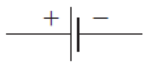
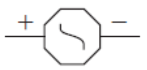
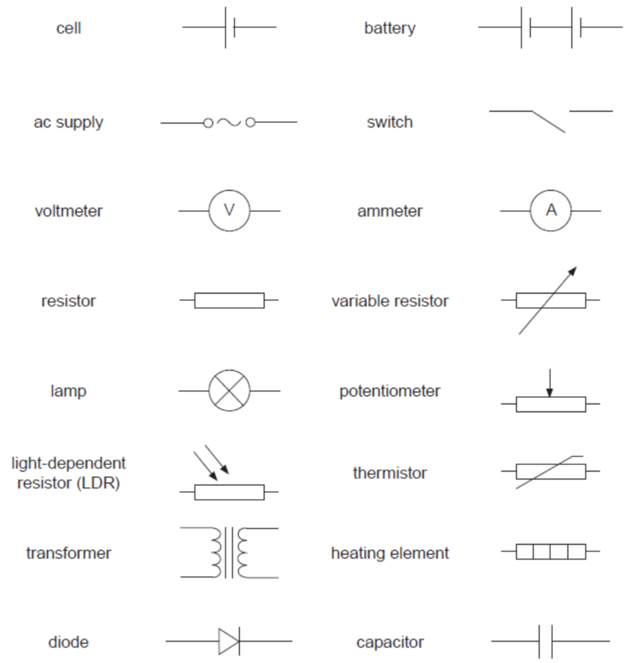
Making Diagrams of Circuits (closed electrical paths)

Table 1 Circuit Symbols

Part of circuit	Circuit symbol
battery	
variable DC power supply	
connecting wire	
resistor	
lamp	
motor	
open switch	
closed switch	

IB designated



Series Circuits - one path from start to finish

Parallel Circuits - multiple paths from start to finish

Section 1.6 - Kirchhoff's Laws

He was able to describe two important laws:

one law describes the electric potential difference

and the other

the electric current in circuits .

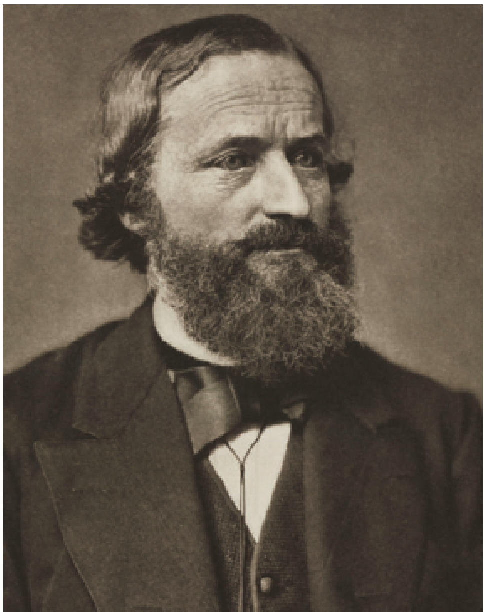


Figure 1 Gustav Kirchhoff developed laws that describe voltage and current in circuits.

Kirchhoff's Current Law

Junctions are points at which you can travel in more than one direction. In electric circuits, junctions are points where the current can split to follow more than one path. **Kirchhoff's current law (KCL)** is stated as follows:

Kirchhoff's Current Law

In a closed circuit, the amount of current entering a junction is equal to the amount of current exiting a junction.

A series circuit has only one path, so there can be only one possible current. If I_{series} is the current going through the source of electrical energy, and the subscripts identify the loads, then

$$I_{series} = I_1 = I_2 = I_3 = \cdots$$

A parallel circuit has more than one complete path, so the current can split, depending on the number of paths. The more complete paths there are, the more ways the current can be divided among the paths. If $I_{parallel}$ represents the current going through the source of electrical energy, and the subscripts identify the loads, then

$$I_{parallel} = I_1 + I_2 + I_3 + \cdots$$

Kirchhoff's Voltage Law

Recall that electric potential difference can also be referred to as voltage. **Kirchhoff's voltage law (KVL)** is stated as follows:

Kirchhoff's Voltage Law

In any complete path in an electric circuit, the total electric potential increase at the source(s) is equal to the total electric potential decrease throughout the rest of the circuit.

Electric potential increases at the source, so there must be an electric potential difference or voltage gain across the source. Similarly, electric potential decreases across the loads in the circuit, so there must be an electric potential difference or voltage drop. The sum of the voltage gains and drops in a complete path in a circuit is zero. The electric potential in a complete path in a circuit remains constant.

A series circuit has only one complete path, so the loads must share the amount of electric potential. The total electric potential across the loads must add up to the electric potential at the source (or sources). If V_{series} is the electric potential difference across the source of electrical energy, and the subscripts identify the loads, then

$$V_{series} = V_1 + V_2 + V_3 + \cdots$$

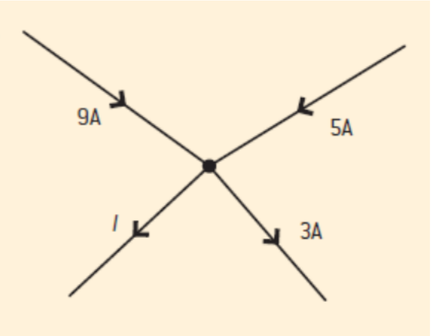
A parallel circuit has more than one complete path, so the electric potential decrease across each load must be the same as the electric potential increase at the source (or sources). Thus, the electric potential difference across the loads and source must be the same. If $V_{parallel}$ is the electric potential difference across the source of electrical energy, and the subscripts identify the loads, then

$$V_{parallel} = V_1 = V_2 = V_3 = \cdots$$

Kirchoff's Circuit Law - First Law - Junction Rule

The sum of the currents entering a junction must sum to zero.

$$\sum I = 0$$



Kirchoff's Circuit Law - Second Law - Loop Rule

The sum the voltage (gains, drops) must equal zero for a closed loop.

$$\sum V = 0$$

Summary - Series and Parallel Circuits

$$V_{series} = V_1 + V_2 + V_3 + \cdots$$

$$I_{series} = I_1 = I_2 = I_3 = \cdots$$

$$V_{parallel} = V_1 = V_2 = V_3 = \cdots$$

$$I_{parallel} = I_1 + I_2 + I_3 + \cdots$$

Items will either consume energy, resulting in a voltage "drop" or will contribute energy resulting in a voltage "gain".

An item that removes energy from the circuit is referred to as a potential difference (pd).

An item that adds energy to the circuit is referred to as a EMF (electromotive force).

A battery is an example of a "gain" and would have a positive voltage value, also called an EMF.

A lamp would consume energy, and would have voltage "drop", or be called a potential difference (negative value).

An ideal battery is referred to as an EMF (electromotive force), a real life battery has internal resistance and has a voltage value less than listed on its side.

IB specific

Device					**pd or emf?**
Cell	***converts energy from***	chemical	***into***	electrical	emf
Resistor		electrical		internal	pd
Microphone		sound		electrical	emf
Loudspeaker		electrical		sound	pd
Lamp		electrical		light (and internal)	pd
Photovoltaic cell		light		electrical	emf
Dynamo		kinetic		electrical	emf
Electric motor		electrical		kinetic	pd

Series Circuits - Basic

$$I_{series} = I_1 = I_2 = I_3 = \cdots$$

$$V_{series} = V_1 + V_2 + V_3 + \cdots$$

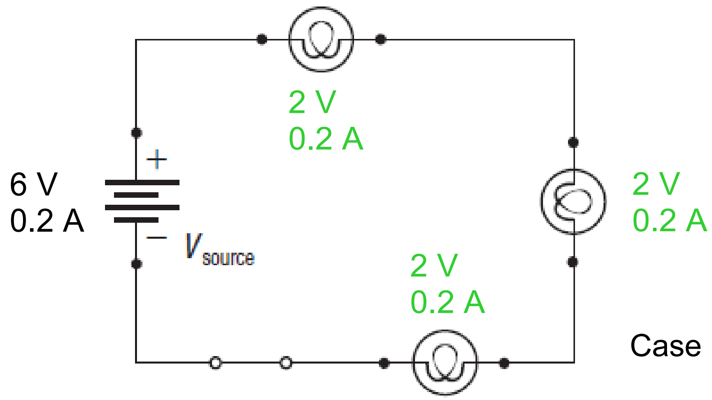


Figure 2 Series circuit

Case 1 - three **identical** loads (lights)

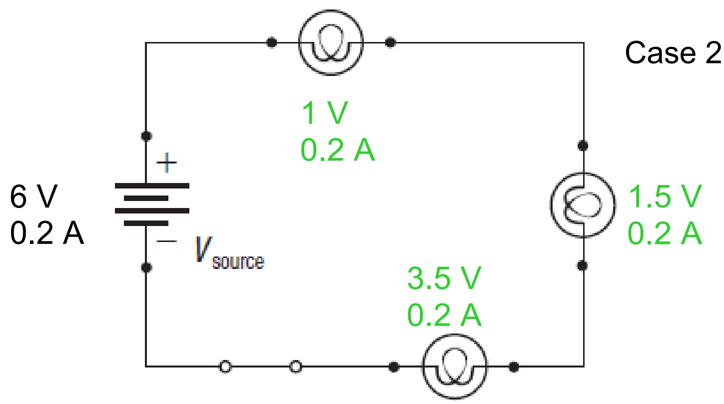


Figure 2 Series circuit

Case 2 - three **different** loads(lights)

Check

$$\sum I = 0$$

$$\sum V = 0$$

Parallel Circuits - Basic

$$V_{parallel} = V_1 = V_2 = V_3 = \cdots$$

$$I_{parallel} = I_1 + I_2 + I_3 + \cdots$$

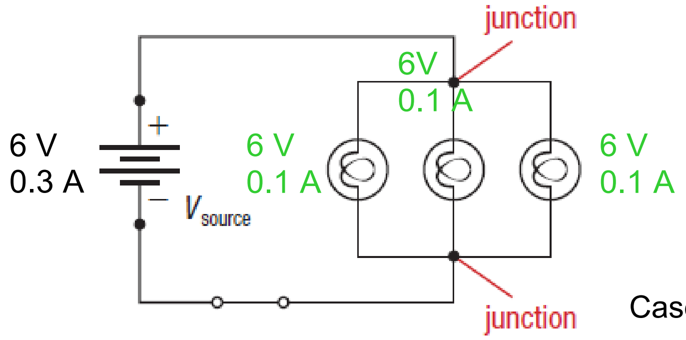


Figure 3 Parallel circuit

Case 1 - three **identical** loads (lights)

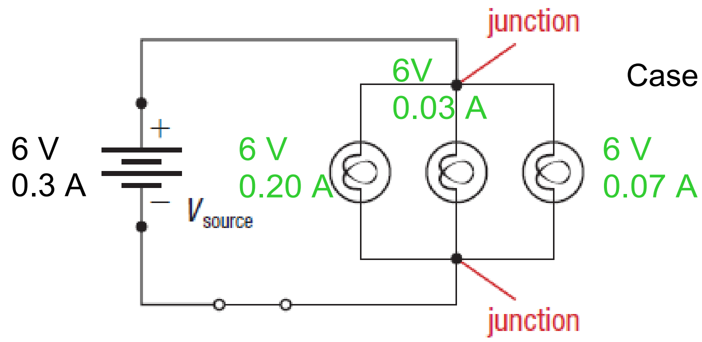


Figure 3 Parallel circuit

Case 2 - three **different** loads(lights)

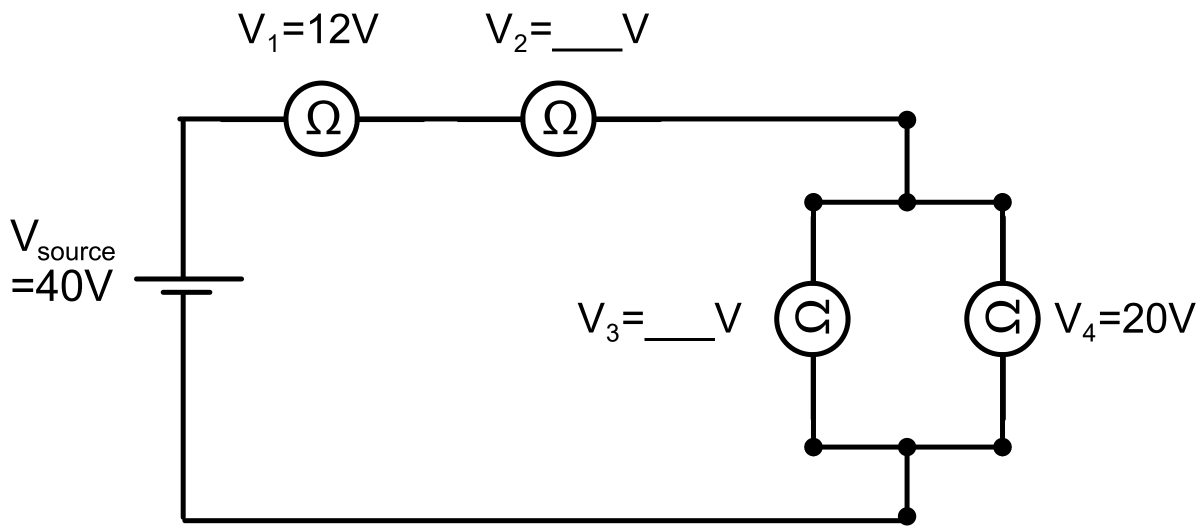
Check

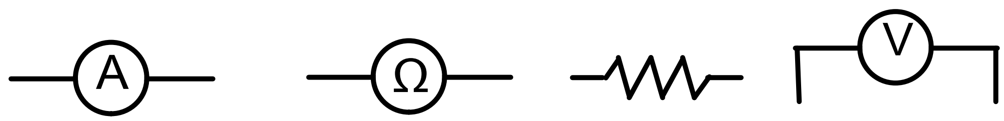
$$\sum I = 0$$

$$\sum V = 0$$

Working with Mixed Circuits (Series and Parallel)

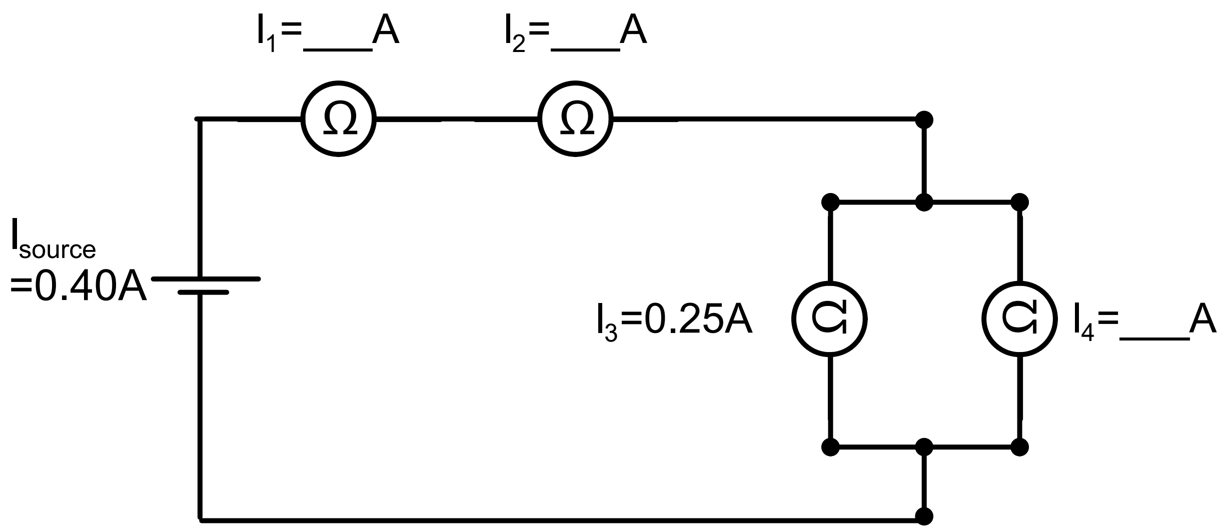
Find the missing voltage values

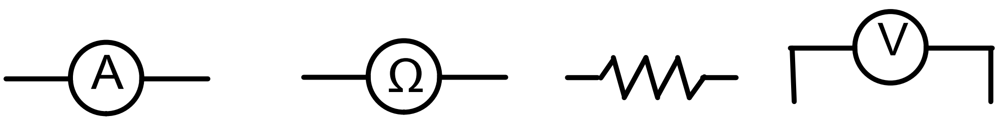




Working with Mixed Circuits (Series and Parallel)

Find the missing current values





Practice

1. For the circuit in **Figure 7**, $V_{source} = 60.0$ V, $V_1 = 20.0$ V, and $V_3 = 15$ V. Determine V_2, V_4, and V_5. T/I [redacted]
2. For the circuit in Figure 7, $I_1 = 0.70$ A, $I_3 = 0.10$ A, and $I_5 = 0.20$ A. Determine I_{source}, I_2, and I_4. T/I [redacted]

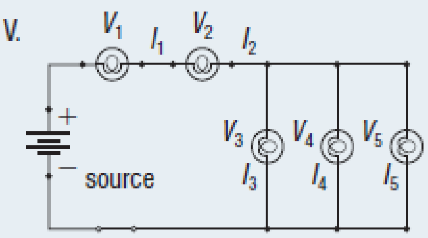
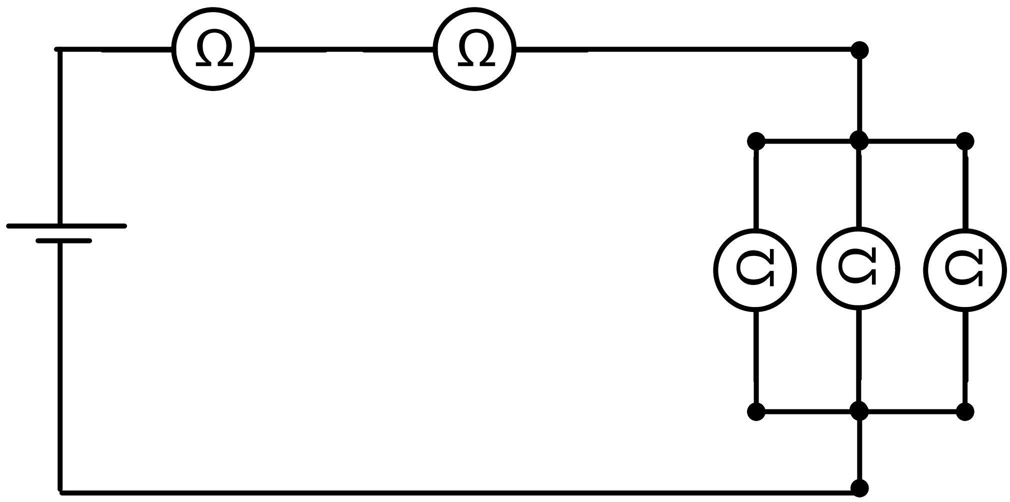


Figure 7



11.6 Summary

- Kirchhoff's voltage law (KVL) states that the voltage gains are equal to the voltage drops in a complete path in a circuit.
- Kirchhoff's current law (KCL) states that the current entering a junction is equal to the current exiting a junction in a circuit.
- The equations for Kirchhoff's laws are

$$V_{series} = V_1 + V_2 + V_3 + \cdots \qquad V_{parallel} = V_1 = V_2 = V_3 = \cdots$$

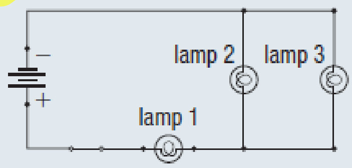
$$I_{series} = I_1 = I_2 = I_3 = \cdots \qquad I_{parallel} = I_1 + I_2 + I_3 + \cdots$$

$$\sum I = 0 \qquad \sum V = 0$$

11.6 Questions

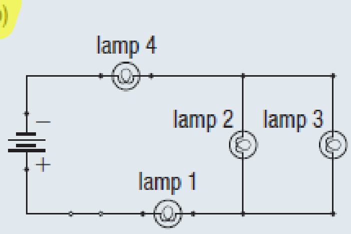
1. What is wrong with the following information? State whether you are applying KCL or KVL in your answer. K/U C
   (a) The current going into a parallel circuit is listed as 0.50 A and the current coming out of the parallel circuit is listed as 0.30 A.
   (b) A student measures the voltage across each of the three loads in a series circuit to be 10 V each. The voltage across the source is measured to be 10 V.
   (c) For a circuit with two lamps connected in parallel, a student measures the voltage drop across one lamp to be 20 V. The student measures the voltage drop across the second lamp to be 10 V.
   (d) A student is using an ammeter and notes that it reads 0.15 A on the first lamp, 0.20 A on the second lamp, and 0.25 A on the third lamp. The student says the lamps are connected in series.
2. For each of the following circuits, the given values are listed in a table. Copy each table into your notebook and find the missing values. T/I C

(a)



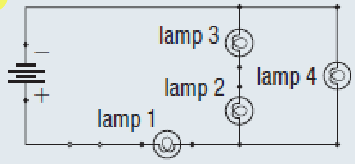
Item	*V* (V)	*I* (A)
source		
lamp 1	2.0	3.0
lamp 2	1.0	1.5
lamp 3		

(b)



Item	*V* (V)	*I* (A)
source	24.0	2.0
lamp 1	10.0	
lamp 2	6.0	1.0
lamp 3		
lamp 4		

(c)

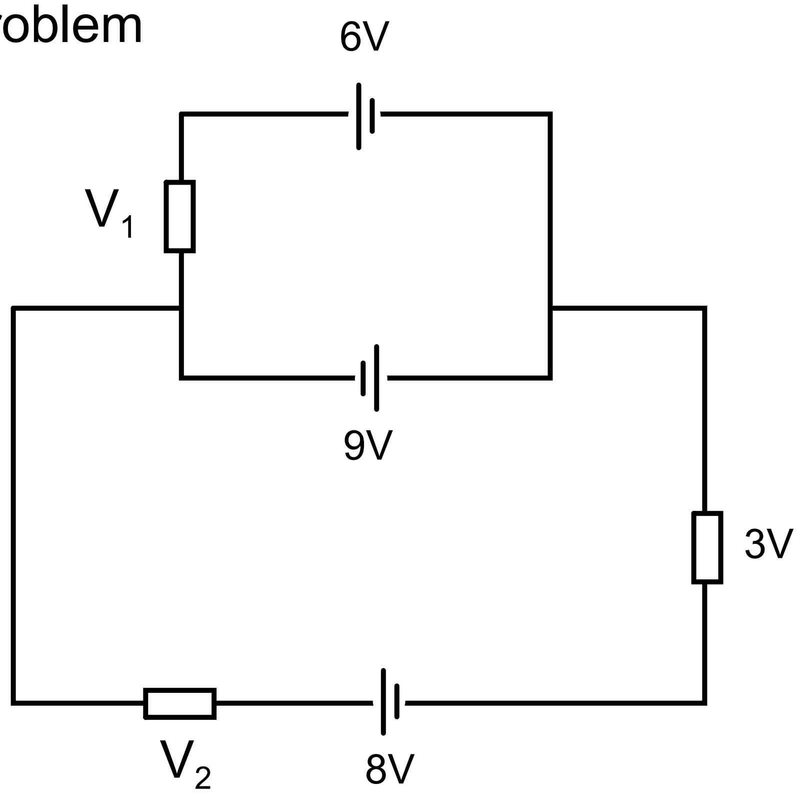


Item	*V* (V)	*I* (A)
source	6.0	4.0
lamp 1		
lamp 2	1.0	2.0
lamp 3	2.0	
lamp 4		

Section 11.6 #2

A tricky Voltage problem

IB Specific



Three loops

Important take aways:

- direction of batteries is important: same direction, additive; opposite direction, subtractive