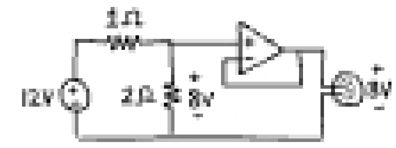
Lecture 8

PCAP

Primitives, Combinations, Abstractions, Patterns
Abstractions reduce complexity by combining multiple primitives into a single entity

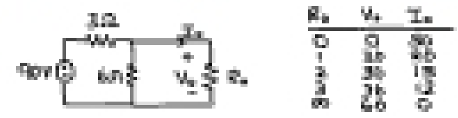
Buffers with Op-Amps

Buffers can be used to increase modularity
The voltage divided on the left acts as a module that produces 8V, regardless of loading of bulb on the right

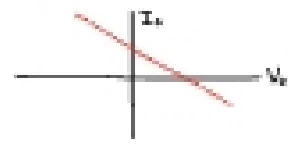


Patterns

Changing an element changes voltages and currents systematically
Consider the changes in V_s and I_s when R_s is changed



Check yourself: Patterns
Correct answer: 3
The equations for the three leftmost elements are linear

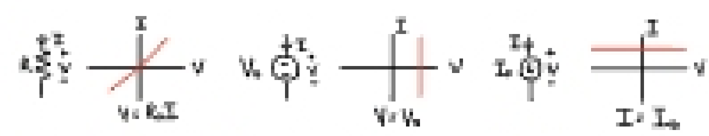


Current-Voltage Relations

The current-voltage relation summarizes all possible behaviors of circuit—regardless of what the circuit is connected to
We can think about an entire circuit as a single element: a one-port

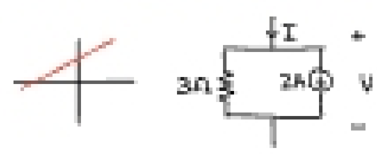
One-Ports

If a circuit connects to the world via two terminals, then that circuit can be represented by a single generalized element called a one-port
This is regardless of how many components are in the circuit
This is analogous to
- replacing delays, gains, and adders with a system function
- combining a sequence of operations in a procedure call
- combining diverse data in a list



These representations are compositional: they replace multiple elements with a single element that can be used in the same way that primitives are used

Concept Question: Graphing One-Ports
Correct answer: 3



Parallel One-Ports

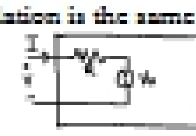
If the I-V curves for two one-ports are both straight lines, then the I-V curve for the parallel combination is a straight line
This is because the sum of two straight lines is a straight line

Series One-Ports

If the I-V curves for two one-ports are both straight lines, then the I-V curve for the series combination is a straight line
This is because the sum of two straight lines is a straight line

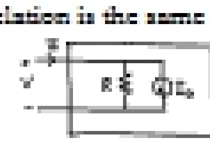
Thevenin Equivalents

If the current-voltage relation is linear, the current-voltage relation is the same as that for a voltage source in series with a resistor
From the circuit, $I = \frac{V - V_0}{R}$
If I = 0, the $V = V_0$ (the x-intercept of the plot)
The rate of growth of $I = \frac{V}{R} - \frac{V_0}{R}$ with V is the slope 1/R



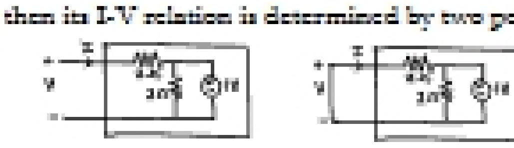
Norton Equivalents

If the current-voltage relation is linear, the current-voltage relation is the same as that for a current source in parallel with a resistor
From the circuit, V =
If I = 0, the I = I (the y-intercept of the plot)
The rate of growth of I = with V is the slope 1/R



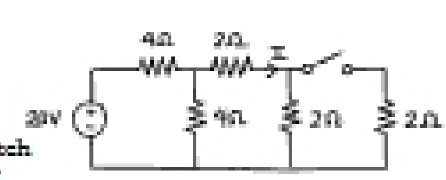
Open-Circuit Voltage and Short-Circuit Current

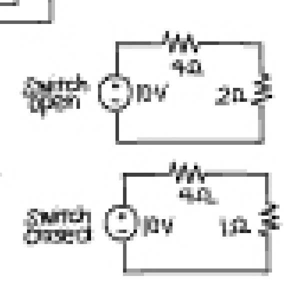
If a one-port contains just resistors and currents and voltage sources, then its I-V relation is determined by two points
First point: open-circuit voltage $V = V_0 = 1V$
Second point: closed-circuit voltage $I = I_0 = -\frac{1}{2}A$
The equivalent resistance is the slope $R = V_0 / -I_0 = 2\Omega$



Conceptual Value of Equivalent Circuits

Equivalent circuits have conceptual values
Example: Will closing the switch increase or decrease I?
Replace the parts to the left and right of I by equivalent circuits
Equivalent circuit to the right of I depends on the state of the switch
Closing the switch decreases equivalent resistance to the right of I
Therefore, closing the switch increases I





Consequences of Linearity

If a one-port contains just linear elements (resistors, voltage sources, and current sources then the current-voltage relation will be linear are it can be represented by a Thevenin or Norton equivalent circuit
Linear one-ports can be characterized by two points on their I-V curve

Op-Amps as Abstractions

We have treated op-amps as fundamental building blocks for circuits, but op-amps are in fact complicated circuits, but op-amps are in fact complicated circuits that contain dozens of transistors and resistors plus a few capacitors