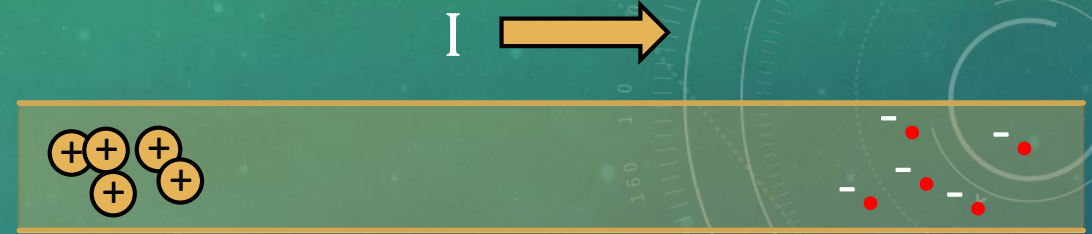




# CURRENT AND RESISTANCE

PES 1000 – PHYSICS IN EVERYDAY LIFE

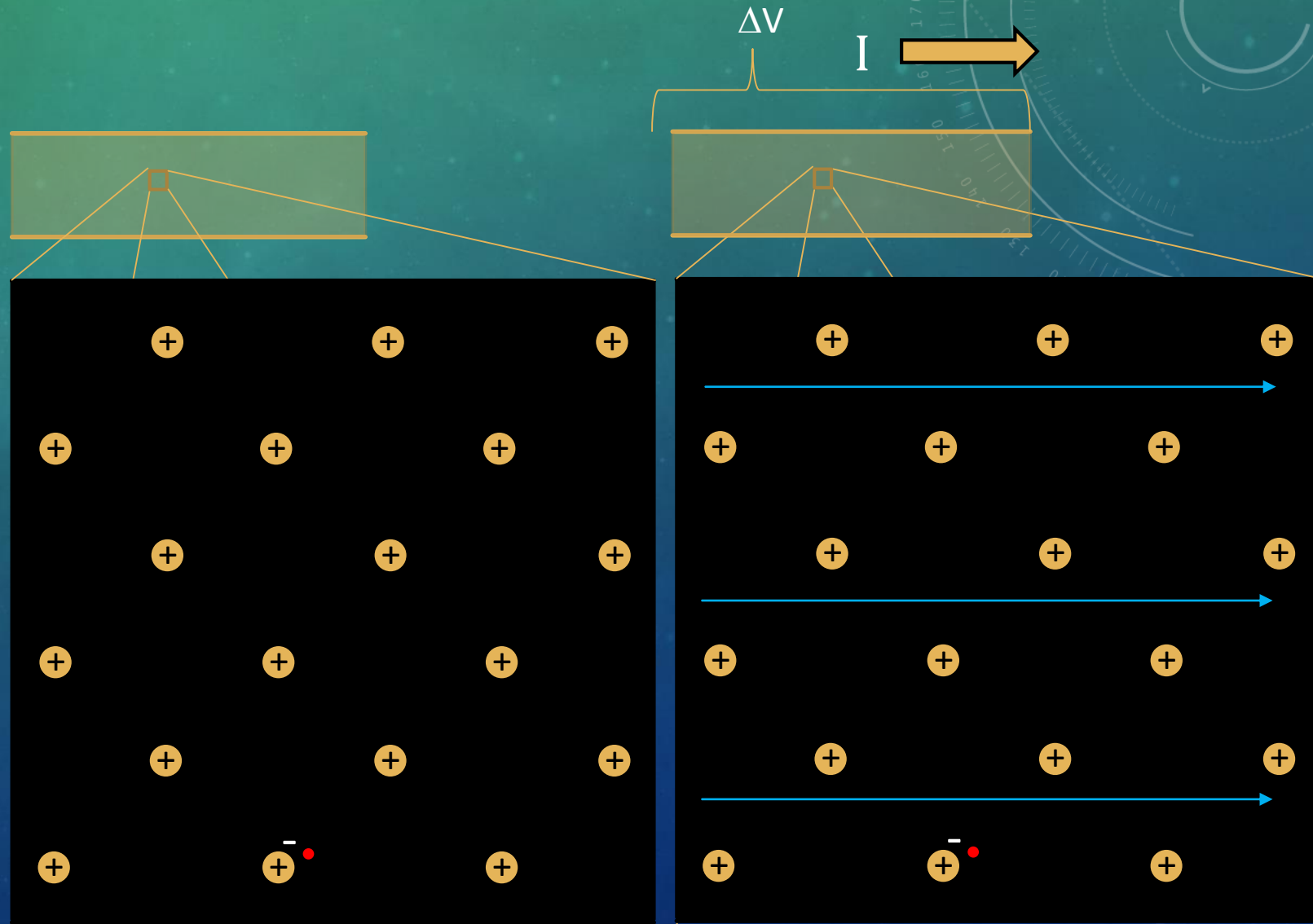
# DEFINITION OF CURRENT



- When **charge** moves, we call this 'current'.
  - By definition, current is the direction of motion of **positive charge**. Thus, it is opposite the direction of motion of **negative charge**, and it is **electrons** that usually move.
  - We usually ignore this detail and model current as some **positive charge** moving in the opposite direction of the **electrons**. This conceptual swap amounts to the same effect.
  - Variable:  $i$  or  $I$
  - Units: Ampere (A)     $1 \text{ A} = 1 \text{ C/s}$
  - Equation:  $I = \frac{Q}{t}$
- Example:
  - How many electrons pass through a section of wire in **one second** if the current is 1 milli-Amp (mA)?
  - Answer:  $Q = I * t = 0.001 \text{ C}$ . Each electron has  $1.602 \times 10^{-19} \text{ C}$ , so **6.24 million billion** electrons

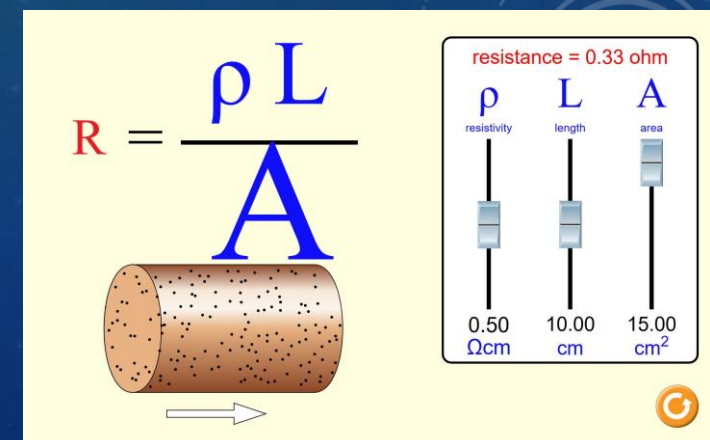
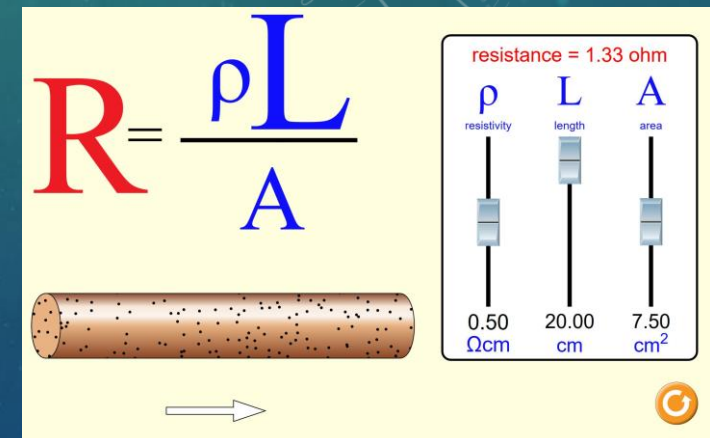
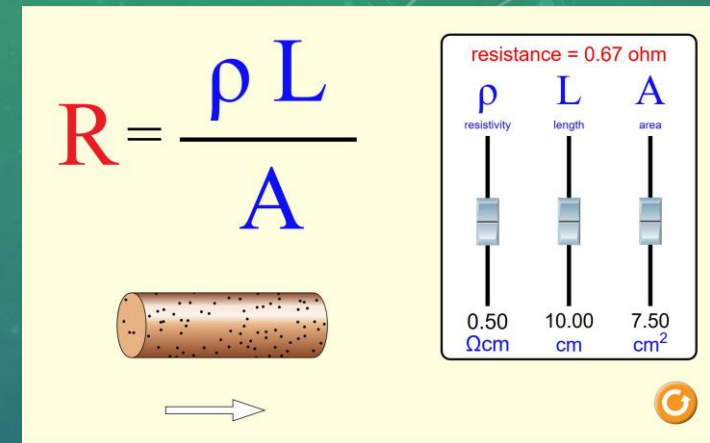
# MICROSCOPIC VIEW OF CURRENT AND RESISTANCE

- If we were to follow **one electron** as it moves around inside the metal, it would randomly skip between **nuclei** in a **random walk**.
  - On average, it **doesn't move far** from its starting point.
- If we apply a voltage between the ends of the wire, though, an **electric field** is established within the metal.
  - **The random walk gains a bias** along the field in the wire.
  - The electron begins to 'fall' down the wire in parabolic trajectories.
  - The electron's speed between nuclei is fast, but the **average drift velocity** down the wire is **quite slow**.
  - The **electric field**, however, is established throughout the wire at **speed of light**. All the electrons begin to drift down the wire at essentially the same time.



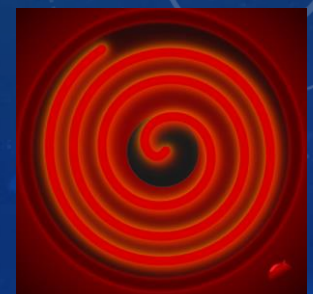
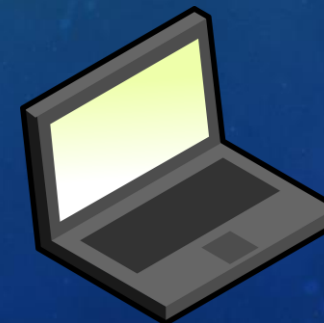
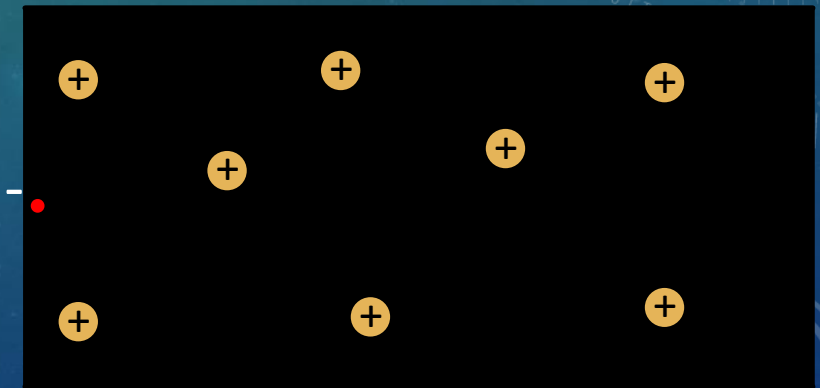
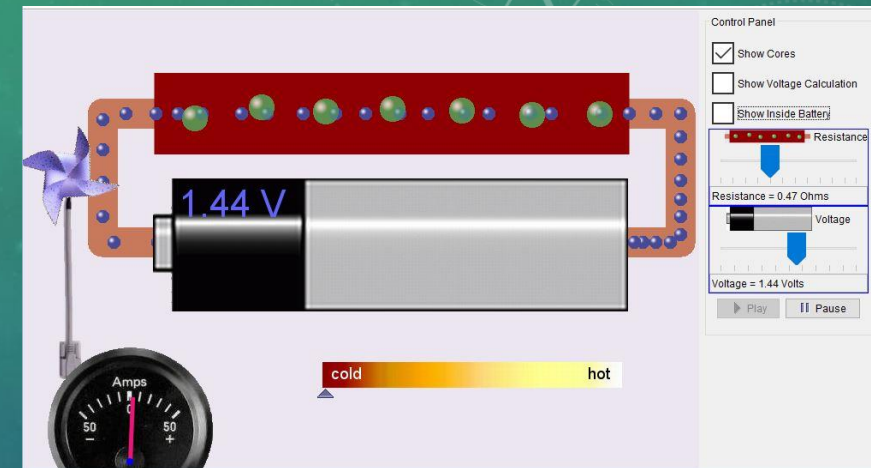
# RESISTANCE

- Again we see one of the common themes in physics:
  - **Action = motivation/opposition**. Here, **action** is the **current**, **voltage** is the **motivation** for current to flow, and the **opposition** is a phenomenon we call **resistance**.
- The **resistance** of an object (say, a wire) depends on:
  - The **resistivity** of the material from which it is made ( $\rho$ ).
  - Its geometry (**length**,  $L$  and **cross-sectional area**,  $A$ )
  - Its temperature.
- Variable:  $R$  or  $r$
- Units: **Ohms** ( $\Omega$ )
- The **longer** the wire, the **more resistance** it offers.
- The **greater the area** (thickness), the **less resistance** it offers.
- An analogy is walking through a crowded hallway. The longer hallway offers more overall resistance, but a wider hallway decreases the opposition to walking.



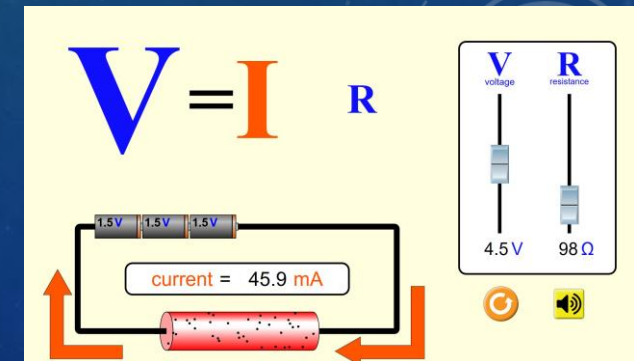
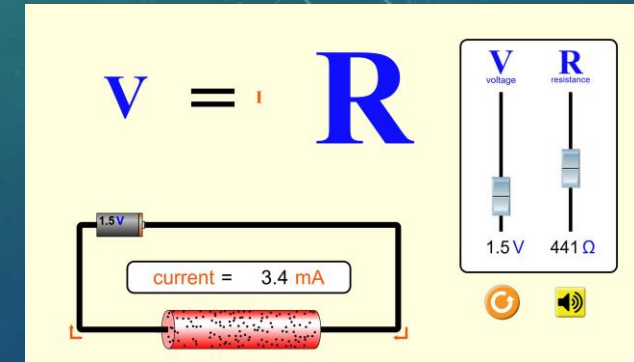
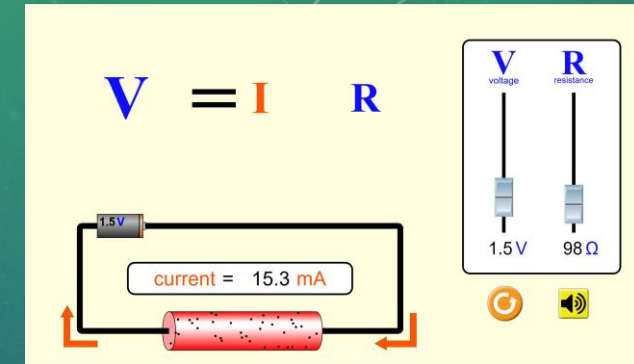
# THERMAL MODEL

- **Resistance** also depends on **temperature** of the material.
- As the atoms in the material vibrate due to internal **thermal energy**, the passage of electrons is further impeded.
- In most applications, this increased resistance is not desirable. In computers, for instance, the **heat must be vented** or the extra resistance causes performance issues.
- In an oven burner, however, the **heat is desired**. The motion of the electrons against the atoms of the nickel-cadmium heating element causes heat, which causes more resistance, until it reaches an operating temperature.



# OHM'S LAW

- Our statement of *action = motivation/opposition* is known as Ohm's Law, named for Georg Ohm (1789-1854).
- So **current** is **voltage** / **resistance**, or, as it is usually written:
  - $V = I * R$
  - We can relate resistance units to current and voltage:  
 $1 \Omega = 1 \text{ V/A}$
- If **resistance** increases, the **current** diminishes.
- If the **voltage** rises, the **current** increases.
- The phrase 'path of least resistance' applies here. If there is a branching in the circuit, **more current will follow the path of least resistance**, and vice versa.
- Ohm's law is used extensively in circuit analysis in order to find current passing through and voltage across resistors.

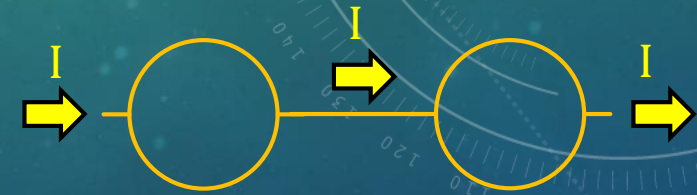


# PARALLEL AND SERIES

- Any two components of an electrical circuit can be connected in either of two configurations:

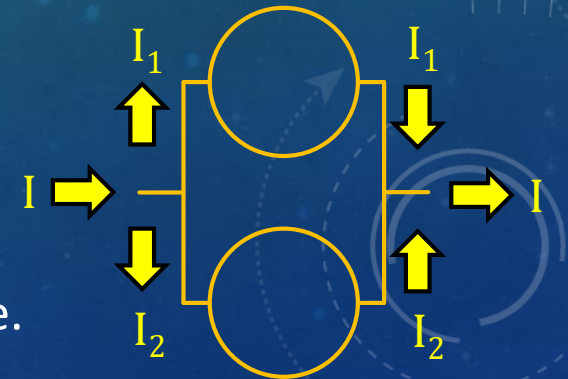
- **Series**

- The **same current** that passes through the first component also passes through the second component.
- Analogy: Water meters at both ends of a water pipe.



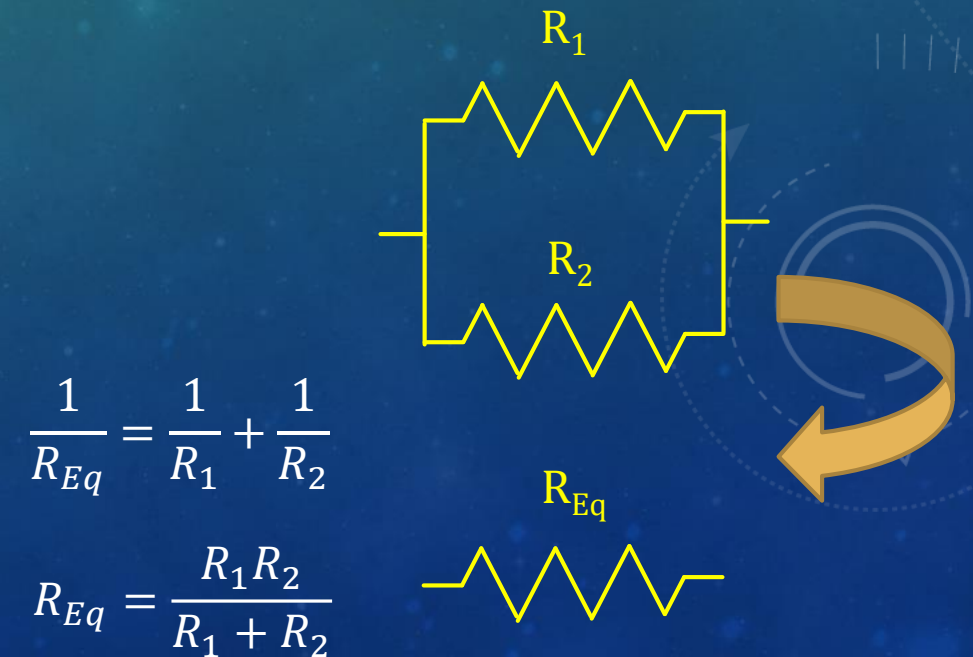
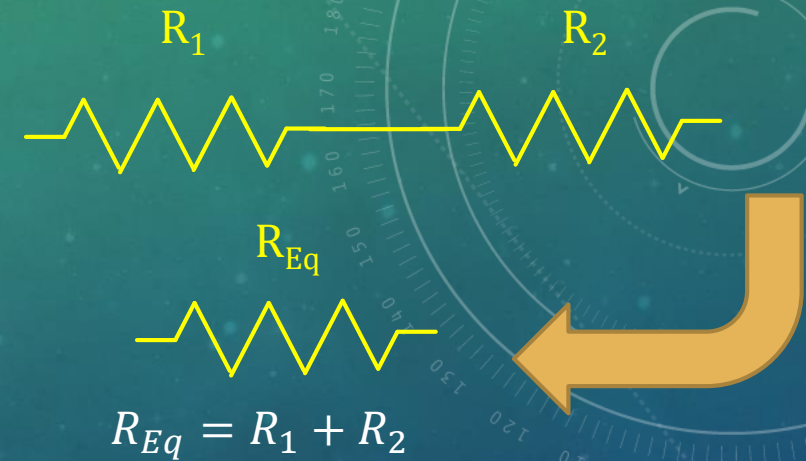
- **Parallel**

- **Current splits** at the junction before the two components.
- **Some portion** of the current passes through **one component**.
- **Another portion** passes through the **other component** at the same time.
- Both **current streams re-join** at the junction after the parallel components, reforming the original current.
- Analogy: A river passing around an island in the stream.



# RESISTORS IN PARALLEL AND SERIES

- The **symbol for a resistor** in a circuit looks like the tungsten filament in a light bulb.
- **Collections of resistors** in a circuit can be replaced with a **single resistance** for the system. Pairs of resistors can be combined using the series and parallel rules:
  - **Series** – resistance increases
  - **Parallel** – resistance decreases
- This makes sense when you look at the physics of resistors:
  - **Two resistors in series** are like having a **longer resistor**, which **increases resistance**.
  - **Two resistors in parallel** are like having a **thicker wire** which offers **less resistance**.



# CONCLUSION

- **Current** is defined as the **charge per unit time** that passes through an area of wire.
- In the microscopic view of the wire, **electrons are 'falling'** between the atoms due to an **electric field** when a **voltage** is applied.
- Interactions with the atoms of the wire leads to a **resistance** to the flow of charge.
  - Resistance depends on the geometry of the wire (**length** and **area**).
  - Resistance usually rises as the **temperature** of the wire increases.
- **Ohm's Law** lets us relate **current** to the **voltage** (motivation) and **resistance** (opposition).
- Pairs of resistors can be connected in **parallel** or **series** configurations.
  - In **parallel**, resistance **decreases**.
  - In **series**, resistance **increases**.