

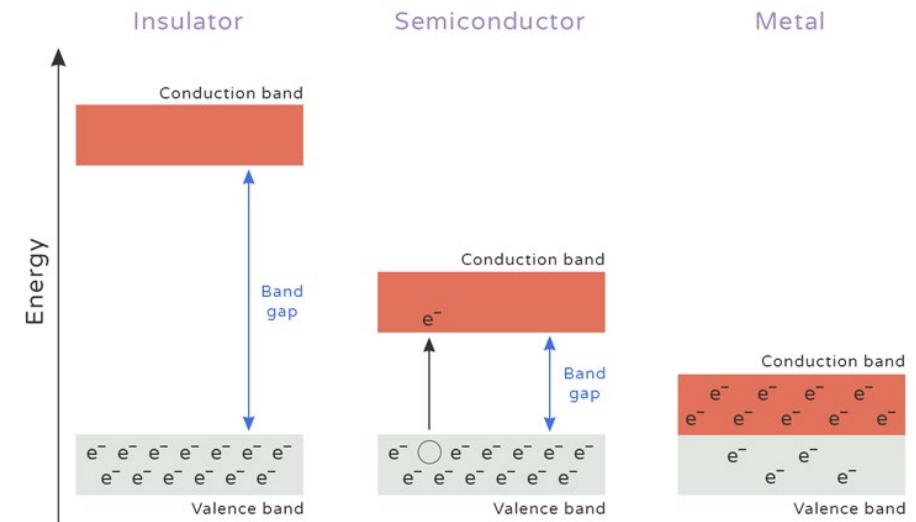
Diodes



& **UNIVERSITY
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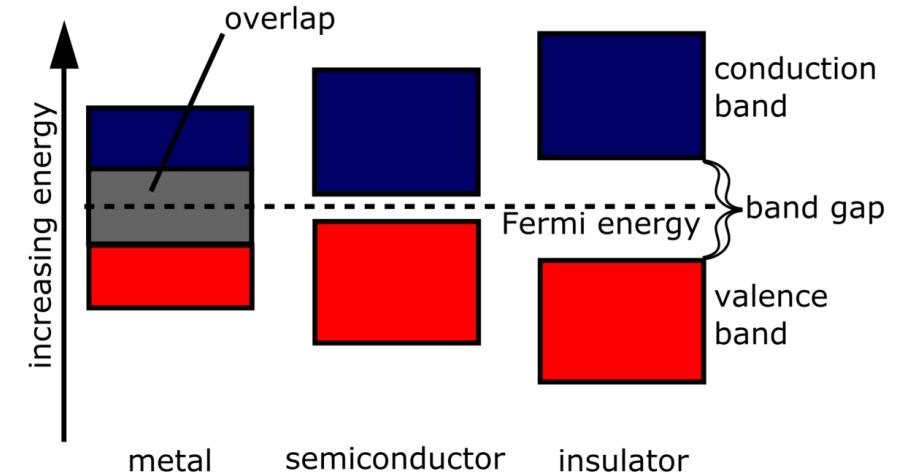
Atomic Structure

- In a single atom, electrons occupy shells (discrete energy levels).
- In solids, these levels overlap and form continuous energy bands.
- The valence band holds bound electrons.
- The conduction band holds electrons free to move.
- The band gap is the energy needed to jump from the valence to conduction band.



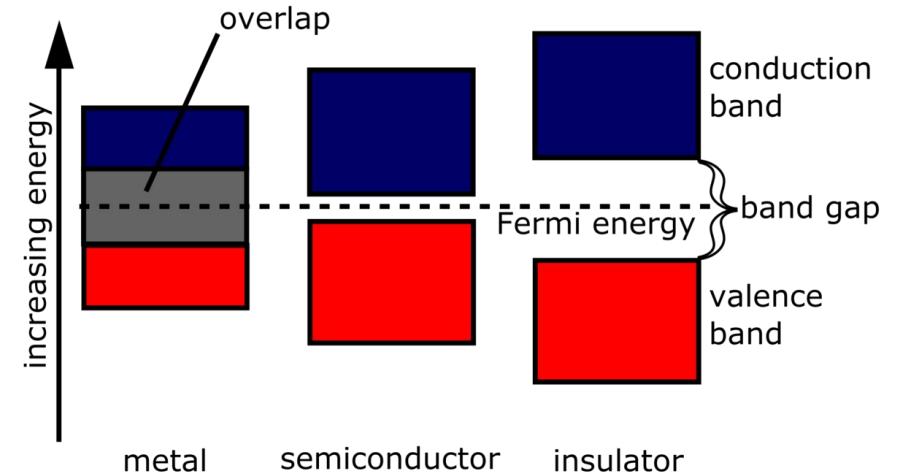
Band Gap

- A band gap is the energy gap (energy required) for an electron to swap from being attached to an atom to jump to a conduction band, where it can move freely and participate in electrical conduction.
- If electrons can easily jump the gap, then it is likely a metal
- If electrons can't jump the gap easily then it is an insulator
- And if the gap is medium but jumpable with some extra power then it is a semiconductor



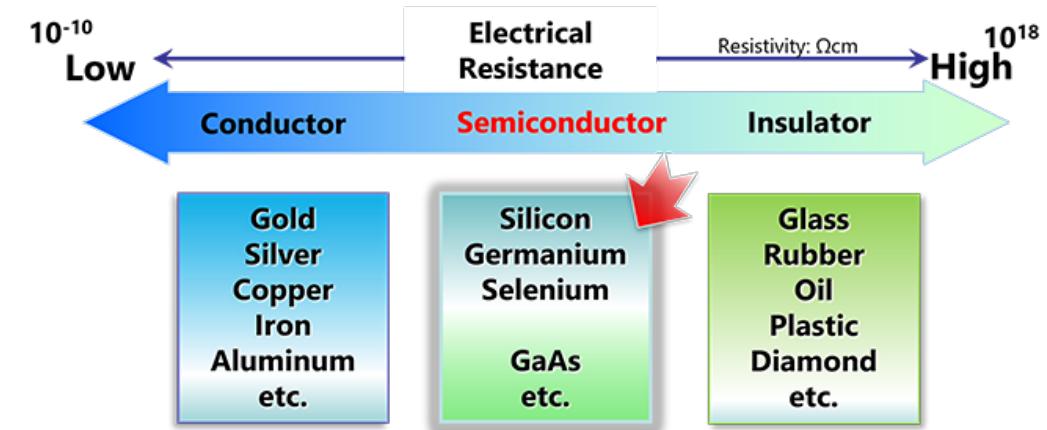
Band Gap

- We measure band gap in electron volts (eV)
- Typical values of band gaps are:
 - **Silicon (Si):** 1.12 eV
 - **Germanium (Ge):** 0.66 eV
 - **Gallium Arsenide (GaAs):** 1.43 eV
- Increasing the temperature of a material reduces the band gap making it easier for the electrons to bridge the gap



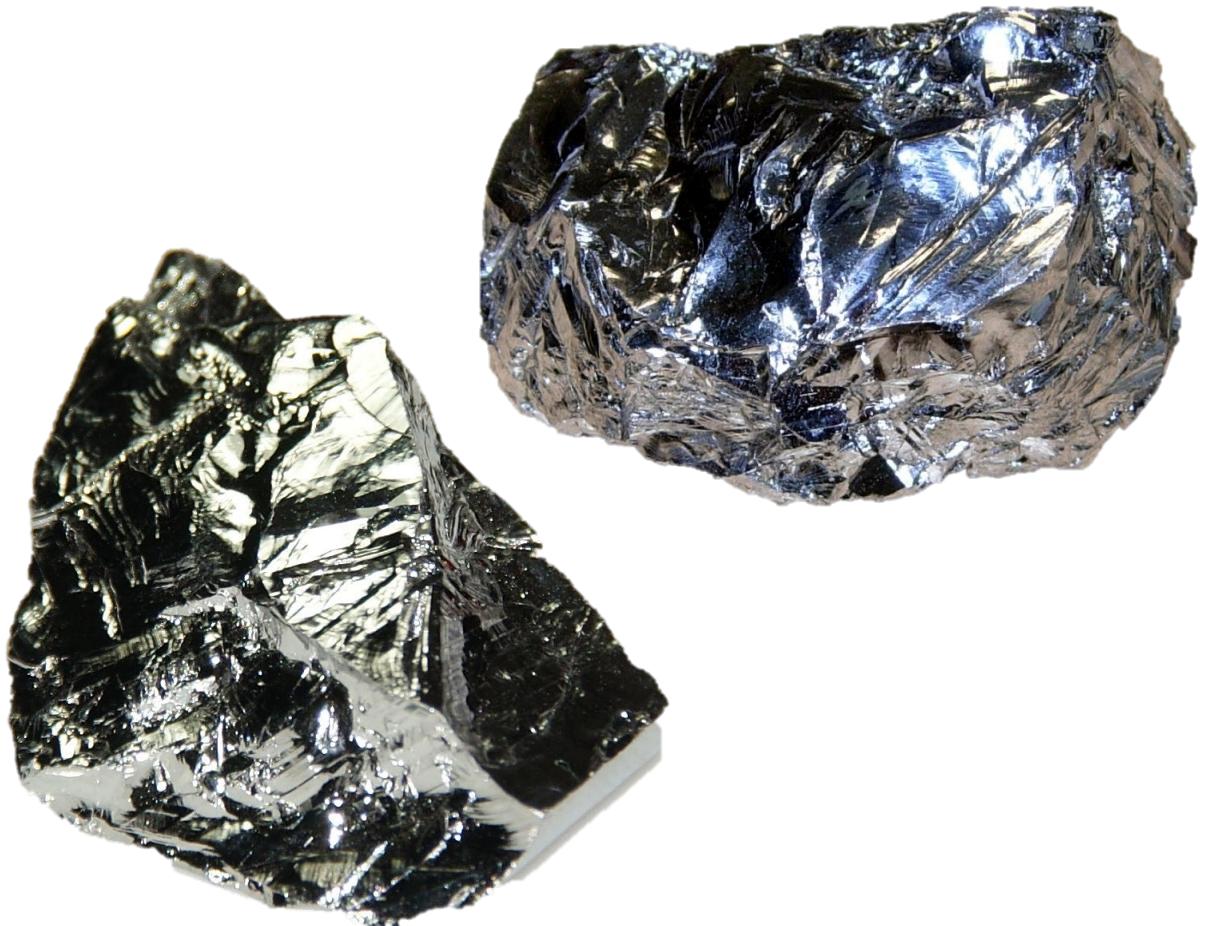
What are semiconductor materials

- Semiconductor is a term used for a material that has a resistivity somewhere between a conductor and an insulator
- This means it can play the role of both
- Typically, we can control its resistivity using an external source such as heat or external voltage
- This ability to control them makes them essential for everyday electronics



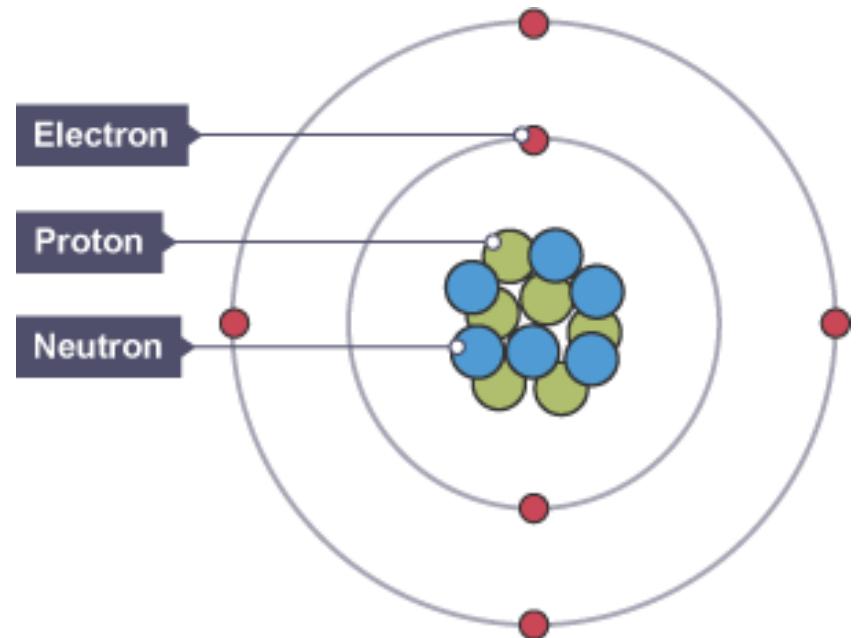
Typical semiconductor materials

- Typically, devices will use either silicon (Si) or germanium (Ge)
- Both silicon and germanium are most common due to their low 'band gap'
- A low band gap means less power is required to swap it to and from conductive and non conductive states
- They are also used as they are very abundant and found everywhere meaning they are cheap



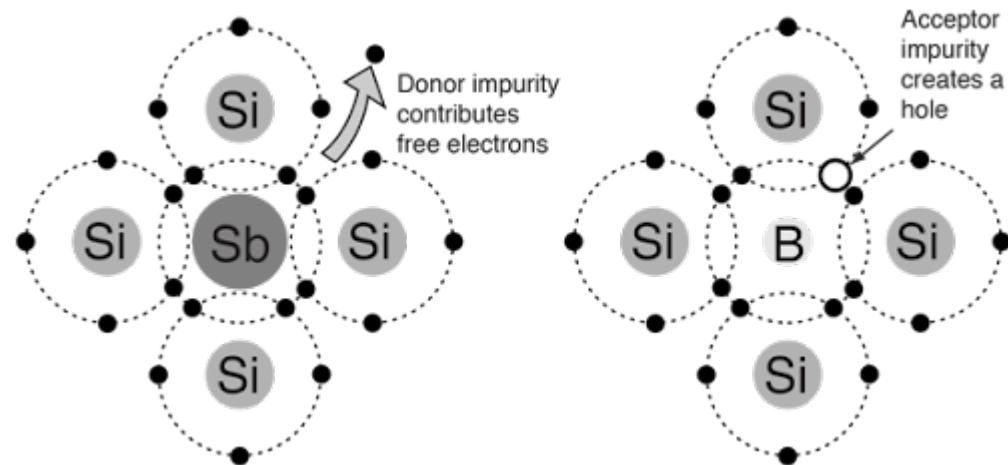
Atomic makeup

- Atoms are made up of bands of electrons
- The outermost band is loosely attached to the atom
- They freely detach and reattach to different atoms
- This is how electricity flows in a wire
- We can refer to the atoms the electron has jumped to as a “hole”



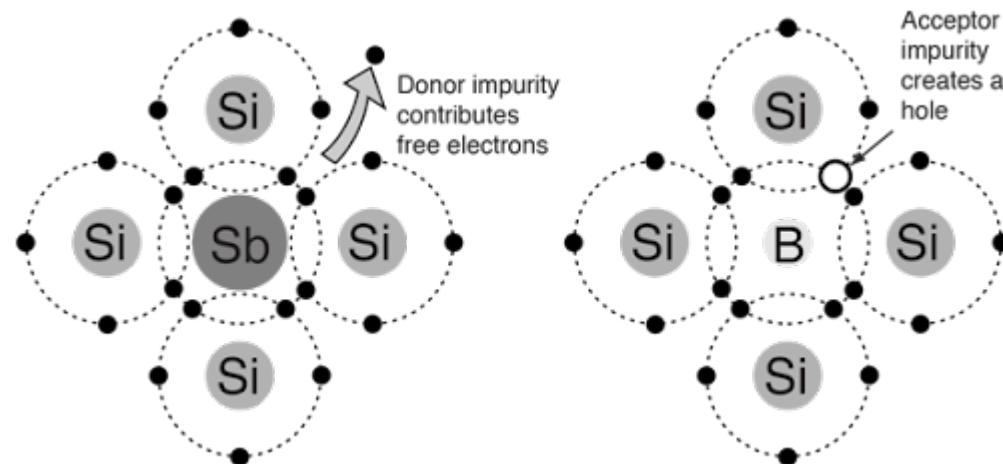
Doping

- The process of doping involves adding impurities to a semiconductor materials
- This mostly involves adding *impurity atoms* (dopants) such as boron or phosphorus to the semiconductor.
- This gives the semiconductor electrical properties and improves conductivity
- Pure semiconductors have low conductivity
- The addition of the impurities adds more electrons and holes making a better electric component



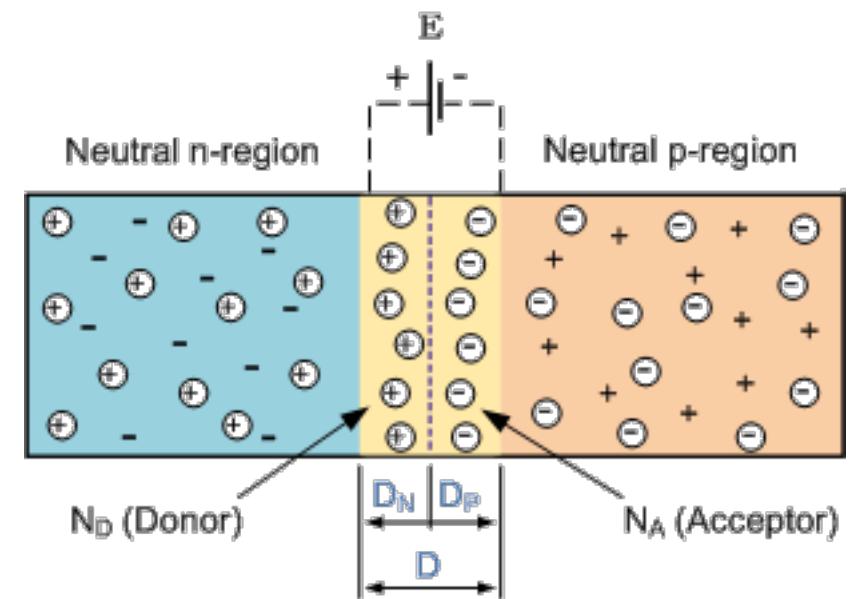
P vs N

- **P-Type (Positive-Type) Doping** adds more holes to the material (more atoms with free electron spots).
- **N-Type (Negative-Type) Doping** adds more electrons to the material.



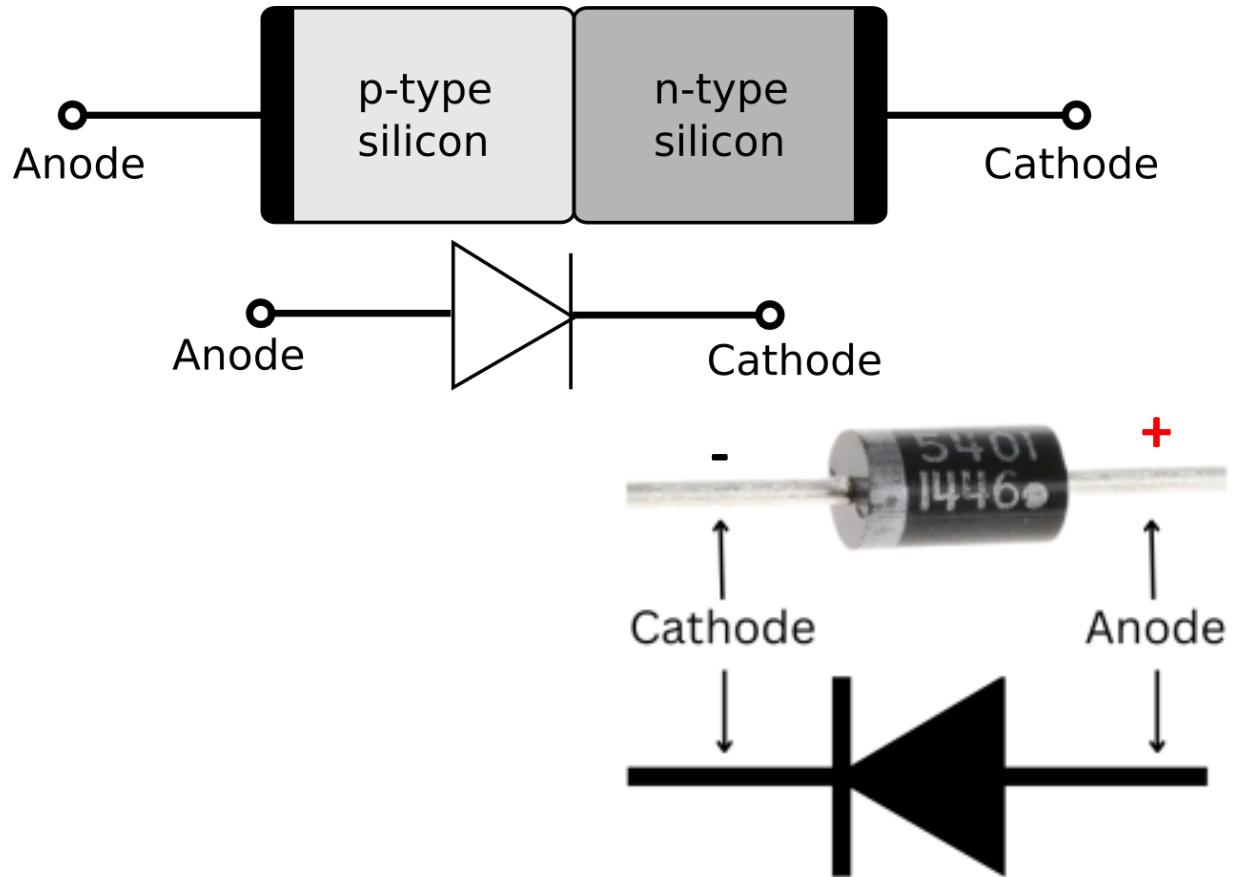
Forming a PN junction

- When we make a PN junction we stick two materials together, a P doped semiconductor and an N doped semiconductor
- At the junction, free electrons from the N-side recombine with holes from the P-side, creating a region depleted of charge carriers (the depletion region).
- In the depleted region there are no free charge carriers meaning this region acts like an insulator
- Applying a forward bias reduces the depletion width, allowing current to flow across the junction



Junction Diode

- A junction diode is just a basic PN junction
- This means its one way and blocks flow in the opposite direction
- In forward bias it allows current to flow normally
- In reverse bias it blocks current flow until a breakdown voltage is reached at which point current flows, but it permanently damages the diode

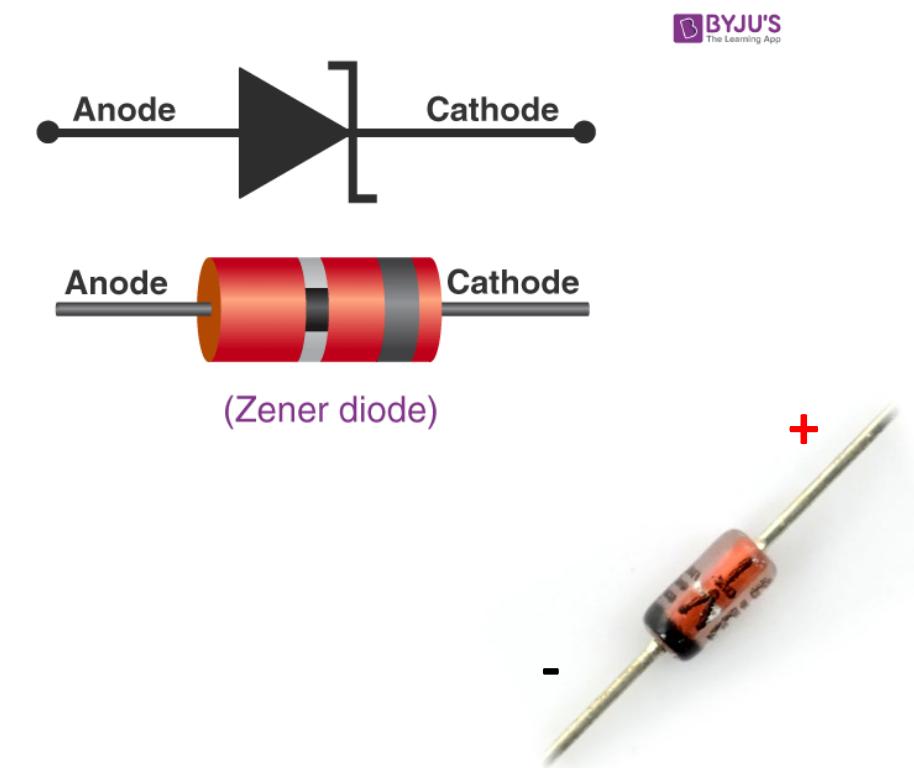


Why Junction diodes break in reverse

- **When breakdown occurs:**
 - The current increases extremely rapidly (essentially limited only by the circuit's resistance).
 - This produces localised heating within the depletion region.
 - The junction temperature rises, causing thermal runaway:
 - higher temperature → higher current → more heat → junction failure.
 - The silicon lattice or metal contacts can literally melt or fuse, permanently shorting the junction.

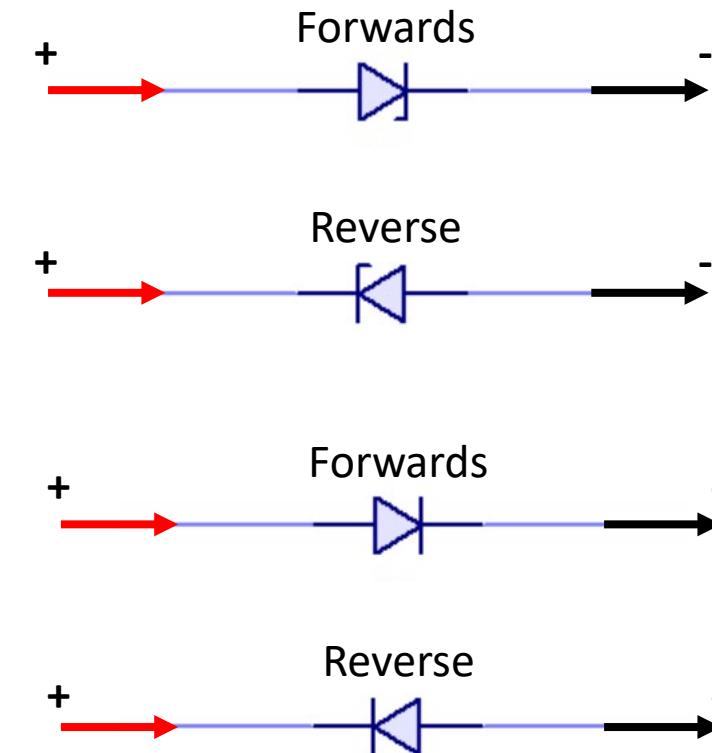
Zener Diode

- A Zener diode is just a PN junction which is specially doped to make it able to work in reverse
- Current can usually only flow one way unless a breakdown voltage is applied to in reverse
- In forward bias it allows current to flow normally
- In reverse bias it blocks current flow until a breakdown voltage is reached at which point current flows without damaging the diode
- Zener diodes are designed to operate safely in reverse breakdown without being damaged, maintaining a nearly constant voltage.



Reverse vs Forwards Bias

- The bias of a diode depends on how it's connected in the circuit.
- If the diode is forward biased, it's connected in the direction of current flow, allowing current to pass once the forward voltage is reached.
- If the diode is reverse biased, it's connected opposite to current flow, so it blocks current (except for a tiny leakage current).



Voltage Regulator

- We can use a Zener diode in reverse as a voltage regulator
- This clamps the voltage to a certain value and stops it rapidly increasing
- Often used as protection to ensure circuits continue to function properly

