Definitions

- **Node** – a connecting point between two or more circuit elements
- **Branch** – part of a circuit; one or more circuit elements with two terminals
- **Gaussian surface** – enclosed surface where charge & electromagnetic flux is calculated
- **Parallel circuit** – two or more branches linked by two nodes
- **Series circuit** – two or more branches linked by one node
Definitions

• **Closed path** – series of connected nodes with the same beginning & end

• **Closed node sequence** – series of nodes where the same beginning & end

• **Connected circuit** – a circuit in which all nodes are connected to each other via a path of circuit elements
Kirchoff’s Current Law

• Sum of all currents entering a node or Gaussian surface is zero at all times

• From the conservation of charge:

\[ Q(t) = \int_0^t \sum_{k=1}^{N} dQ_k = 0, \text{ for all } t \]

\[ Q(t) = \int_0^t dt \sum_{k=1}^{N} I_k(t) = 0, \text{ for all } t \]

\[ \sum_{k=1}^{N} I_k(t) = 0, \text{ for all } t \]
Example 1

- At node A, input currents look like this:

$$I_1 = t^2$$

$$I_2 = 4t$$

$$I_3 = 4$$

What is the output current $I_4$?
Example 1: Solution

- At node A, input currents look like this:

\[ I_1 = t^2 \]
\[ I_2 = 4t \]
\[ I_3 = 4 \]

What is the output current \( I_4 \)?

\[ I_4 = t^2 + 4t + 4 = (t+2)^2 \]
Example 2

• Given an ideal current source $I_o$ connected to 4 parallel resistors, how is the current divided?

![Resistor network diagram]

10 $\Omega$  2.5 $\Omega$  6 $\Omega$  3 $\Omega$  $I_o$

• What if 2 identical ICS’s are connected in parallel? In series? What if only one has its current doubled?
Example 2: Solution

• Given an ideal current source $I_o$ connected to 4 parallel resistors, how is the current divided?

$$I_{k} = \frac{V}{R_{k}} = \frac{I_{o}}{R_{k}} \sum_{l=1}^{N} \frac{1}{R_{l}}$$

• Equal voltage drop across every resistor implies:
Example 2: Solution, Cont’d

• What if 2 identical ICS’s are connected in parallel?
  – All currents in resistors double

• In series?
  – No change

• What if only one has its current doubled?
  – Currents triple in parallel; unphysical in series
Kirchoff’s Voltage Law

• Since voltage is a unique quantity at a given place and time (see Lecture 2):
  – Voltage drop between any two nodes is given by the difference of their voltages, independent of path (i.e., $V_{AB} = V_A - V_B$)
  – It is directionally dependent (e.g., $V_{AB} = -V_{BA}$, since $V_A - V_B = -(V_B - V_A)$)
  – Sum of voltage drops over any closed loop is zero (otherwise, voltage would be non-unique)
Kirchoff’s Voltage Law

• Alternative statements:
  – For connected circuits and any node sequence, the voltage difference between the end points equals the sum of the voltage drops across each element: e.g., $V_{AD} = V_{AB} + V_{BC} + V_{CD}$, since $V_{AB} + V_{BC} + V_{CD} = V_A - V_B + V_B - V_C + V_C - V_D = V_A - V_D$
  – For connected circuits, the sum of node-to-node voltages over any closed node sequence is always zero (a special case of the last rule)
• What are $V_{DA}$, $V_{FD}$, and $V_{EC}$?
Example 3: Solution

• What are $V_{DA}$, $V_{FD}$, and $V_{EC}$?
  
  $- V_{DA} = V_{DB} + V_{BA} = 9\, V + 4\, V = 13\, V$
  
  $- V_{FD} = V_{FE} + V_{ED} = 2\, V + 3\, V = 5\, V$
  
  $- V_{EC} = V_{ED} + V_{DB} + V_{BC} = 3\, V + 9\, V - 2\, V = 10\, V$
Homework

• HW #2 solution posting this morning
• HW #3 due today by 4:30 pm in EE 325B
• HW #4 due Wed. – DeCarlo & Lin, Chapter 2:
  – Problem 2(a)
  – Problem 3
  – Problem 6
  – Problem 12