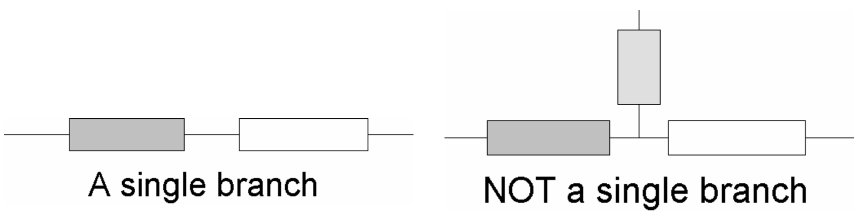
Lecture 3

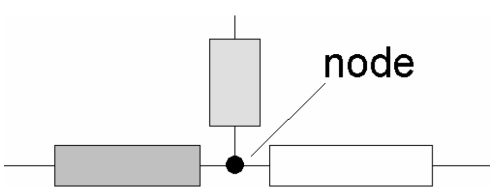
- Definitions: Circuits, Nodes, Branches
- Kirchoff's Voltage Law (KVL)
- Kirchoff's Current Law (KCL)
- Examples and generalizations
- RC Circuit Solution

BRANCHES AND NODES

Branch: elements connected end-to-end, nothing coming off in between (in series)



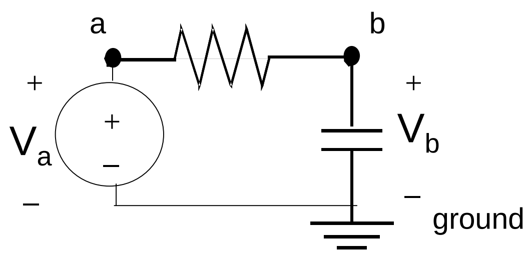
Node: place where elements are joined—entire wire



NOTATION: NODE VOLTAGES

The voltage drop from node X to a reference node (ground) is called the **node voltage** V_x.

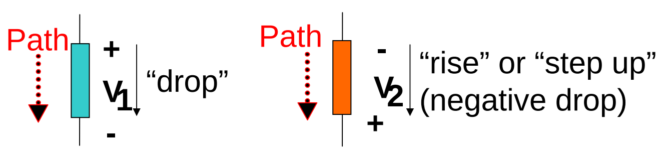
Example:



KIRCHOFF’S VOLTAGE LAW (KVL)

The sum of the voltage drops around any closed loop is zero.

We must return to the same potential (conservation of energy).

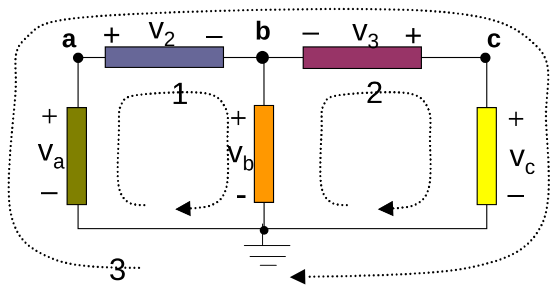


Closed loop: Path beginning and ending on the same node

Our trick: to sum voltage drops on elements, look at the first sign you encounter on element when tracing path

KVL EXAMPLE

Examples of three closed paths:



Path 1:

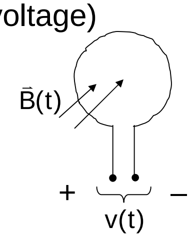
Path 2:

Path 3:

UNDERLYING ASSUMPTIONS OF KVL

Assume no time-varying magnetic flux through the loop …

If there was, Faraday's Law → induced emf (voltage)



Antennas are designed to "pick up" electromagnetic waves

"Regular circuits" often do the same thing → not desirable!

$\boxed{\text{Avoid these loops!}}$

How do we deal with antennas (EECS 117A)?

Include a voltage source as the circuit representation of the emf or "noise" pickup.

We have a lumped model rather than a distributed (wave) model.

ALTERNATIVE STATEMENTS OF KIRCHHOFF'S VOLTAGE LAW

1) For any node sequence A, B, C, D, …, M around a closed path, the voltage drop from A to M is given by

$$v_{AM} = v_{AB} + v_{BC} + v_{CD} + \cdots + v_{LM}$$

2) For all pairs of nodes i and j, the voltage drop from i to j is

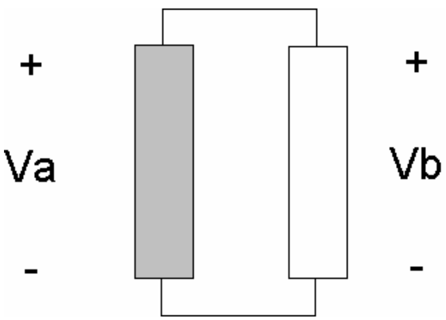
$$v_{ij} = v_i - v_j$$

where the node voltages are measured with respect to the common node.

MAJOR IMPLICATION

KVL tells us that any set of elements which are **connected at both ends** carry the **same voltage**.

We say these elements are **in parallel**.



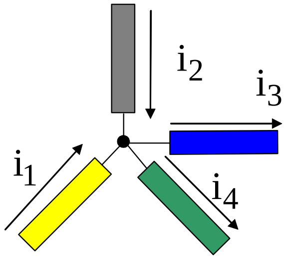
KVL clockwise, start at top:

Vb – Va = 0

Va = Vb

KIRCHOFF'S CURRENT LAW

Circuit with several branches connected at a node:



KIRCHOFF's CURRENT LAW "KCL":

(Sum of currents <u>entering</u> node) – (Sum of currents <u>leaving</u> node) = 0

Charge stored **in node** is zero (e.g. entire capacitor is part of a branch)

USING KCL

Kirchhoff's Current Law (KCL)

Formulation 1:

Sum of currents **entering** node = sum of currents **leaving** node

Use/write **reference directions** to determine "entering" and "leaving" currents--**no concern** about **actual** current directions

ALTERNATIVE KCL FORMULATIONS

Formulation 2:

“Algebraic sum” of currents **entering** node = 0

where “algebraic sum” means currents **leaving** are included with a **minus sign**

Formulation 3:

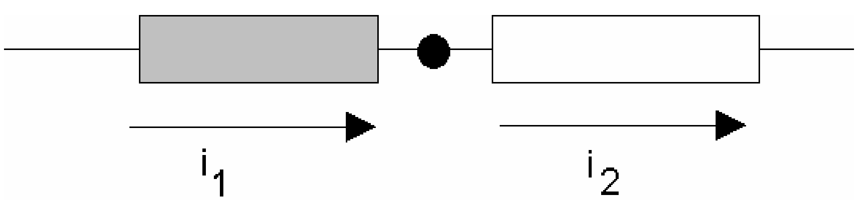
“Algebraic sum” of currents **leaving** node = 0

currents **entering** are included with a **minus sign**

MAJOR IMPLICATION

KCL tells us that all of the elements **in a single branch** carry the **same current**.

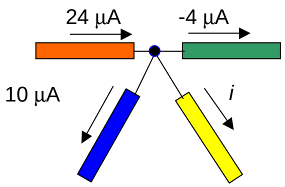
We say these elements are **in series**.



Current entering node = Current leaving node

$$i_1 = i_2$$

KIRCHHOFF'S CURRENT LAW EXAMPLE



Currents entering the node:

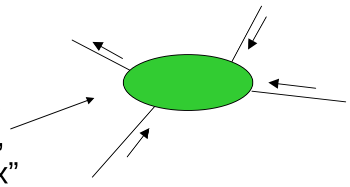
Currents leaving the node:

Three formulations of KCL:

GENERALIZATION OF KCL

Sum of currents entering/leaving a **closed surface** is zero

Could be a big chunk of circuit in here, e.g., could be a "Black Box"

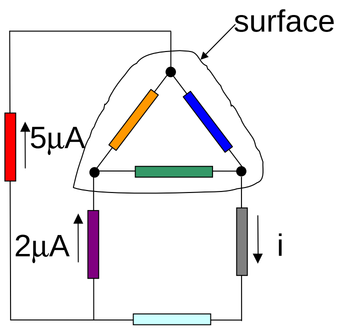


Note that **circuit branches** could be inside the surface.

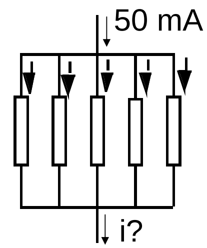
The surface can enclose more than one node!

KIRCHOFF'S CURRENT LAW USING SURFACES

Example



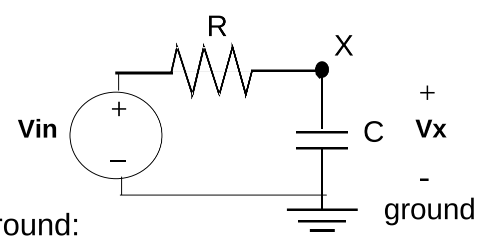
Another example



KCL EXAMPLE: RC CIRCUIT

KCL at node X:

Current into X from the left:



Current out of X down to ground:

KCL:

→

Solution: