ECE 205 “Electrical and Electronics Circuits”

Spring 2024 – LECTURE 1

MWF – 12:00pm

Prof. Umberto Ravaioli

2062 ECE Building

Lecture 1 - Summary

- **Brief introduction to course organization**
- **Importance of electrical and electronics systems for *non-ECE* engineering fields**
- **Charge and current**
- **Circuit elements**

Course organization - Canvas

- **All information and communications will be through the class Canvas space**

https://canvas.illinois.edu/courses/42722

- **Online discussion board: Campuswire**

Join using link on Canvas

Course organization - Grading

• Homework	15% (Prairielearn) + 5% (written)
• Extra Credit	4%
• Quizzes	40% (Prairielearn)
• Final Exam	15% (Prairielearn)
• Lab	25%
• Total	104%

Course organization - Homework

- **Homework on Prairielean can be submitted late, with grade reduction.**

- **Written homework is submitted on Canvas and CANNOT be late. Plan for it.**

- **The LOWEST homework grade is going to be dropped.**

Course organization - Laboratory

- Professor Chandra Radhakrishnan (ECE 205 Course Director) will be in charge of the laboratory.
- Lab sessions will start the third week of classes. Groups will meet every other week.
- Arrangements will be communicated. Please, be patient. It takes time to set things up while enrollment stabilizes.

Course organization - Exams

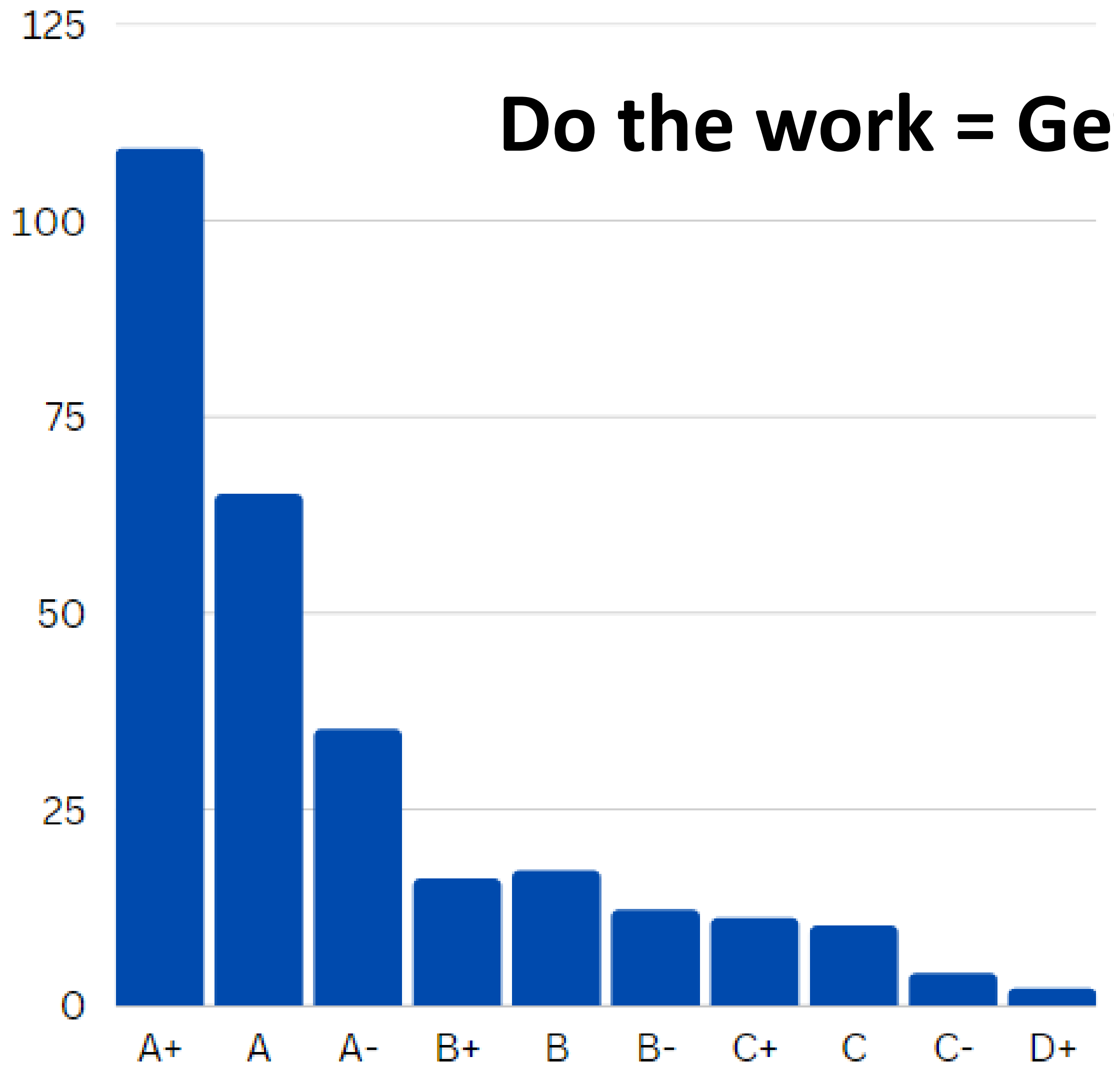
- **There will be 4 (four) Prairielearn quizzes to be taken at CBTF, each on flexible schedule over a period of three days.**
- **Final exam (1h 50min). When enrollment stabilizes we will know if this can be administered at CBTF, depending on capacity.**
- **Final exam score may replace a lower quiz score.**

Course organization – Extra Credits

- Extra credit assignments will be opened shortly after each of the four quizzes.
- You will have a stated time limit for completion on Prairielearn.
- You may earn up to a total of 4% toward your final score.

Because of the generous course allowances, no other extensions will be given, except for documented extenuating circumstances.

Grade Distribution – Spring 2023



Do the work = Get the reward

Course organization – Material

- Available material will be posted with links at the “MODULES” section of the Canvas site.
- The lectures slides will be posted ahead of class.
- Lectures will be taped, with videos accessible through Illinois Media Space (university login needed). Last semester’s videos will remain posted until the new lecture is ready.
- The slides repository is at (no login necessary):

urlectures.web.illinois.edu

Course organization – Material

- **Lecture recordings are NOT intended to be the equivalent of "online lectures". They are a record posted for your convenience in case you need to review something you missed.**

- **Lecture slides are provided ahead of class whenever possible. You are not expected to copy down everything since there will be circuit schematics and many derivations.**

Course organization – Material

- Due to time limitations, we may not have time to go through extra examples/problems and additional videos will be posted.
- And yes, sometimes slides will be busy when discussing problems, because I prefer to unpack most derivations, step-by-step, whenever possible. Try again the problems on your own without looking, if you want to study effectively.

A COUPLE OF

FREQUENTLY

ASKED

QUESTIONS

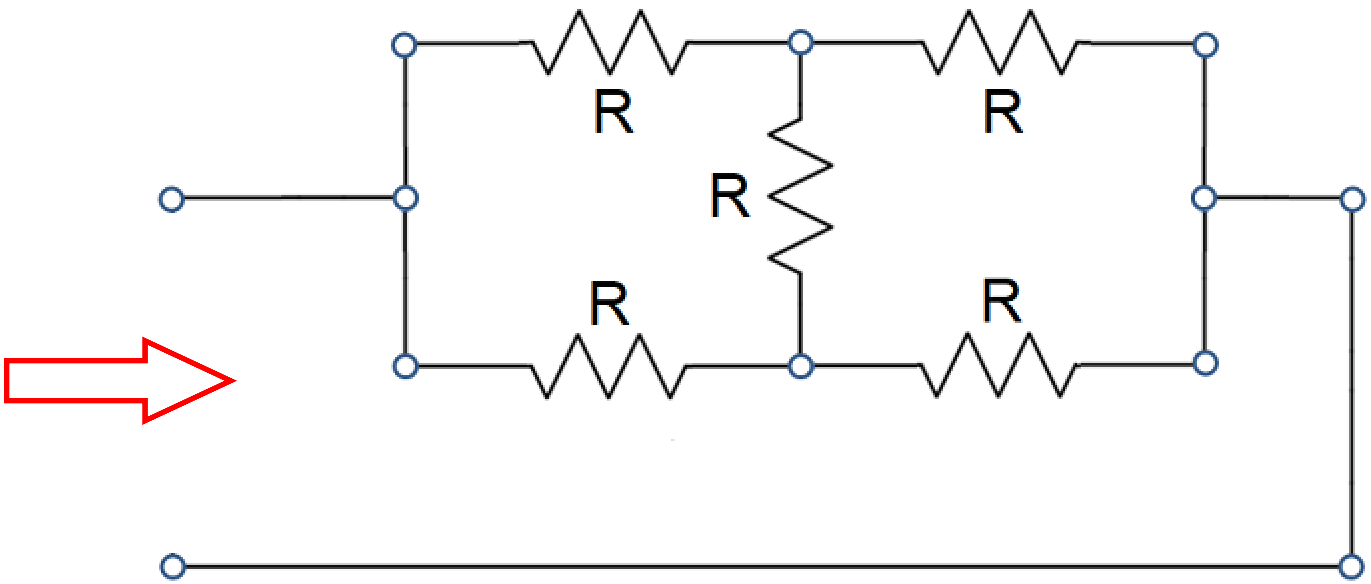
ECE 205 is just a repeat of PHYS 212, why even bother to study this stuff all over again?

- **You'll find out soon enough that this is not the case.**
- **Yes, some topics have been introduced already because PHYS 212 is the necessary prerequisite, but you still have to go to the next level of complexity in applications.**

Let's do some diagnostics with the problem on the next slide.

You have seen parallel and series resistors in PHYS 212. Can you calculate the equivalent resistance of this network?

R_{eq} =



I am in Mechanical Engineering. Why do I have to take a lab in ECE 205 and then take ECE 206? It's a waste of time!

- **ECE 206 builds on the ECE 205 lab experience.**
- **The curriculum was designed in close synergy by the MECHSE and ECE Departments.**
- **The contents are periodically revised for professional relevance of the topics covered.**

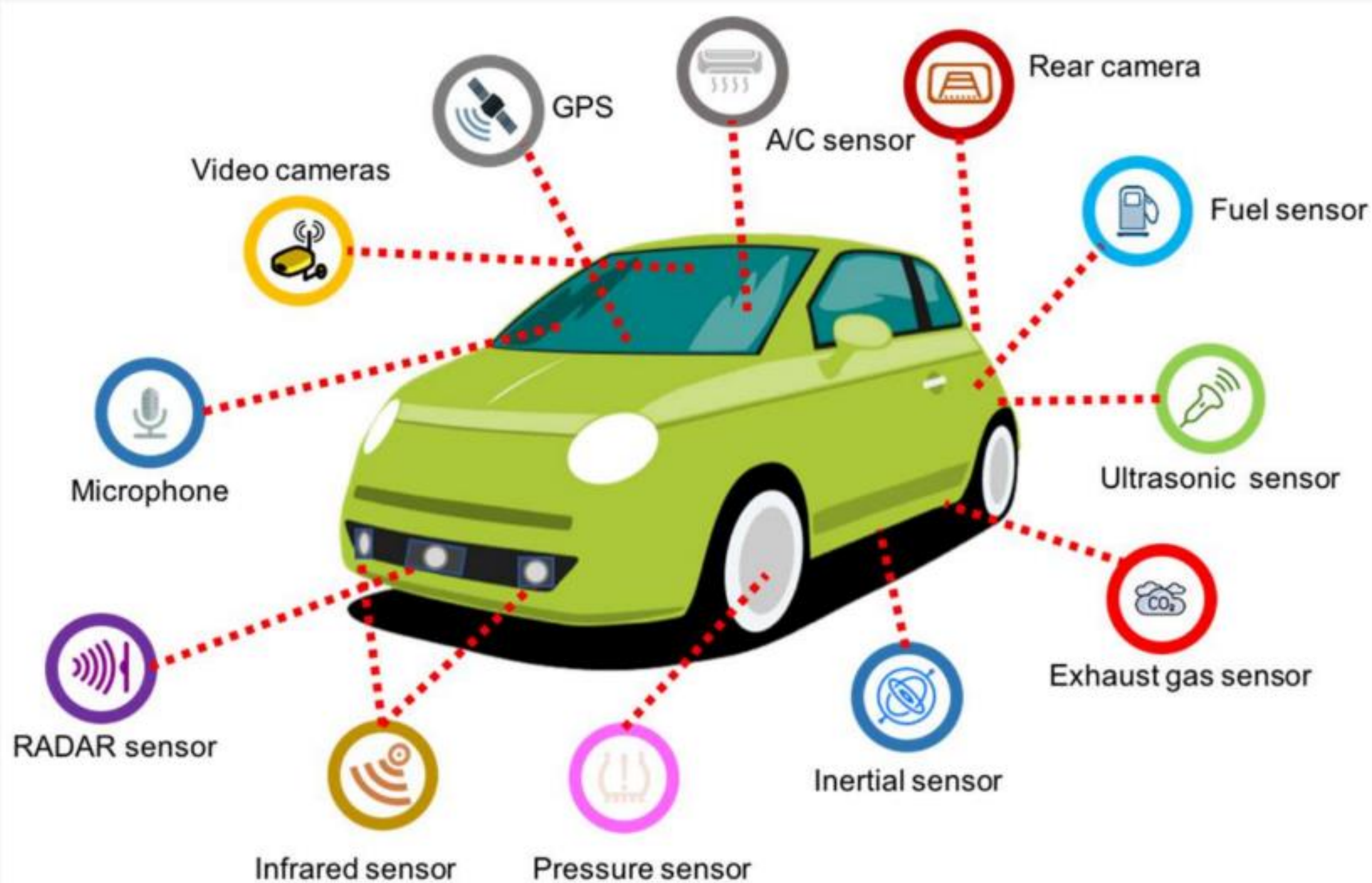
- **But you are probably right, it is totally unfair for Illinois graduates to be better prepared than students from other schools.**

Why is ECE 205 important for non-ECE majors?

- Electrical sensors and actuators (controls systems)
- Electrical power generation & battery storage
- Electrical/Computer systems in Robotics
- Computerized vehicle management systems
- Electrical propulsion
- Autonomous systems
- Internet of Things (IoT)

just to name a few...

Figure 1. Different types of in-vehicle sensors.



https://www.mdpi.com/1424-8220/18/4/1212

Guerrero-Ibáñez J, Zeadally S, Contreras-Castillo J. "Sensor Technologies for Intelligent Transportation Systems." *Sensors*. 2018; 18(4):1212. https://doi.org/10.3390/s18041212

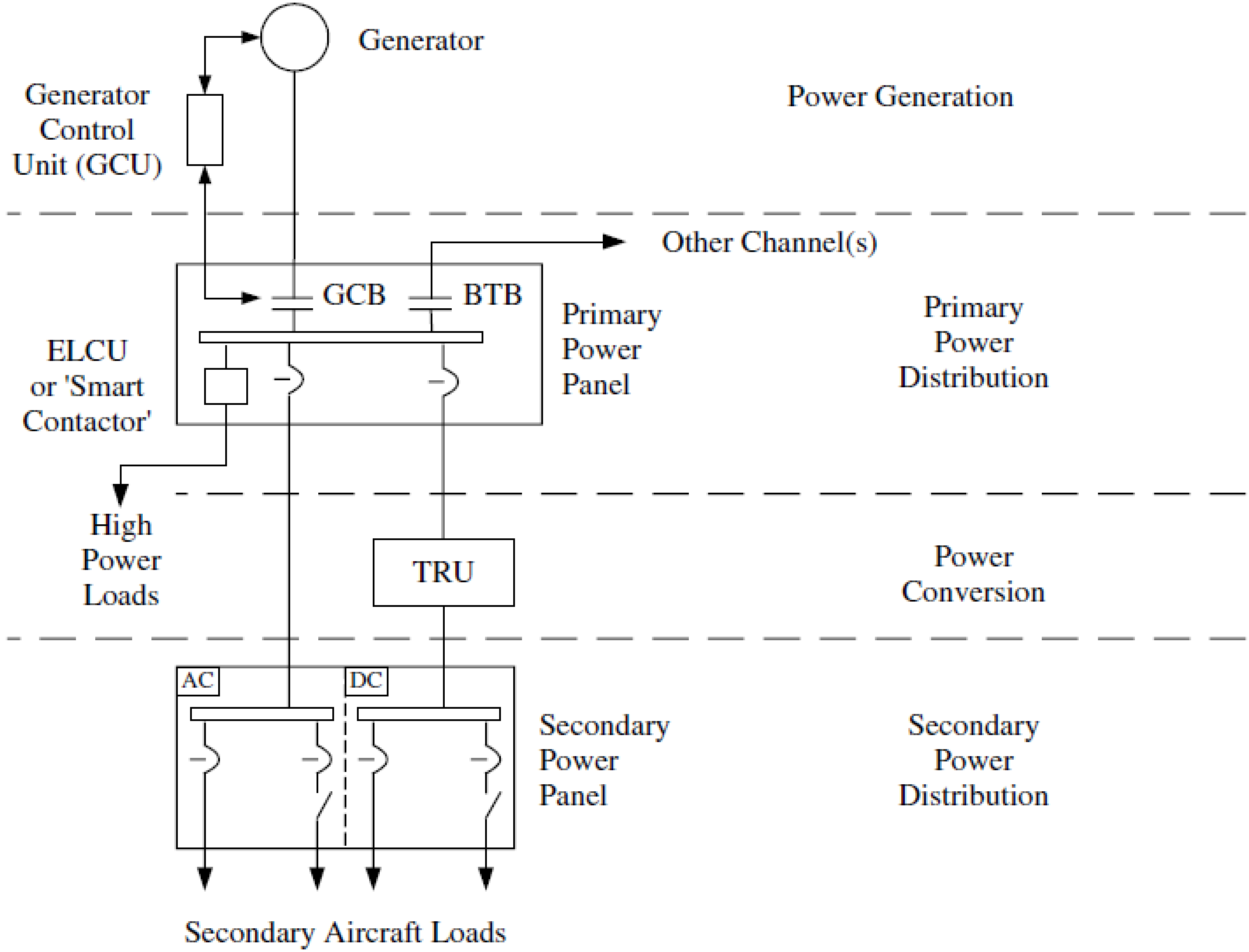


Figure 5.3 Generic aircraft AC electrical system

https://onlinelibrary-wiley-com.proxy2.library.illinois.edu/doi/book/10.1002/9780470770931

Ian Moir, Allan Seabridge. "Aircraft Systems: Mechanical, electrical, and avionics subsystems integration, Third Edition," Wiley Online Library (2008)

The rise of the electrical wiring interconnect system (EWIS)

The move towards a digital transformation is critical to the growth and innovation of the Aerospace industry

https://resources.sw.siemens.com/en-US/e-book-electrical-analysis-design?gclid=EAIaIQobChMI-rz_m9ur_AIVDoRaBR2crwzSEAAYASAAEgLoqPD_BwE&id=EAIaIQobChMI-rz_m9ur_AIVDoRaBR2crwzSEAAYASAAEgLoqPD_BwE:G:s

Electric propulsion

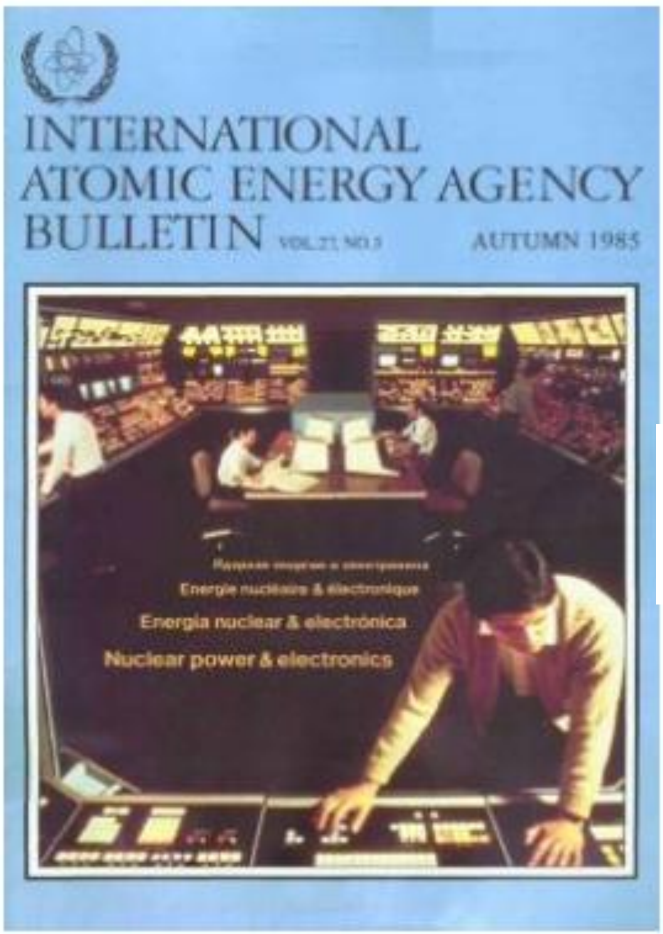
Bullet Trains

Drones

IAEA
International Atomic Energy Agency

Nuclear power and electronics

Journal issue from September 1985 already!!!



Nuclear power and the electronics revolution. From video systems to robots, electronic tools are influencing nuclear plant operations

Remote and automation technologies: Review of Japan's experience in the nuclear field

Robots for nuclear power plants. In the USA, robotics technology used at the TMI-2 cleanup

Advanced computerized operator support systems in the FRG. In the Federal Republic of Germany, automation carries increasing emphasis

Mechanical systems are routinely solved using electrical circuit analogy

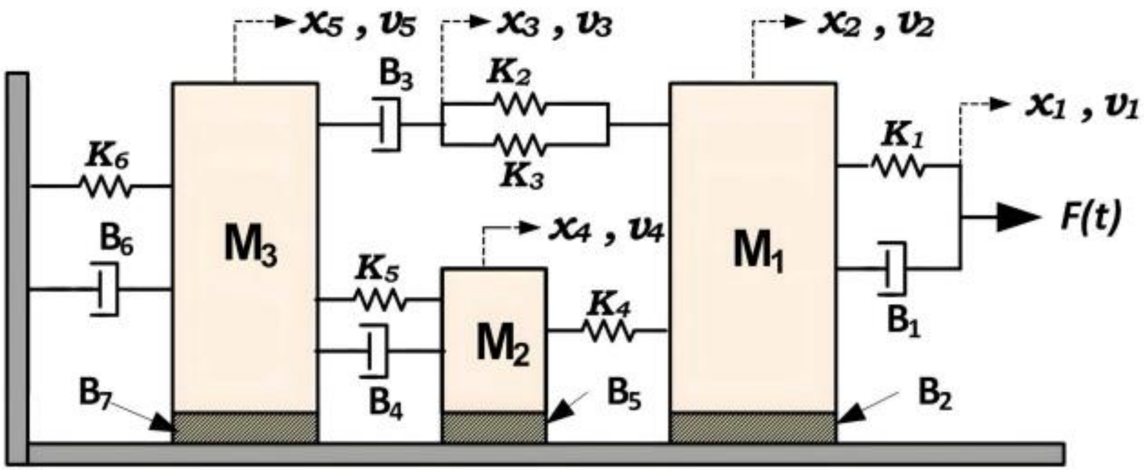


FIGURE 1. A translational mechanical system.

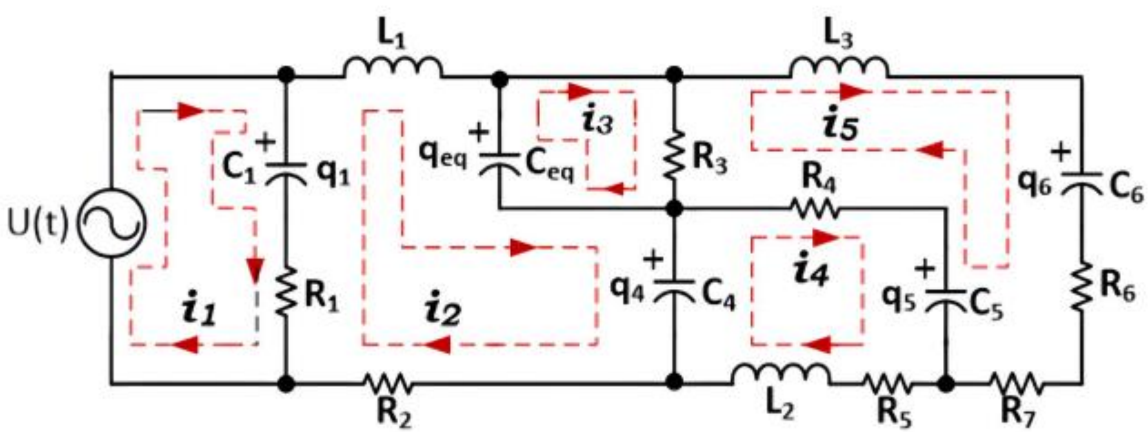


FIGURE 2. Electric circuit equivalent of the translational mechanical system given in Figure 1.

https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=9803041

Lecture 1 – Learning Objectives

1. Intuitively define charge and current
2. Use fluid flow analogy to identify current magnitude and direction
3. Identify circuit electrical elements and sketch circuit schematic diagrams
4. Define Voltage
5. Write difference between two points in symbolic form

Charge

Matter is constituted by a collection of atoms which contain elementary particles:

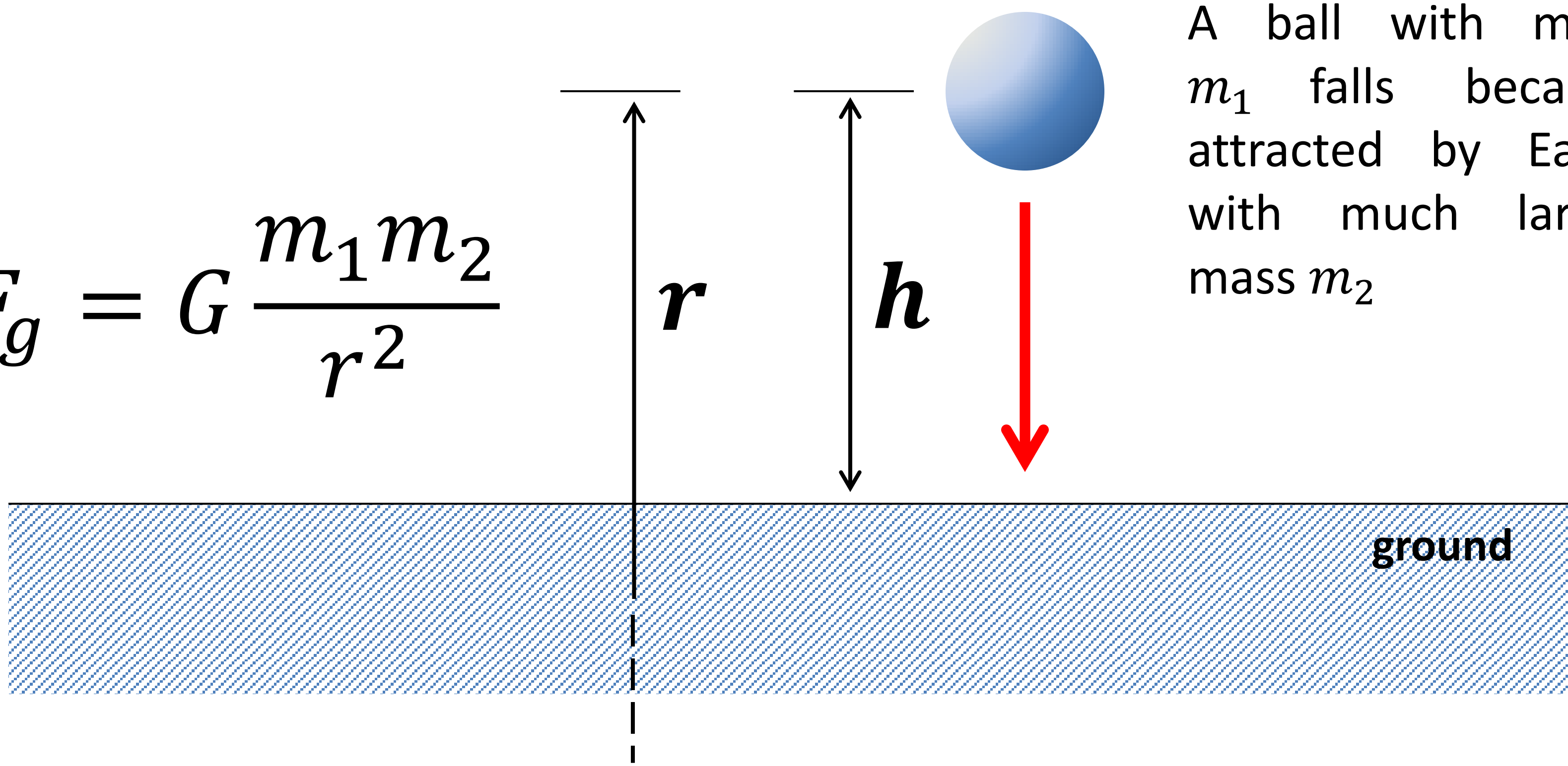
- **positively charged protons and uncharged neutrons (forming the nucleus)**
- **negatively charged electrons orbiting the nucleus**

The electrons in the valence orbitals (occupying the higher energy shells around the nucleus) determine the type of bonding and the main electrical properties of the material.

Analogy between Mass & Charge

Gravity is a property of matter which causes attraction according to the masses involved

$$F_g = G\frac{m_1 m_2}{r^2}$$



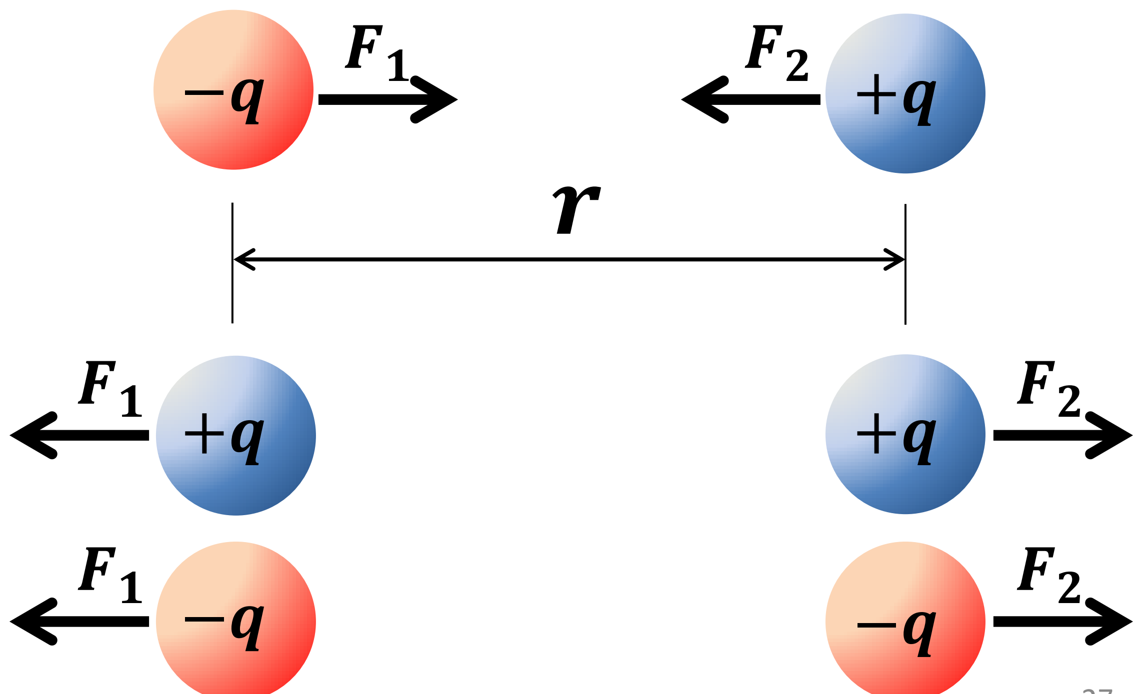
A ball with mass m_1 falls because attracted by Earth with much larger mass m_2

Force of gravity is always attractive

Analogy between Mass & Charge

Similarly, charges interact due to Coulomb force, but charges with opposite polarity attract each other while charges with same polarity repel each other.

$$F_C = K\frac{Q_1 Q_2}{r^2}$$



Unit of Charge

Unit of Charge is the <u>Coulomb</u> with symbol [C]

The charge of one electron is

$$\boldsymbol{e} = -\mathbf{1.602} \times \mathbf{10^{-19}}\ [\mathbf{C}]$$

Therefore, one Coulomb of electron charge is

$$-\mathbf{1}[\mathbf{C}] = \mathbf{6.24} \times \mathbf{10^{18}}\ \boldsymbol{e}$$

Conductors

Circuit connections are normally realized with metal wires. Electrons in the atomic valence orbitals are abundant (comparable to the number of atoms in the solid) and can move easily from atom to atom.

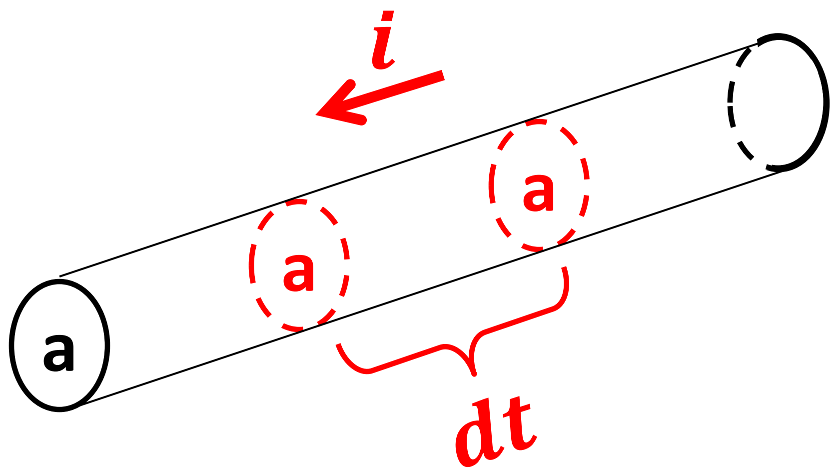
Under the influence of electric forces, electrons in a metal move as a whole in a way similar to a viscous fluid.

Mobile electrons are not very fast in a metal, due to strong interactions (scattering) with nuclei and among themselves, but they are so many that the associated flow of charge (current) can be very large.

Current

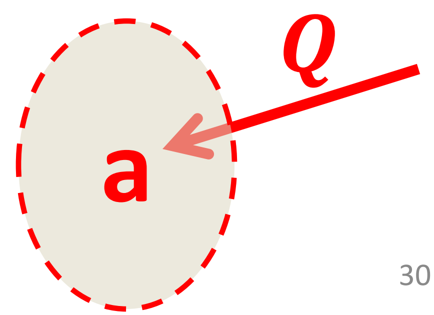
Charge in motion represents <u>current</u> which is defined as the rate of flow of charge through an area "a"

$$i = \frac{dq}{dt}$$



Alternatively we can say:

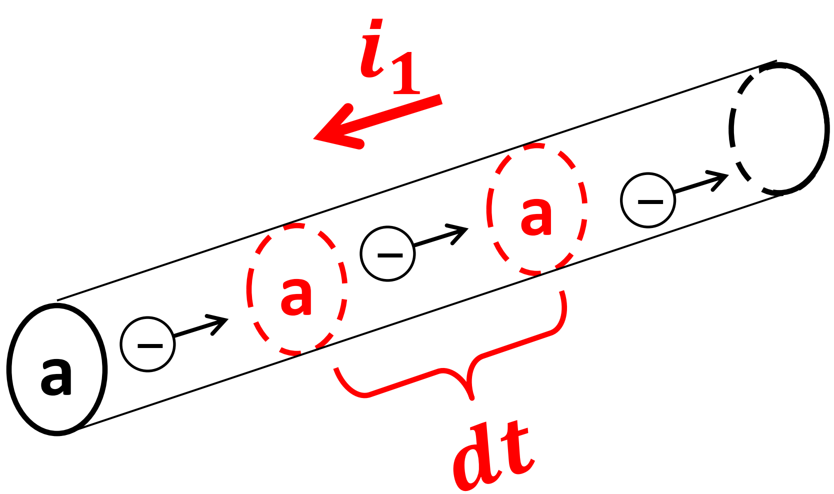
"Current is the (positive) charge that crosses an area "a" per second"



Current (can be confusing)

Current in metal wires was defined by Ampère in the 1820's when we did not know that it was due to electrons (discovered in 1897 by Thomson).

The positive direction of current, chosen at the time, turned out to be opposite to the flow of electrons. Therefore, electrons were assigned a negative charge.



Current units

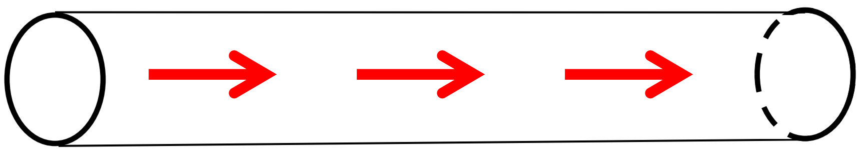
The unit of current is the <u>Ampere</u> with symbol [A]

A current of one ampere corresponds to a flow of one Coulomb of charge per second

$$\mathbf{1\ [A] = 1\ \left[\frac{C}{s}\right]}$$

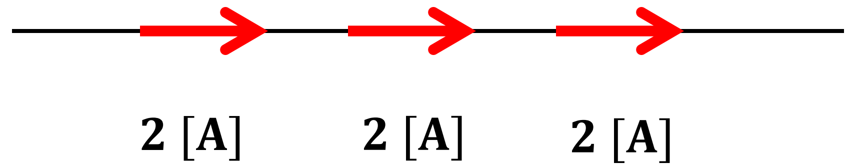
Fluid analogy

PIPES



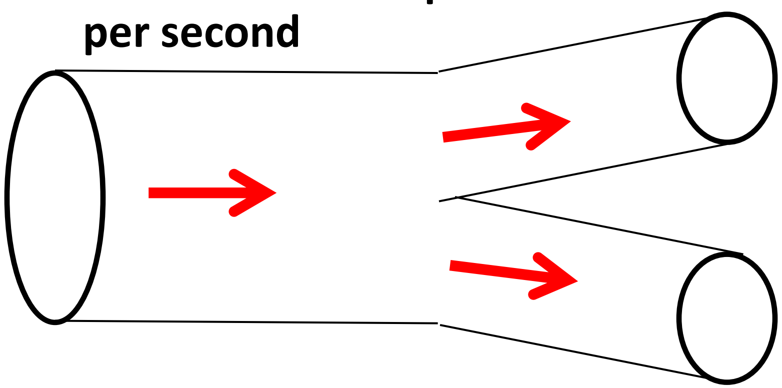
2 gallons per second

WIRES

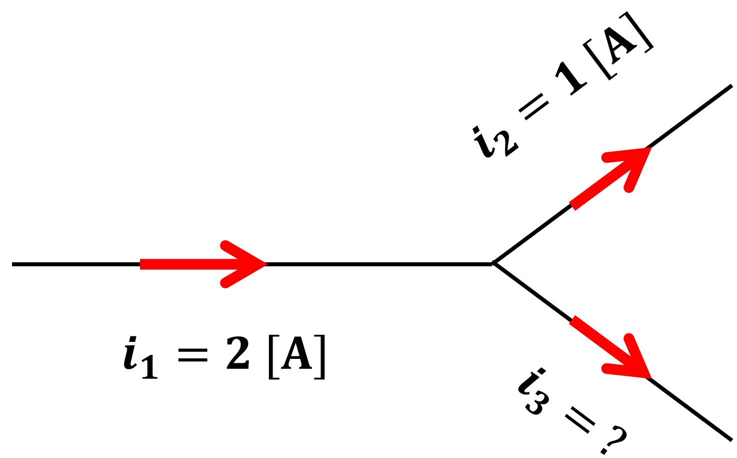


2 gallons per second

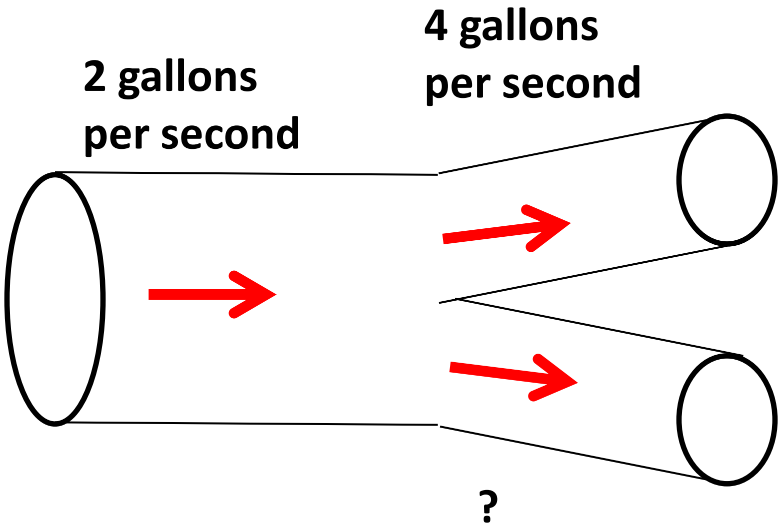
1 gallon per second

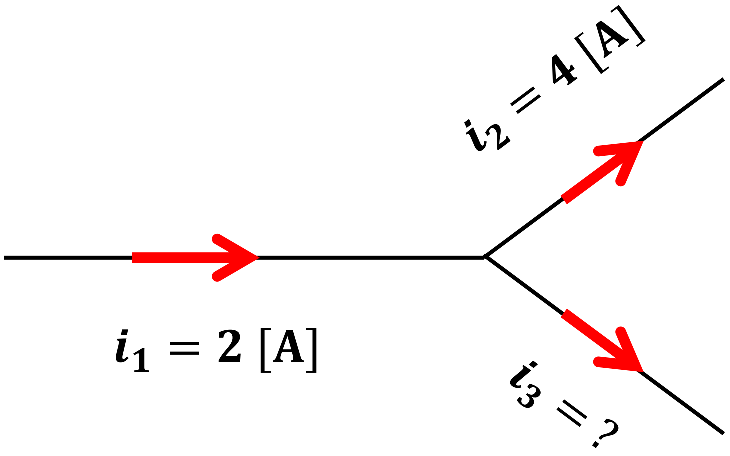


gallons per second?

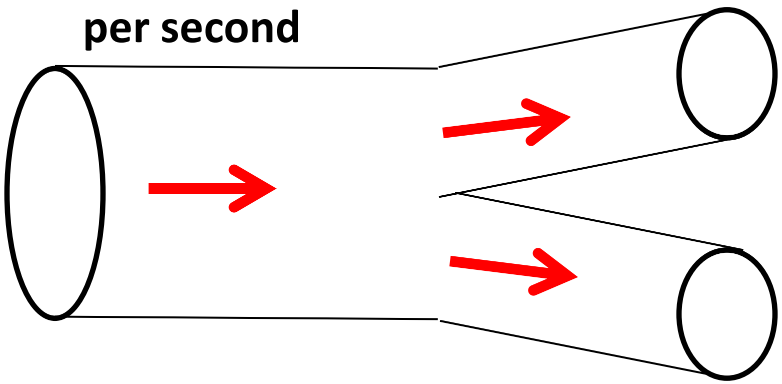


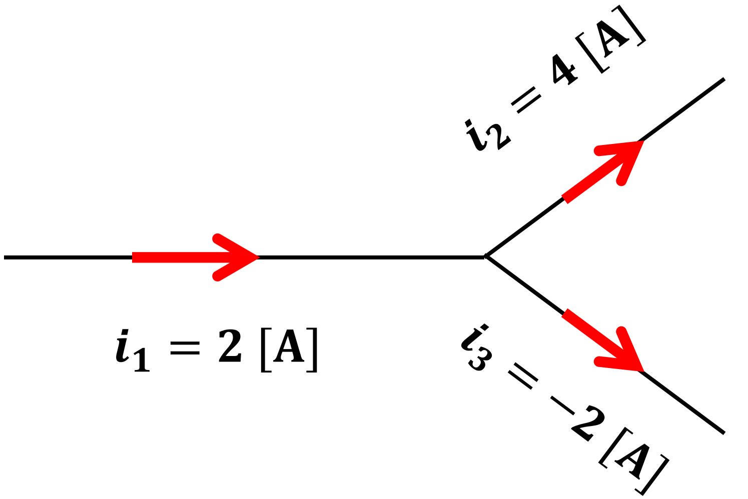
Fluid analogy

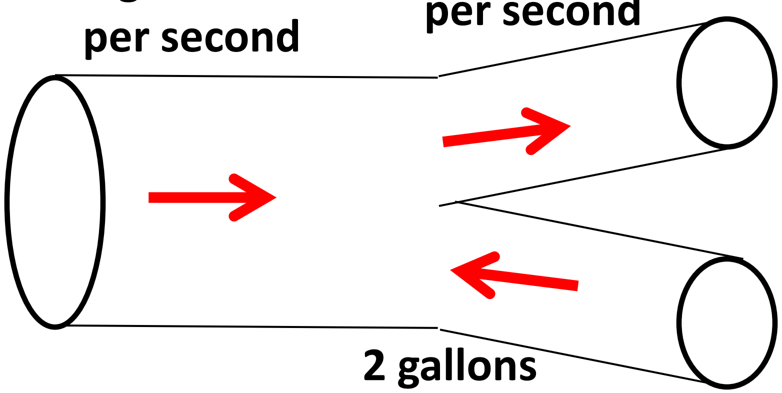


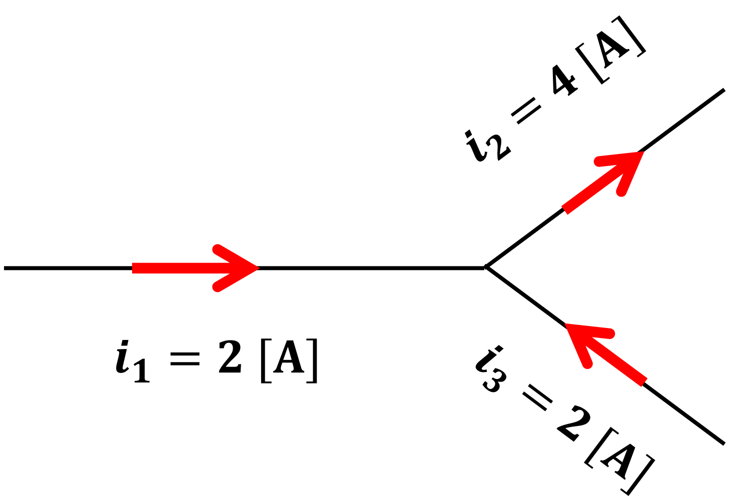


Fluid analogy



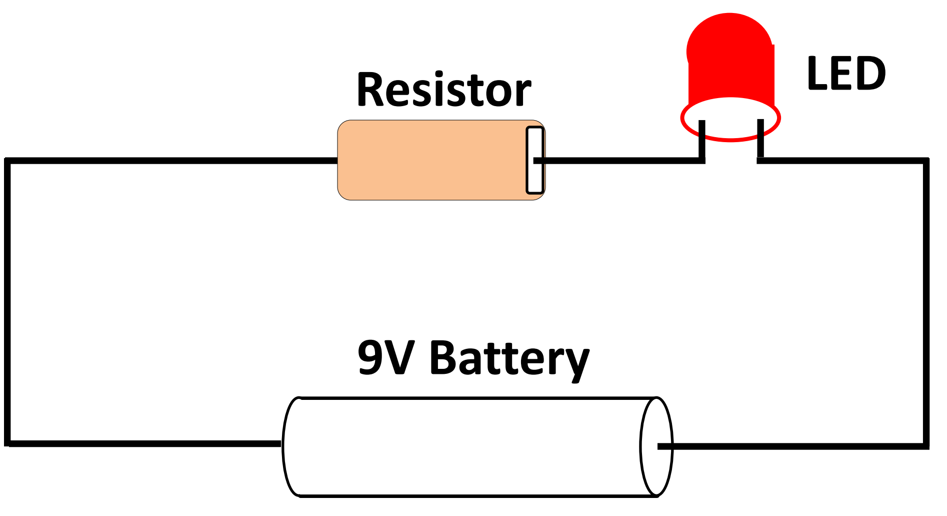






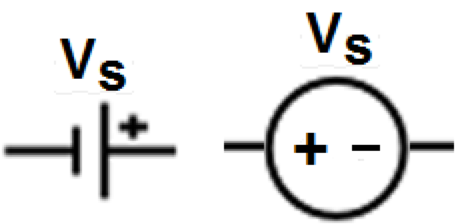
Electric circuits, elements, schematics

An electrical circuit is an interconnection of electrical elements through which current can flow. Electrical elements can be seen as a model or an abstraction of electrical devices. For example, let us say we would like to light up an LED using a battery. We may sketch a physical arrangement of this set-up as shown below.

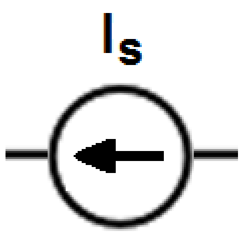


Symbols for common circuit elements

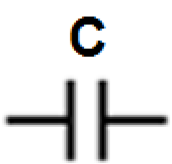
Resistor



Voltage source

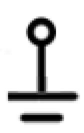


Current source

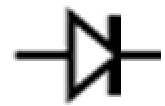


Capacitor

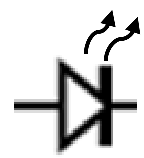
Inductor



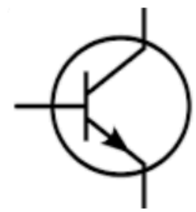
Ground node connection (zero reference voltage)



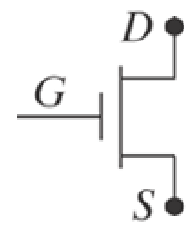
Diode



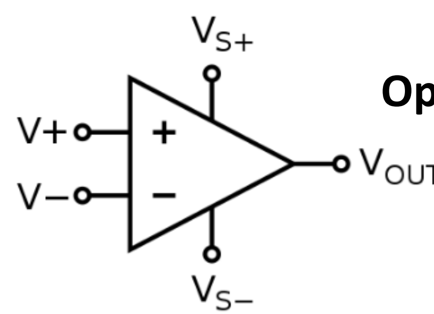
Light Emitting Diode (LED)



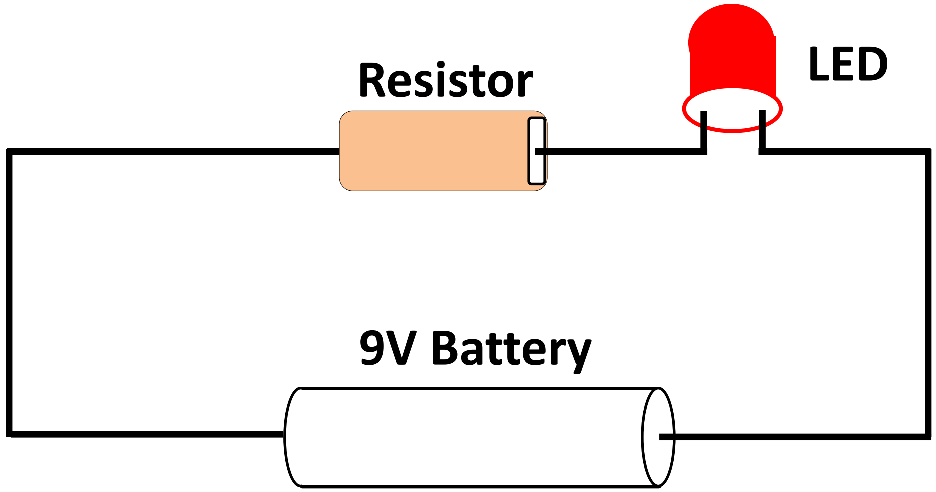
Bipolar Transistor



MOS Transistor



Operational Amplifier



Circuit Schematic Diagram