Durham University

Electrical Engineering II

ENGI2191

Circuit Analysis in Phasor Domain

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E108

Lecture Objectives:

Aim of this lecture:

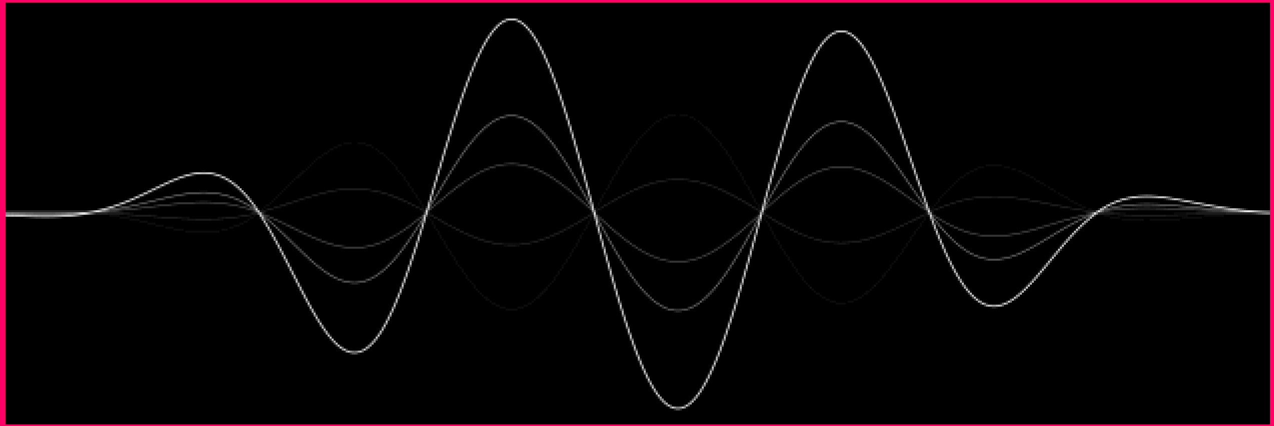
The aim of this lecture is to analyse electric circuits in phasor domain.

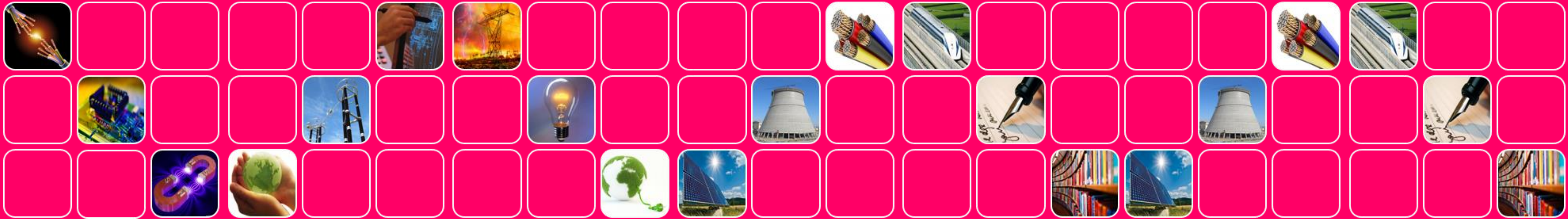
Intended Learning Outcomes:

At the completion of the lecture and associated problems you should be able to:

- Understand the characteristics of sinusoidal functions.
- Identify phasor representation of sinusoids.
- Converting between time and frequency domains.
- Identify the performance of the basic ideal circuit elements in phasor domain.
- Analyse the electric circuits in phasor domain.

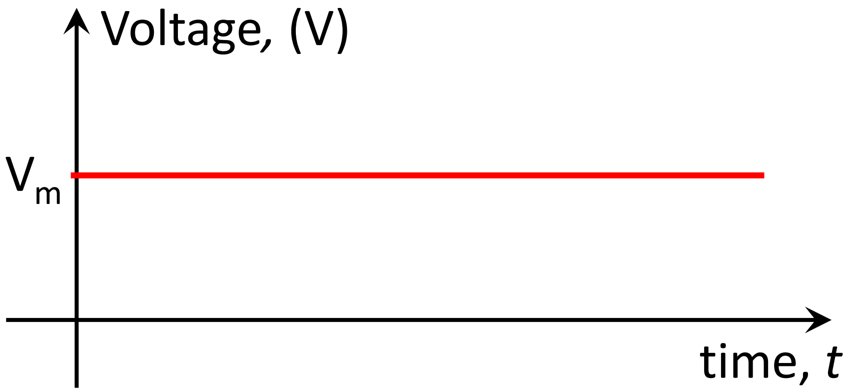
Alternating Currents
(AC)





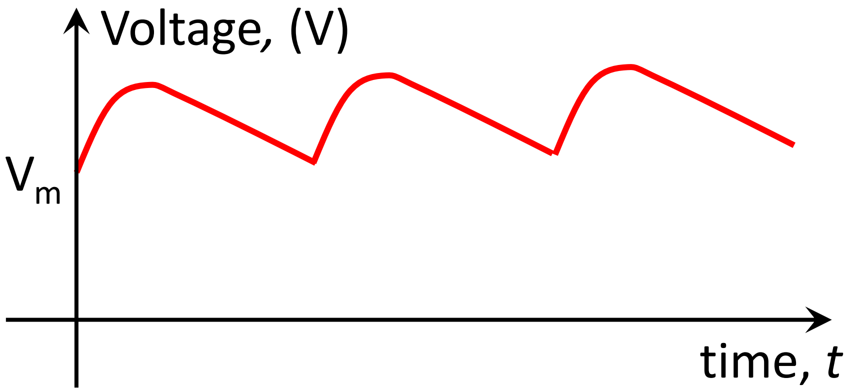
Direct Currents:

Direct Current (DC) is the unidirectional flow of electric charge. The amplitude of the current can vary with time, but the general direction of movement stays the same at all times.



Output voltage of a DC voltage source

(Battery)



Output voltage of a rectifier

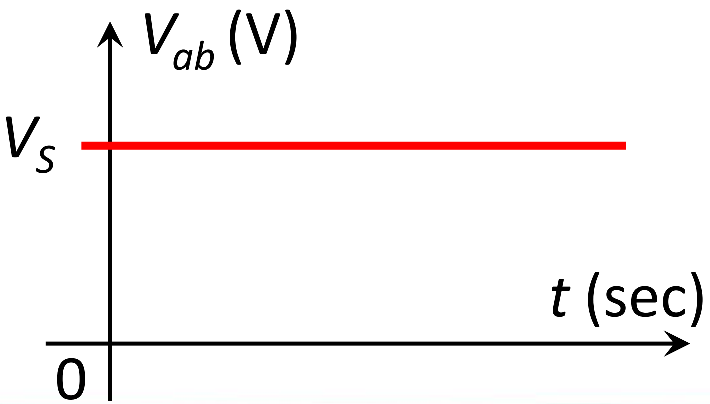
(Rectifier)

Direct Currents:

Direct current is produced by sources such as batteries, DC power supplies (DC generators), solar cells, thermocouples, etc.

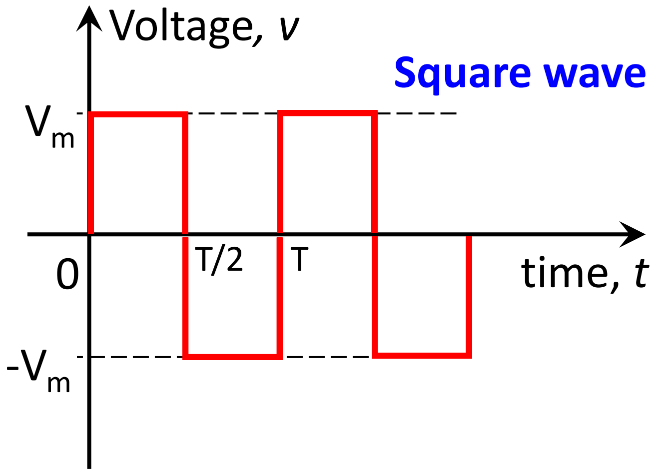
Car battery

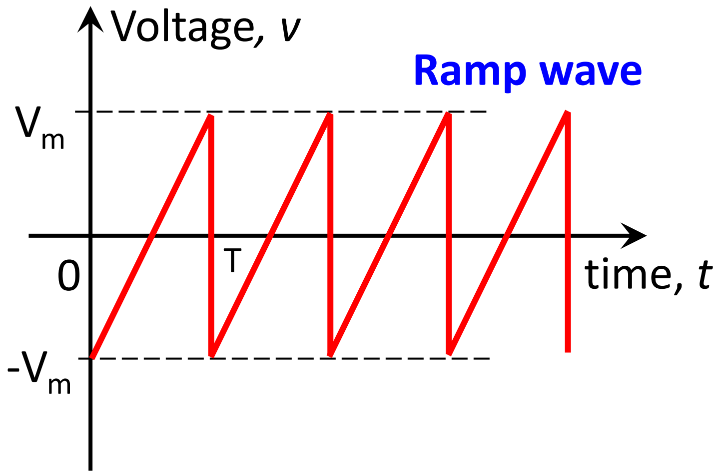
Phone battery

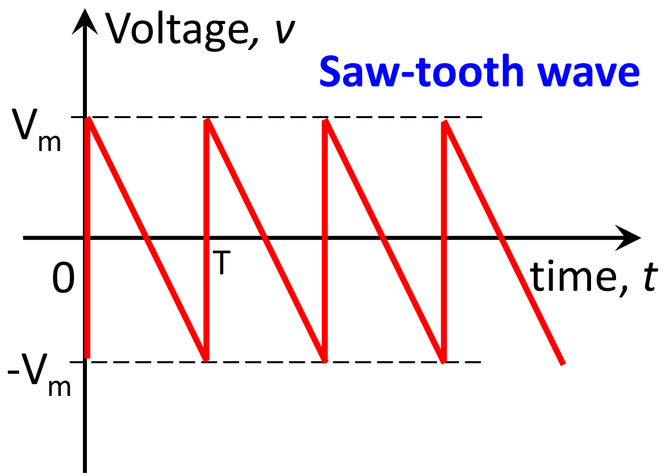


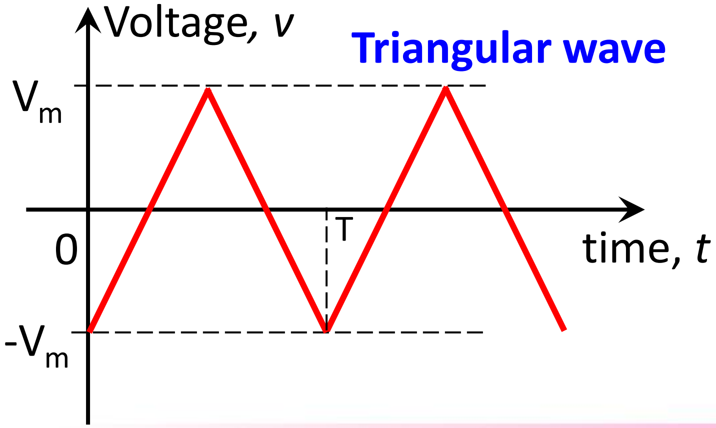
Alternating Currents:

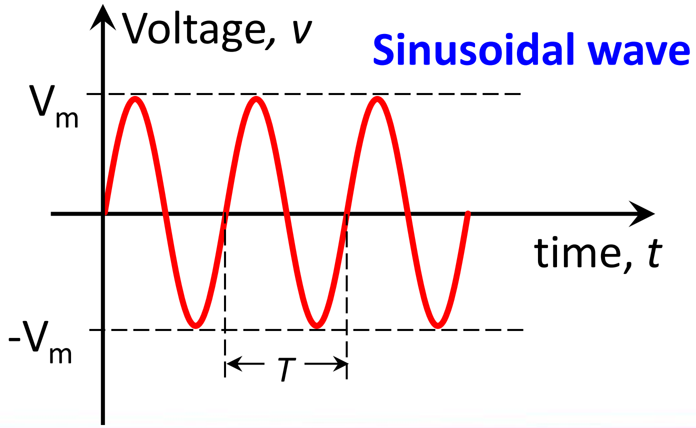
Alternating Current (AC), is an electric current in which the flow of electric charge periodically reverses by time.



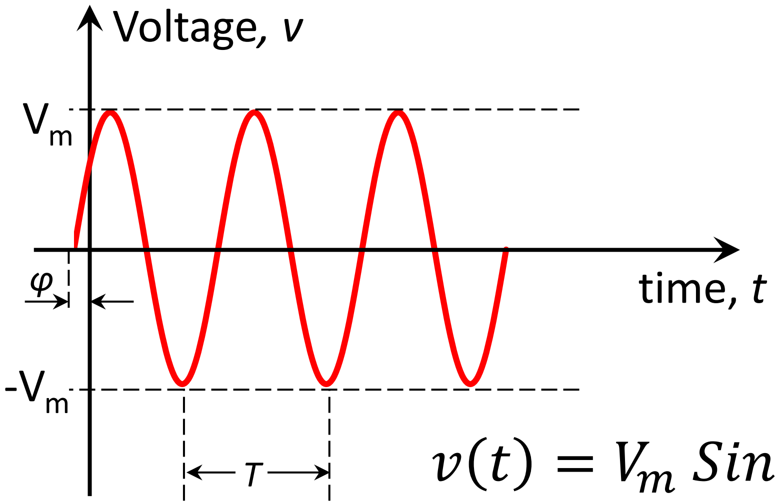




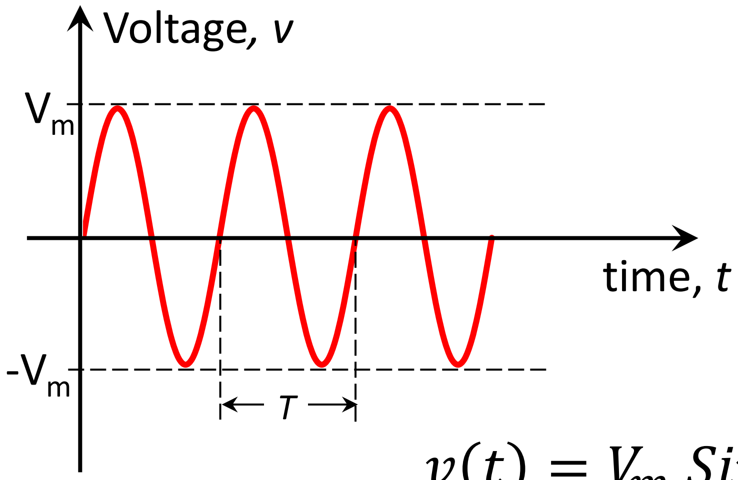




Alternating Currents:



$$v(t) = V_m\, Sin\,(\omega t + \varphi)$$



$$v(t) = V_m\, Sin\,(\omega t)$$

V_m: Peak value or amplitude

φ : Phase shift of the signal

ω : Angular frequency in *rad/sec*

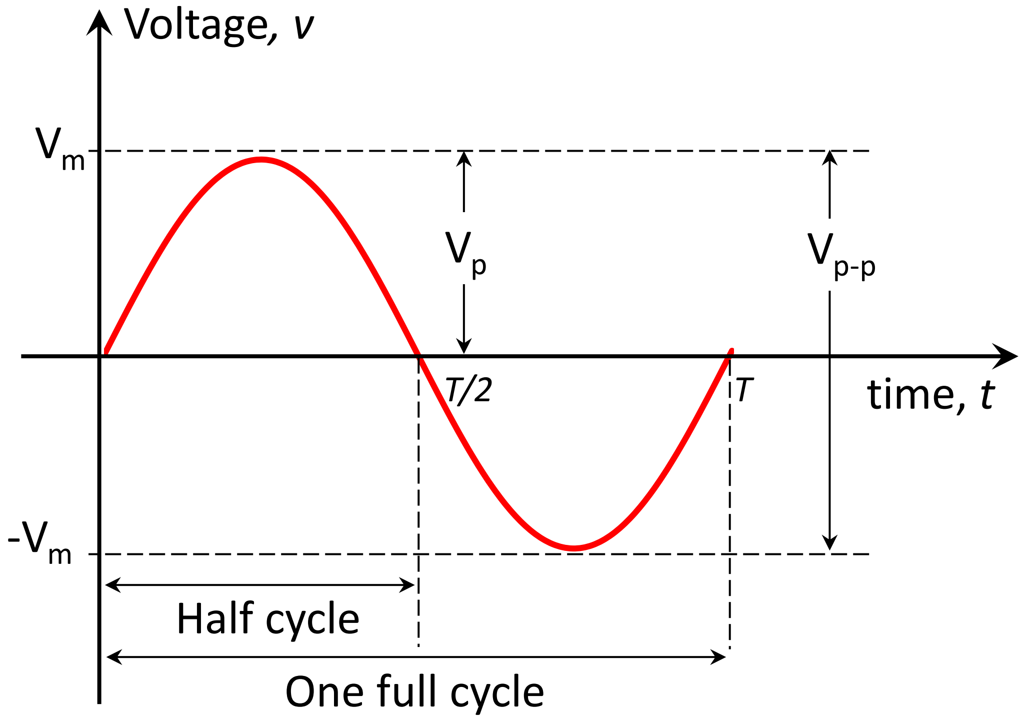
$$\omega = 2\pi f \qquad [rad/sec]$$

f: Frequency of the signal in Hz

$$f = \frac{1}{T}$$

T: Period of the signal in sec

Alternating Currents:



Root-mean-square (*rms*) refers to the most common mathematical method of defining the effective voltage or current of an AC signal.

rms value of a periodic function:

$$f_{rms} = \sqrt{\frac{1}{T_2 - T_1} \int_{T_1}^{T_2} [f(t)]^2 \, dt}$$

$$f_{rms} = \sqrt{\frac{1}{T} \int_{0}^{T} [f(t)]^2 \, dt}$$

For a sinusoidal voltage:

$$V_{rms} = \frac{V_m}{\sqrt{2}} = 0.707 \, V_m$$

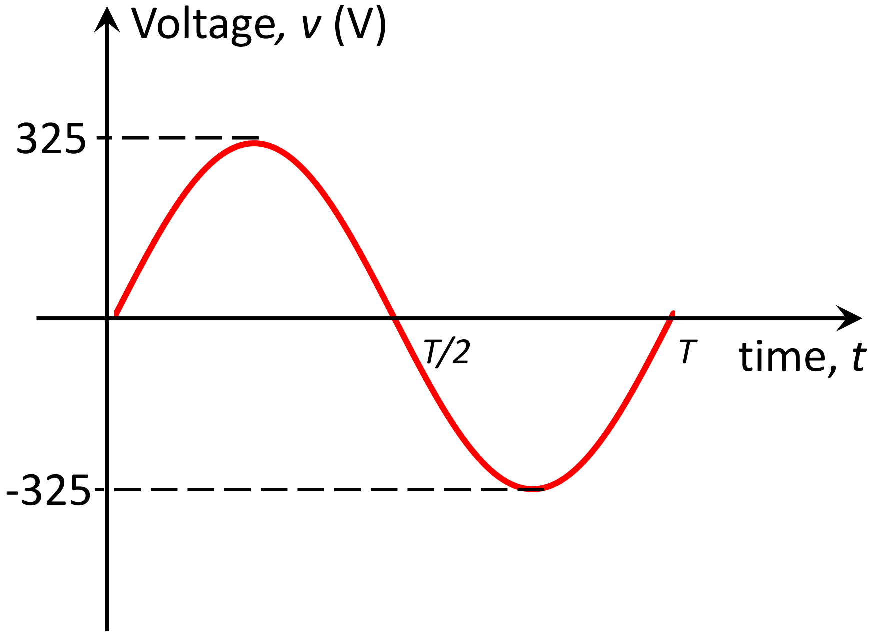
Alternating Currents:

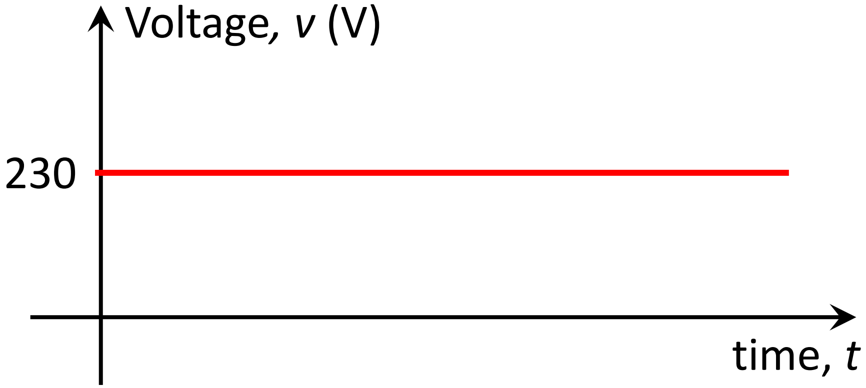
In electrical engineering, *rms* is equal to the value of the direct current that would produce the same power dissipation in a resistive load.

For example, if an AC source of 230 volts *rms* is connected across a resistor, and the resulting current causes 500 watts of heat to be dissipated by the resistor, then 500 watts of heat will also be dissipated if a 230 V DC source is connected to the resistor.

$$V_m = 325 \quad [\mathrm{V}]$$

$$V_{rms} = \frac{V_{pk}}{\sqrt{2}} = \frac{325}{\sqrt{2}} = 230 \quad [\mathrm{V}]$$

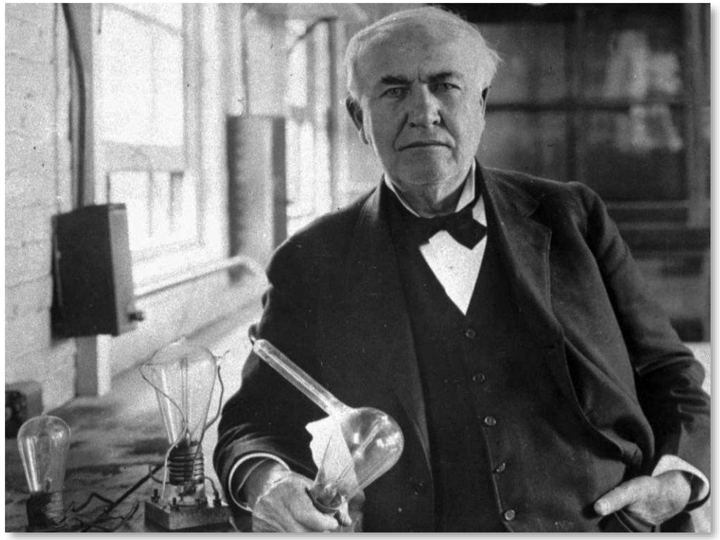




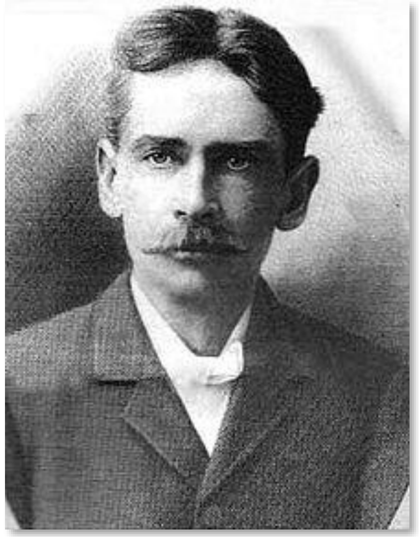
Alternating Currents:

The Current War, or Battle of Current:

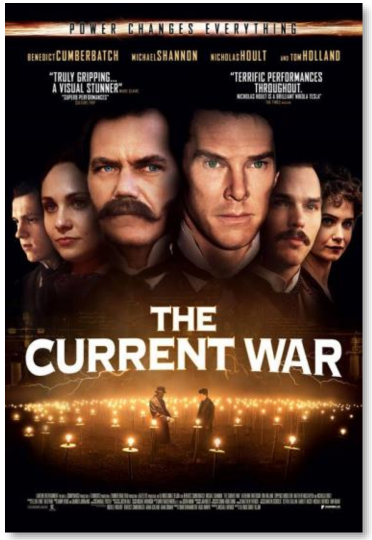
- The first commercial transmission and distribution system was installed in 1882 based on a Direct Current system located at Thomas Edison's Pearl Street Station in lower Manhattan.
- The first practical AC distribution system was developed in 1886 by William Stanley to supply 150 bulbs at Great Barrington, Massachusetts.



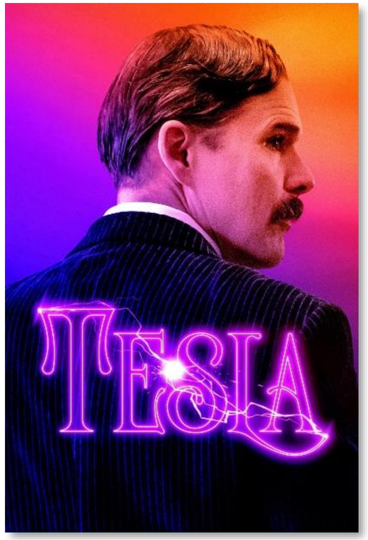
Thomas Alva Edison
1847-1931



William Stanley
1858-1916



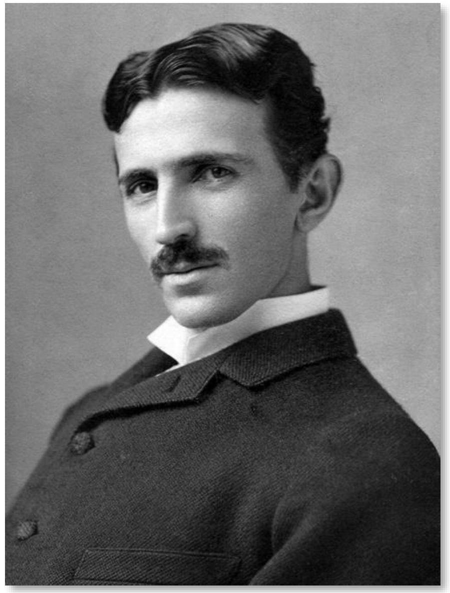
The Current War
2017

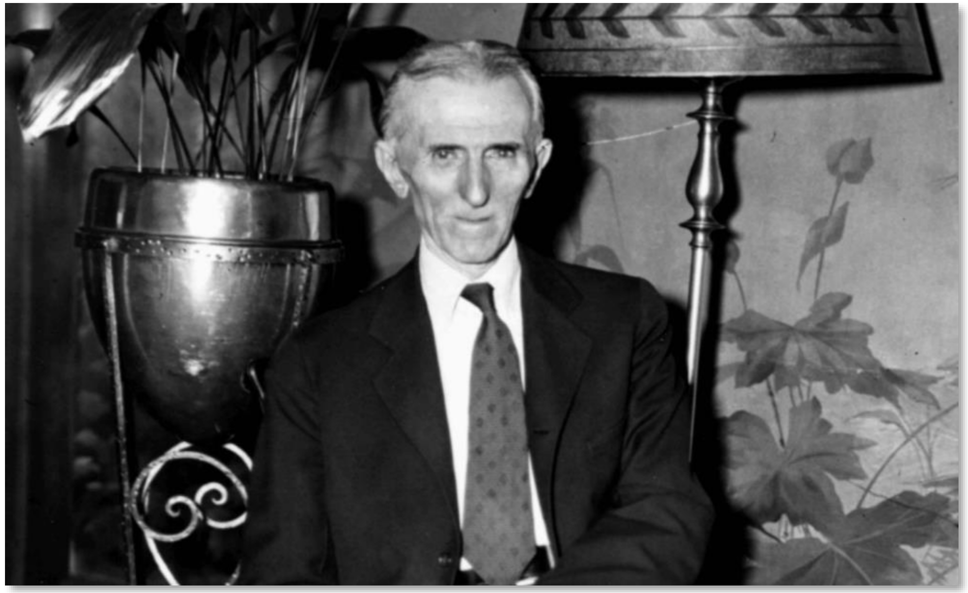


Tesla
2020

Alternating Currents:

Nickola Tesla, the man who invented Alternating Current.





- A forgotten genius who invented our future.
- While Edison was maybe known as the man who invented the light bulb, it can be argued that Tesla is the one who turned it on!
- He died in poverty, but he was one of the most useful and successful men who ever lived.
- Tesla is not dead; he is very much alive among us!

Alternating Currents:

The Current War, or Battle of Current:

Both DC and AC systems were developed in parallel by the 1890s, with a great battle in terms of safety, suitability and feasibility of these systems.

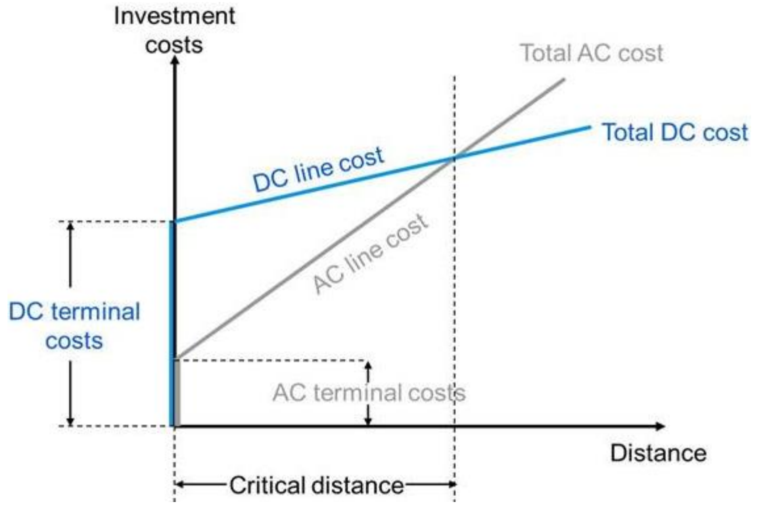
Alternating Currents:

The Current War, or Battle of Current:

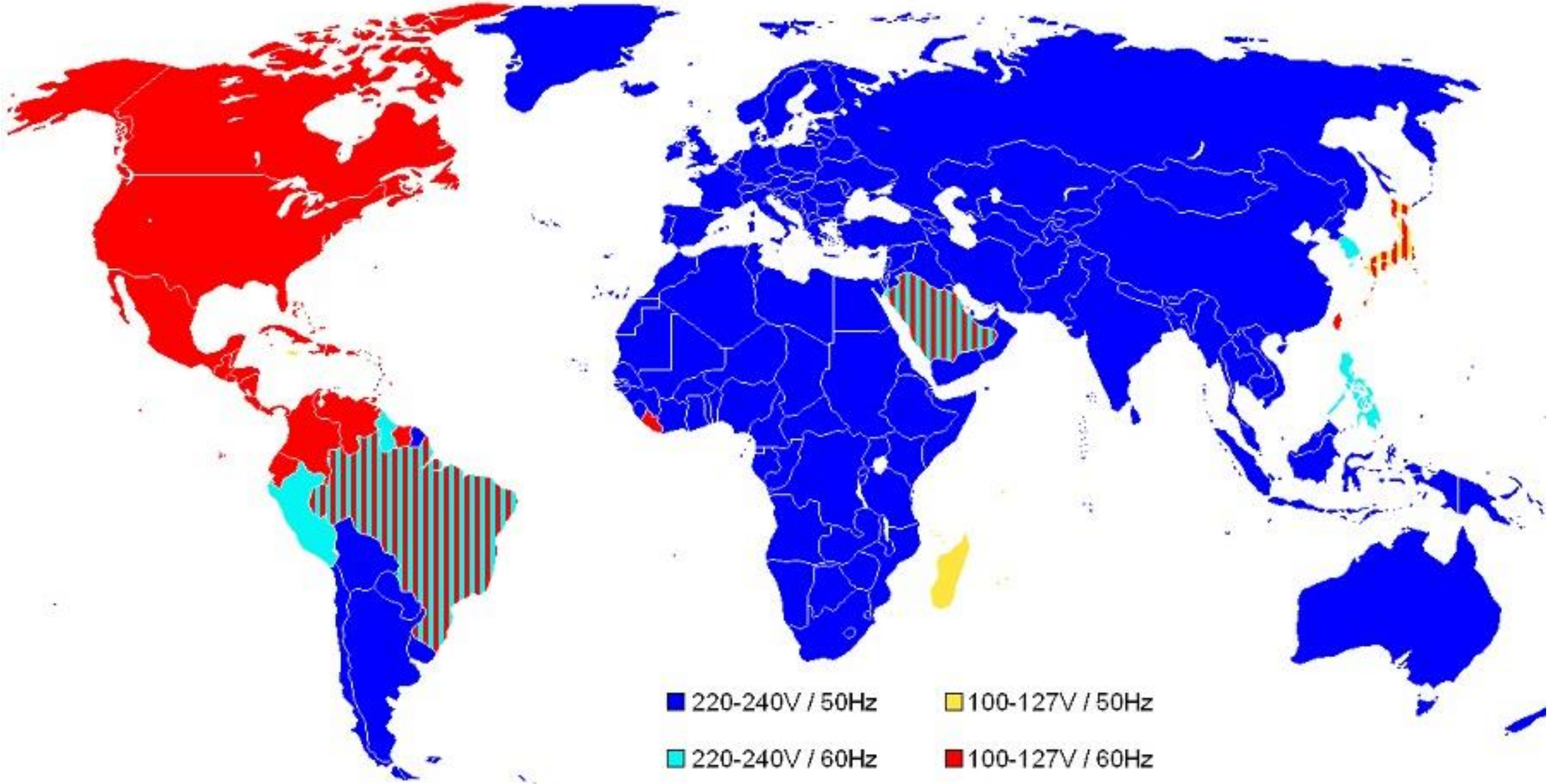
Ultimately, considering the various advantages of AC system, such as simplicity of voltage transformation and possibility of long-distance High Voltage AC (HVAC) transmission lines, the AC system was preferred over the DC system.

AC transmission lines at **power frequencies** of 50 Hz and 60 Hz with rated voltages of 132 kV, 230 kV and 400 kV are standardised and commercialised over years.

For bulk electrical power transmission over long distances (approximately in the range of 600-800 km) HVDC systems become more economic. A comparison between the overall costs of HVAC and HVDC systems is shown.

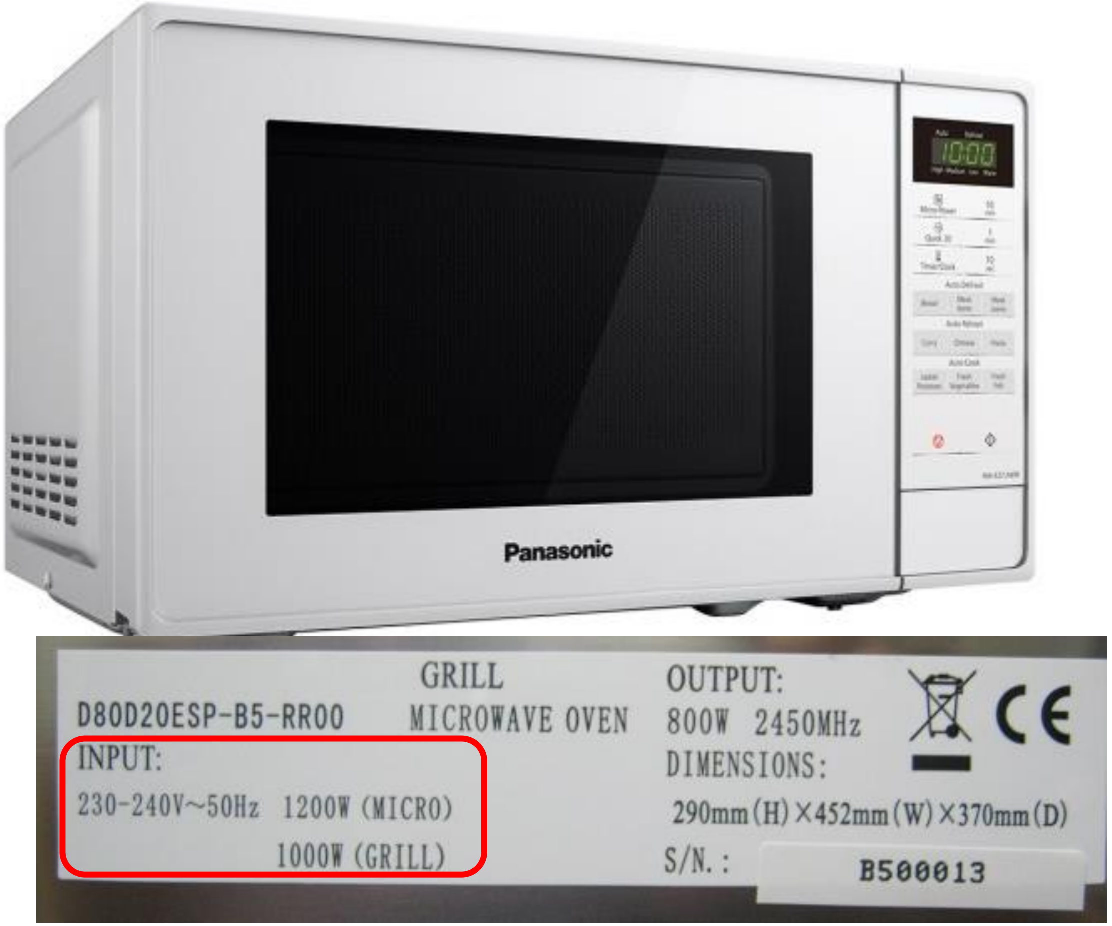


Alternating Currents:



www.canadian-power.com

Alternating Currents:



Module description:

Recommended text books:

- DeCarlo Lin, “*Linear Circuit Analysis*”, Oxford University Press, Second Edition, 2003
- W H Hayt, J E Kemmerly, S M Durbin, “*Engineering Circuit Analysis*”, McGraw-Hill, 9th Edition, 2019