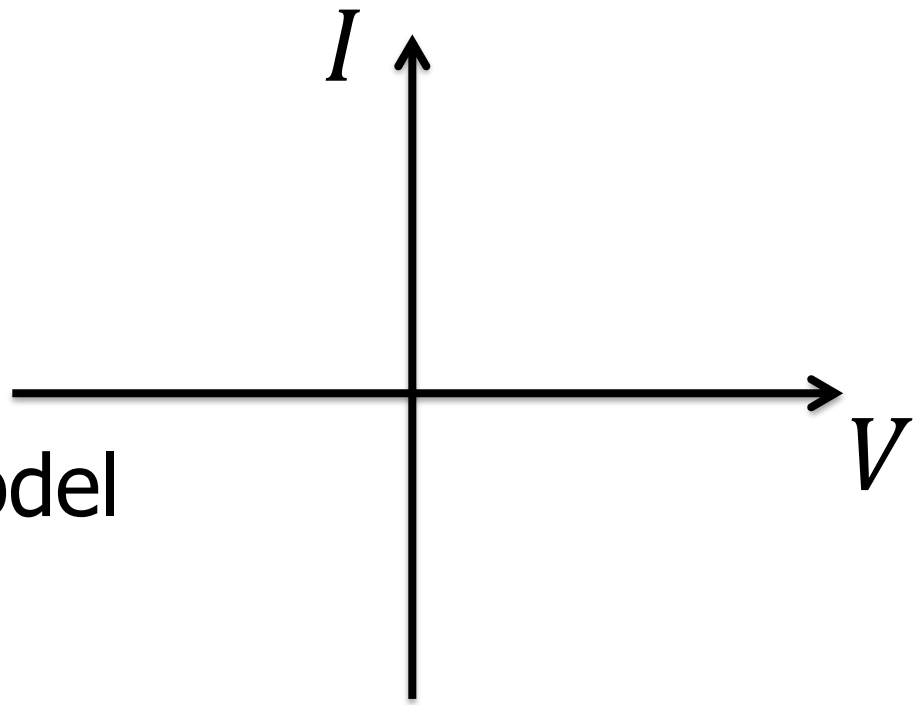
Lecture 2: Current and Voltage

- Charge
- Current
- Voltage
- Schematics and Lumped-Circuit model
- Series and Parallel



Electric Charge

- One of the basic properties of the elementary particles
- The two kinds of charge are given negative and positive algebraic signs
- Measured in units of coulombs (C)
- Q or q is the typical variables used for charge
- the coulomb is extremely large compared to the charge of a single electron

$$\frac{-1.6 \times 10^{-19} C}{electron} \qquad \left(\frac{-1.6\ \mathrm{e} - 19\ \ C}{electron}\right)$$

Electric Current

- The time rate of flow of electric charge
- measured in amperes or "amps", A
- I or i is the variable typically used to represent current…
- I stands for *intensity*
- Formally:

$$i(t) = \frac{dq(t)}{dt}$$

and $1\ A = 1\ C/s$

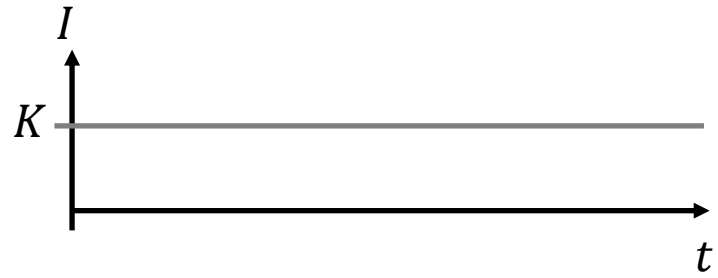
- Current is measured by an *ammeter*

Image is public domain.

"DC" Current

For *constant* rates called "Direct Current" or "DC", we typically use capitalized variables and can replace the differential with observations in some time, Δt.

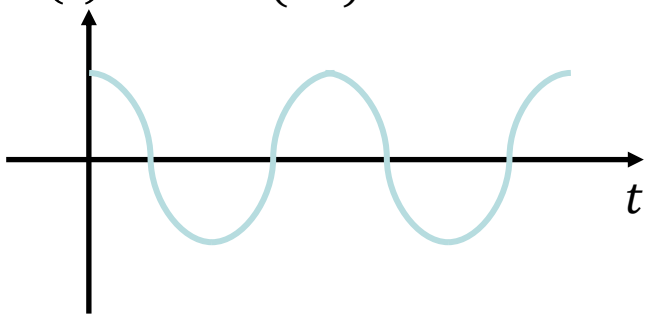
$$I = \frac{\Delta Q}{\Delta t} = K, a\ constant$$



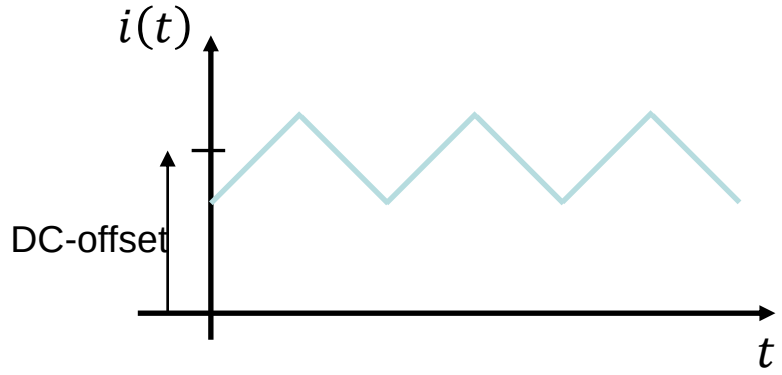
"AC" Current

Most usage of the term "alternating current" or "AC" means sinusoidal.

$i(t) = Acos(\omega t)$



"Time-varying" is more general and will often refer to a signal with a zero-mean portion (called AC) and a "DC-offset."

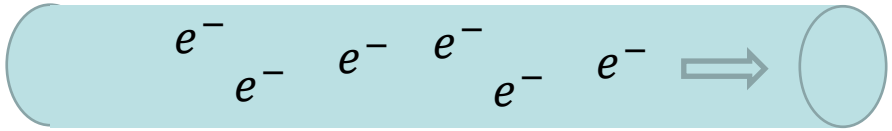


Current's Curious Sign Convention

The *direction* of current is defined as the *direction of equivalent* ***positive*** *charge* flow.

Q: If the electrons are moving left to right in the wire segment below, **what direction is the electric current**?

A. Left to right
B. Right to left



https://www.explainxkcd.com/wiki/index.php/567:_Urgent_Mission

Charge and Current

Help Sheet:

$$\frac{-1.6\ \mathrm{e}-19\ C}{electron}$$

$$I = \frac{\Delta Q}{\Delta t}$$

$$1\ A = \frac{1\ C}{1\ s}$$

Q: What is the charge of 1 billion electrons?

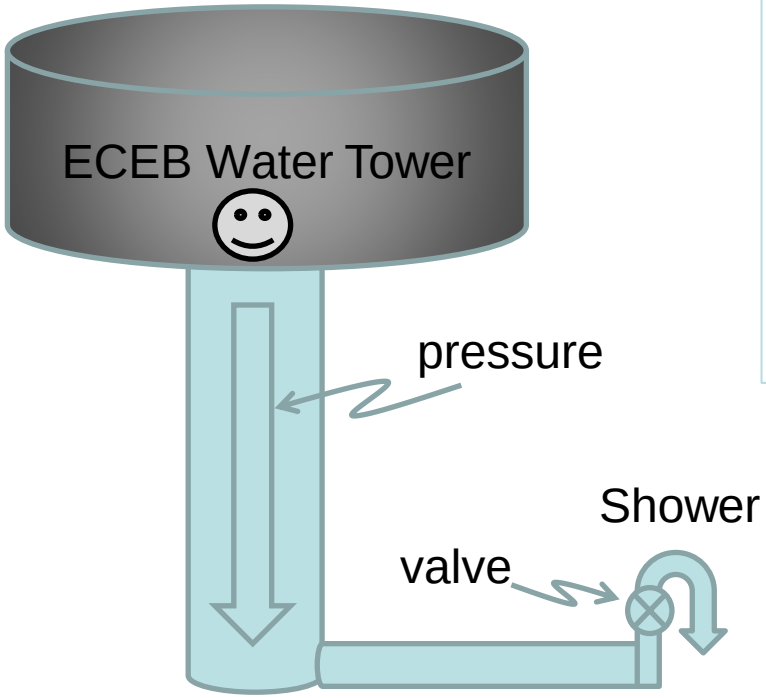
A. 160 e-12 C
B. 16 e-12 C
C. 1.6 e-12 C
D. 1.6 C
E. 160 C

Q: A “typical” electronics circuit might have 1 billion electrons pass a cross section of a wire every nanosecond, what is the electric current in amps?

A. 0.00000016 A
B. 0.160 A
C. 1 A
D. 1e-9 A
E. 160e-12 A

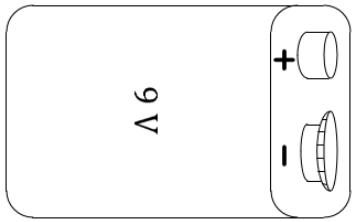
Voltage: The Water Analogy

If electrical charge is water, and electrical current is water flow, then…



Voltage is like the pressure difference that makes water *want* to flow.

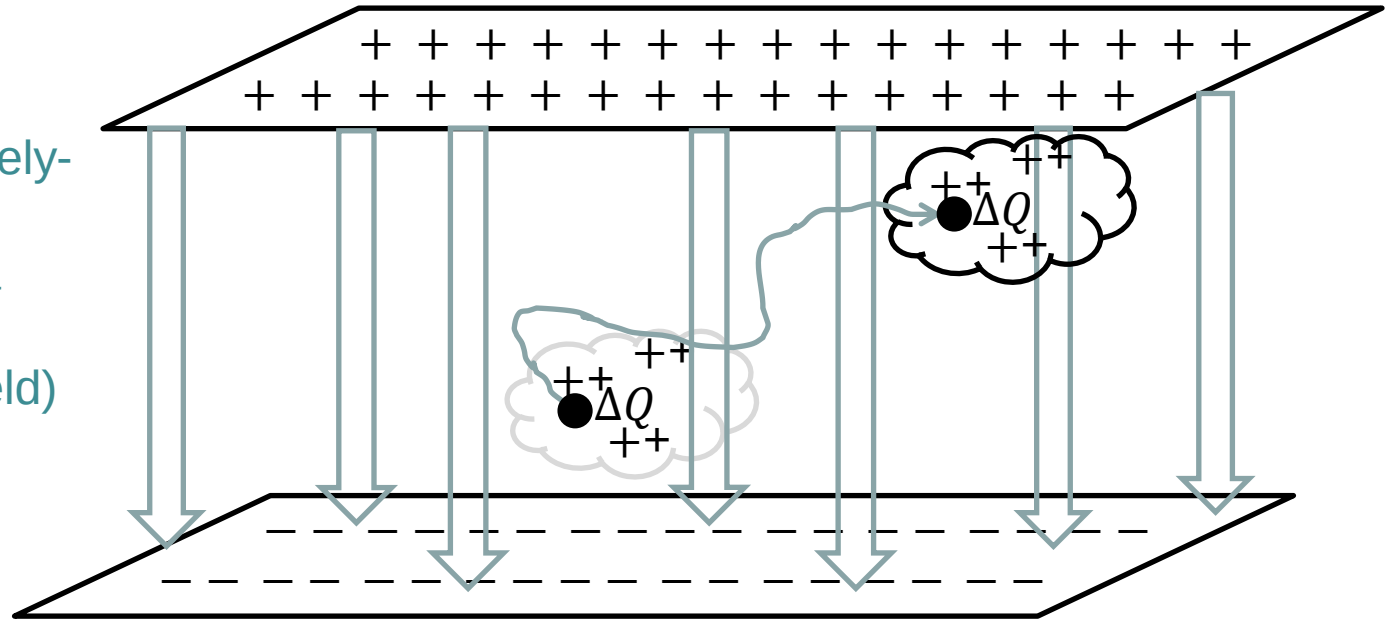
A path must be available for current to happen.



Voltage: compares two locations

- Voltage across two points in space is the energy it requires to move each "unit" of charge between those two points. Alternately, it is the energy released when one unit of charge is allowed to move between two points in space (moving from a higher potential to a lower potential).

Example: Infinitely-big sheets of charge create a uniform electric field (voltage field) represented by these arrows

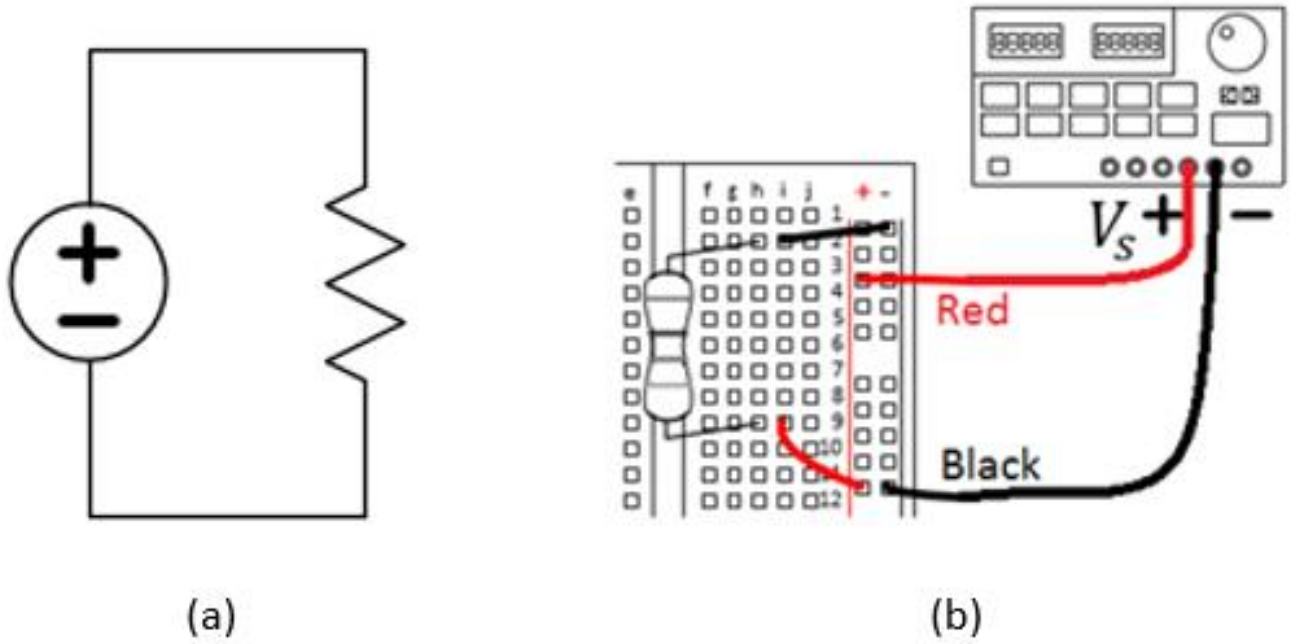


ΔE is released in moving ΔQ along the arrow-path between these two points in space

$$\Delta V = \frac{\Delta \mathrm{E}}{\Delta Q}$$

- Voltage is measured with a voltmeter in units of volts $[V]$.

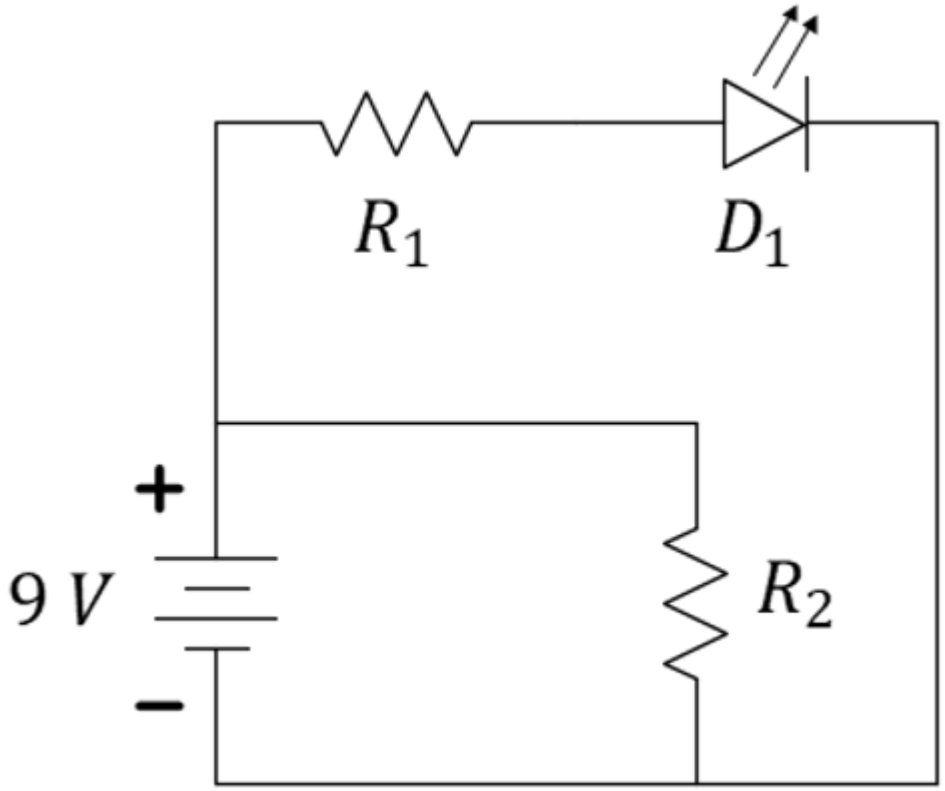
Circuit Schematic



(a) (b)

Figure 1: (a) A circuit schematic and (b) a physical diagram for the same circuit.

Circuit Schematics and the "Lumped" Circuit Model



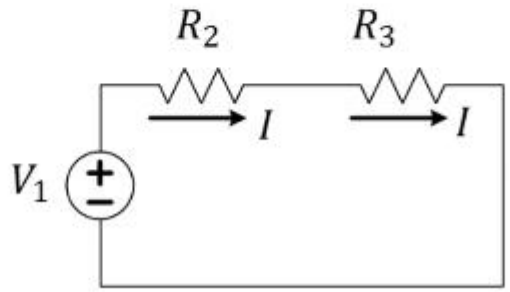
Lumped circuit elements…

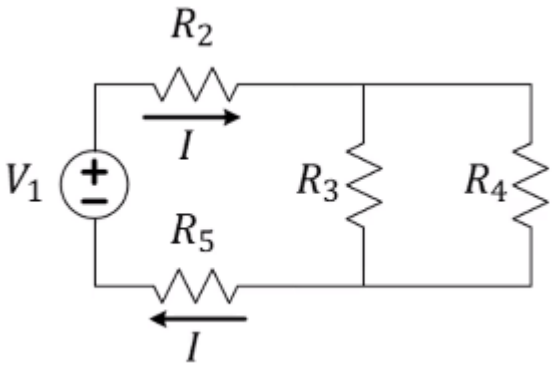
Nodes…

Series

Series: A Standard Definition

Two elements in series are connected along a single conductive path such that if the current path through one is broken (open-circuited), no current will pass through the series element(s).

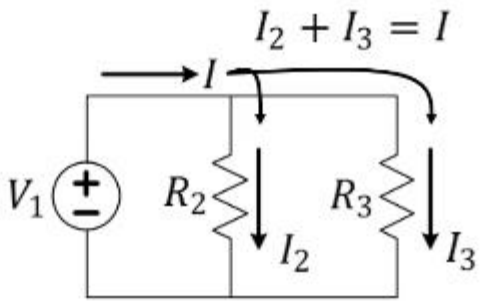


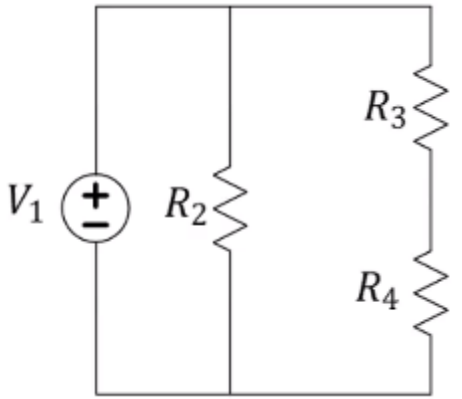


Parallel

Parallel: A Standard Definition

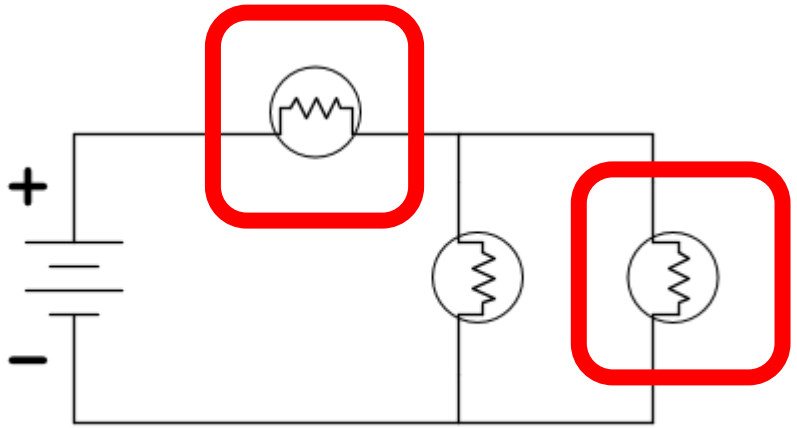
Two branches in parallel are connected such that the current in the adjacent branch mush split/combine. If the current path through one branch is broken, current can still flow through the parallel branch(es).





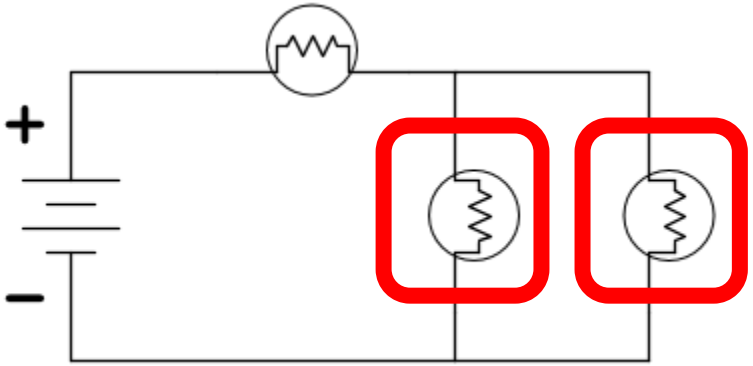
Series, Parallel

Q:



A. Series
B. Parallel
C. Neither
D. Both

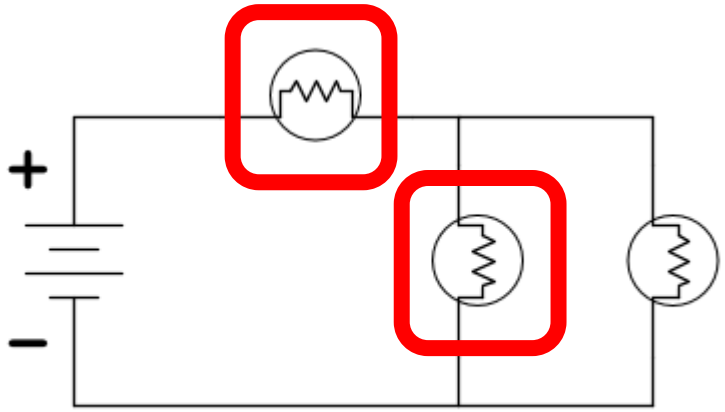
Q:



A. Series
B. Parallel
C. Neither
D. Both

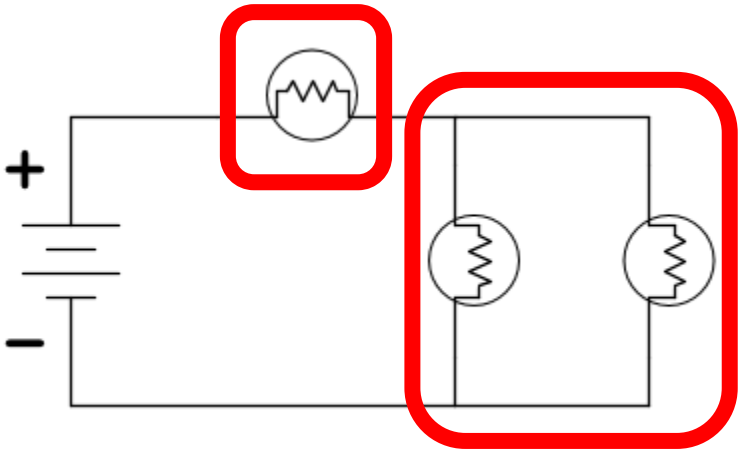
Series, Parallel

Q:



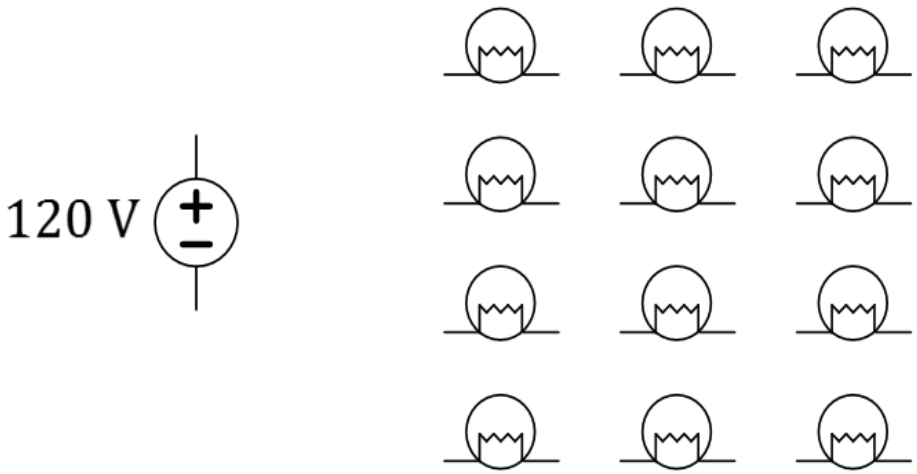
A. Series
B. Parallel
C. Neither
D. Both

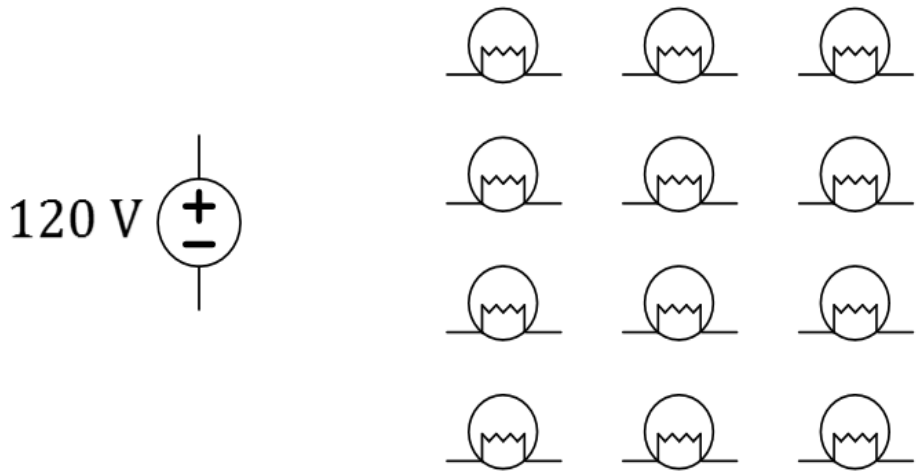
Q:



A. Series
B. Parallel
C. Neither
D. Both

Decorative lights: multiple ways to connect bulbs to the wall power plug





Q: Draw a circuit for these 12 lightbulbs connected in *series* in one loop.
Q: Draw a circuit for these 12 lightbulbs connected in two *parallel* strands.

L2 Learning Objectives

a. Compute relationships between charge, time, and current.
b. Define current and voltage.
c. Identify series and parallel elements in a circuit.

$$I = \frac{\Delta Q}{\Delta t} \qquad V = \frac{\Delta \mathrm{E}}{\Delta Q}$$