# MODULE 4: LEDs

## BU SUMMER CHALLENGE
## Electrical Engineering: Smart Lighting Project

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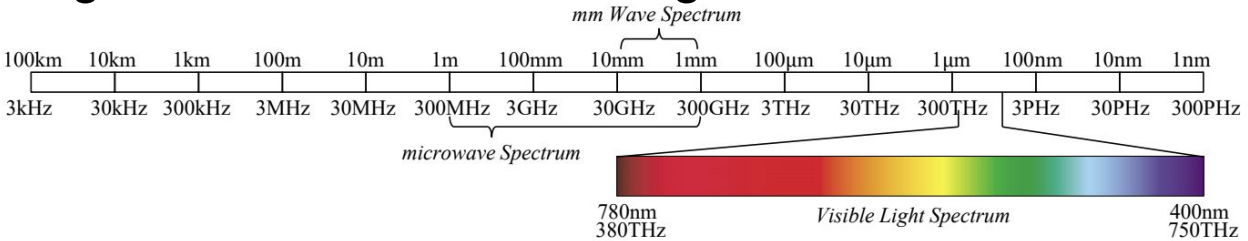
# Overview

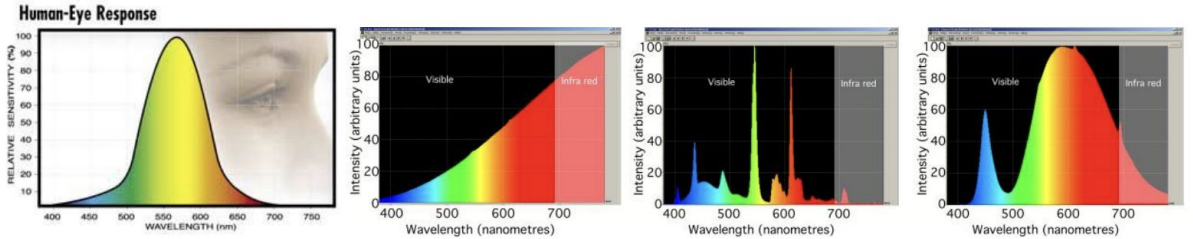
- From “Lighting” to Smart Lighting
- What is a Diode?
- LEDs!
- Electrical Power
- LED Drivers

# Lighting & Color Science

- Visible Light is a form of electromagnetic radiation



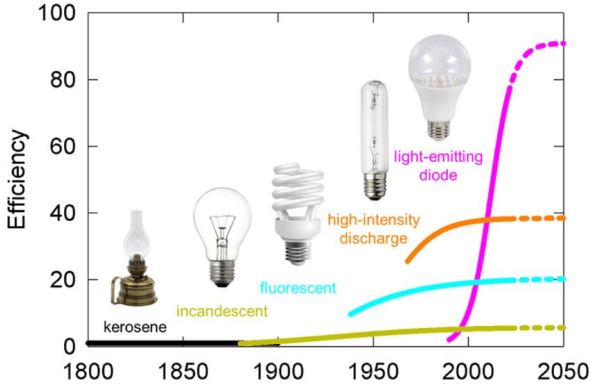

- The human eye responds to the visible light spectrum
- White light is the presence of all colors



# Smart Lighting

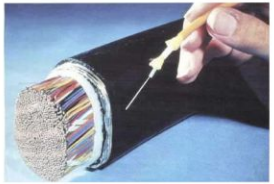
In what ways can using light be better?

- Energy Efficiency

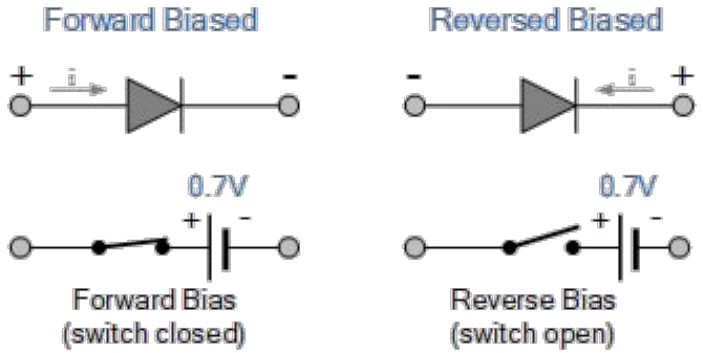

- Healthy Lighting

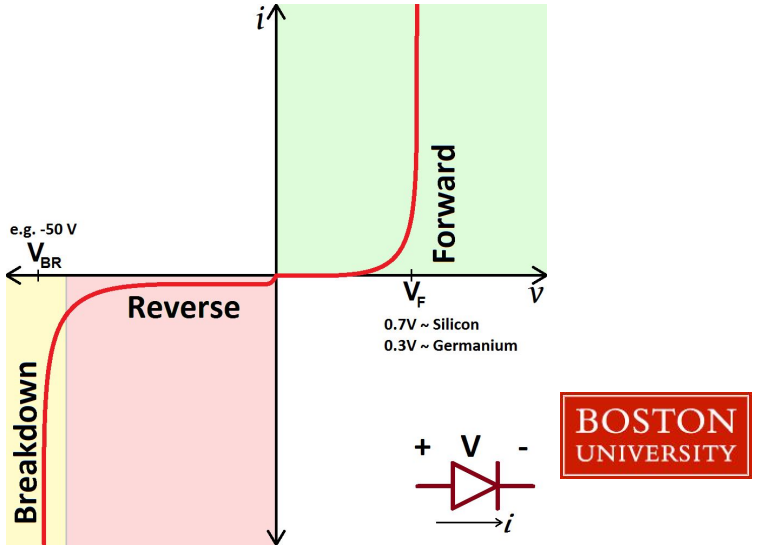

- Productivity (Data access)




# What is a diode?

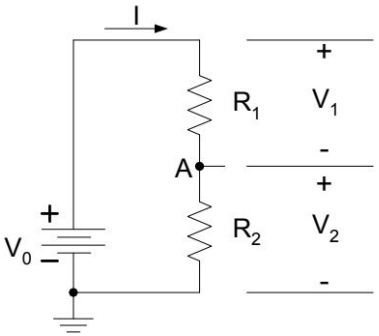
- A device that allows current to flow in one direction and always has polarity (e.g., LED)
- Forward Bias Voltage
  - For current to flow, diodes require a turn-on voltage (i.e., forward bias voltage)
  - In an ideal diode, voltage drop remains constant



# Kirchhoff's Voltage Law

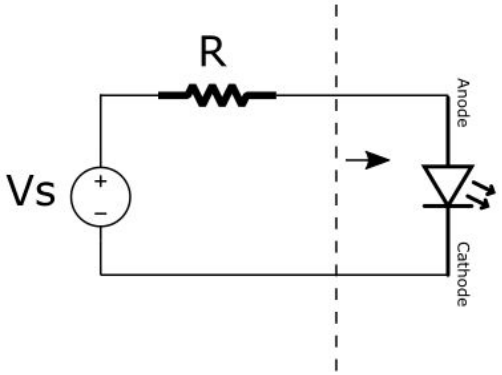
*The algebraic sum of all voltages in a loop must equal 0.*



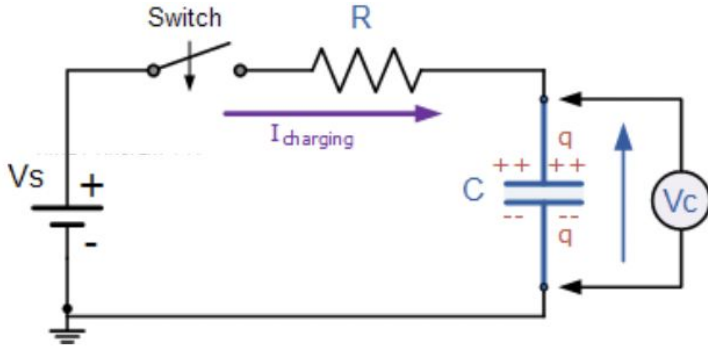

$$V_0 + (-V_1) + (-V_2) = 0$$

- Relationship to Diode circuits
  - Once the diode reaches the turn on voltage, $V_R$ increases with $V_S$
  - Current through the circuit increases with increase in $V_R$

$$V_S + (-V_D) + (-V_R) = 0$$



# RC Circuits - The mystery of ‘e’

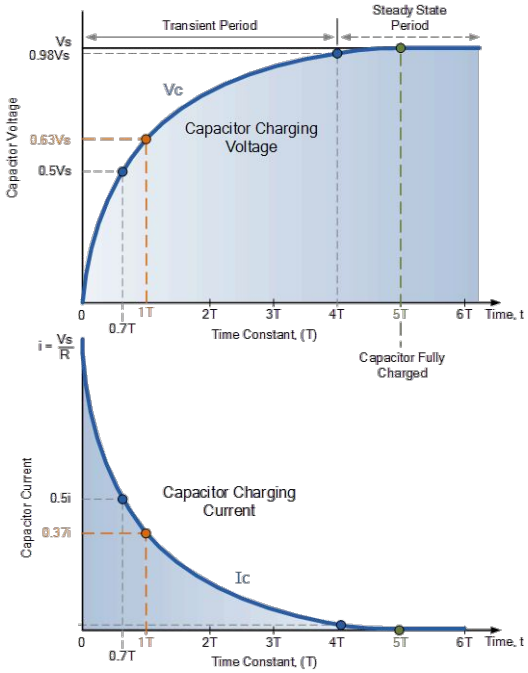


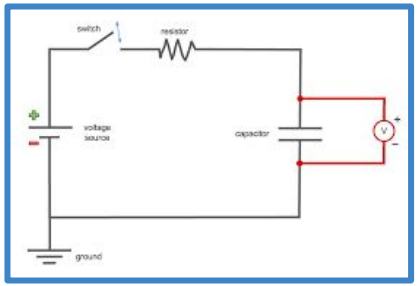

1. Kirchhoff’s Voltage Law (KVL)
2. Ohm’s Law
3. Capacitor Voltage
4. Current = Rate of change of charge
5. Substitute into KVL
6. Express i(t) in terms of Q(t)
7. Rearrange to form a differential equation
8. Solve the differential equation

$$\tau \equiv RC$$
$$V_c = V_s\left(1 - e^{-t/\tau}\right)$$

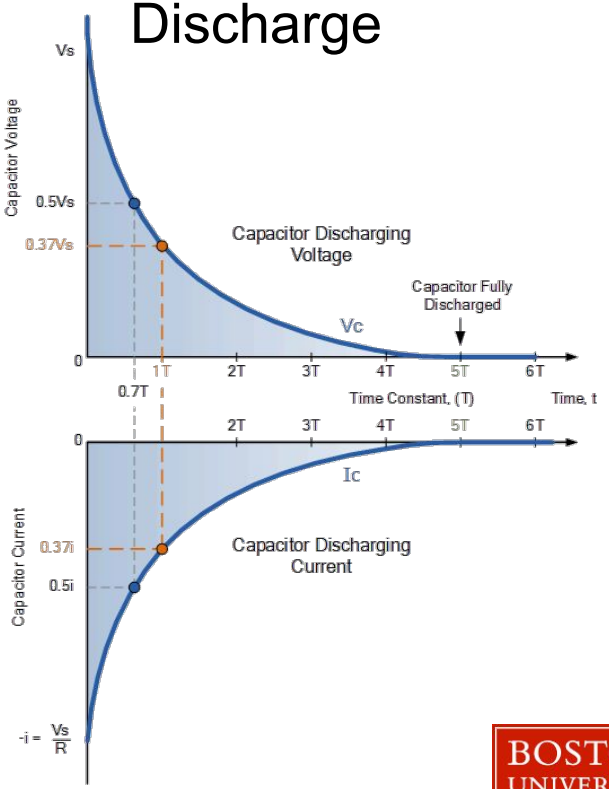
# RC Circuits - Recap

## Charge




## Discharge

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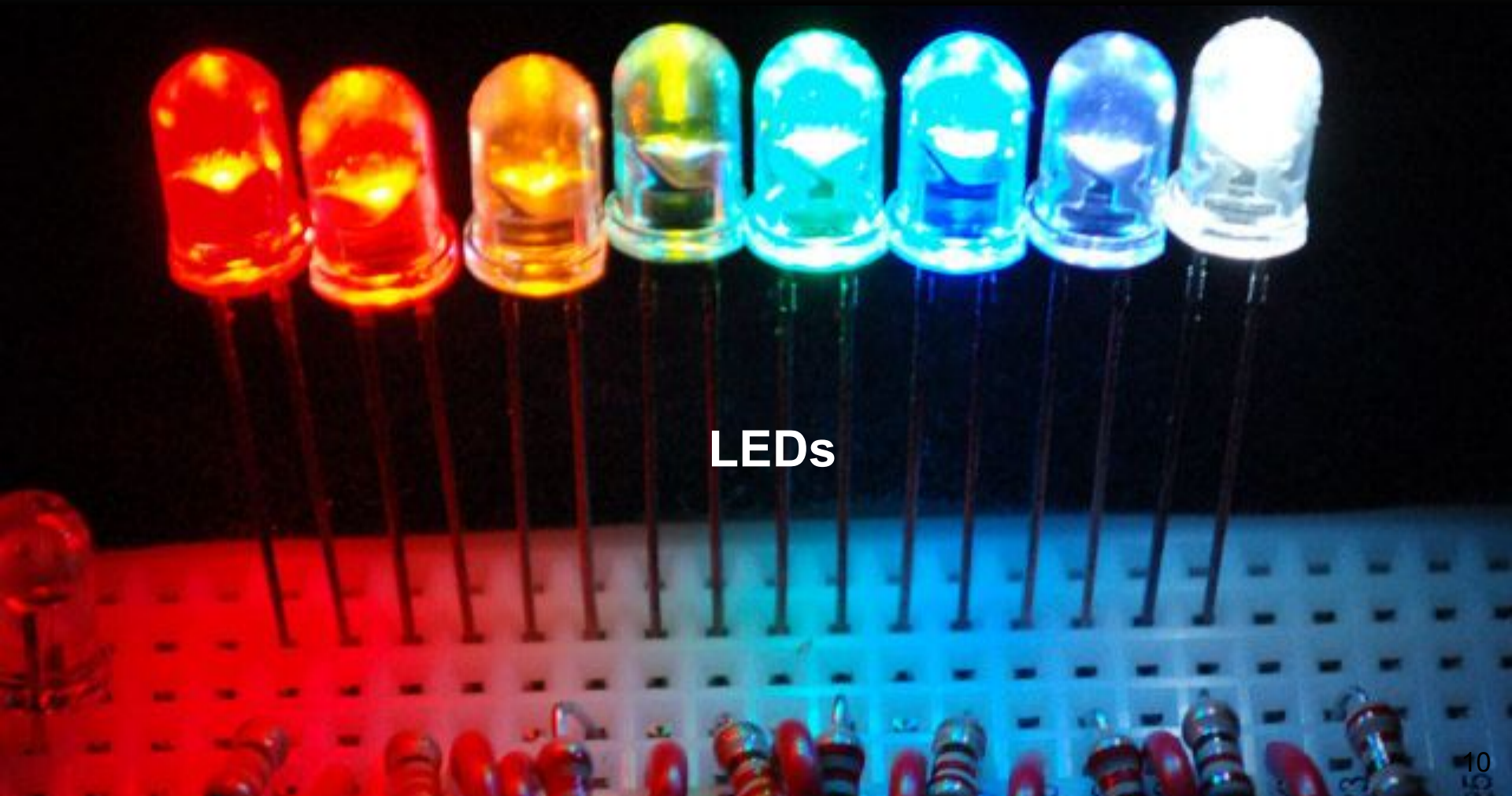
- ★ Reflect on what you learned so far!

- References:
  - http://www.physicsclassroom.com/
  - http://www.allaboutcircuits.com/


LEDs

# How Do LEDs Work?

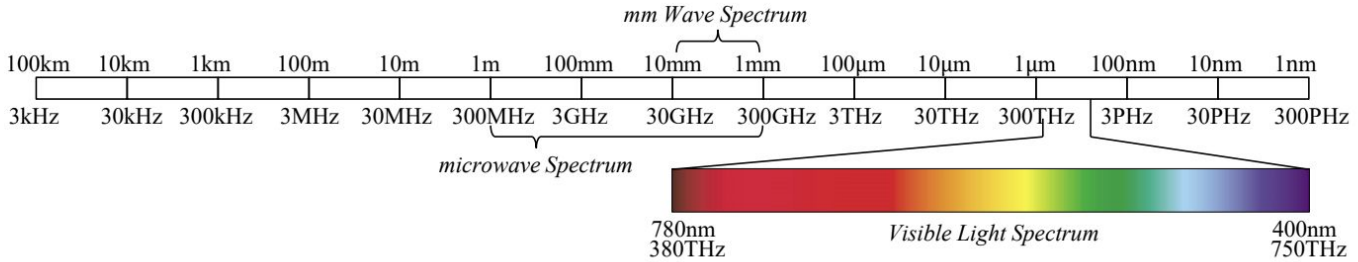
- LED Materials
  - Semiconducting materials: Resistance levels between those of a conductor and an insulator
  - Current can only flow in one direction
- Passing through the LED, electrons lose energy
  - Lost energy creates photons
  - Photons have discrete wavelength related to band-gap
- Band-gap width and energy
  - The wider the band-gap, the greater the energy of the photon released
  - Specialized materials & processes required to achieve wide band-gap

# Planck's Relation

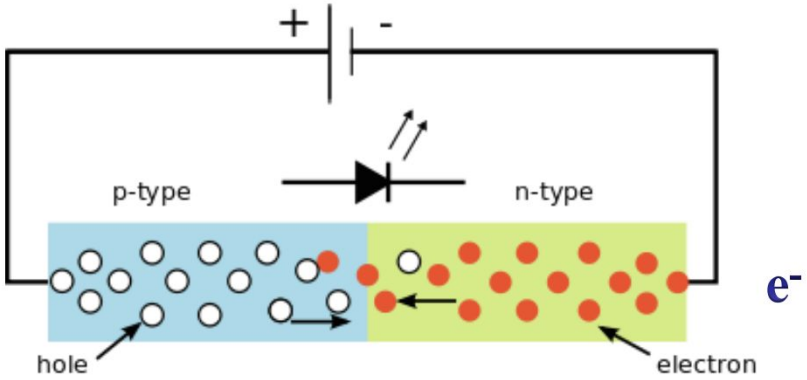
$$E = h\nu = \frac{hc}{\lambda}$$

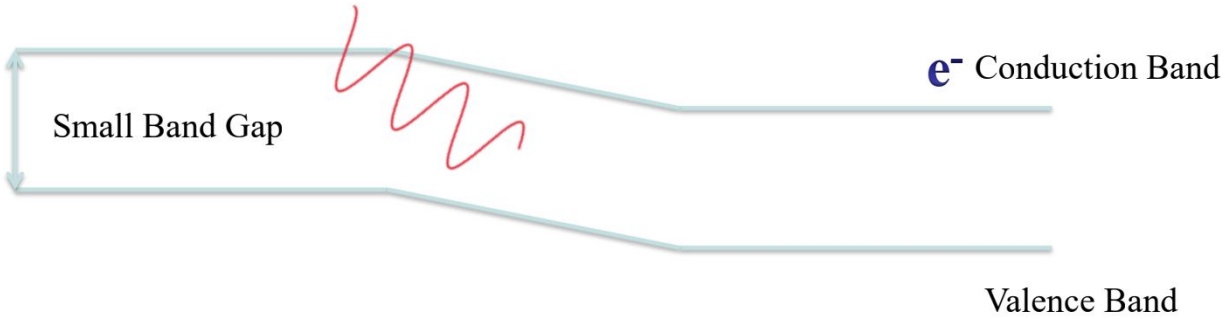
where:

E = energy
h = Plank constant
v = frequency
c = speed of light
$\lambda$ = wavelength

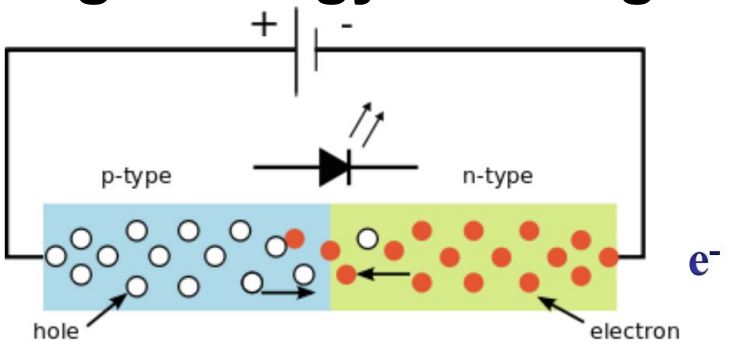


# Small Band Gap: Low Energy Red Light



# Large Band Gap: High Energy Blue Light




# Experiment I

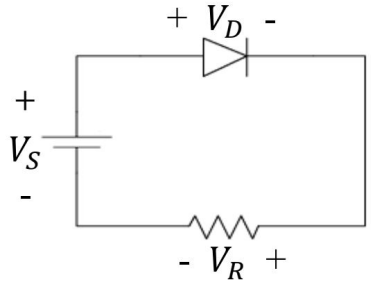
- Go to “**Lab Module 4: LEDs “** in your experiment manual
- LED circuit
- Determining the turn-on voltage

# Electrical Power

- Power is the rate at which energy is consumed.

$$P = VI$$

- Power is measured in Watts [W] or [J/s]
- Energy sources (such as batteries) produce power while the load of the circuit absorbs power.




$$I = \frac{V_R}{R} = \frac{V_S - V_D}{R}$$

$$P_D = V_D I = \frac{V_D(V_S - V_D)}{R}$$

# Electrical Power

$$P = VI$$

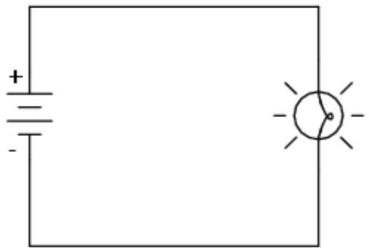
Combining the previous equation with Ohm's…

Law:

$$P = VI = I^2R = V^2/R$$

*Exercise:* Consider a 60W incandescent attached to a 120V source.

How does current change if you replace the 60W bulb with 120W bulb?



# Experiment II

- LED Drivers
- Power Consumption

**Reminder:** Team Formation!

# Think – Pair – Share