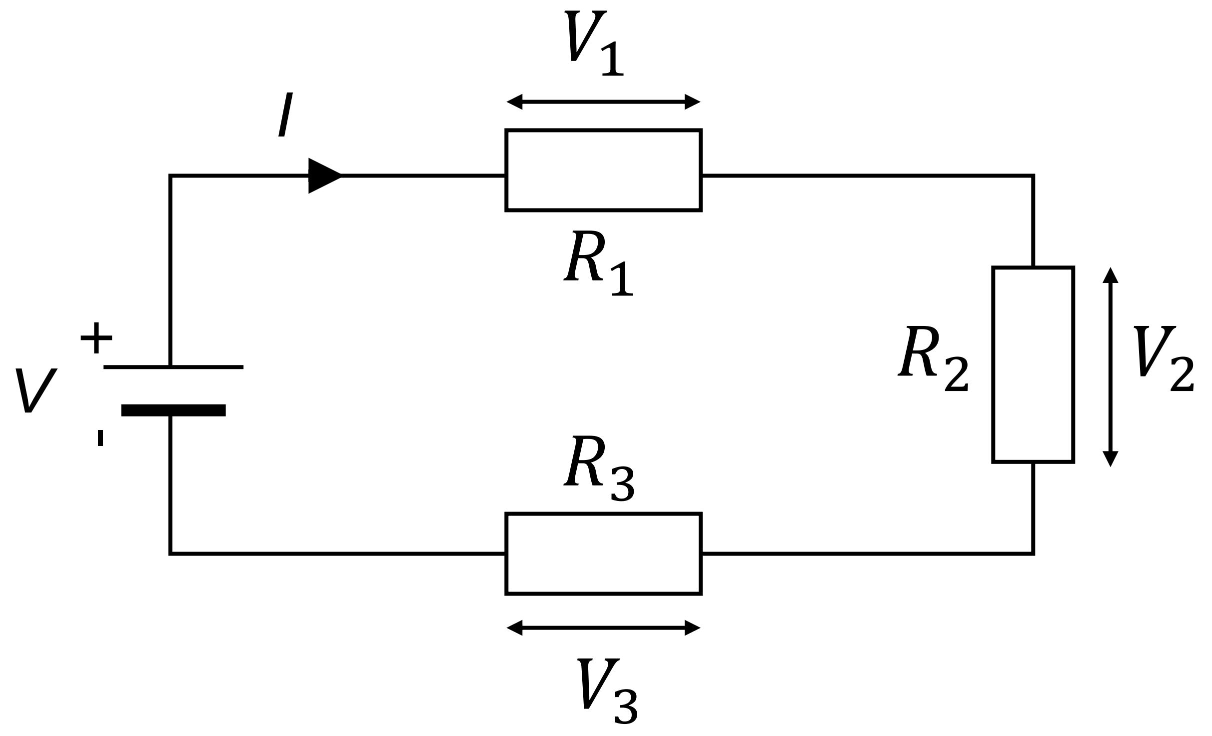


Electrical potential in a series circuit

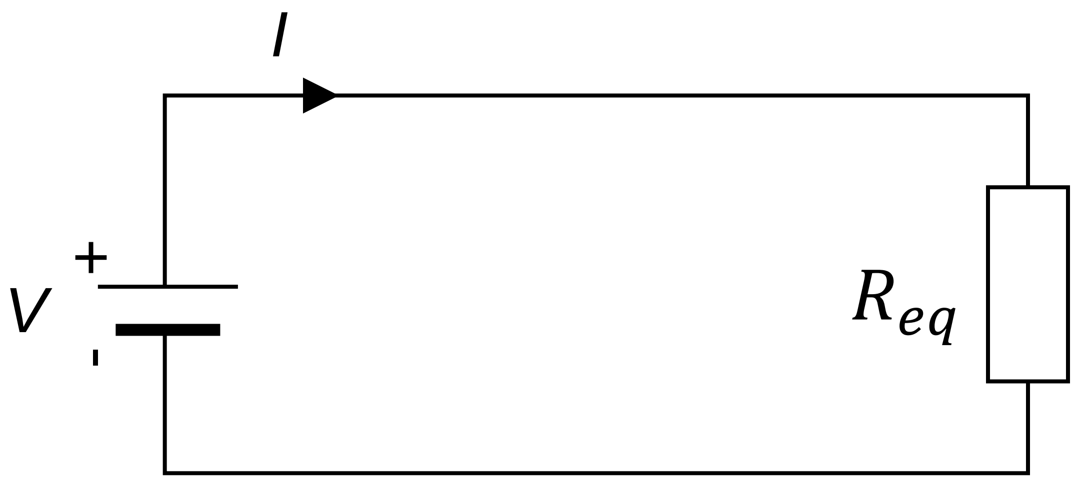




Resistors in series



Equivalent circuit



1) **Energy** is conserved: $V = V_1 + V_2 + V_3$

2) The **current** through each resistor is the same.

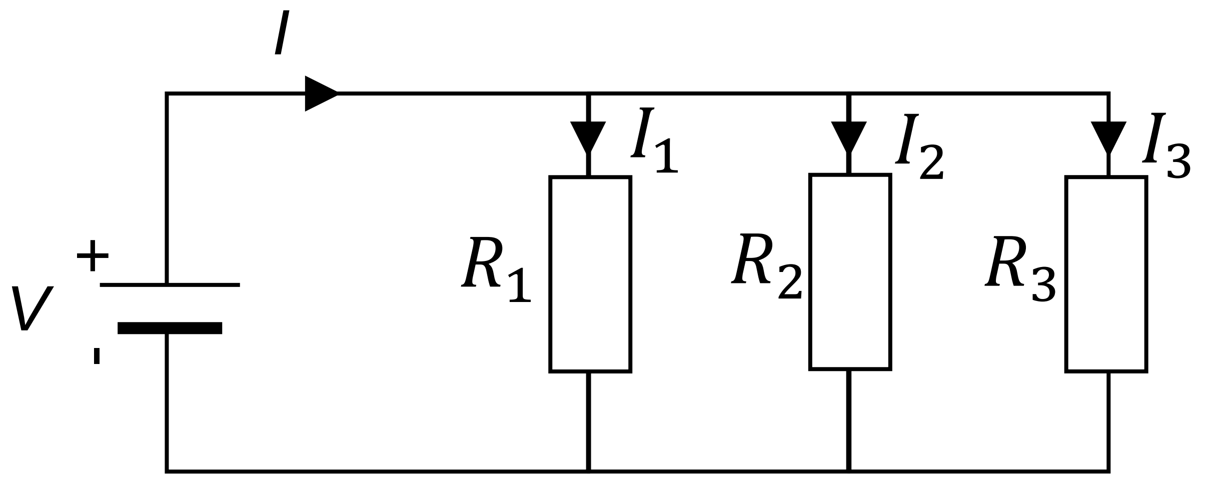
3) By **Ohm's law**: $V_1 = IR_1, \quad V_2 = IR_2, \ldots$

4) Substituting 3) into 1):

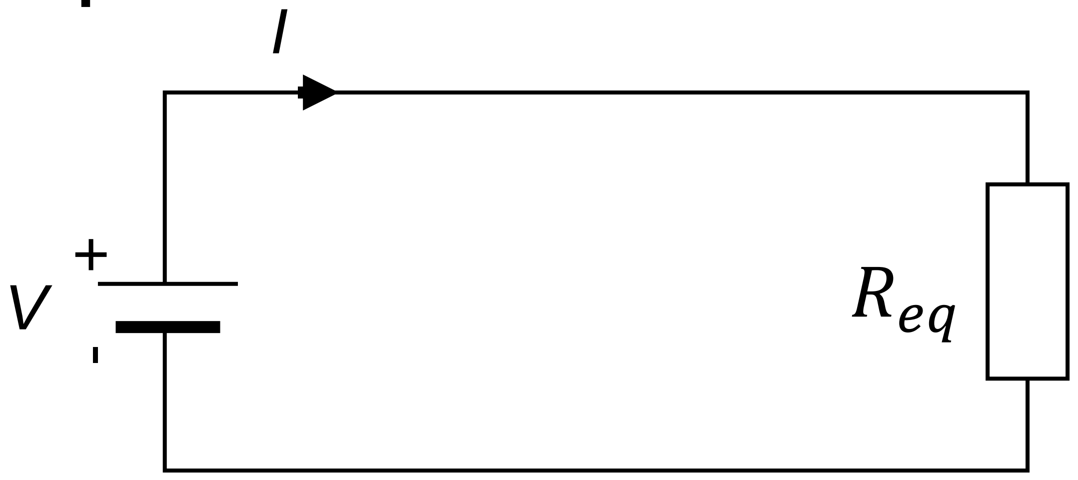
$$V = I(R_1 + R_2 + R_3) = IR_{eq}$$

$$R_{eq} = R_1 + R_2 + R_3$$

Resistors in parallel



Equivalent circuit



1) **Charge** is conserved: $I = I_1 + I_2 + I_3$

2) The **voltage** across each resistor is the same.

3) By **Ohm's law**: $I_1 = \dfrac{V}{R_1}, \quad I_2 = \dfrac{V}{R_2}, \ldots$

4) Substituting 3) into 1):

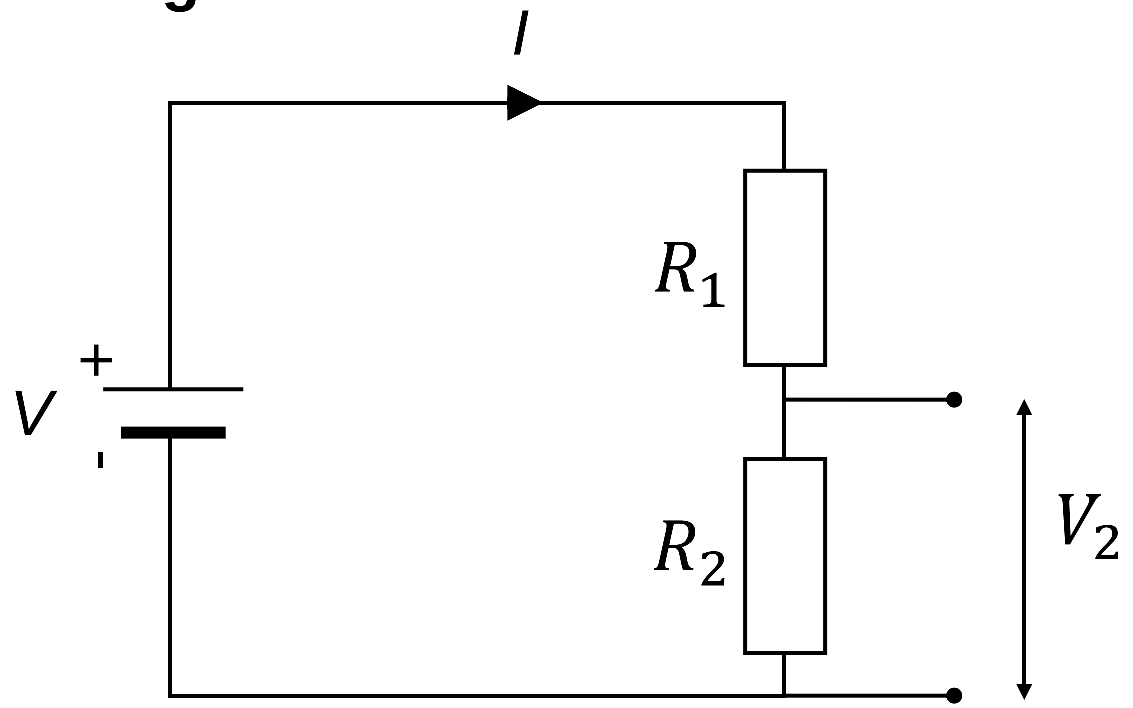
$$I = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) = \frac{V}{R_{eq}}$$

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

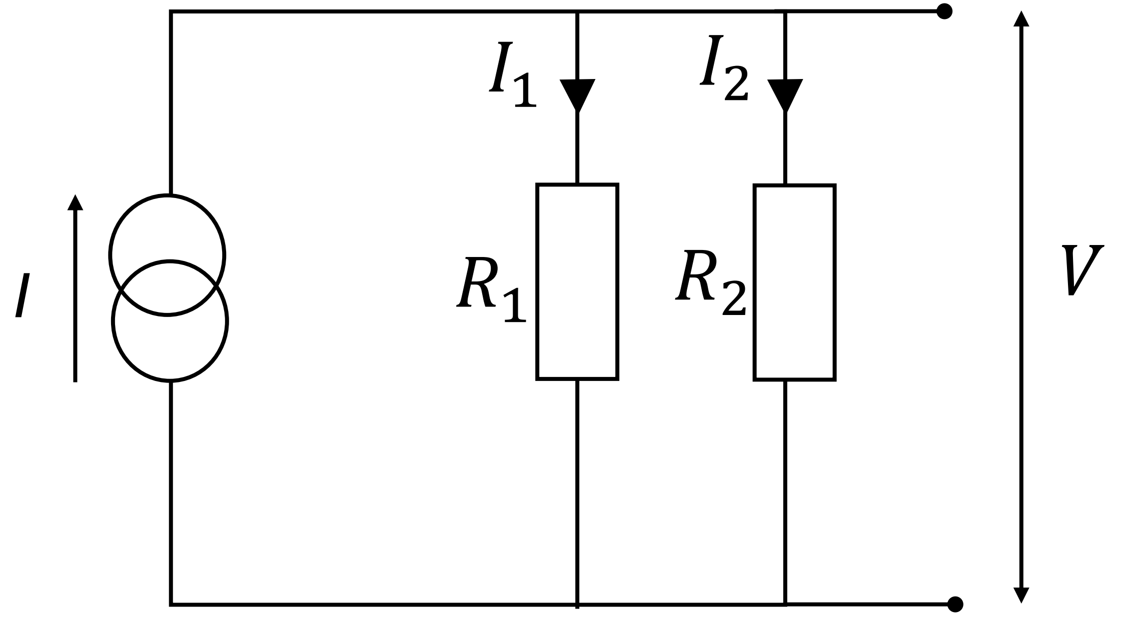
$$R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$$

Two important circuit topologies

Voltage divider



Current splitter



$$I = \frac{V}{R_{eq}} = \frac{V}{R_1 + R_2} = \frac{V_2}{R_2} = \frac{V_1}{R_1}$$

$$V_2 = V\frac{R_2}{R_1 + R_2}$$

$$V = IR_{eq} = I\frac{R_1 R_2}{R_1 + R_2} = I_2 R_2 = I_1 R_1$$

$$I_2 = I\frac{R_1}{R_1 + R_2}$$

Practical applications

Electronic equipment is used every day at home and work.

What fuse would you use for:

a) a typical electric lamp?	3A 5A 13A 60A
b) a 2 kW electric kettle?	3A 5A 13A 60A
c) an electric cooker?	3A 5A 13A 60A

Where do we start?

Starting point

Ohm's law $\boxed{V = IR}$

What is V?	V is a **potential** i.e. **potential energy** per unit charge

$$V = \frac{E}{q}$$

Energy $E = qV$

Power $P = \frac{dE}{dt} = V\frac{dq}{dt} = VI$ assuming constant V (DC)

$$\boxed{\text{P}= VI = RI^2}$$

Practical applications

What fuse would you use for:

a) a typical electric lamp? 3A 5A 13A 60A
b) a 2 kW electric kettle? 3A 5A 13A 60A
c) an electric cooker? 3A 5A 13A 60A

Where do we start?

$$V = IR \qquad P = IV$$

a) Lamp 10-20W/240V ≈ 0.04-0.08 A — 3A 5A 13A 60A
b) Kettle 3000W/240V ≈ 12 A — 3A 5A 13A 60A
c) Cooker 12000W/240V ≈ 48 A — 3A 5A 13A 60A

Some fuses designed to blow if current exceeds limit for short time others designed to survive current spikes.

Week 01: summary

Units and definitions: current, voltage, power

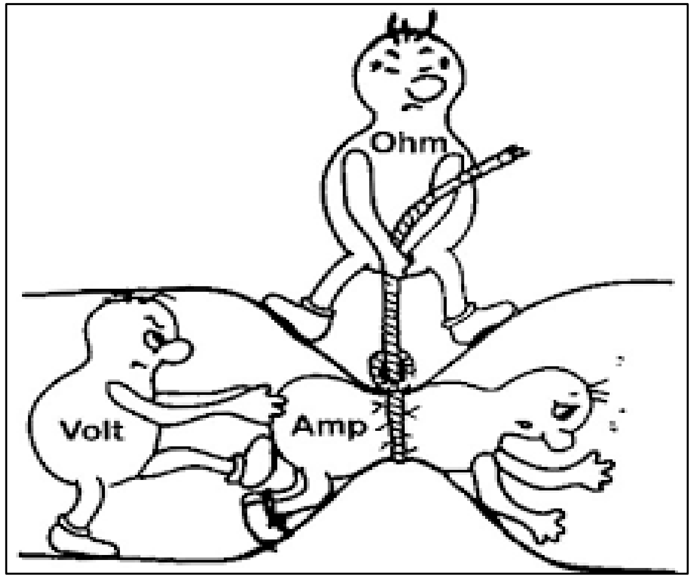
Resistance, Ohm's law

Dimensional analysis

Resistors in series and in parallel

Voltage divider and current splitter

Practical applications



Further reading: Tipler, 26-1 to 26-4
Powell, Chapters 1 and 2