CLASS 6: ELECTRICAL SIGNALS & KIRCHHOFF'S LAWS

ENGR 102 – Introduction to Engineering

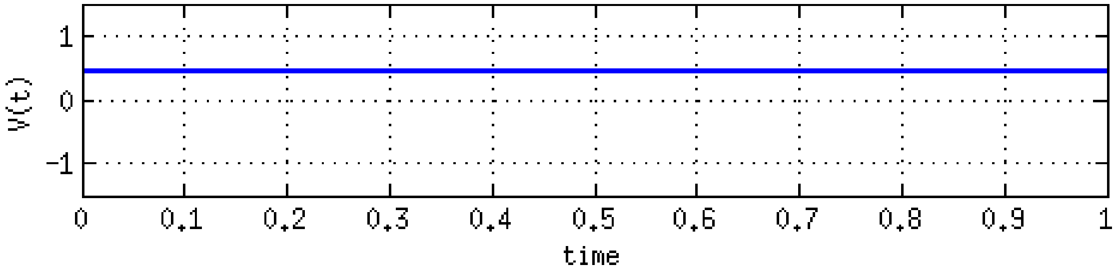
Electrical Signals & Waveforms

Electrical Signals

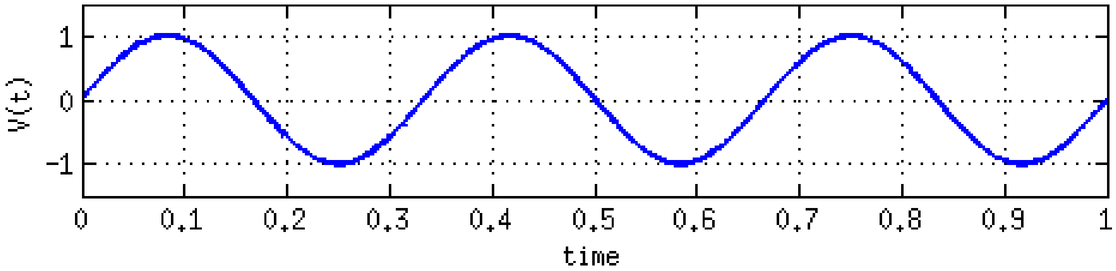
- ***Voltage*** and ***current*** are the two properties of electrical circuits that we are most often concerned with
  - Voltages and currents may be ***constant as functions of time***
    - Direct current, ***DC***
  - Or they may be ***time-varying***
    - Alternating current, ***AC***
  - We can refer to these quantities as electrical ***signals***
    - They carry information
    - More appropriate terminology in the world of electronics than power systems
- Voltages and currents can be plotted as functions of time – ***waveforms***

DC vs. AC

- ***DC*** (direct current) electrical signals (voltages, currents) are ***time-invariant***
  - In ENGR 201, we will primarily focus on DC signals

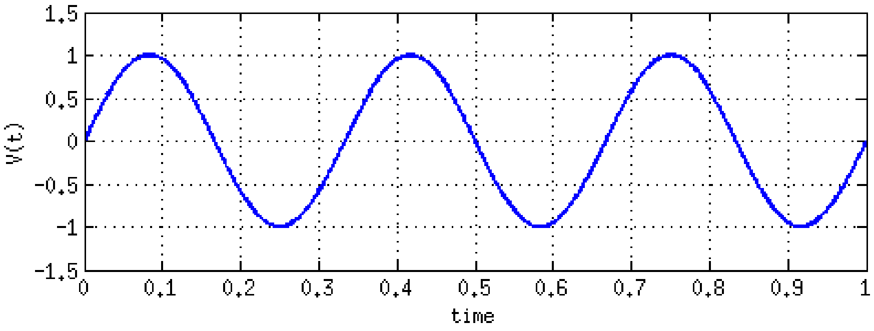


- ***AC*** (alternating current) electrical signals are ***time-varying***
  - Possibly ***periodic***

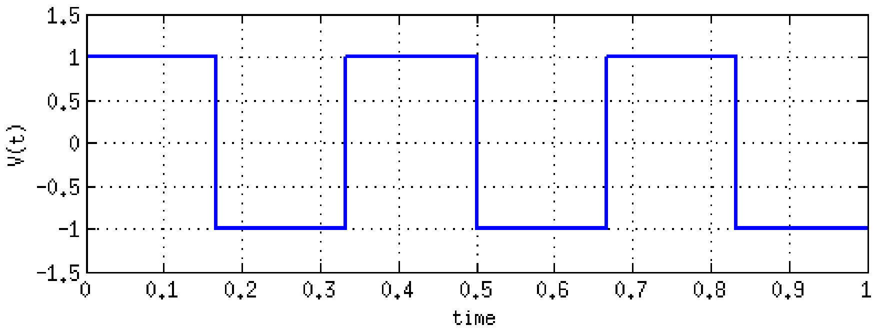


Some Typical Waveforms

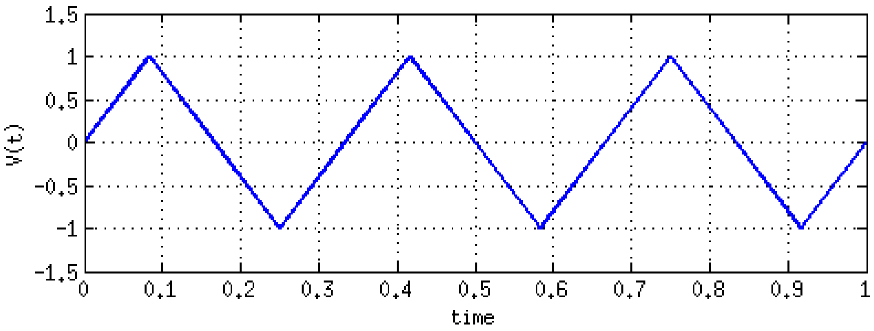
Sinusoid:



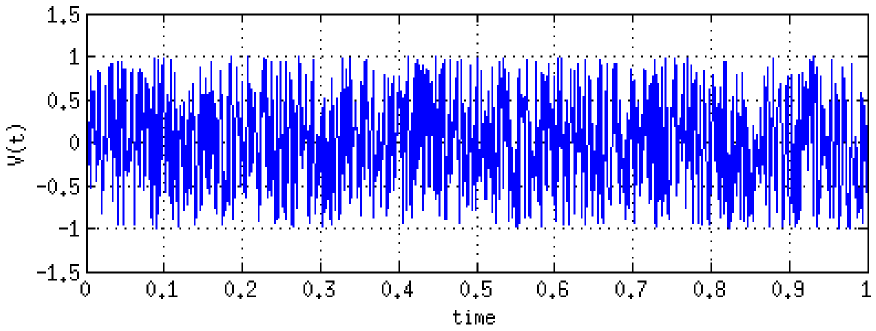
Square wave:



Triangle wave:

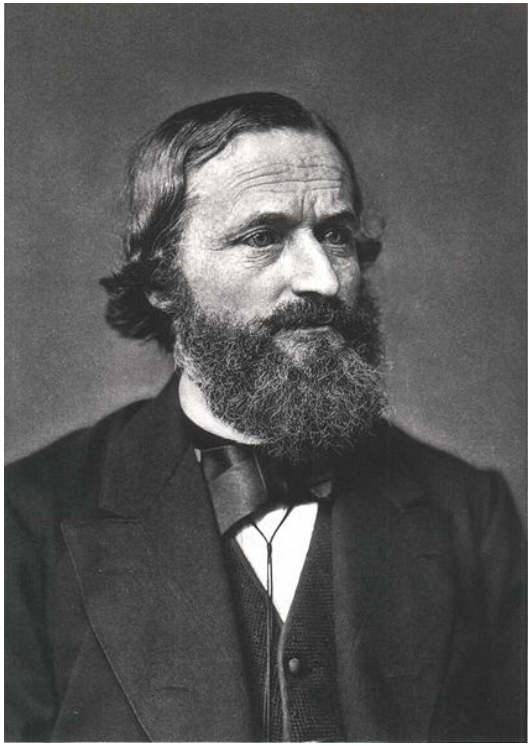


Noise:



Kirchhoff’s Laws

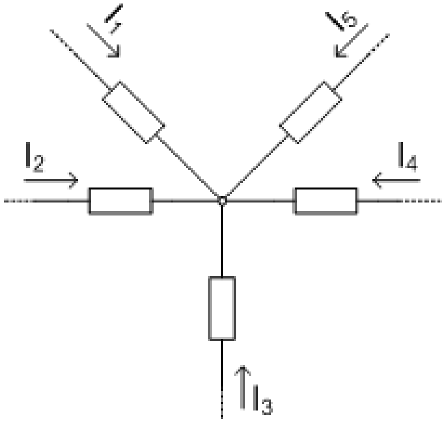
Kirchhoff’s Current Law - KCL



Gustav Kirchhoff, 1824 – 1887

“The algebraic sum of currents entering any node must be zero.”

- Charge cannot accumulate in a node
- What flows in, must flow out



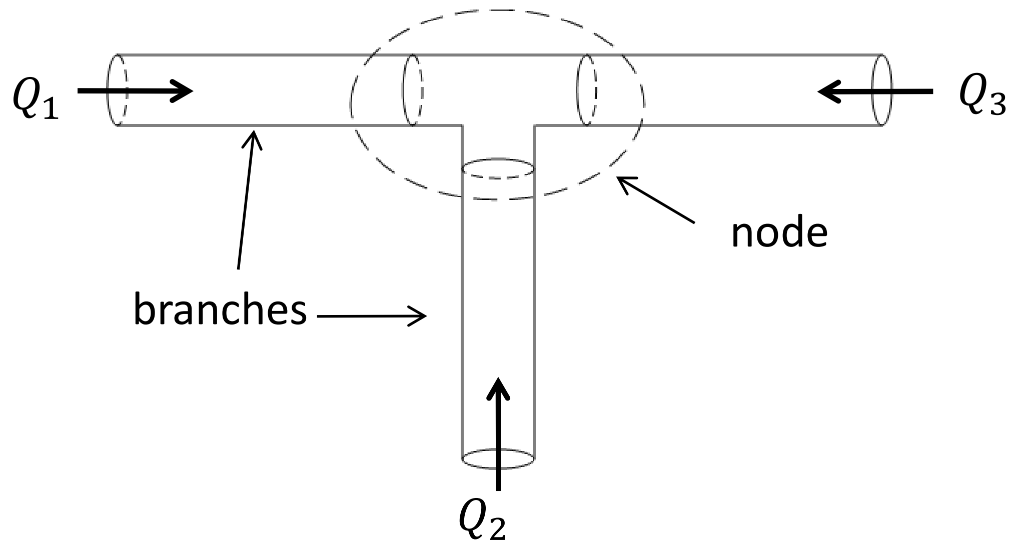
$$I_1 + I_2 + I_3 + I_4 + I_5 = 0$$

$$\sum_i I_i = 0$$

- Analogous to the conservation of mass

KCL & the Conservation of Mass

- Consider fluid-carrying pipes connected in a Tee
  - Tee connector is analogous to electrical ***node***
  - Pipes analogous to ***branches***
- According to the conservation of mass, what flows in must flow out
  - ***Sum of the flow rates must be zero***



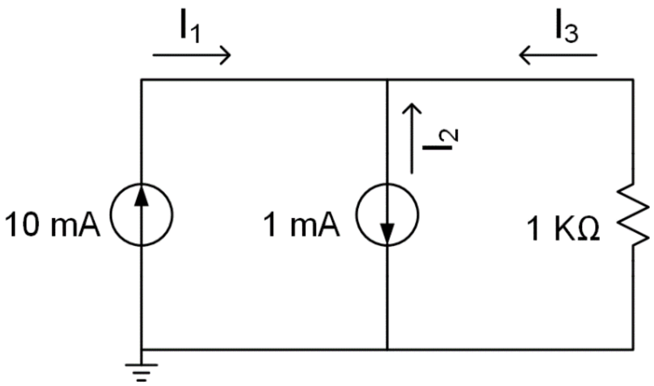
$$\sum_i Q_i = 0$$

KCL - Example

- Determine the current through the $1\ k\Omega$ resistor, I_3
- Applying KCL

$$I_1 + I_2 + I_3 = 0$$

$$I_3 = -I_1 - I_2$$



- I_1 and I_2 are known:

$$I_1 = 10\ mA, \quad I_2 = -1mA$$

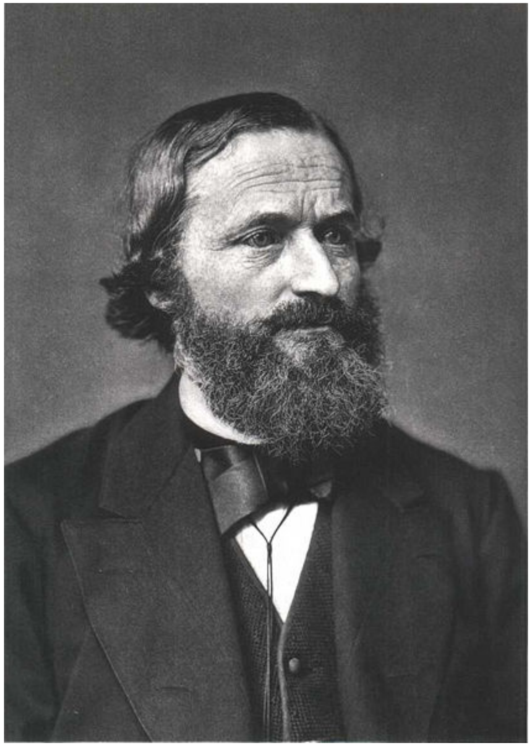
- Solving for I_3:

$$I_3 = -10\ mA + 1\ mA$$

$$I_3 = -9\ mA$$

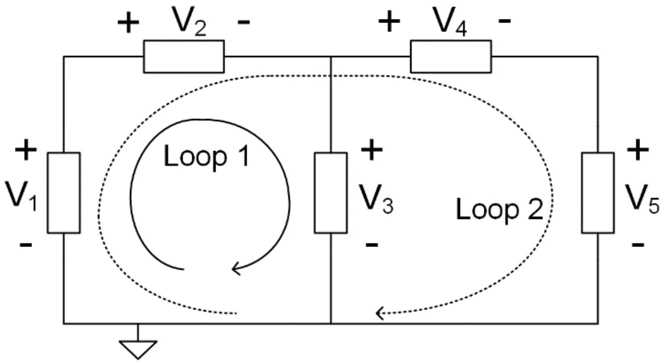
- The negative sign indicates that I_3 flows in the opposite direction of what was assumed

Kirchhoff's Voltage Law - KVL



Gustav Kirchhoff, 1824 – 1887

"The algebraic sum of voltage changes taken around any loop in a network is equal to zero."



KVL around Loop 1

$$V_1 - V_2 - V_3 = 0$$

KVL around Loop 2

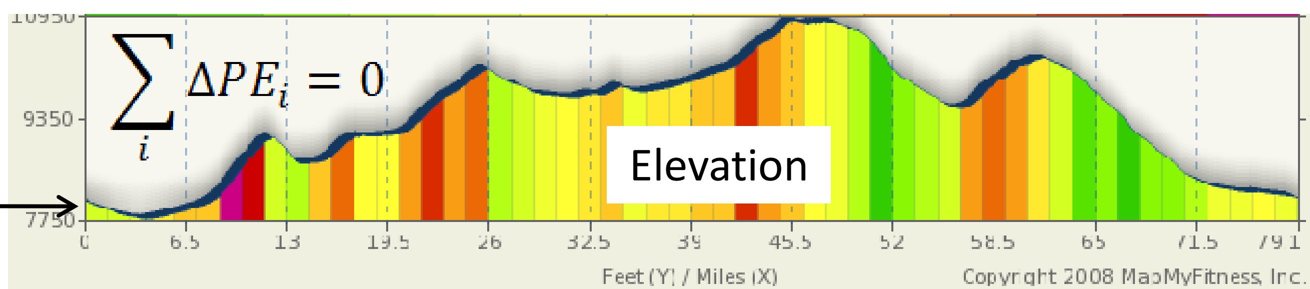
$$V_1 - V_2 - V_4 - V_5 = 0$$

- Conservation of energy applied to electric circuits

KVL & the Conservation of Energy

- Voltage drops around a circuit are analogous to changes in potential energy while traversing a loop
- PE varies with elevation
  - Increases with each climb
  - Decreases with each descent
- Initial/final elevation & PE are the same
  - Sum of PE rises/drops around the loop is zero
  - Just like voltage drops around a circuit

PE_i



$PE_f = PE_i$

KVL – Example

- Determine the voltage, V_2, across the $3.3\ k\Omega$ resistor
- Applying KVL

$$V_1 - V_2 - V_3 = 0$$

$$V_2 = V_1 - V_3$$

- V_1 and V_3 are known:

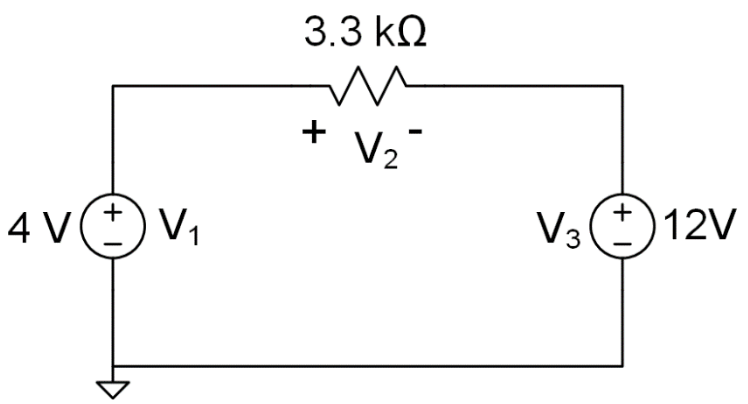
$$V_1 = 4\ V, \quad V_3 = 12\ V$$

- Solving for V_2:

$$V_2 = 4\ V - 12\ V$$

$$V_2 = -8\ V$$

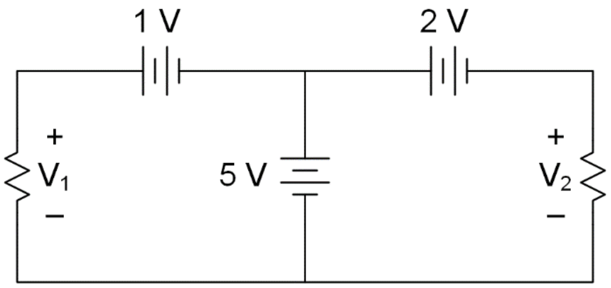
- The negative sign indicates that the polarity of V_2 is the opposite of what was assumed



Kirchhoff's Voltage Law - KVL

Exercise

- Apply KVL to determine V_1 and V_2 in the following circuit.



Kirchhoff's Current Law - KCL

Exercise

- Apply KCL to determine all unknown branch currents and node voltages in the following circuit.