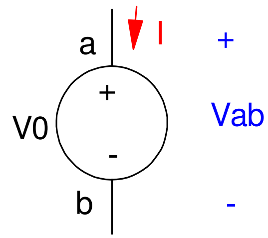
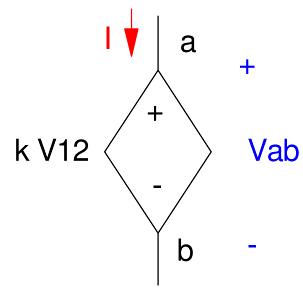
Circuit Elements and Kirchoff's Laws

EE 206 Circuits I

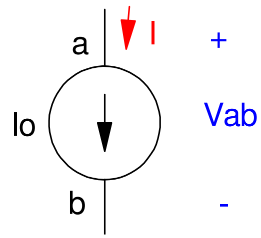
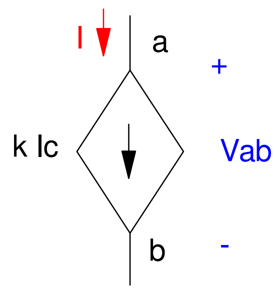
Jake Glower - Lecture #2

Please visit Bison Academy for corresponding
lecture notes, homework sets, and solutions

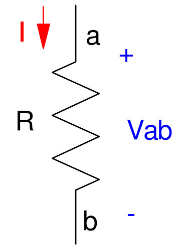
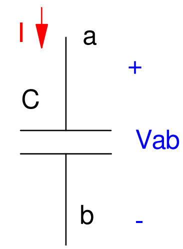
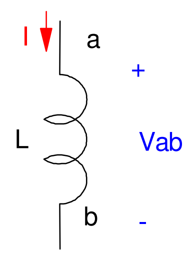
Circuit Elements: Voltage Sources

<table>
<tr><th>Element</th><th>Symbol</th><th>VI Relationship</th></tr>
<tr><td>Voltage Source
(battery)</td><td>
</td><td>$V_{ab} = V_0$
$I = \text{any}$</td></tr>
<tr><td>Voltage Controlled Voltage Source
(amplifier)</td><td>
</td><td>$V_{ab} = kV_{12}$
$I = any$</td></tr>
</table>

Circuit Elements: Current Sources

<table>
<tr><th>Element</th><th>Symbol</th><th>VI Relationship</th></tr>
<tr><td>Current Source
(LED driver)</td><td>
</td><td>$I = I_0$
$V_{ab} = any$</td></tr>
<tr><td>Current Controlled Current Source
(transistor)</td><td>
</td><td>$I = kI_c$
$V_{ab} = any$</td></tr>
</table>

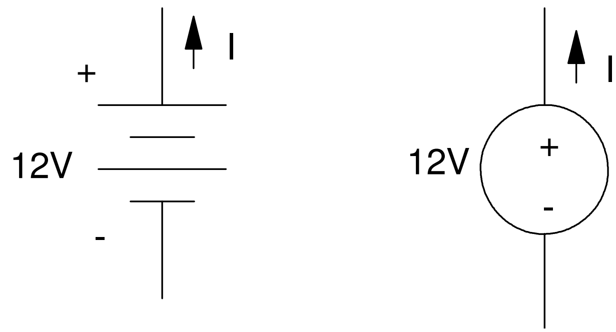
Passive Circuit Elements

Element	Symbol	VI Relationship
Resistor (basic circuit element)		$V_{ab} = IR$
Capacitor (basis circuit element)		$I = C\,\frac{dV_{ab}}{dt}$
Inductor (basic cicuit element)		$V_{ab} = L\frac{dI}{dt}$

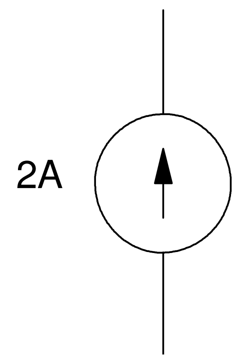
Independent Sources

Voltage Source: Like a battery: the voltage is fixed

- Current depends upon the load (can be anything, positive or negative)

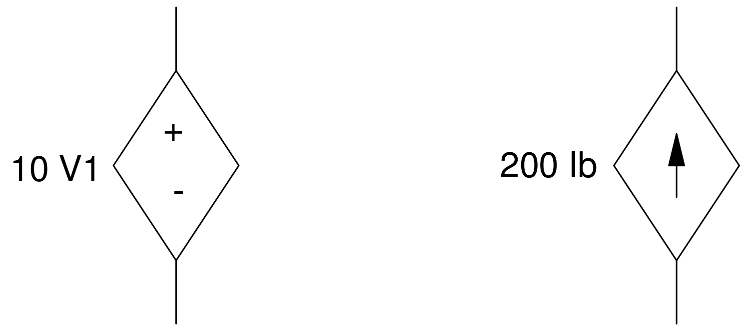


Current Source: LED driver: the current is fixed



Dependent Sources

Controlled Current and Voltage Sources: A diamond indicates a controlled voltage source or a controlled current source.



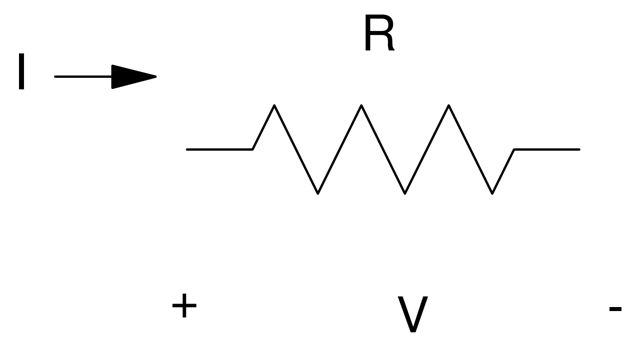
Controlled sources arise from various components covered in ECE 320 Electronics

- Operational Amplifiers (voltage controlled voltage source)
- Transistors (current controlled current source)
- MOSFET (voltage controlled current source)

For this class, just treat them as a device.

Ohm's Law

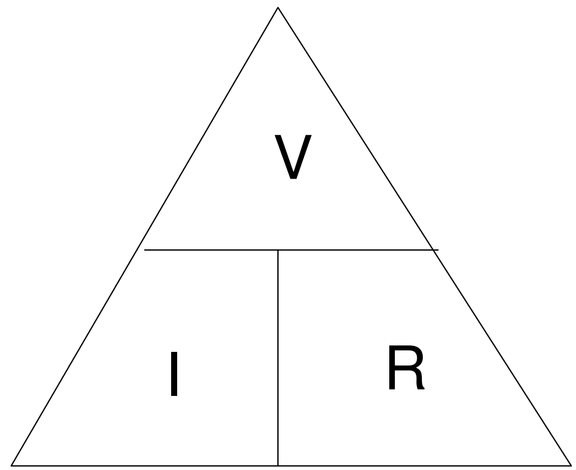
- V = I R
- Current goes into the + terminal



Other Forms:

$$I = \frac{V}{R}$$

$$R = \frac{V}{I}$$



Power:

$$P = V\,I$$

$$P = \frac{V^2}{R}$$

$$P = I^2\,R$$

Kirchoff's Laws

Kirchoff's laws simply restate the conservation of voltage and current:

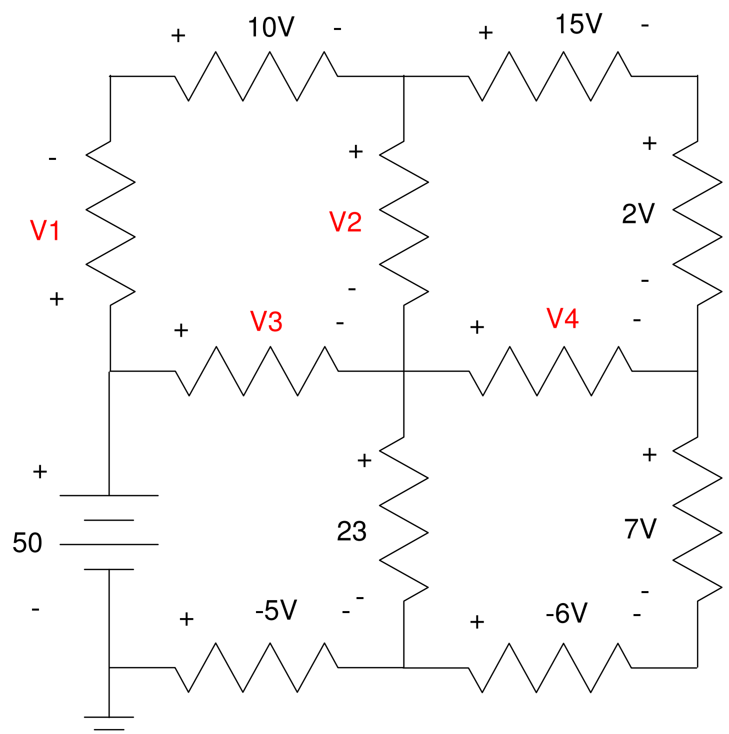
- If you sum the voltages around any closed path, the sum must be zero.
- If you sum the current flowing away from a point, the sum must be zero.

Conservation of Voltage:

Around any closed path, the voltages must add to zero.

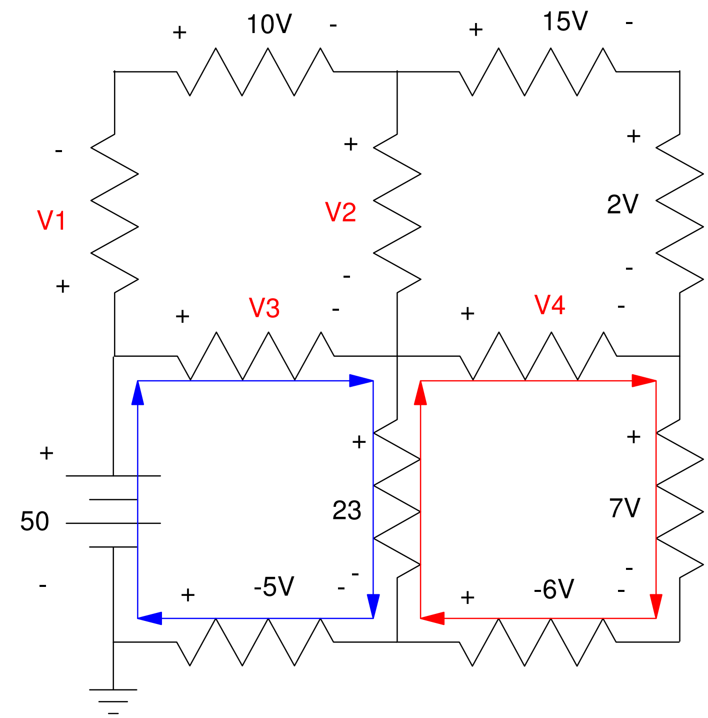
- You can use this to find unknown voltages.

Example: determine the voltages V1..V4 for the following circuit:



Solution:

- Around any closed-path, the voltages must sum to zero.
- Add if you hit the + sign first
- Subtract if you hit the - sign first



Path 1: (Blue)

$$-50 + V_3 + 23 - (-5) = 0$$

$$V_3 = 22V$$

Path 2: (Red)

$$-23 + V_4 + 7 - (-6) = 0$$

$$V_4 = 10V$$

Path 3: (Red)

$$-50 + V_1 + 10 + 15 + 2 - 8 - (-6) - (-5) = 0$$

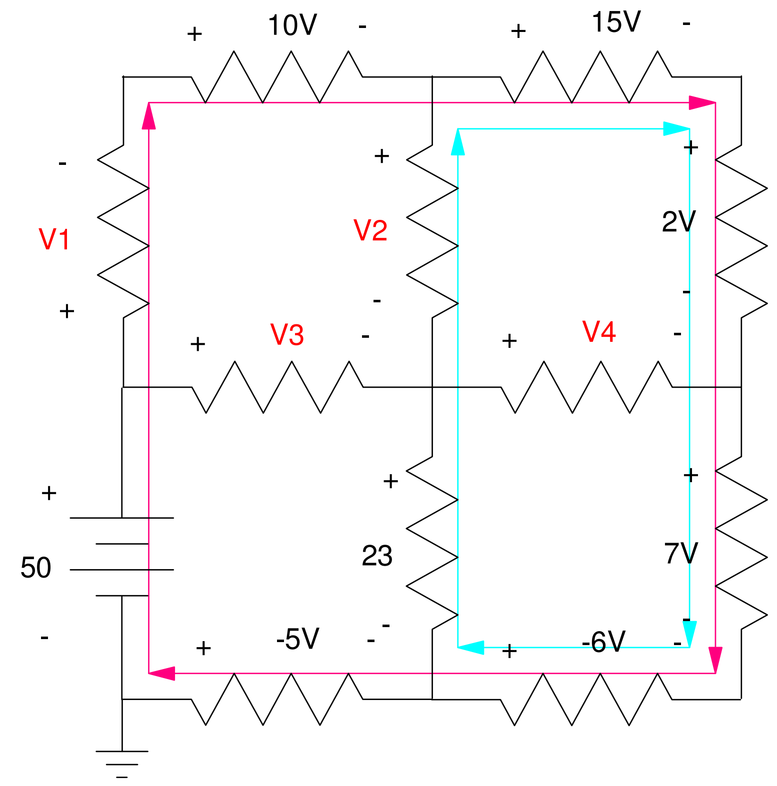
$$V_1 = 5V$$

Path 4 (Cyan)

$$-23 - V_2 + 15 + 2 + 7 - (-6) = 0$$

$$V_2 = 10V$$

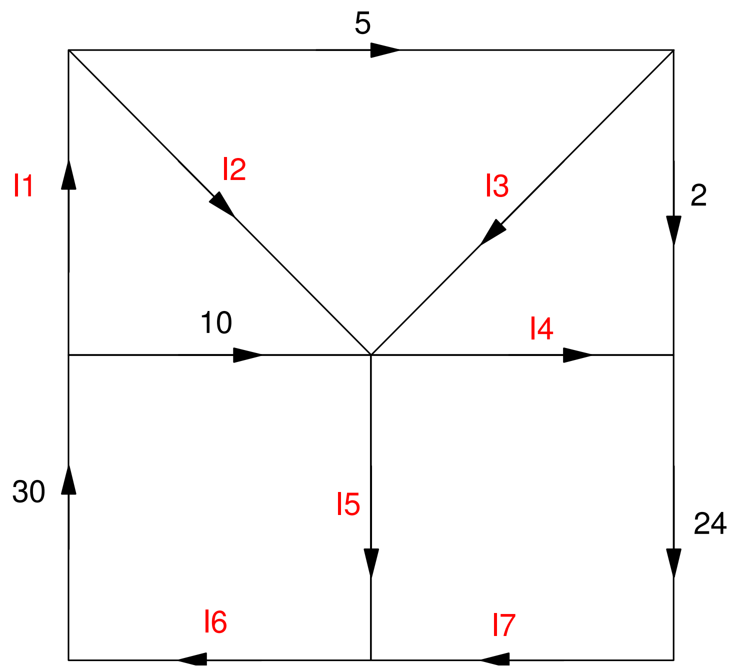
Other paths are also valid



Conservation of Current

- *Electrons cannot be created or destroyed: they can only be pushed around (Uncle Wally)*
- The current into a node must equal the current out of that node
- The sum of the current from a node must add to zero

Example: Determine I1..I7



A: $30 = 10 + I1$

$I1 = 20$

B: $I6 = 30$

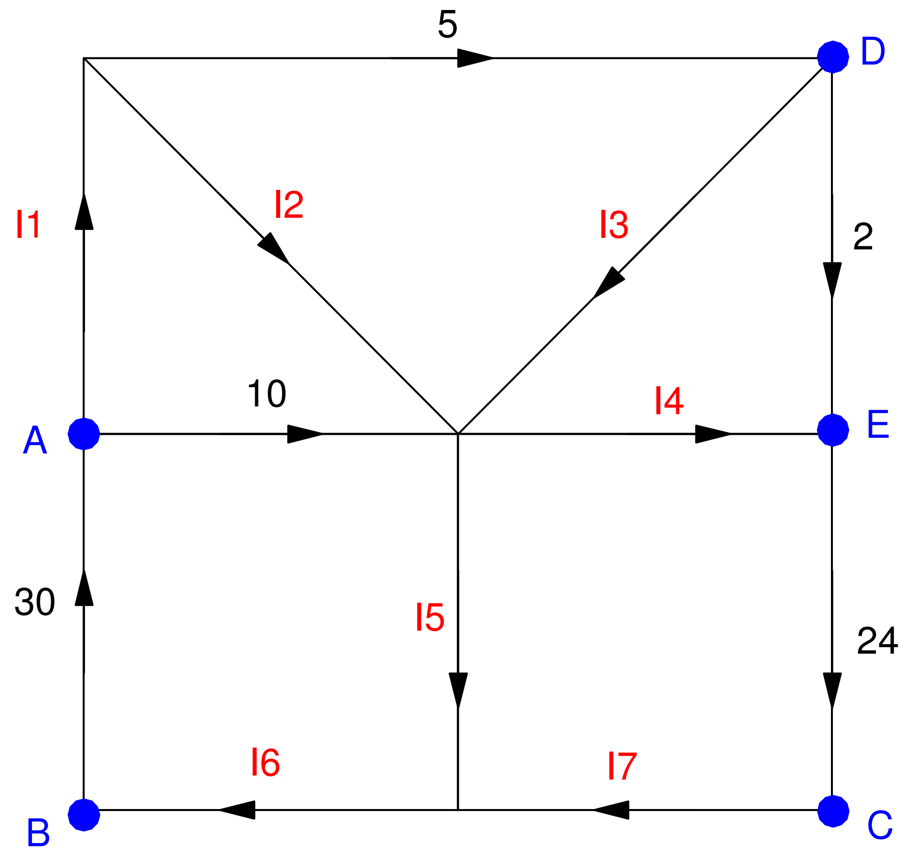
C: $24 = I7$

D: $5 = I3 + 2$

$I3 = 3$

E: $2 + I4 = 24$

$I4 = 22$



This lets you solve for I2 and I5:

F: $20 = I2 + 5$

$I2 = 15$

G: $I5 + 24 = 30$

$I5 = 6$