Ankara University
Engineering Faculty
Department of Engineering Physics

PEN207

Circuit Design and Analysis

Prof. Dr. Hüseyin Sarı

Ankara University
Engineering Faculty,
Dept. of Engineering Physics

Fall

PEN207 Circuit Design and Analysis

***Instructor*: Prof. Dr. Hüseyin Sarı**
A.U. Engineering Faculty, Dept. of Eng. Physics

Office: Department of Eng. Phy., B-Block, Room:105
E-mail: hsari100@gmail.com ● hsari@eng.ankara.edu.tr
web: www.huseyinsari.net.tr
Phone: (312) 203 3424 (office) ● 536 295 3555 (cell)

Course Plan

Credit:	4 ECTS
Class:	Lecture: 3 hours
	Problem Hours: 0
	Lab: 0
Class Hours:	*Monday 09:30-12:15* (3 hours)
Classroom:	Seminar Hall (Seminer Salonu)
Office Hours:	Friday 11:00-12:00
Attendance:	Mandatory

Exams:

Midterm (one midterm exam)	% 30
Final Exam	% 80

Passing Grade: 60 (C3) or higher

Course Materials and Textbook(s)

Lecture notes (Ppoint):

huseyinsari.net.tr →Desler →Circuit Design & Analysis

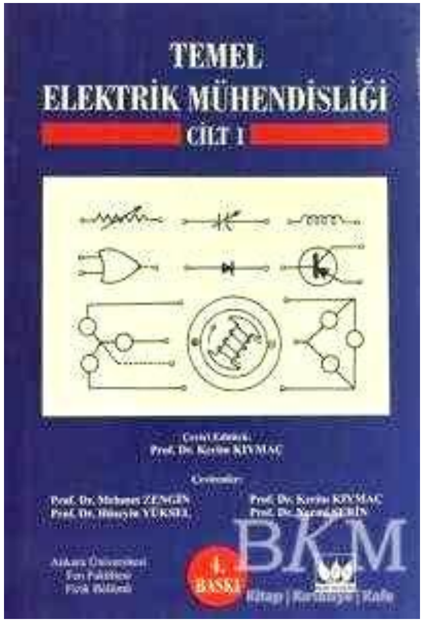
(http://huseyinsari.net.tr/ders-pen207.htm)

Main book:

Temel Elektrik Mühendisliği,

Cilt 1, *Fitzgerald. A. E. Higginbotham D. E.,Grabel A.*

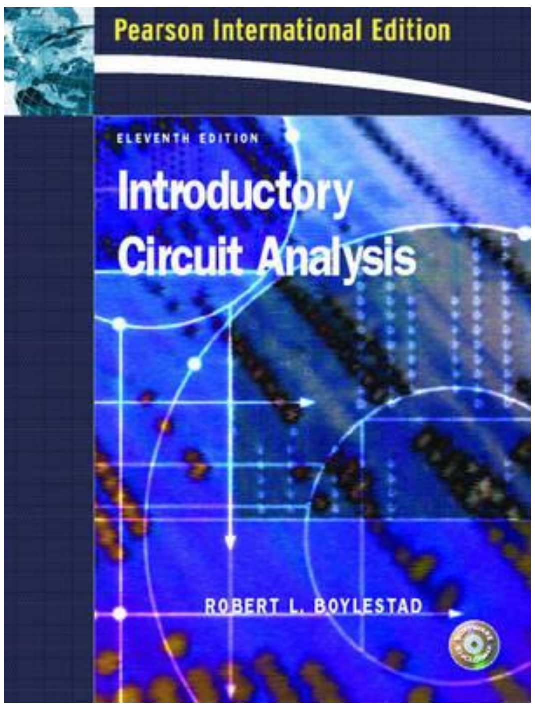
(Editor: Prof. Dr. Kerim Kıymaç, 3.Edition)



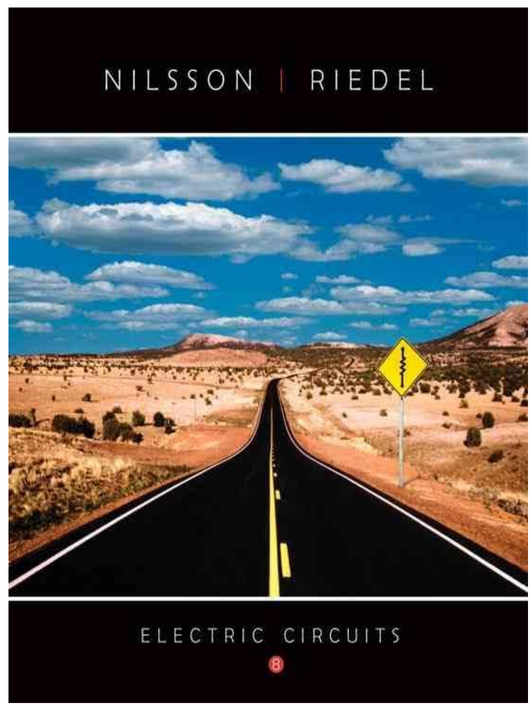
Textbooks

Recommended Textbooks-1:

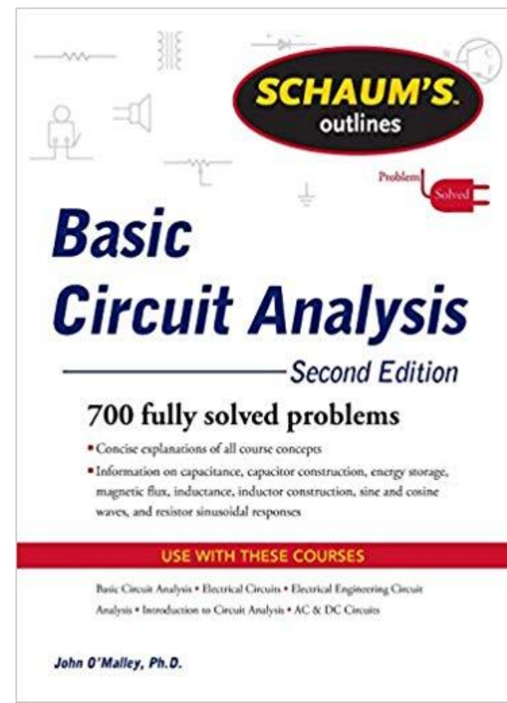
Introductory Circuit Analysis
Robert L. Boylestad
Pearson Int. Edition
(In library)



Electric Circuits
James W. Nilsson, Susan Riedel
6th Ed.
(In library)



Schaum's Outline of
Basic Circuit Analysis, *2nd Edition*
John O'Malley
(In library)



Textbooks

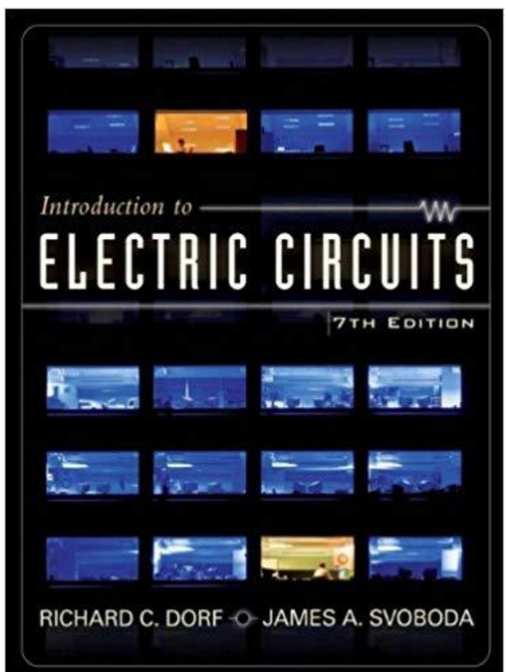
Recommended Textbooks-2:

Introduction to Electric Circuits

Richard C. Dorf

James A. Svoboda

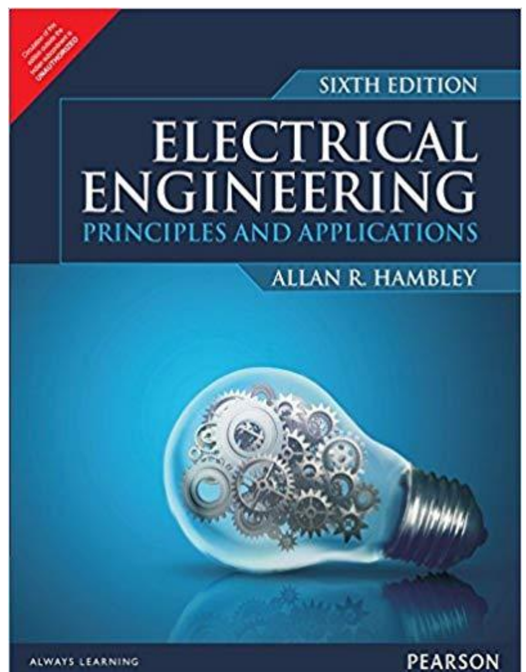
(In library)



Electrical Engineering: Principles & Applications

Allan R. Hambley

(In library)

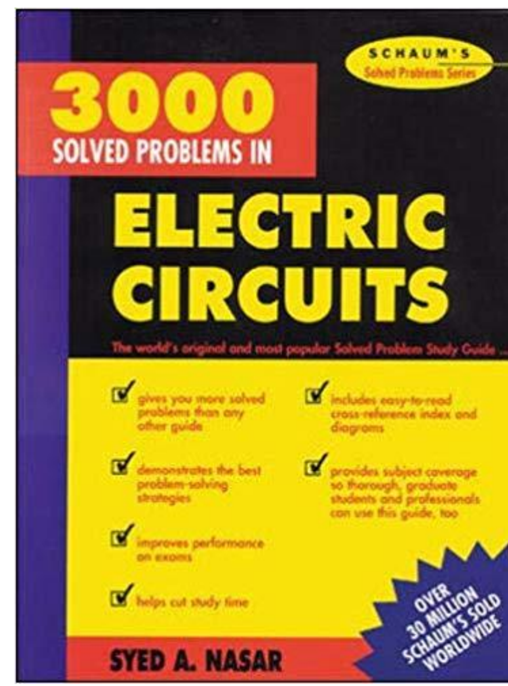


Schaum's Outline of

3000 Solved Problems In Electric Circuits

Syed A. Nasar

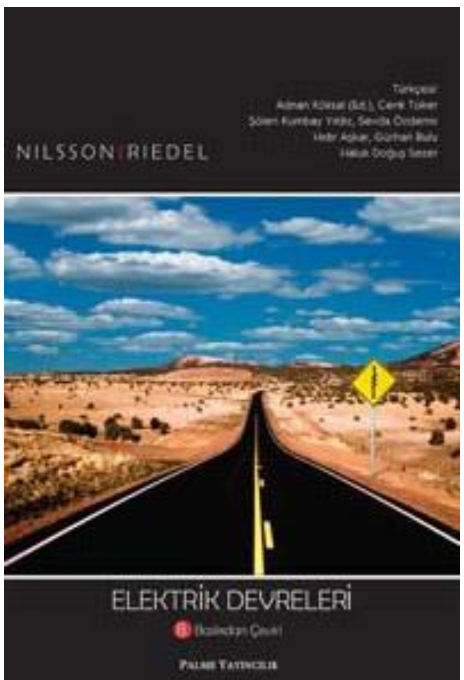
(In library)



Textbooks-Turkish

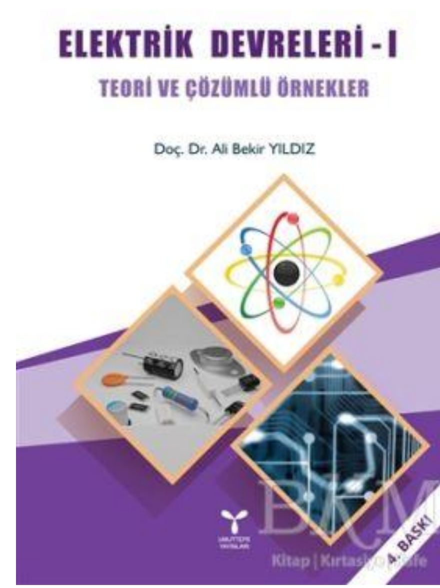
Recommended (Turkish)Textbooks-3:

Elektrik Devreleri
James W. Nilsson, Susan Riedel
Palme Yayınevi



Elektrik Devreleri (Ders Kitabı) - Problem Çözümleri
Turgut İkiz,
Papatya Bilim Yayınları

Elektrik Devreleri-I Teori ve Çözümlü Örnekler
Ali Bekir Yıldız
Volga Yayıncılık



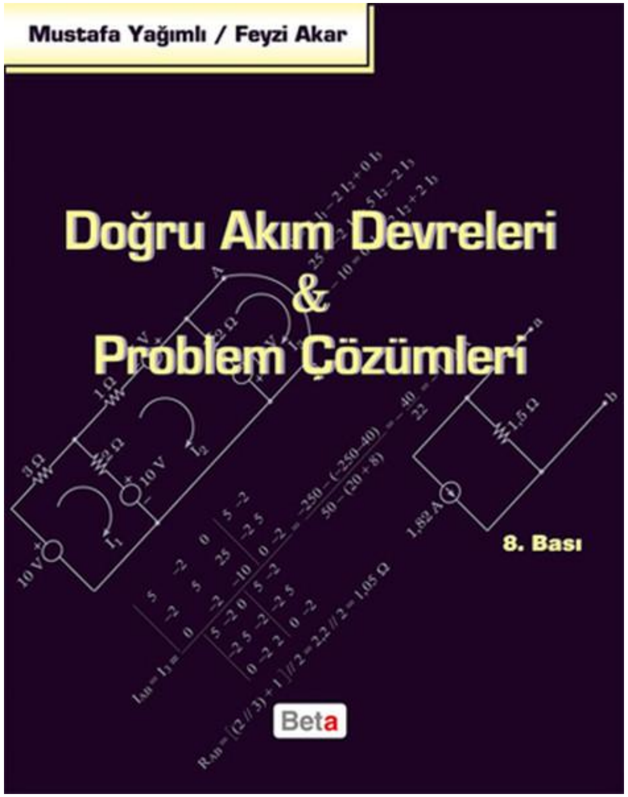
Textbooks-Turkish

Recommended (Turkish)Textbooks-4:

Doğru Akım Devreleri ve Problem Çözümleri

Mustafa Yağımlı-Feyzi Akar

Beta Yayınları,6. Baskı, 2010.

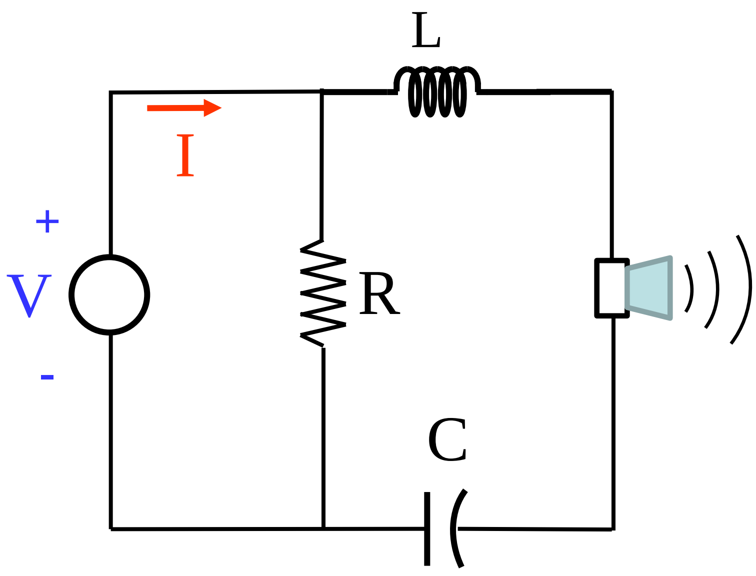


Goal of the Course

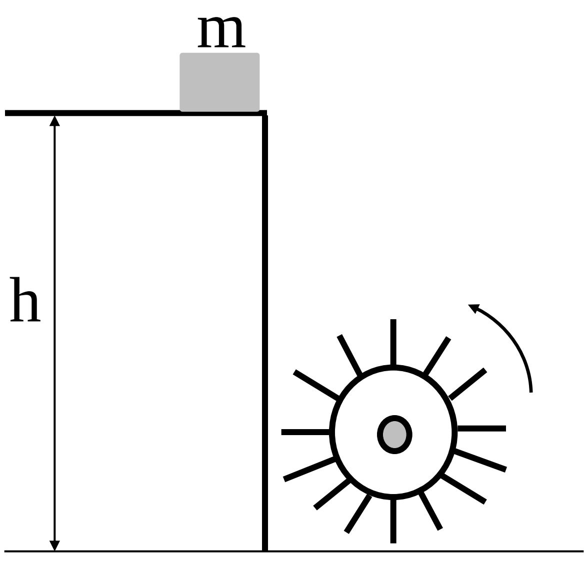
In this class,

- Some definitions in circuit theory will be learned,
- Response of circuit elements (**resistor**, **capacitance**, **inductor (coil)** and **power sources**) will be learned,
- Theories and methods to analyse circuits will be learned…

Electricity vs Mechanics



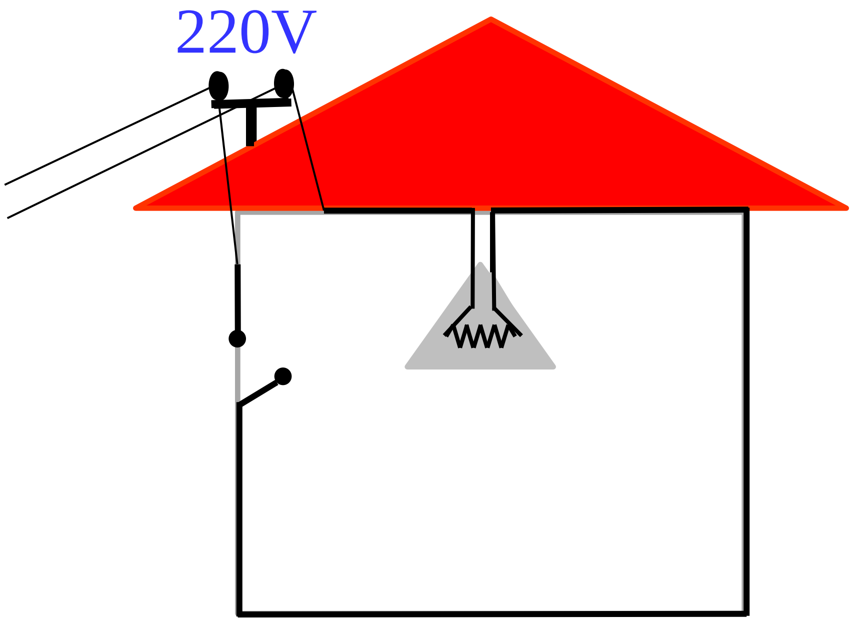
V, I



h, m

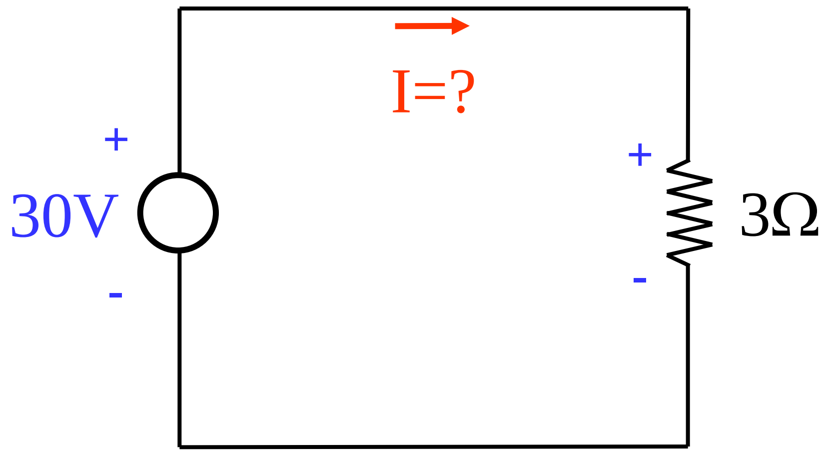
Motivation

We see electric circuits everywhere in our daily life from simple (city power network) to more complicated ones (radio receiver, radar, robot, cell phone, computers)



Motivation

What is the current in the circuit below?

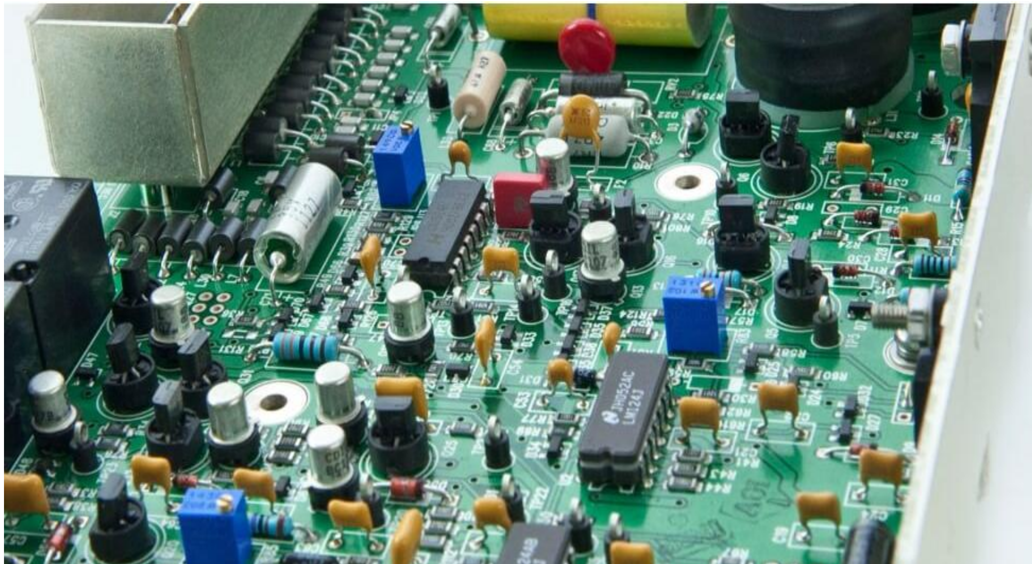


$$V = IR$$

$$I = \frac{V}{R} = \frac{30V}{3\Omega} = 10A$$

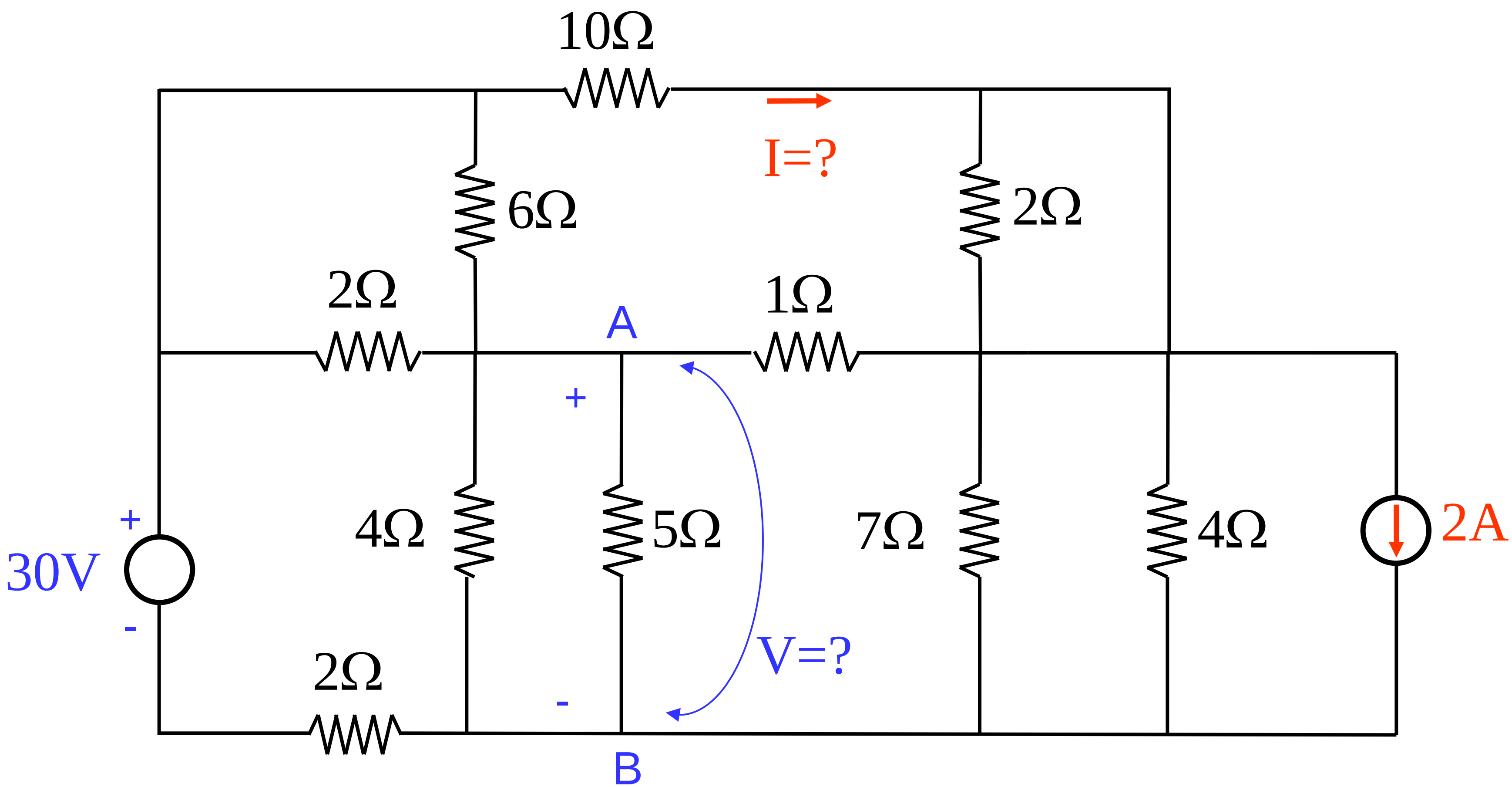
Motivation

There are also very complicated circuits…



Motivation

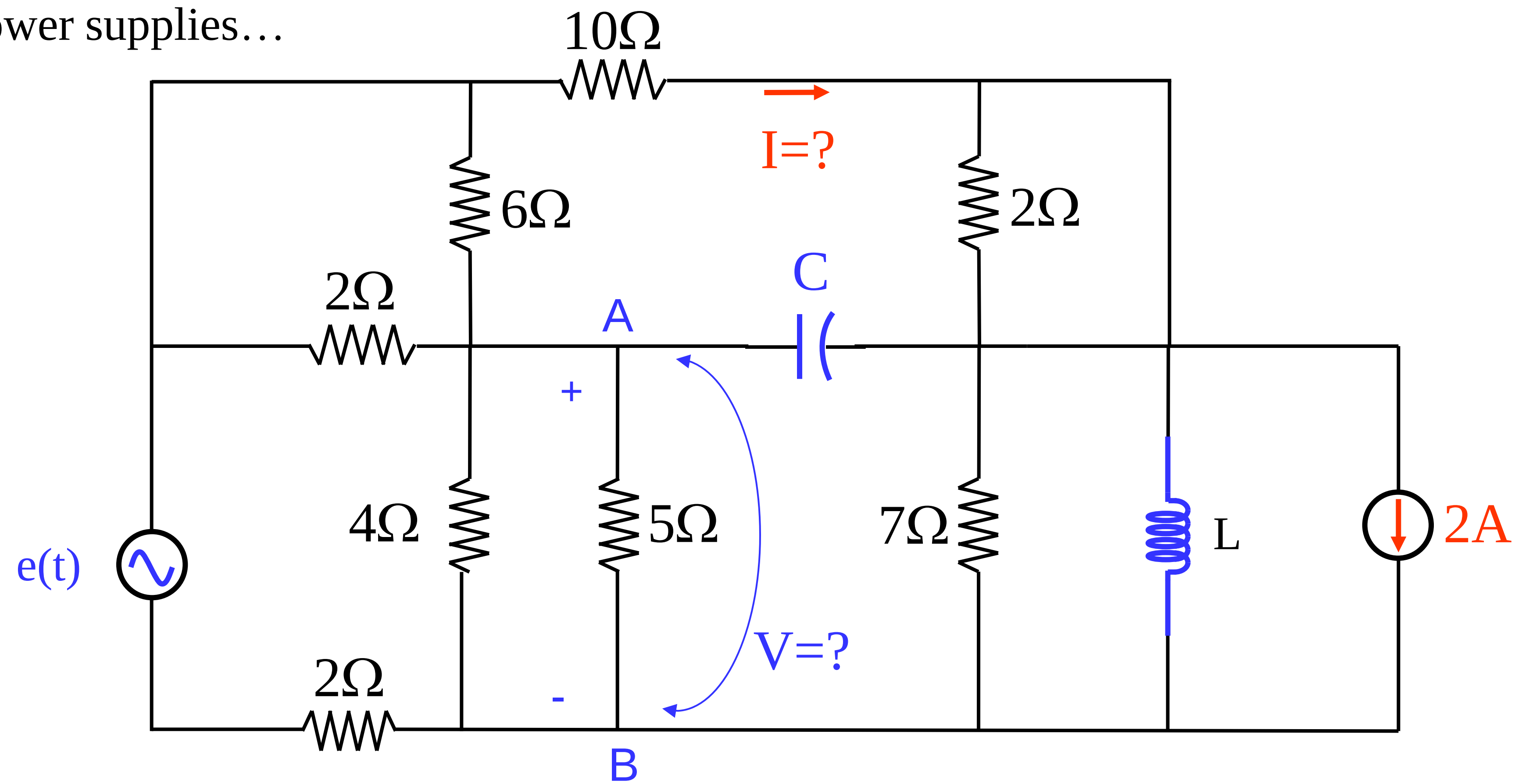
What is the voltage (V=?) between point A and B and the current (I=?) across 10Ω resistance in the circuit below?



It is not easy to solve this circuit!

Motivation

To make a circuit handle more sophisticated tasks we have to add more and also different kind of circuit elements such as inductor, capacitance, and other kind of power supplies…



Can we develop a systematic way to analyse any circuits whether it is simple or very complex?

Motivation

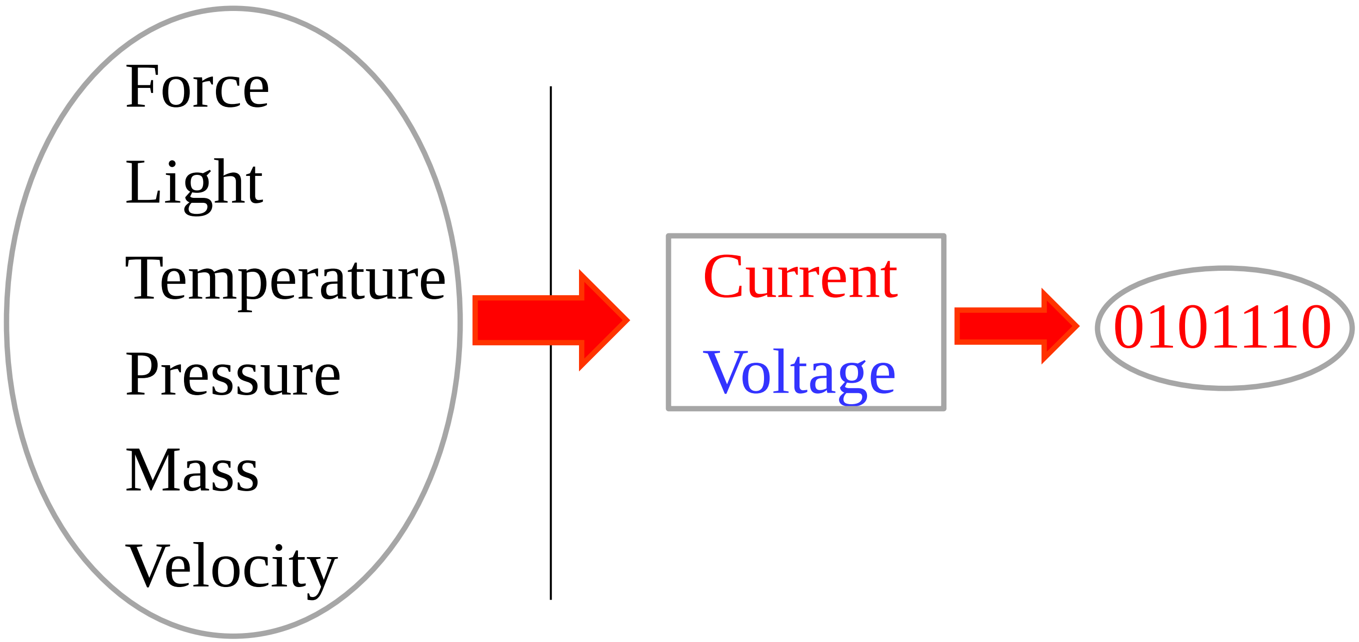
There are already many different softwares to analyse circuit.

SPICE simulation
CircuitLab: Online circuit simulator & schematic editor

- EasyEDA electrionic circuit design, circuit simulation and PCB design
- Circuit Sims
- DcAcLab
- DoCircuits
- PartSim
- 123D Circuits
- TinaCloud
- Computer softwares for circuit simulation
- Qucsis
- **LT Spice Simulator**
- **Ngspice**
- MultiSim National Instruments
- **Proteus**
- CircuitLogix
- **XSPICE**

Motivation

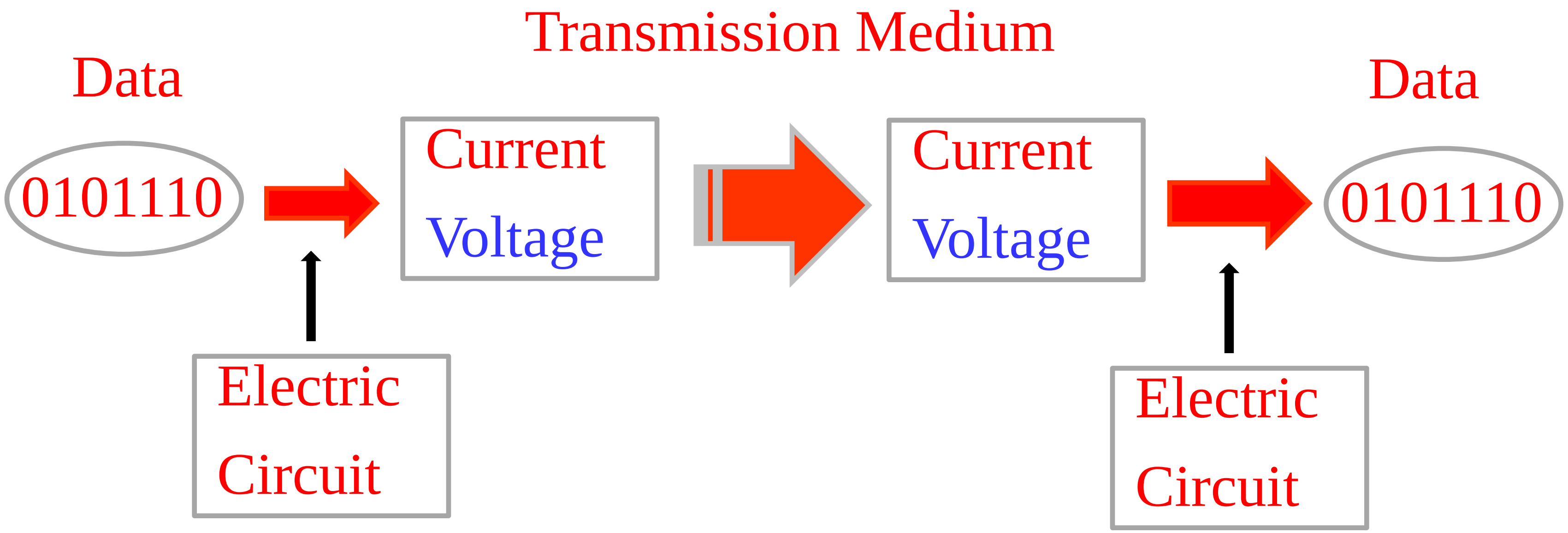
We measure almost all **physical quantities** such as force, light, temperature, pressure, mass, velocity, acceleration, even gravitational waves by converting them to current or voltage.



Physical Quantities → Measurement → Data

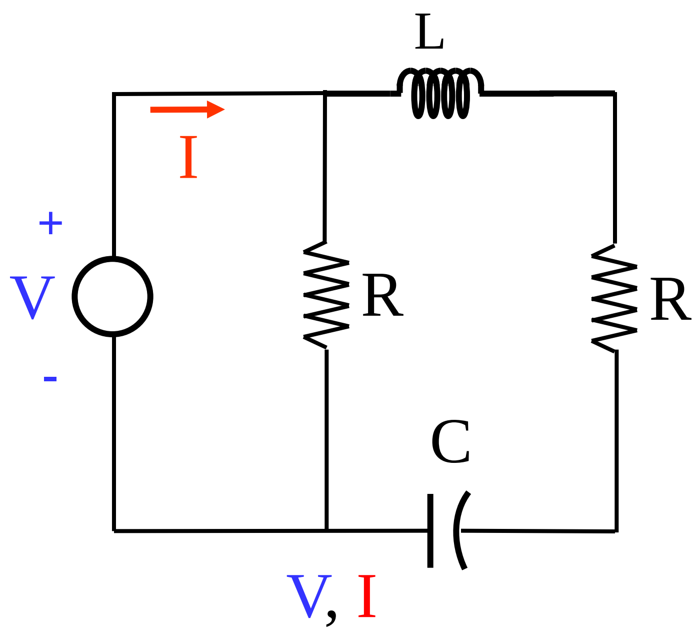
Motivation

We use electric circuits to transmit and process data…



Content of the Course

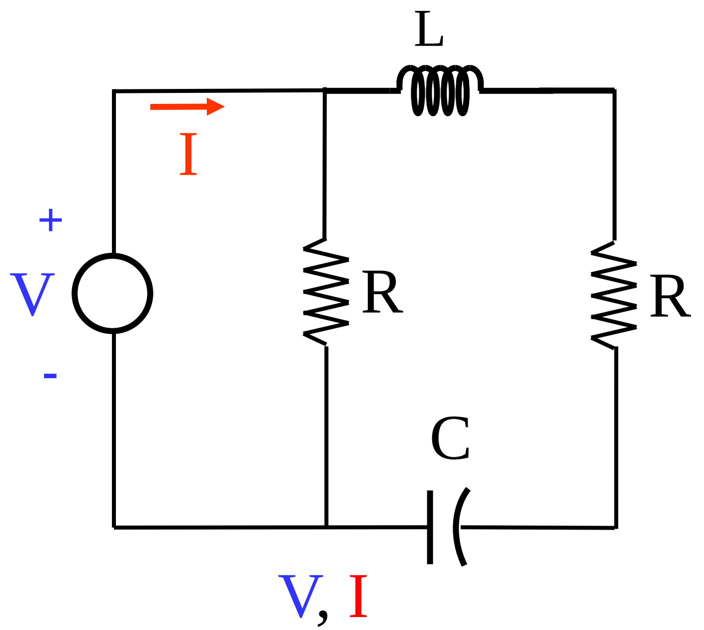
- In this course we will focus on only the circuits consisting of resistance, inductor and capacitors fed by **Direct** (DC) or **Alternative** (AC) sources...



- We will **NOT** deal with the circuits which have diod or transistors!

Content of the Course

- All circuits can be analyzed using only **Ohm's Law** and **Kirchhoff's Law.**



In this course;

- First we will apply these laws directly to circuits.
- Then we will develop more systematic methods such as **Mesh** and **Nodal Analysis**.

Calculus Skill for This Class

Some algebra?

One unknown equation: $ax + b = 0$ x=?

Two unknown equation:

$$a_1 x_1 + a_2 x_2 = b_1 \qquad x_1 = ?$$
$$a_3 x_1 + a_4 x_2 = b_2 \qquad x_2 = ?$$

$$\begin{aligned} a_1 x_1 + a_2 x_2 &= 0 \\ a_3 x_1 + a_4 x_2 &= 0 \end{aligned} \Rightarrow \det \begin{vmatrix} a_1 & a_2 \\ a_3 & a_4 \end{vmatrix} = 0$$

Calculus Skill for This Class

Three unknown equation:

$$a_{11}x_1 + a_{12}x_2 + a_{13}x_3 = b_1$$
$$a_{21}x_1 + a_{22}x_2 + a_{23}x_3 = b_2$$
$$a_{31}x_1 + a_{32}x_2 + a_{33}x_3 = b_3$$

x_1, x_2, x_3 =?

$$\Rightarrow \quad x_1 = \frac{\begin{vmatrix} b_1 & a_{12} & a_{13} \\ b_2 & a_{22} & a_{23} \\ b_3 & a_{32} & a_{33} \end{vmatrix}}{\begin{vmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{vmatrix}} \quad x_2 = \frac{\begin{vmatrix} a_{11} & b_1 & a_{13} \\ a_{21} & b_2 & a_{23} \\ a_{31} & b_3 & a_{33} \end{vmatrix}}{\begin{vmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{vmatrix}} \quad x_3 = \frac{\begin{vmatrix} a_{11} & a_{12} & b_1 \\ a_{21} & a_{22} & b_2 \\ a_{31} & a_{32} & b_3 \end{vmatrix}}{\begin{vmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{vmatrix}}$$

Homework-0

Homework-0.1:

$$3x - y = 1$$
$$x + y = 3$$

x, y=?

Homework-0.2:

$$x + 2y = 5$$
$$2x + 4y = 10$$

x, y=?

Homework-0.3:

$$-2x + y = 0$$
$$4x - 2y = 0$$

x, y=?

Homework-0.4:

$$3x - y + z = 4$$
$$x + y - z = 0$$
$$x + 2y - 3z = -4$$

x, y, z=?

Solutions-Homework-9

Solution-Homework-0.1:

$$3x - y = 1 \qquad x,\ y=?$$
$$x + y = 3$$

$$\det\begin{vmatrix} 3 & -1 \\ 1 & 1 \end{vmatrix} = 3.1-(-1).1 = 4 \qquad x = \frac{\begin{vmatrix} 1 & -1 \\ 3 & 1 \end{vmatrix}}{\det\begin{vmatrix} 3 & -1 \\ 1 & 1 \end{vmatrix}} = \frac{1.1-(-1).3}{4} = \frac{4}{4} = 1 \qquad y = \frac{\begin{vmatrix} 3 & 1 \\ 1 & 3 \end{vmatrix}}{\det\begin{vmatrix} 3 & -1 \\ 1 & 1 \end{vmatrix}} = \frac{3.3-1.1}{4} = \frac{8}{4} = 2$$

Solution-Homework-0.2:

$$x + 2y = 5 \qquad x,\ y=?$$
$$2x + 4y = 10$$

$$\det\begin{vmatrix} 1 & 2 \\ 2 & 4 \end{vmatrix} = 1.4-2.2 = 0 \qquad x = \frac{\begin{vmatrix} 5 & 2 \\ 10 & 4 \end{vmatrix}}{\det\begin{vmatrix} 1 & 2 \\ 2 & 4 \end{vmatrix}} = \frac{5.4-2.10}{0} = \frac{0}{0} = ? \qquad y = \frac{\begin{vmatrix} 1 & 5 \\ 2 & 10 \end{vmatrix}}{\det\begin{vmatrix} 1 & 2 \\ 2 & 4 \end{vmatrix}} = \frac{1.10-2.5}{0} = \frac{0}{0} = ?$$

Solution-Homework-0.3:

$$-2x + y = 0 \qquad x,\ y=?$$
$$4x - 2y = 0$$

$$\det\begin{vmatrix} -2 & 1 \\ 4 & -2 \end{vmatrix} = (-2).(-2)-1.4 = 0 \qquad x = \frac{\begin{vmatrix} 0 & 1 \\ 0 & -2 \end{vmatrix}}{\det\begin{vmatrix} -2 & 1 \\ 4 & -2 \end{vmatrix}} = \frac{0.(-2)-1.0}{0} = \frac{0}{0} = ? \qquad y = \frac{\begin{vmatrix} -2 & 0 \\ 4 & 0 \end{vmatrix}}{\det\begin{vmatrix} -2 & 1 \\ 4 & -2 \end{vmatrix}} = \frac{-2.0-4.0}{0} = \frac{0}{0} = ?$$

Solutions-Homework-0

Solution-Homework-0.4:

$$3x - y + z = 4 \qquad \text{x, y, z=?}$$

$$x + y - z = 0$$

$$x + 2y - 3z = -4$$

$$\det\begin{vmatrix} 3 & -1 & 1 \\ 1 & 1 & -1 \\ 1 & 2 & -3 \end{vmatrix} = 3.[1.(-3)-(-1).2]-(-1).[1.(-3)-(-1).1]+1.[1.2-1.1] = -4$$

$$x = \frac{\begin{vmatrix} 4 & -1 & 1 \\ 0 & 1 & -1 \\ -4 & 2 & -3 \end{vmatrix}}{\det\begin{vmatrix} 3 & -1 & 1 \\ 1 & 1 & -1 \\ 1 & 2 & -3 \end{vmatrix}} = \frac{4.[1.(-3)-(-1).2]-(-1).[0.(-3)-(-1).(-4)]+1.[0.2-1.(-4)]}{-4} = \frac{-4}{-4} = 1$$

$$y = \frac{\begin{vmatrix} 3 & 4 & 1 \\ 1 & 0 & -1 \\ 1 & -4 & -3 \end{vmatrix}}{\det\begin{vmatrix} 3 & -1 & 1 \\ 1 & 1 & -1 \\ 1 & 2 & -3 \end{vmatrix}} = \frac{3.[0.(-3)-(-1).(-4)]-(4).[1.(-3)-(-1).1]+1.[1.(-4)-1.0]}{-4} = \frac{-8}{-4} = 2$$

$$z = \frac{\begin{vmatrix} 3 & -1 & 4 \\ 1 & 1 & 0 \\ 1 & 2 & -4 \end{vmatrix}}{\det\begin{vmatrix} 3 & -1 & 1 \\ 1 & 1 & -1 \\ 1 & 2 & -3 \end{vmatrix}} = \frac{3.[1.(-4)-0.2]-(-1).[1.(-4)-0.1]+4.[1.2-1.1]}{-4} = \frac{-12}{-4} = 3$$

Derivative

In physics most of the time we would like to know the change in physical quantities rather than the quantities itself. **Derivative** is a tool to give us this change.

$$y(t) = Ae^{bt} \quad \Rightarrow \quad \frac{dy(t)}{dt} = Abe^{bt} = by(t)$$

Derivative of some trigonometric functions:

$$y(t) = \sin t \quad \Rightarrow \quad \frac{dy(t)}{dt} = \cos t$$

$$y(t) = \cos t \quad \Rightarrow \quad \frac{dy(t)}{dt} = -\sin t$$

In physics derivative of a function with respect to time (t) can be sometime indicated as follows:

$$\frac{dx(t)}{dt} \equiv \dot{x}(t) = v$$

$$\frac{d^2x(t)}{dt^2} \equiv \ddot{x}(t) = a$$

Differantial Equations

Differential equations are the equations that includes derivatives (dx/dt) as an unknown rather than simple unknown (x) itself.

$$a\frac{dx(t)}{dt} + bx(t) = 0$$

1st order (dx/dt) , linear and homogeneous (=0)

$$a\frac{d^2x(t)}{dt^2} + b\frac{dx(t)}{dt} + cx(t) = 0$$

2nd order (d^2x/dt^2) , linear and homogeneous (=0)

$$a\frac{d^2x(t)}{dt^2} + b\frac{dx(t)}{dt} + cx(t) = f\sin(\omega t)$$

2nd order (d^2x/dt^2) , linear and nonhomogeneous (≠0)

$$a\left(\frac{d^2x(t)}{dt^2}\right)^2 + b\frac{dx(t)}{dt} + cx(t) = f\sin(\omega t)$$

2nd order (d^2x/dt^2), $(d^2x/dt^2)^2$ nonlinear and nonhomogeneous (≠0)

Differantial Equations

$$a\frac{d^2x(t)}{dt^2}+b\frac{dx(t)}{dt}+cx(t)=0 \qquad a\ddot{x}+b\dot{x}+cx=0$$

Solution: $$x(t)=Ae^{st}$$

$$\frac{dx(t)}{dt}=sAe^{st}$$

$$\frac{d^2x(t)}{dt^2}=s^2Ae^{st}$$

$$\left(as^2+bs+c\right)Ae^{st}=0 \qquad Ae^{st}\neq 0 \Rightarrow \left(as^2+bs+c\right)=0$$

We can convert differantial equatin to an algebraic equation

$$as^2+bs+c=0$$

$$s=\frac{-b\pm\sqrt{b^2-4ac}}{2a}=\alpha\pm i\omega$$

$$\alpha=\frac{-b\pm\sqrt{b^2-4ac}}{2a} \quad b^2>4ac$$

$$\omega=\pm\frac{\sqrt{b^2-4ac}}{2a} \quad b^2<4ac$$

i) If b=0 the root s become pure imaginary s=iω:

$$a\frac{d^2x(t)}{dt^2}+b\frac{dx(t)}{dt}+cx(t)=0 \qquad x(t)=e^{i\omega t}$$

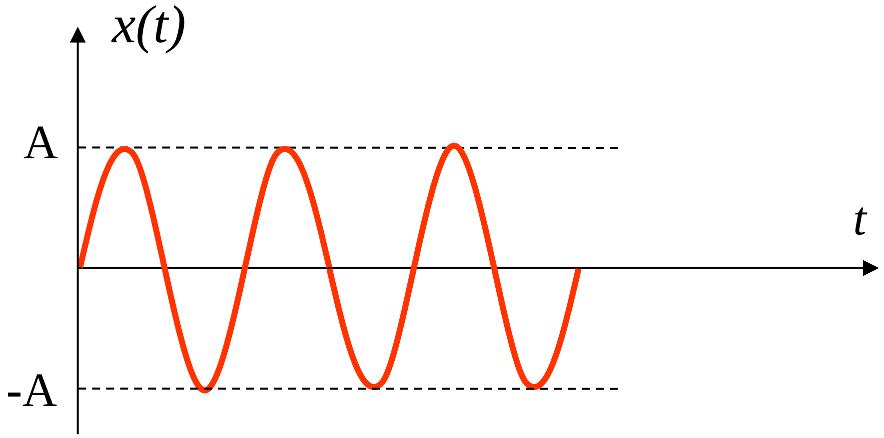
ii) If b≠0 the roots are become complex number s=α+iω:

$$a\frac{d^2x(t)}{dt^2}+b\frac{dx(t)}{dt}+cx(t)=0 \qquad x(t)=e^{(\alpha+i\omega)t}=e^{\alpha t}e^{i\omega t}$$

Expression of a **periodic** function in terms of **exponential function**

i) If b=0 the root s become imaginary s=iω:

$$a\frac{d^2x(t)}{dt^2}+b\frac{dx(t)}{dt}+cx(t)=0$$



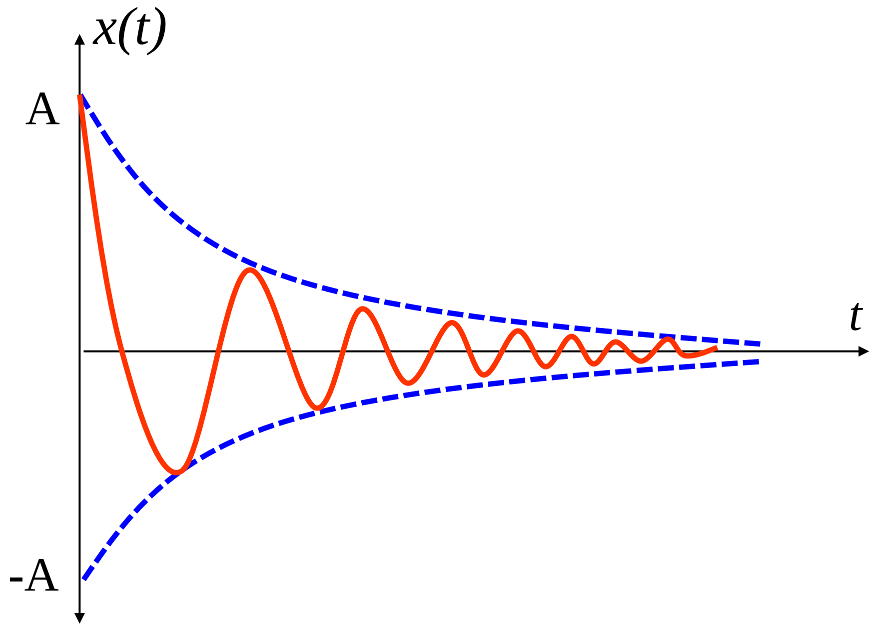
$$a\frac{d^2x(t)}{dt^2}+cx(t)=0$$

$$x(t)=Ae^{i\omega t}$$

$$x(t)=A\cos(\omega t+\phi)$$

ii) If b≠0 the roots are become complex number s=α+iω:

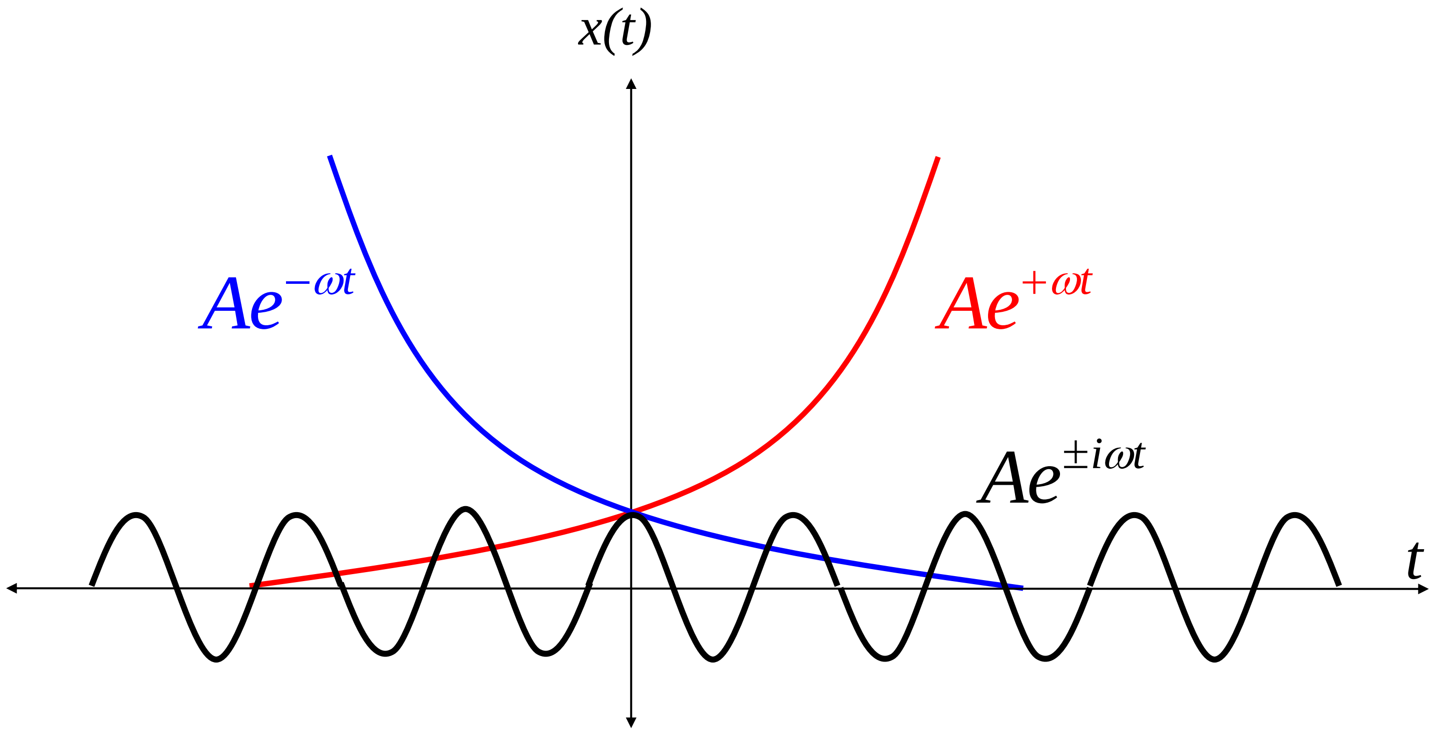
$$a\frac{d^2x(t)}{dt^2}+b\frac{dx(t)}{dt}+cx(t)=0$$



$$x(t)=Ae^{(\alpha+i\omega)t}=Ae^{\alpha t}e^{i\omega t}$$

$$x(t)=Ae^{\alpha t}e^{i\omega t}=(Ae^{-at})\cos(\omega t)$$

Exponential Functions



Depending on the independent variable (real or imaginary number) behaviour of exponential function can be very different.

Some topics that we will cover in this course

- Response of Circuit Elements (Resistor, Inductor, Capacitance)
- Power Sources (Voltage and Current Sources)
- Ohm’s Law
- Kirchhoff’s Voltage Law (KVL)
- Kirchhoff’s Current Law (KCL)
- Series and Parallel Circuits; Δ-Y, Y-Δ Conversion
- Mesh Analysis
- Nodal Analysis
- Alternating Current (AC) and Circuits
- Avarage, Root Mean Square (RMS)

Weekly Course Plan

- Chapter-0: Introduction & Motivation (This week)
- Chapter-1: Circuit Elements (2 weeks)
- Chapter-2: Circuits with Resistance (3 weeks)
- Chapter-3: Transition Response of Circuits (2 weeks)
- Chapter-4: Exponential Inpute and Transformed Circuits (2 weeks)
- Chapter-5: Steady-State AC Circuits (2 weeks)