Revision : Semiconductors

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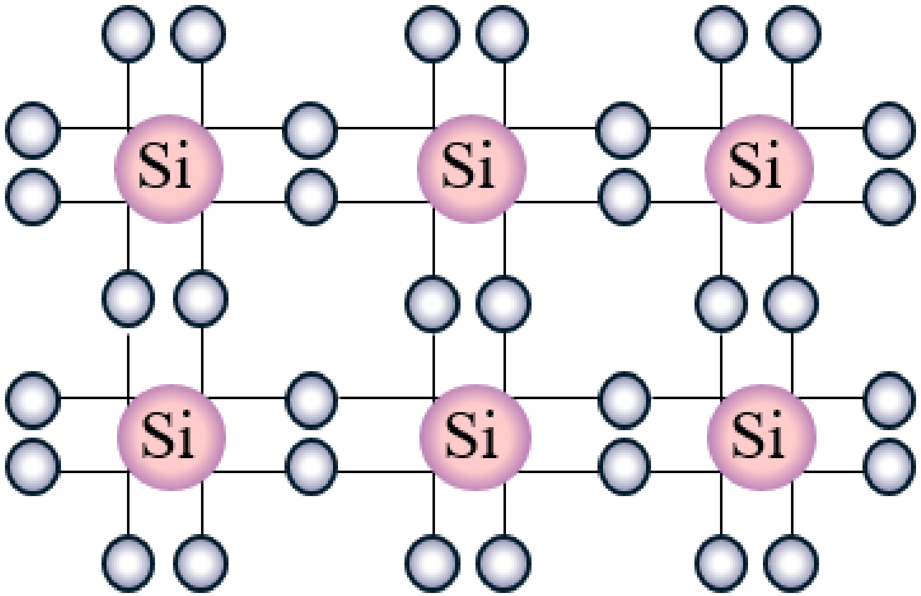
Semiconductors : What are they?

- Semiconductors are materials which have a conductivity between conductors and insulators
- Semiconductors can be pure elements, such as silicon or germanium, or compounds such as gallium arsenide or cadmium selenide
- In a process called doping, small amounts of impurities are added to pure semiconductors causing large changes in the conductivity of the material
- Semiconductors are an important part of our lives; smaller, faster, and more reliable

SIARS

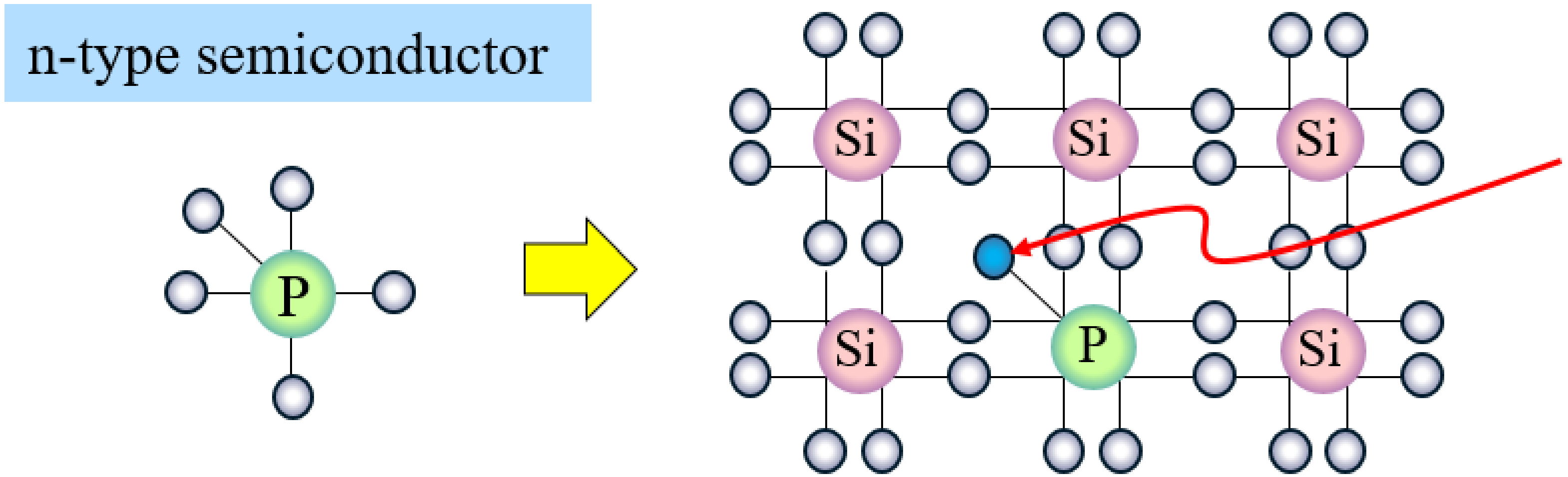
Silicon : a closer look

- Silicon is a very common element; for example, it is the main element in sand and quartz
- Silicon has four electrons in its outer orbit, leading them to form crystal lattices, leaving no free electrons to conduct electricity
- This can be changed by "doping" silicon; adding impurities



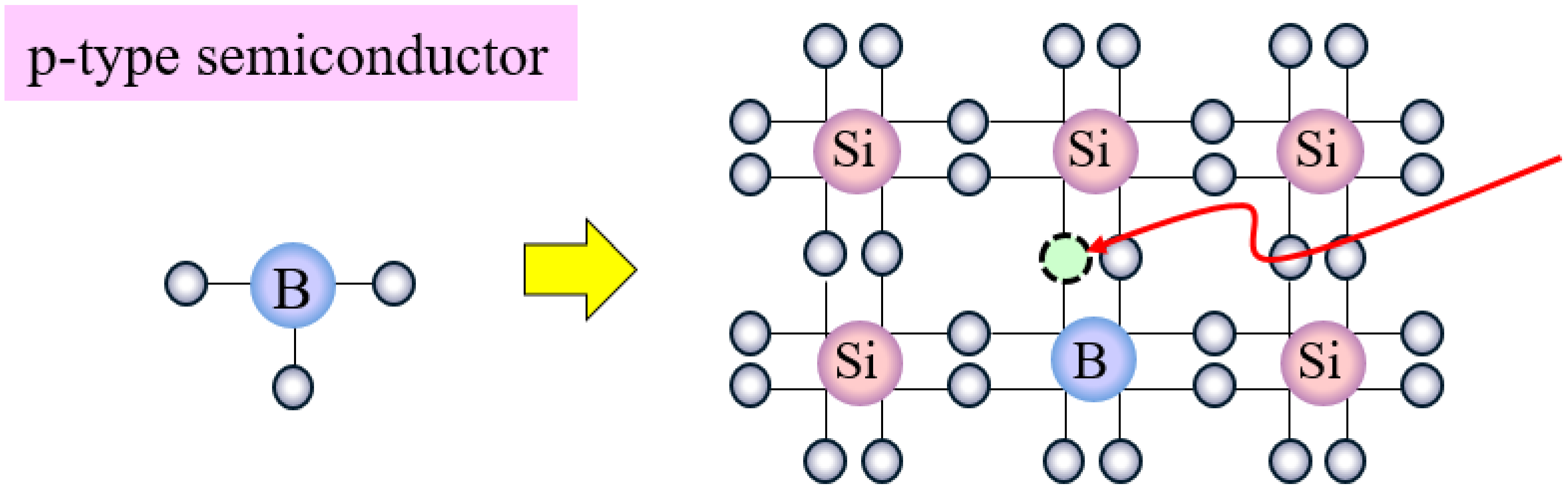
Doping : N-type

- N- Type : Phosphorus or arsenic is added in small quantities; adds extra electron to structure – good conductor. Negatively charged, hence, N-type



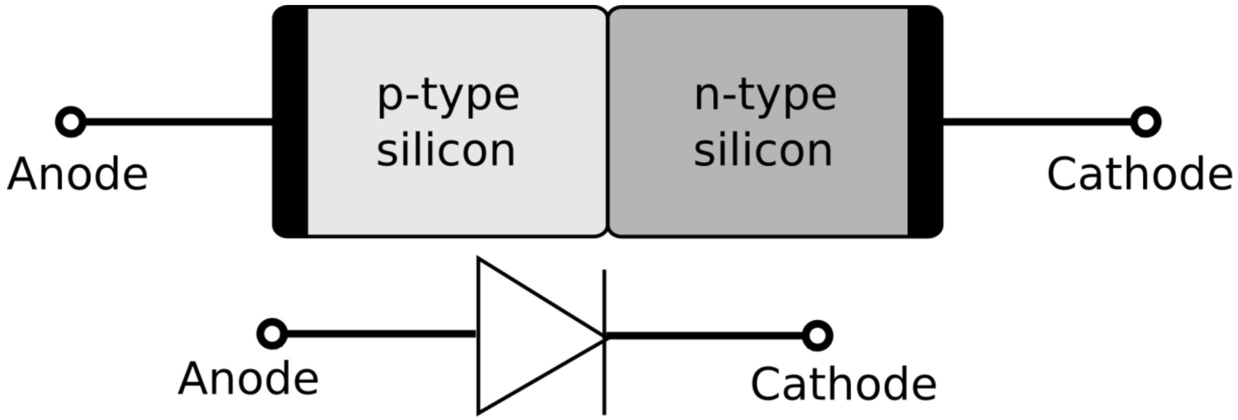
Doping : P-type

- P- Type : Boron or gallium is added in small quantities; they form "holes" in the lattice where a silicon electron has nothing to bond to, this leads to positive charge – hence, P-type



P-N junctions

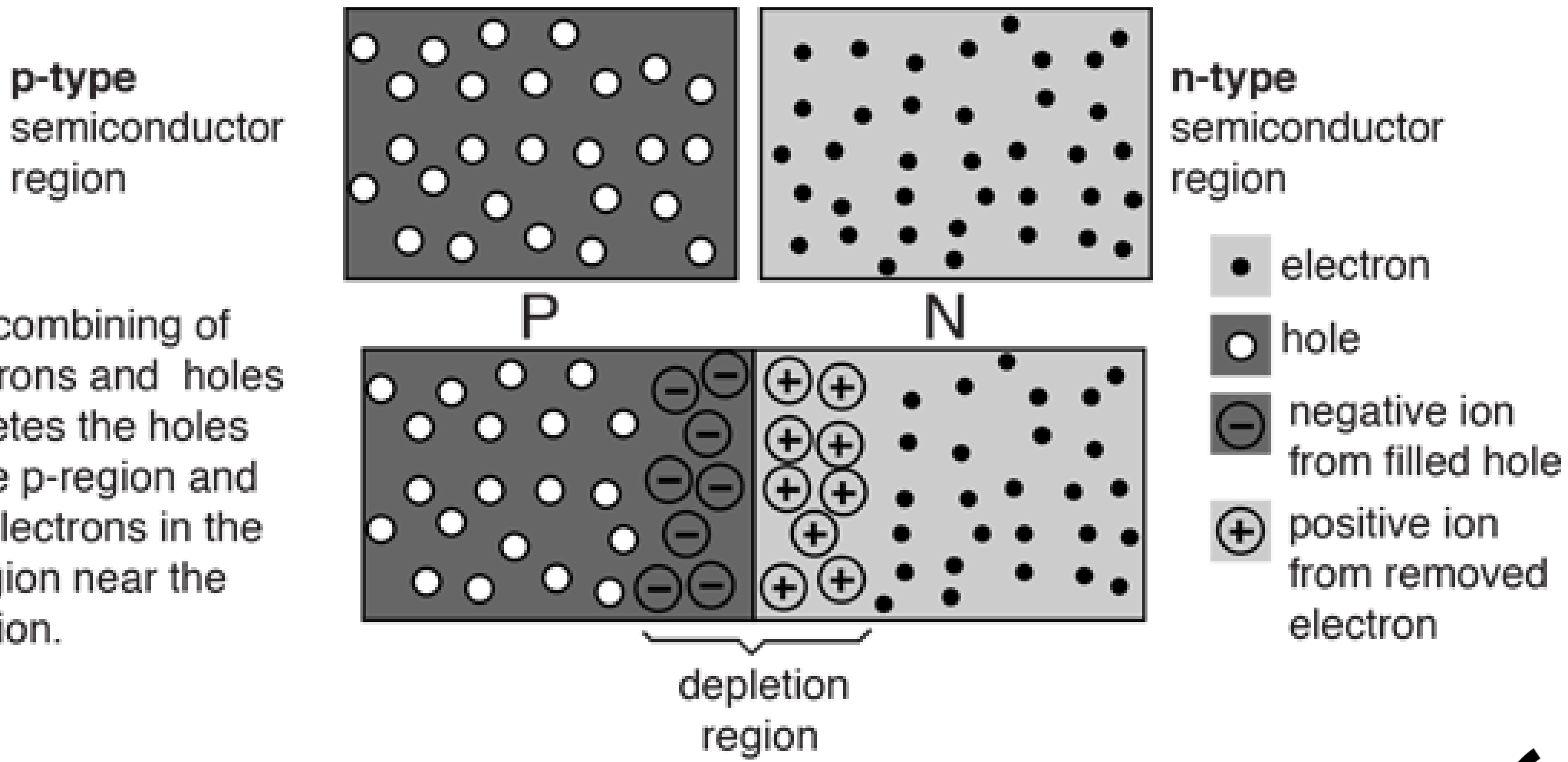
- P and N type silicon are not very interesting by themselves ; when they are bonded with each other, they display interesting properties
- A diode is a simple P-N bonded junction; it allows the flow of current in only one direction – just like the flow of traffic in a one-way street



Depletion layer

- When a P-N junction is formed, free electrons in the n-type material diffuse across the junction to combine with the holes in the p-type material; in doing so, they leave behind positive ions in the n-type
- These positive ions inhibit the flow of electrons, unless helped by adding extra electrons to the n-type layer so that they can help electrons breach the junction and flow onto the p-type layer
- The area around the P-N junction where this happens is known as the depletion layer; some extra voltage is often required for electrons to breach past this layer; if this is not provided the depletion layer acts like an insulator, blocking the flow of electrons

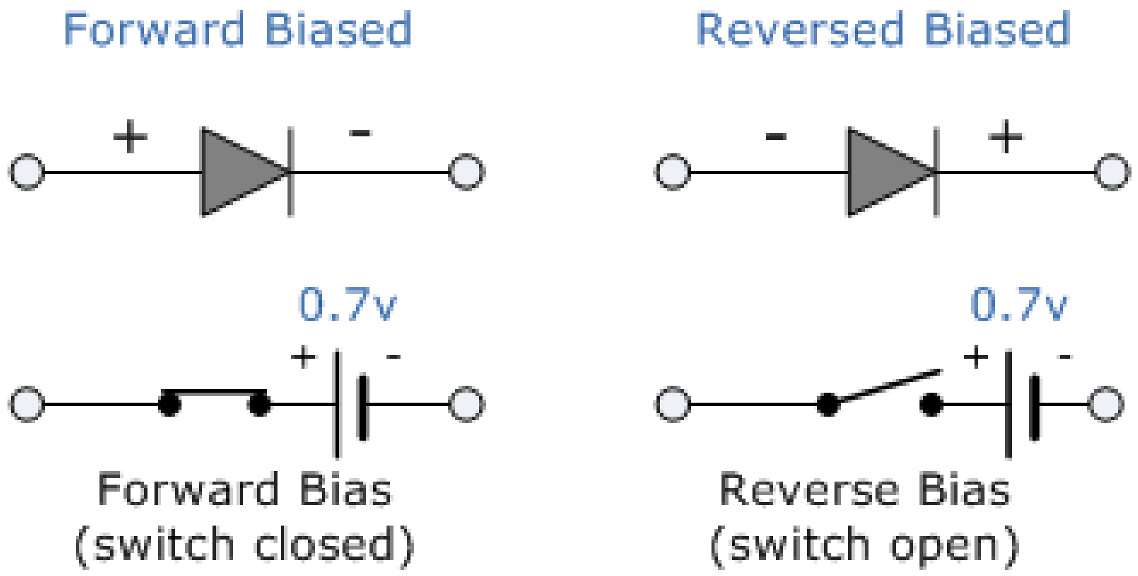
The combining of electrons and holes depletes the holes in the p-region and the electrons in the n-region near the junction.

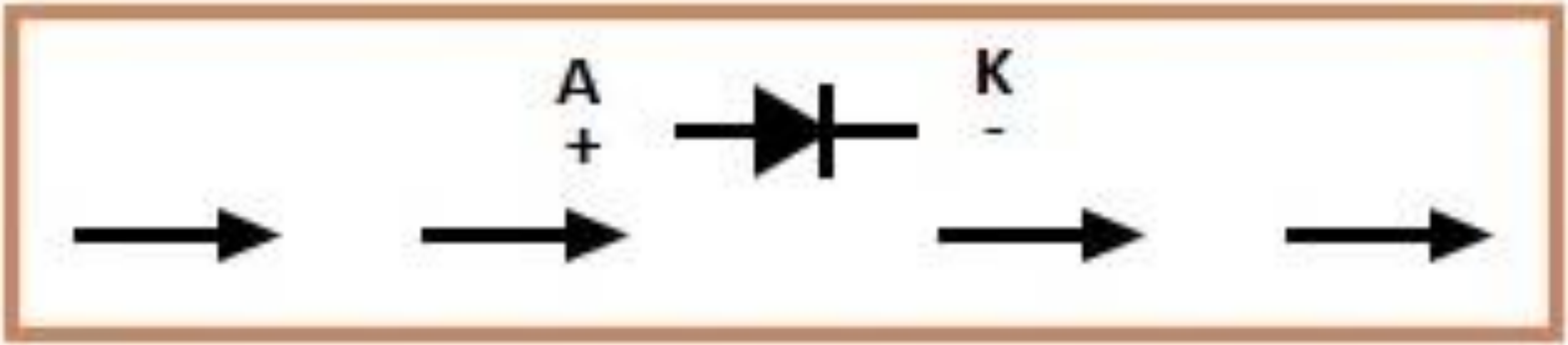


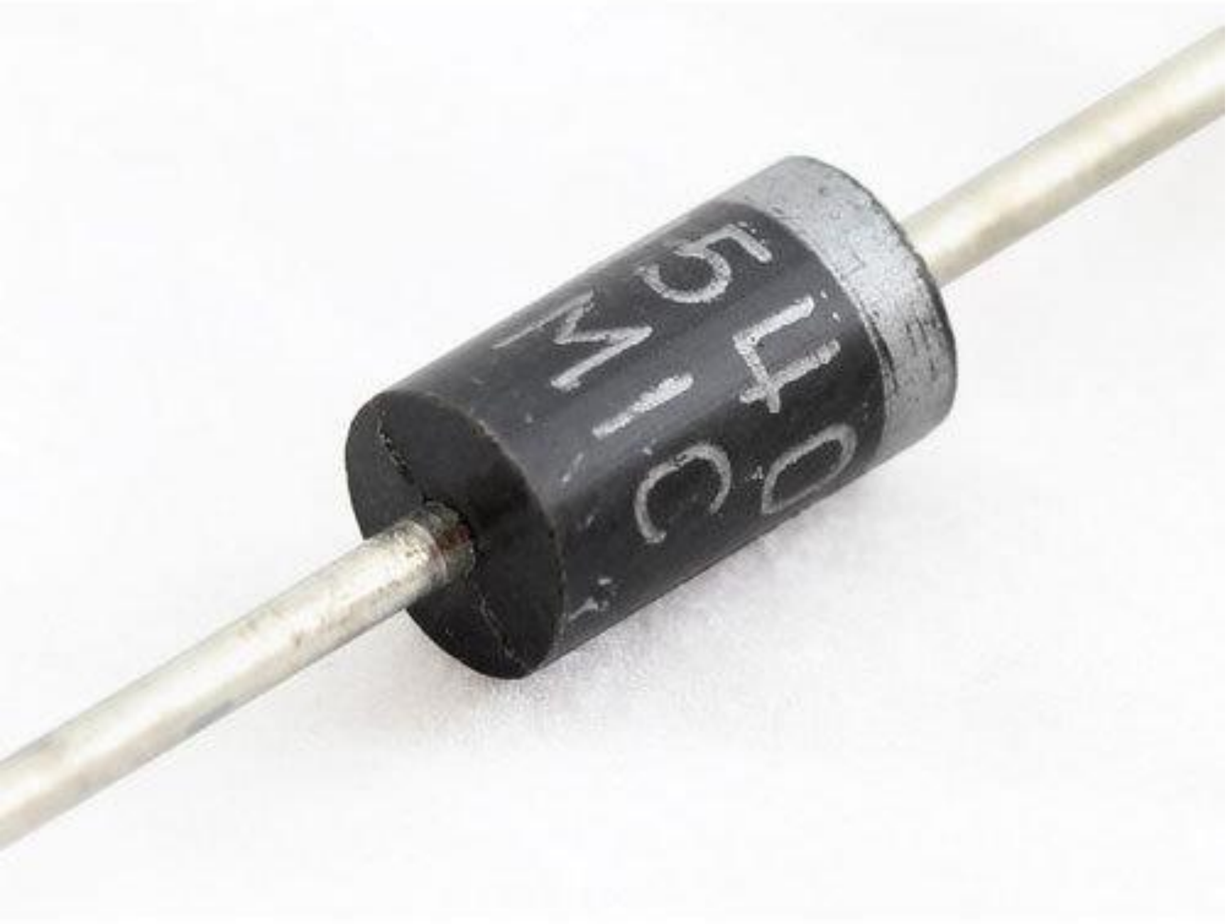
SiArS

Diode Operation – Forward Bias

- A diode acts like a one-way street to the flow of current; when the electrons are flowing in the right direction, the diode is said to be forward biased

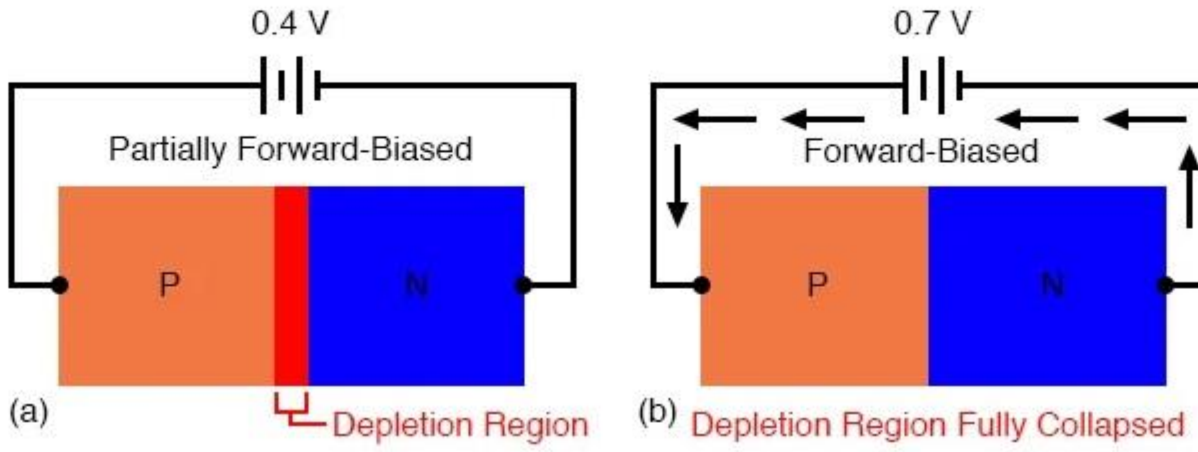



A
+
K
-



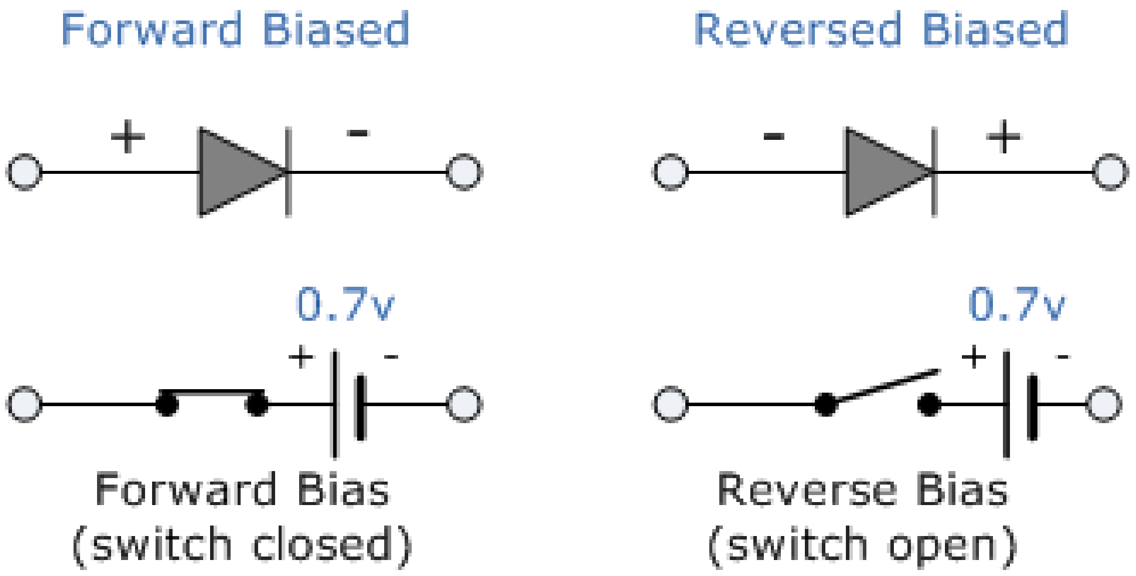
Diode Operation – Forward Bias ...

- In forward bias configuration, the depletion layer is collapses, as long as the minimum voltage required for the electrons to jump past the depletion layer is provided. This voltage is known as forward bias voltage
- For Silicon diodes, this is usually 0.7 V and for germanium it is 0.3 V



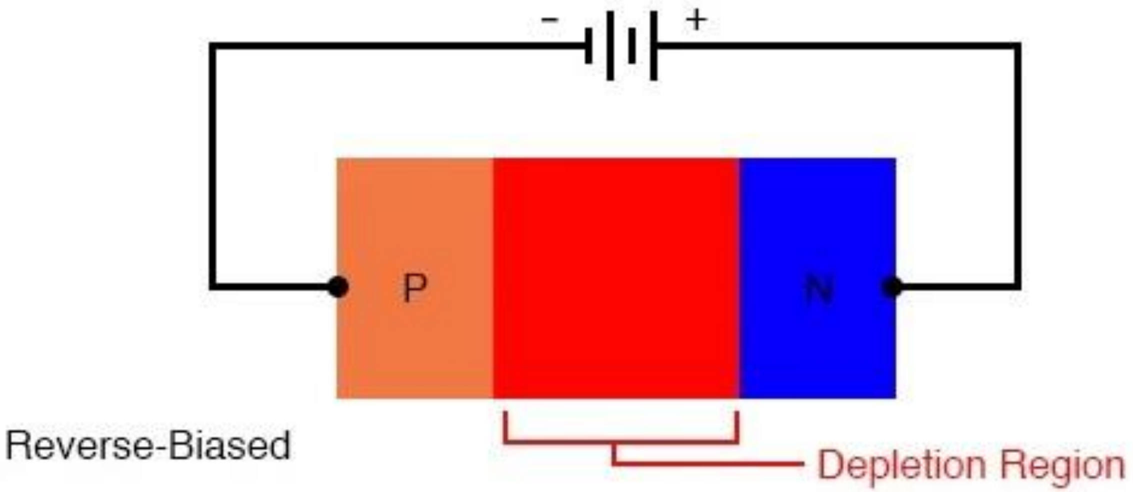
Diode Operation – Reverse Bias

- when the electrons are flowing attempting to flow in the wrong direction, the diode is said to be reverse biased



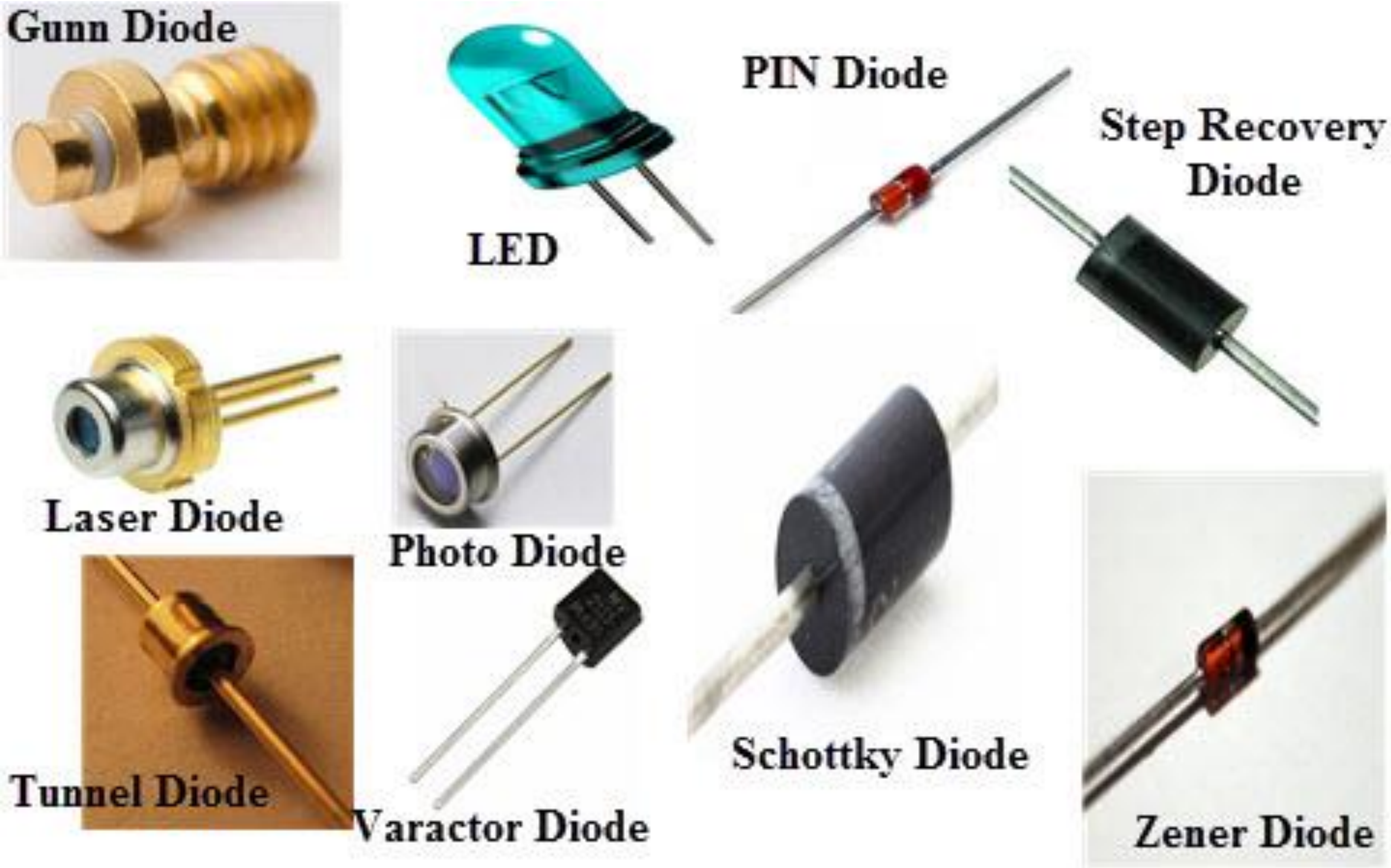
Diode Operation – Reverse Bias

- when the electrons are flowing attempting to flow in the wrong direction, the diode is said to be reverse biased
- When a diode is reverse biased, the depletion layer expands, resisting the flow of electrons through it



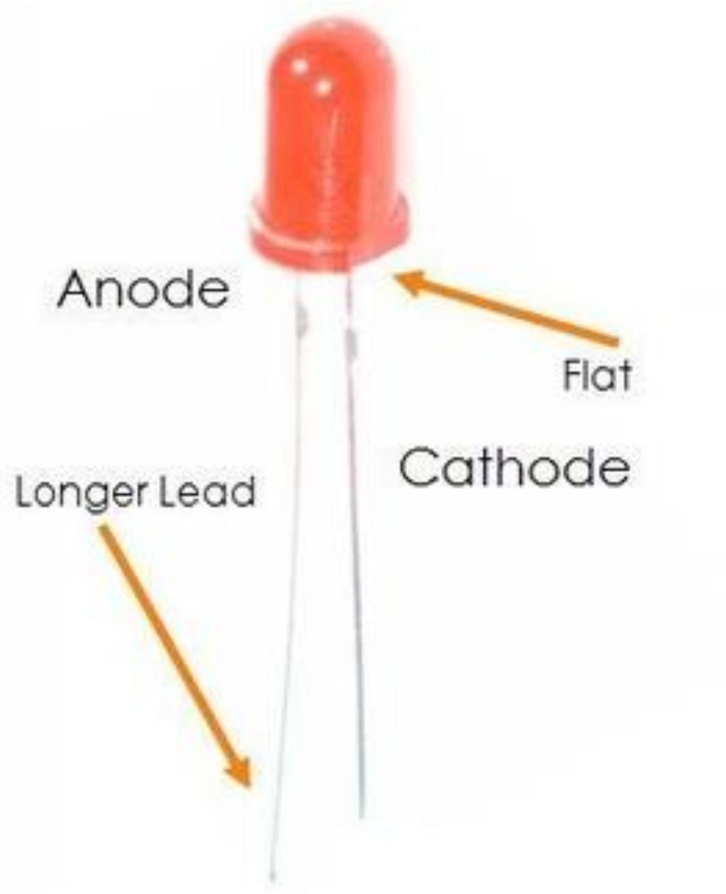
Diode Operation – Reverse Bias

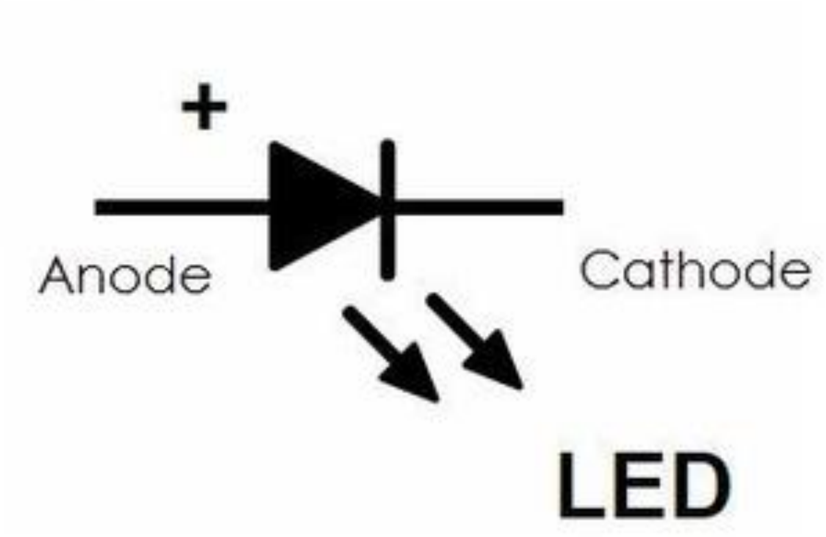
- In reality, a very small amount of current can and does go through a reverse-biased diode, called the leakage current, but it can be ignored for most purposes.
- The ability of a diode to withstand reverse bias is given by its *Peak Inverse Voltage (PIV)*
- A diode will experience a destructive breakdown past the *PIV*


Gunn Diode
LED
PIN Diode
Step Recovery Diode
Laser Diode
Photo Diode
Schottky Diode
Tunnel Diode
Varactor Diode
Zener Diode

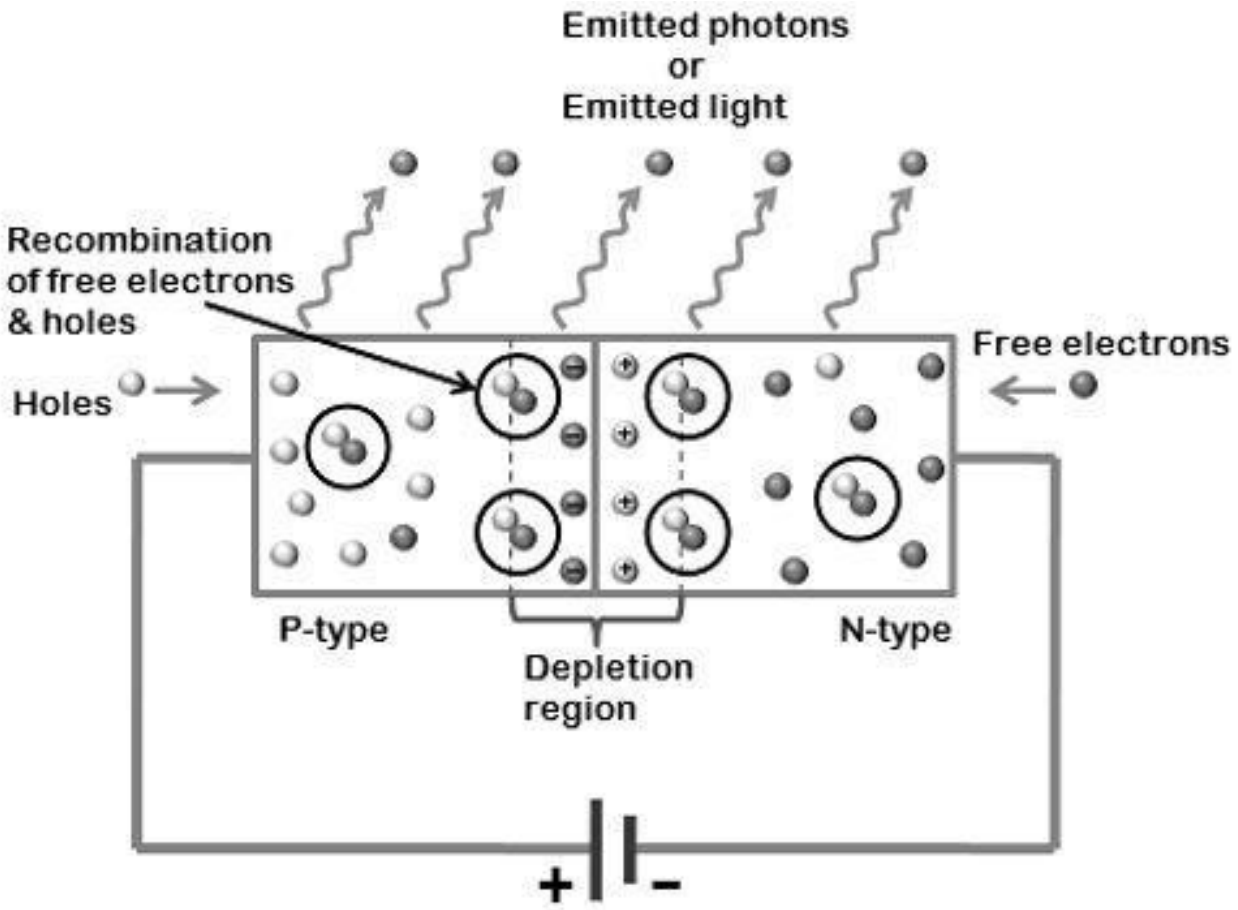
Light Emitting Diodes (L.E.D)

- LEDs are special kinds of diodes which emit light when forward biased; They are made of Gallium Arsenide Phosphide
- When these diodes are forward biased, electrons from the n-type move into the p-type region with holes and "fall" into them; this involves electrons in a higher orbit fall into a lower orbit, during which they release energy in the form of photons
- This happens is regular diodes too, but they are engineered such that they do not travel far, or at UV or IR frequencies
- They require about 20 mA of current to function

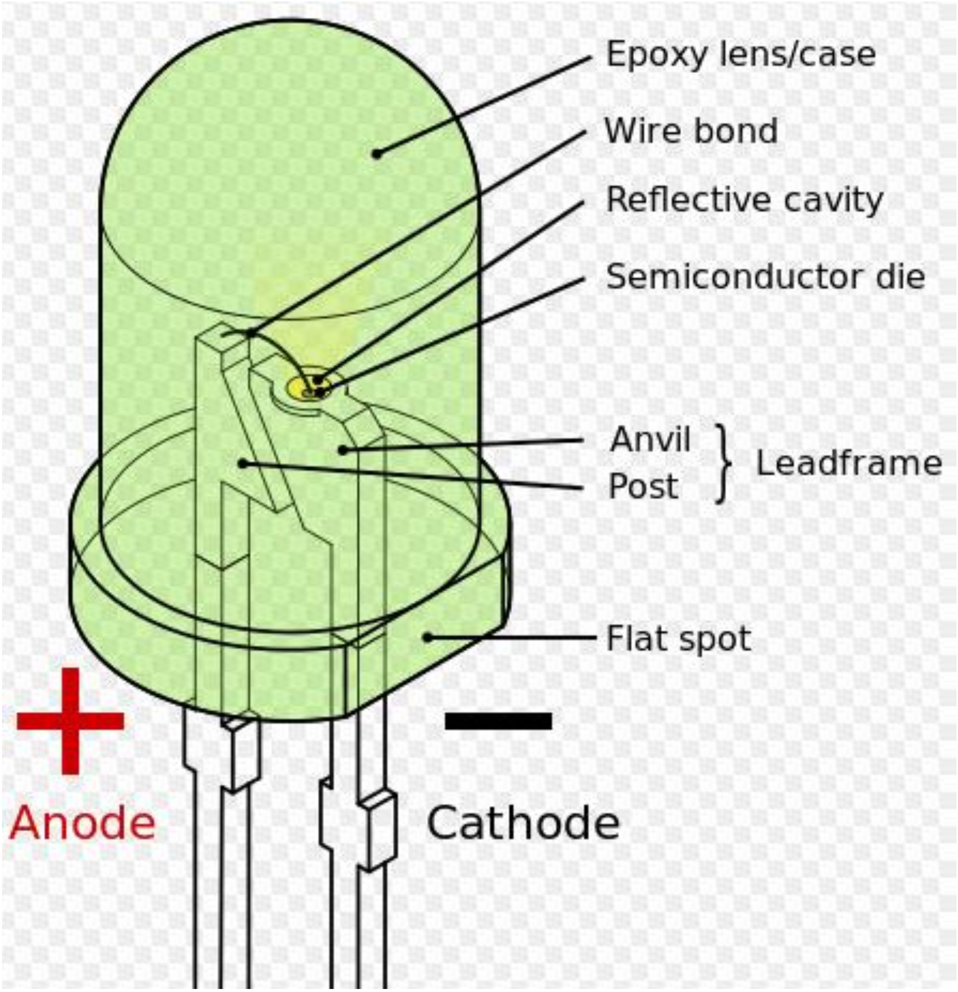

Anode
Flat
Cathode
Longer Lead


+
Anode
Cathode
LED

Light Emitting Diodes (L.E.D)



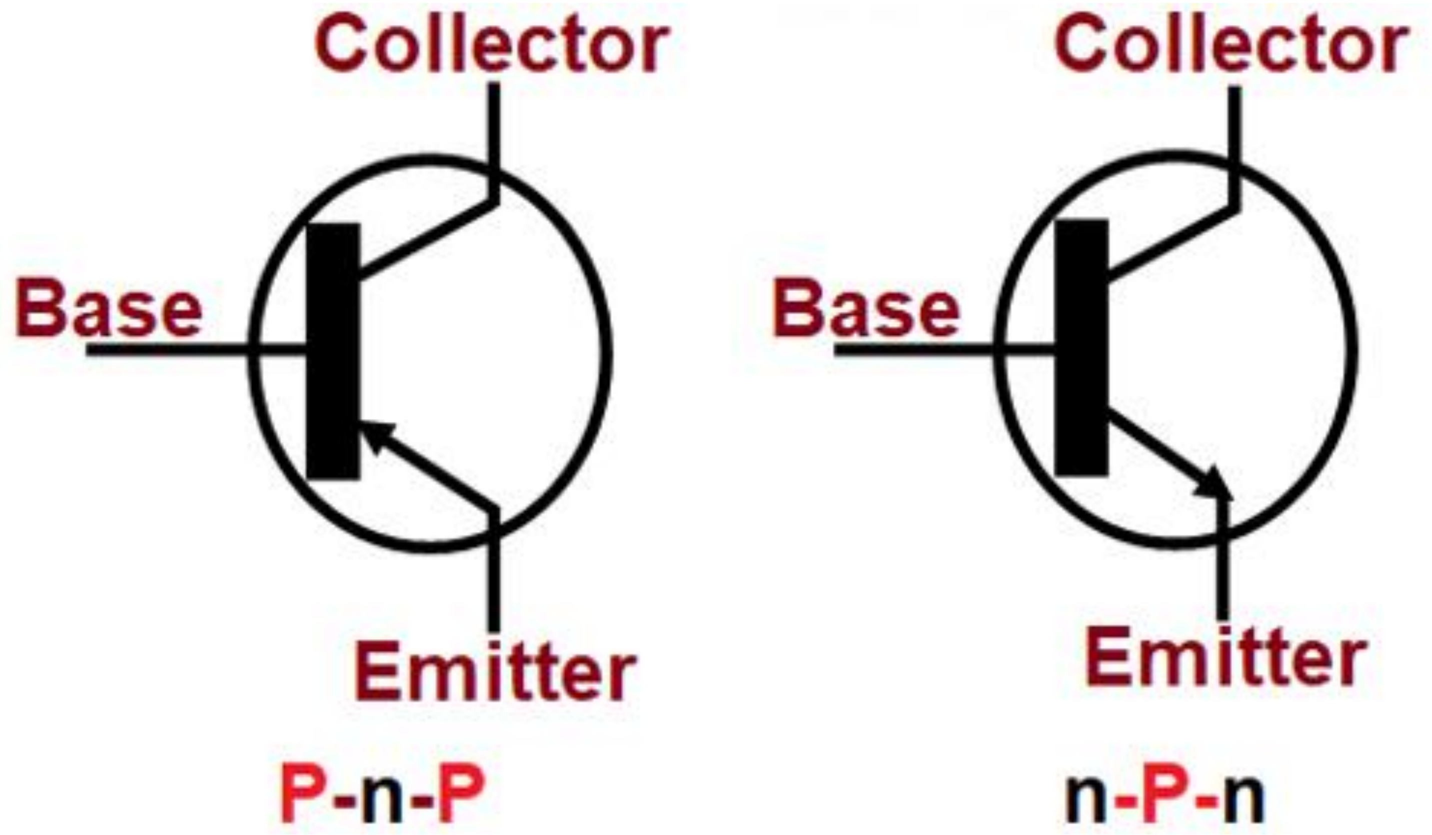
Light Emitting Diodes (L.E.D)



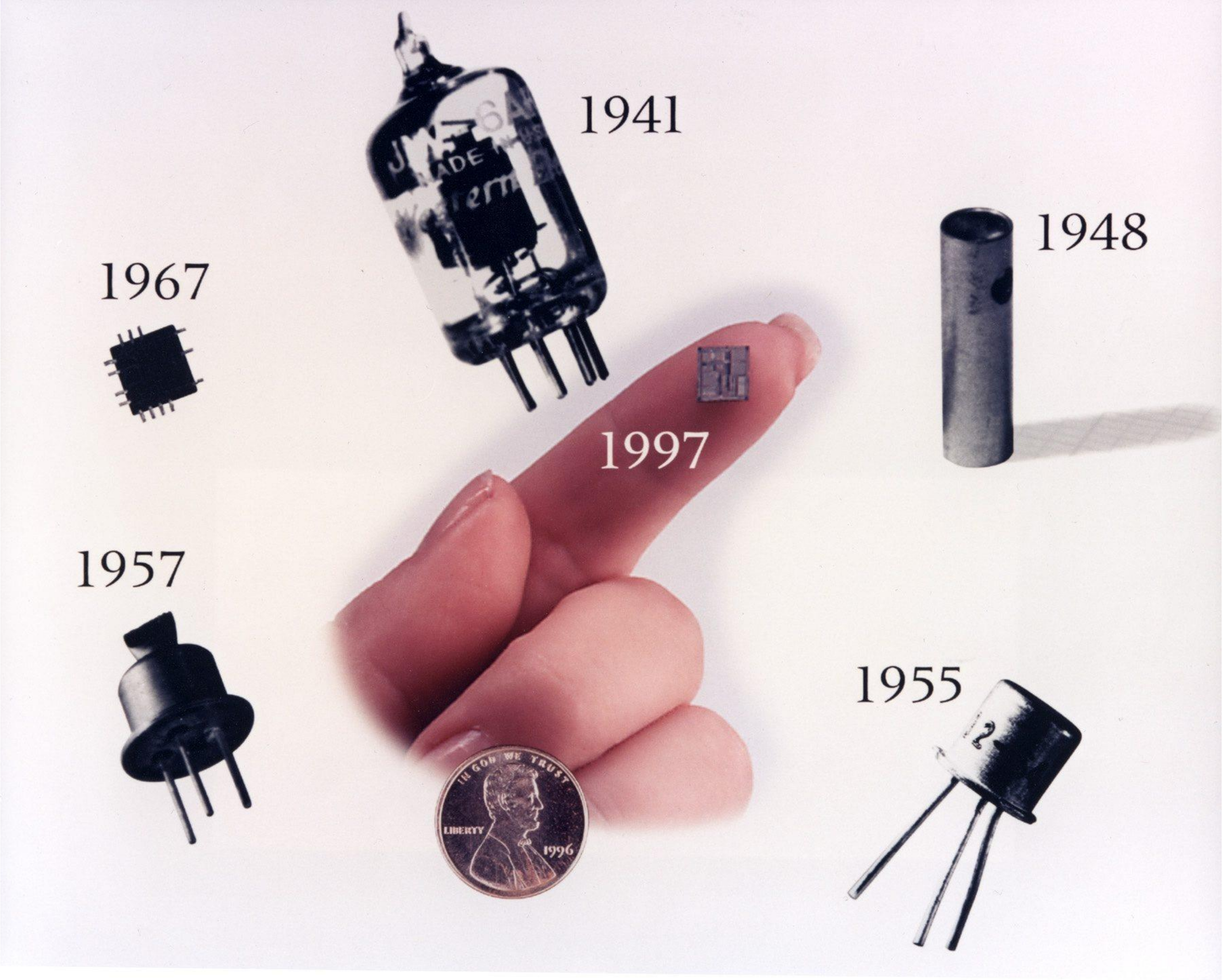
Transistors

- Transistors are used to either amplify signals or to act as a switch in electronics ; they are fundamental building blocks in circuits
- These are three terminal devices; a voltage or current applied to one pair of the transistor's terminals changes the current through another pair of terminals
- The controlled (output) power can be higher than the controlling (input) power, a transistor can amplify a signal
- They are classified as NPN or PNP based on their construction

Transistors …

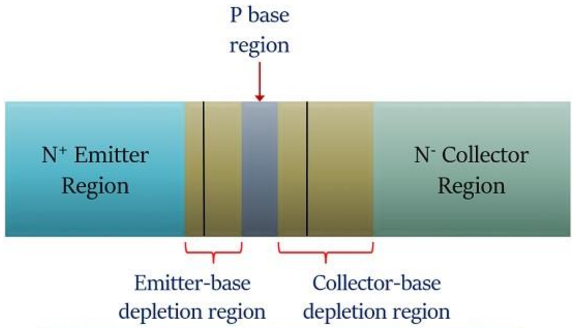



E W6
C 39
PH
BD647
m8805
C4313
B C E


1941
1948
1967
1997
1957
1955

How do Transistors work? (NPN)

- A transistor has 3 regions; emitter, base, and collector
- The doping levels of all the 3 regions are different. The **emitter region is highly doped**; the **base region is lightly doped;** the **collector region is moderately doped**
- Due to the presence of 2 junctions in between 3 regions, it acts like 2 PN junction diodes; **Emitter and collector are not interchangeable**



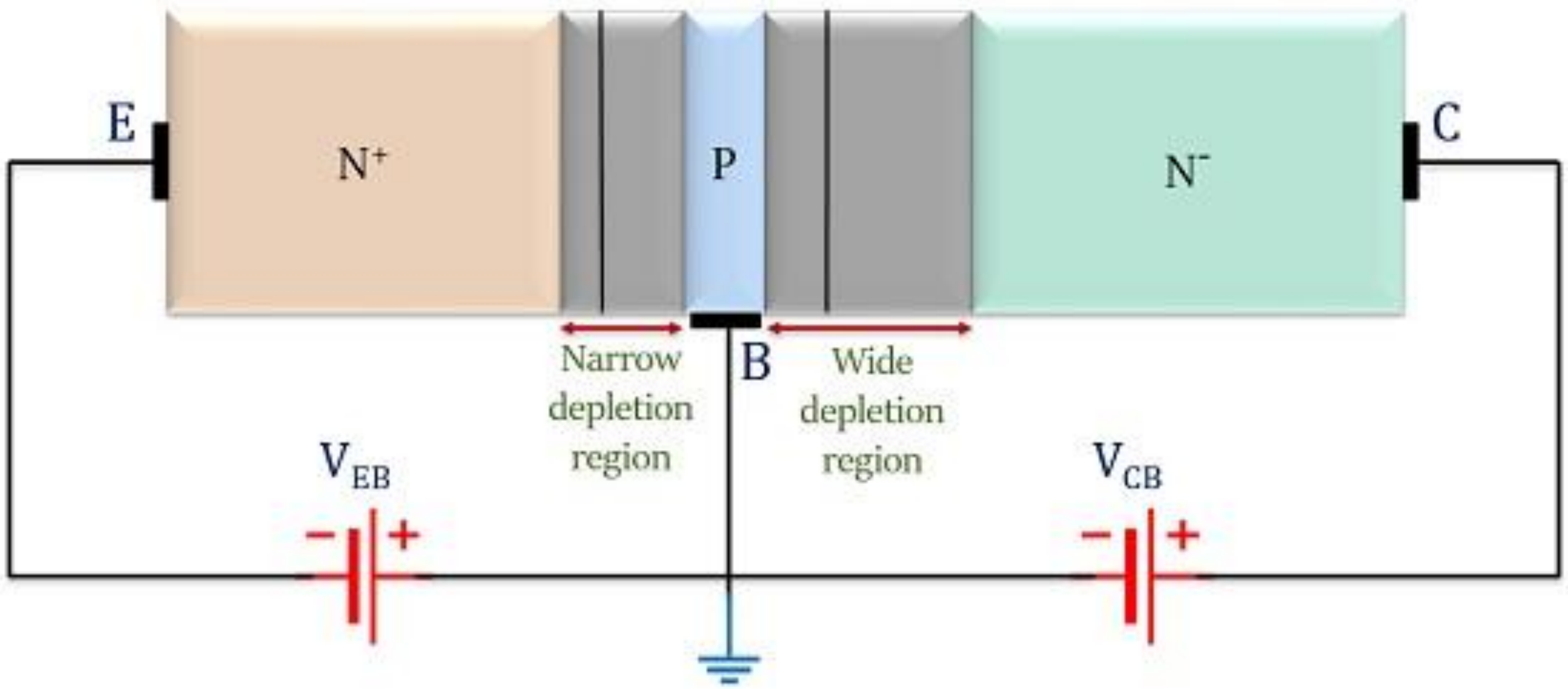
Structure of NPN transistor

How do Transistors work? (NPN)

- In a transistor, there are 2 depletion layers; the collector-base (CB) and the emitter-base (EB) depletion layers
- The collector-base depletion layer is wider than the emitter-base depletion layer; These two **depletion regions act as the potential barrier** for any further flow of current
- In an unpowered state, the electrons in the emitter region begin moving towards the base; this leads to the formation of the emitter-base depletion layer. A similar phenomena takes place at the collector-base junction leading to the formation of the collector-base depletion layer

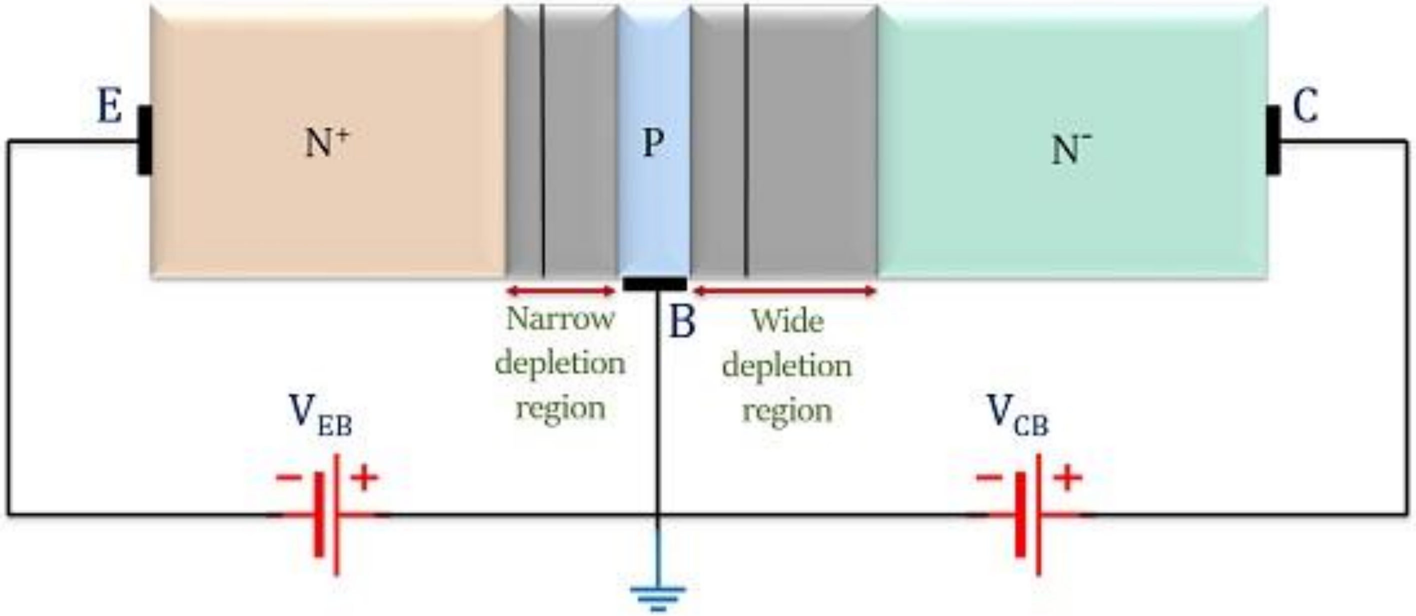
How do Transistors work? (NPN)

- Let us forward bias the EB junction and reverse bias the CB junction



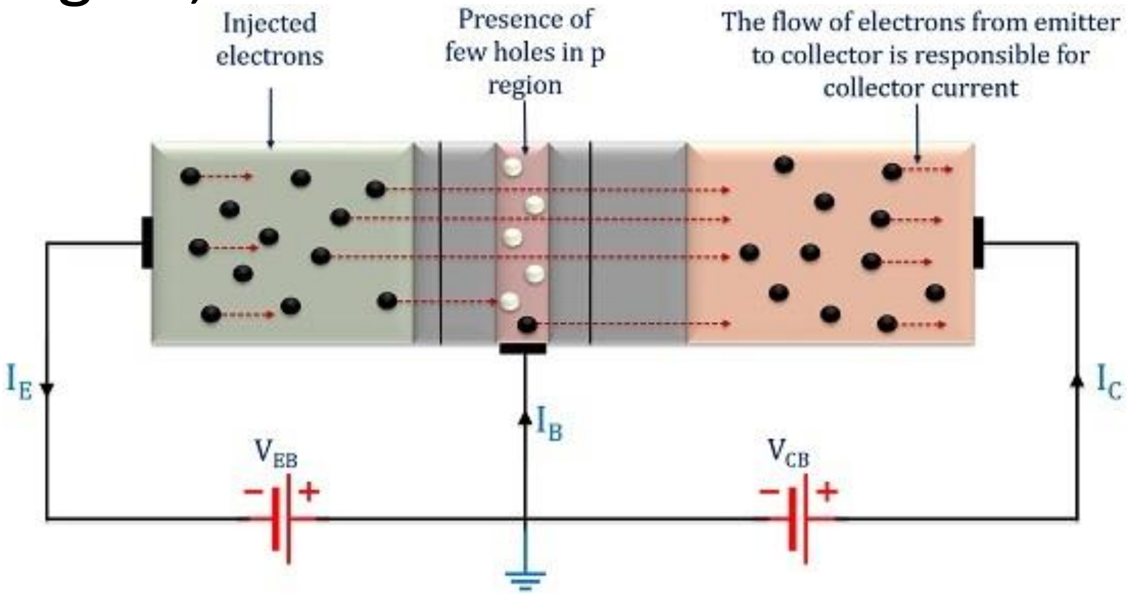
How do Transistors work? (NPN)

- Due to the forward applied voltage at the emitter-base junction, the width of the depletion region gets narrowed. Similarly, the reverse applied voltage broadens the width of the collector-base junction.



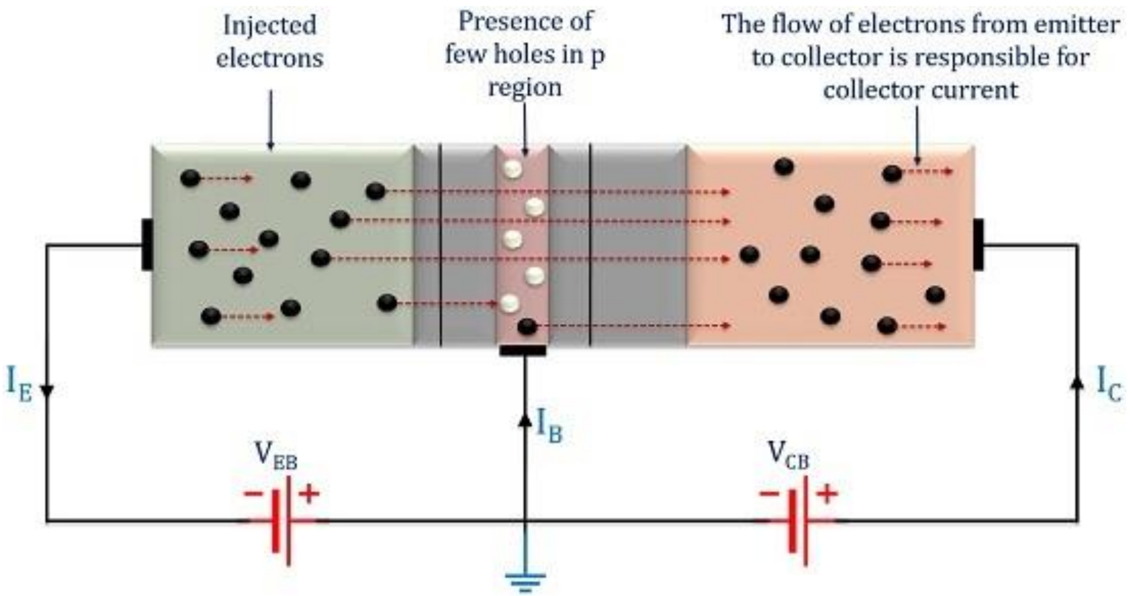
How do Transistors work? (NPN)

- Due to the forward applied voltage V_{EB}, electrons start injecting into the emitter region. The electrons in this region have sufficient energy by which it overcomes the barrier potential of the EB junction to arrive the base region; This is called base current.



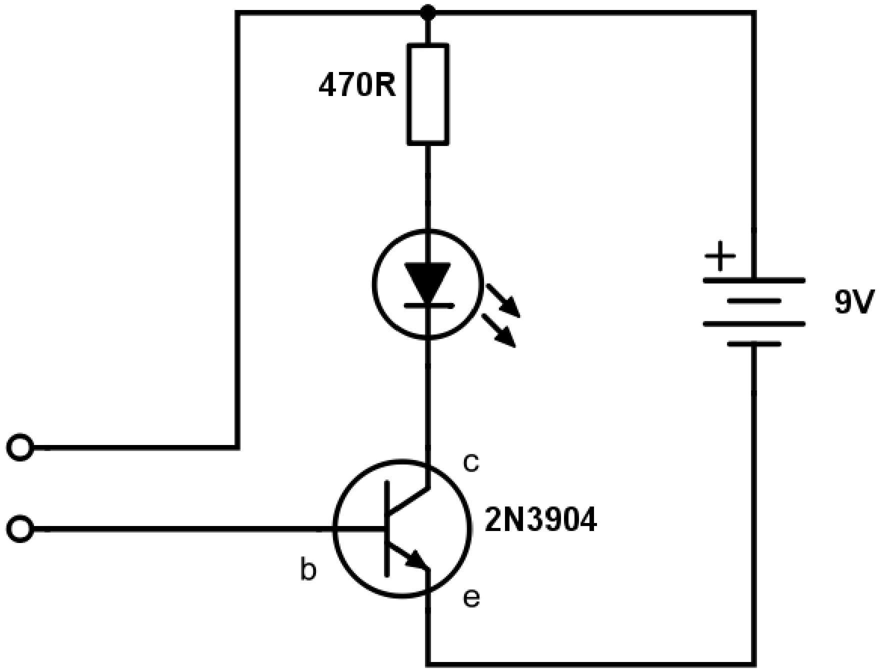
How do Transistors work? (NPN)

- Most electrons will be sucked through the BC depletion layer and fill the holes in the BC depletion layer. This causes electron flow in the opposite direction, from emitter to collector; this is called collector current.



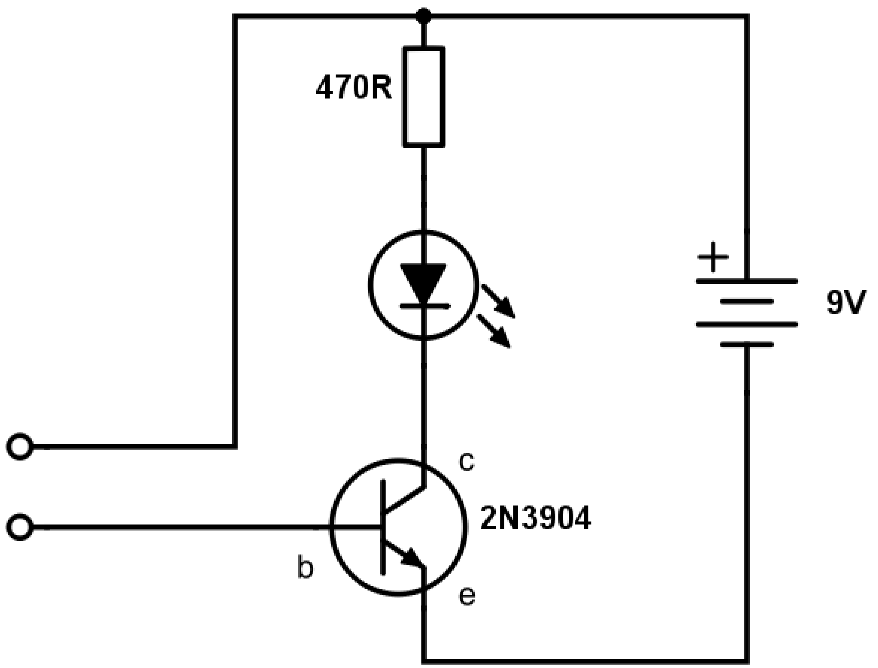
Transistor as an amplifier

- An amplifier is a circuit that increases the strength of a signal by boosting the current or voltage given at its input according to its gain



Transistor as an amplifier

- When a finger is placed between the contacts, the resistance of the skin is enough to allow a weak current of about .1 - .2mA through the BE junction
- Given the gain of the transistor, the CE current is much higher than the BE current (usually by a factor of 100)
- .2 mA x 100 (Gain)= .02A = 20mA (enough to bias an LED!)

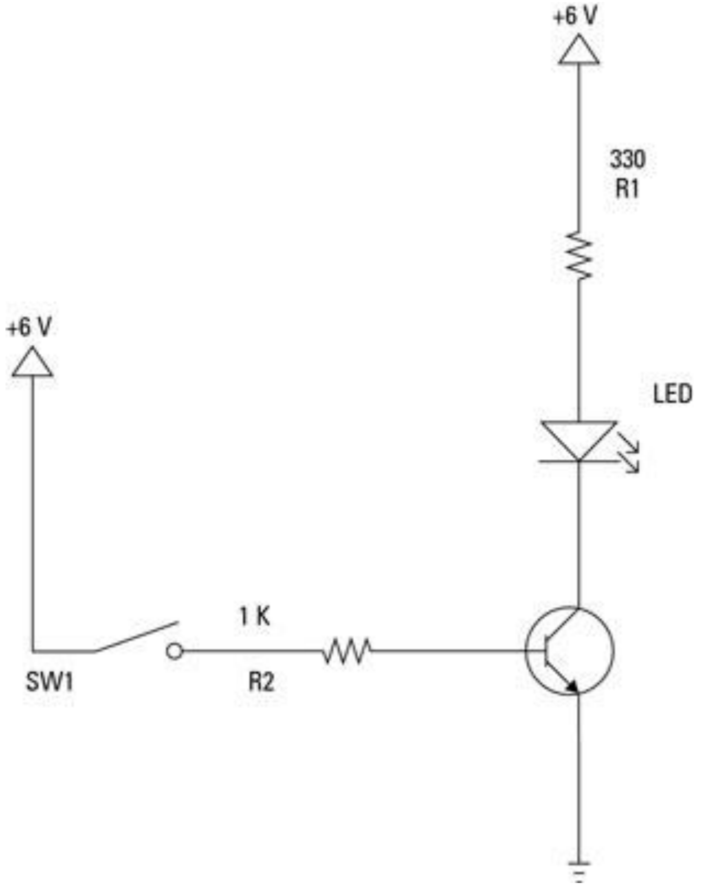


Transistor as a switch

- One of the most common uses for transistors in an electronic circuit is as simple switches. In short, a transistor conducts current across the CE path only when a voltage is applied to the base
- When no base voltage is present, the switch is off; When base voltage is present, the switch is on
- The transistor is off when there's no bias voltage or when the bias voltage is less than 0.7 V. The switch is on when the base is saturated so that collector current can flow without restriction

Transistor as a switch …

- When Switch SW1 is closed, a voltage is applied to the base , the transistor allows the flow of CE current, lighting the LED up

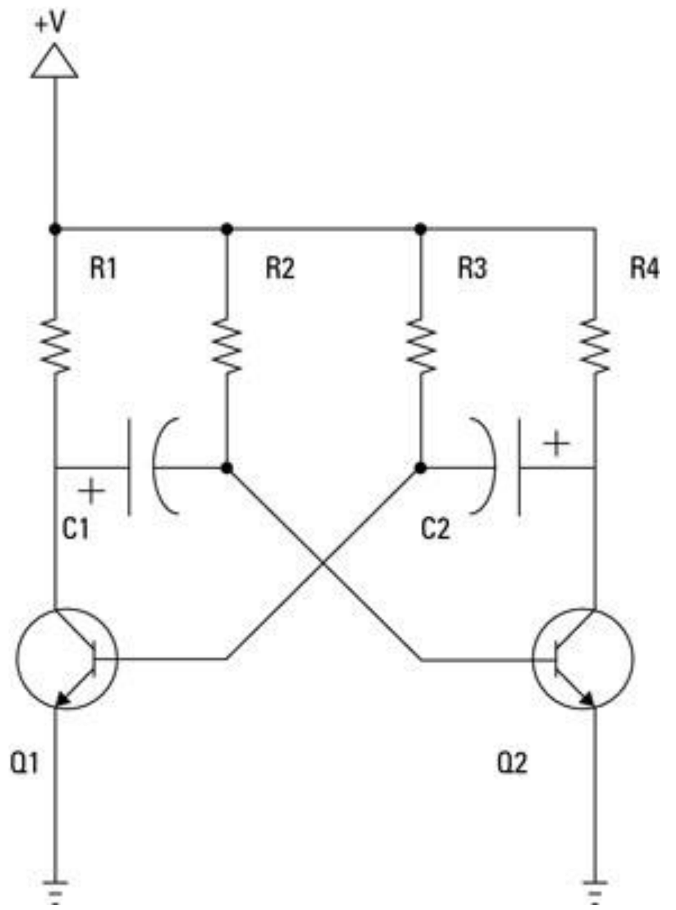


Transistor as an oscillator

- An oscillator is an electronic circuit that generates repeated waveforms
- The exact waveform generated depends on the type of circuit used to create the oscillator
- An oscillator is an amplifier with positive feedback

Transistor as an oscillator

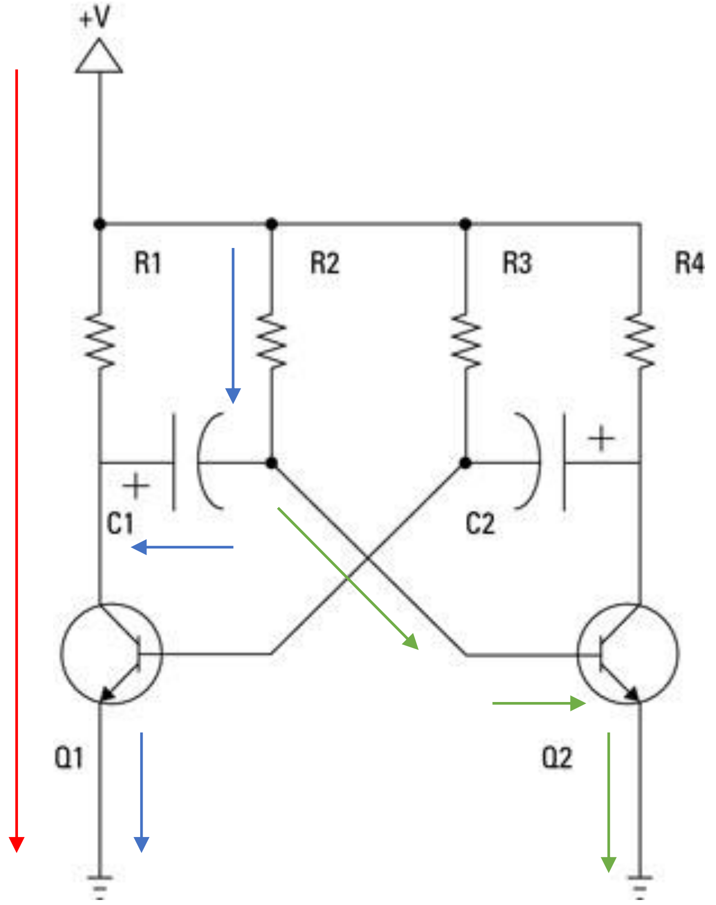
- This is a simple oscillator known as “astable multivibrator”; it is not stable and keeps switching between the two transistors
- Only one of the two transistors is on at any given time
- Let’s look at it in detail …



Transistor as an oscillator …

When Q1 is on :

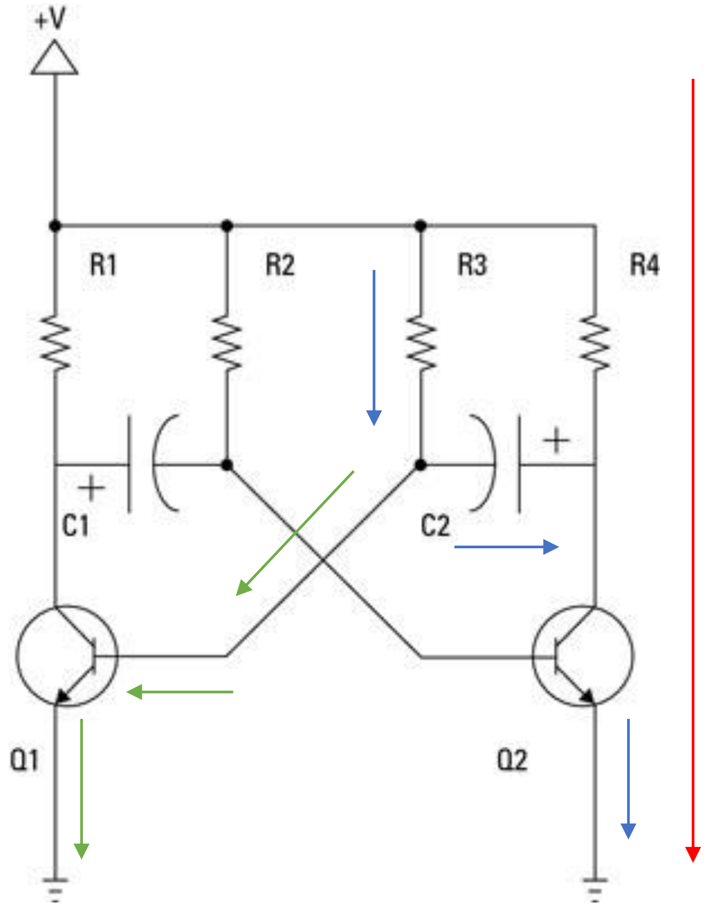
- Current flows through R1 and Q1 CE to ground
- C1 starts charging through R2
- Positive voltage develops at C1 and Q2 base
- Once C1 is charged, voltage at the base of Q2 switches it on



Transistor as an oscillator …

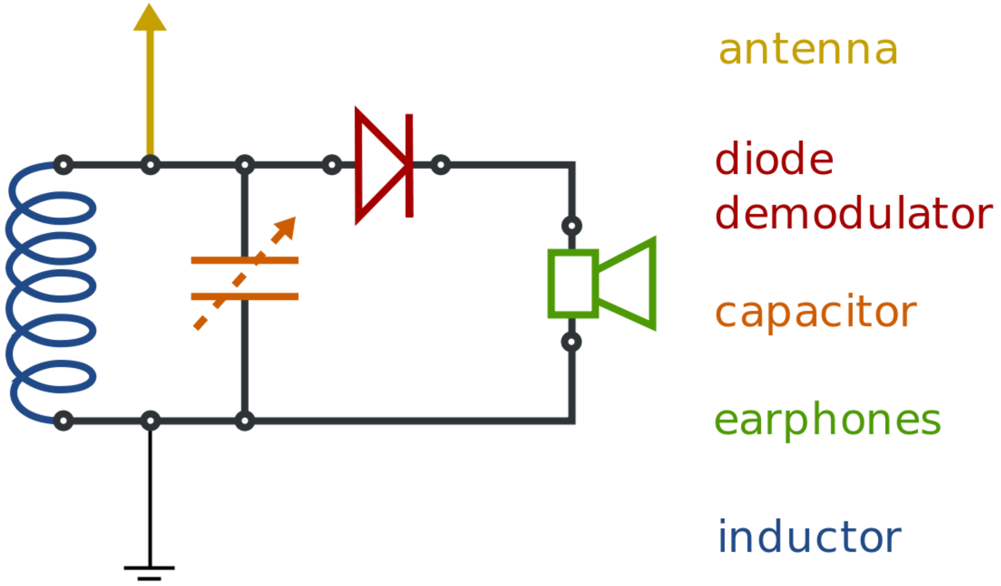
When Q2 is on :

- Current flows through R4 and Q2 CE junction to ground
- C2 charges via R3
- Voltage at C2 and Q1 base goes negative and Q1 turns off
- C1 discharges as C2 charges, and the cycle is repeated



Crystal Radio

- A crystal radio is a simple radio receiver that uses only a few components and no batteries to function
- Crystal radios use the power of the transmitted radio waves (in KW) to convert radio signals into audio signals.

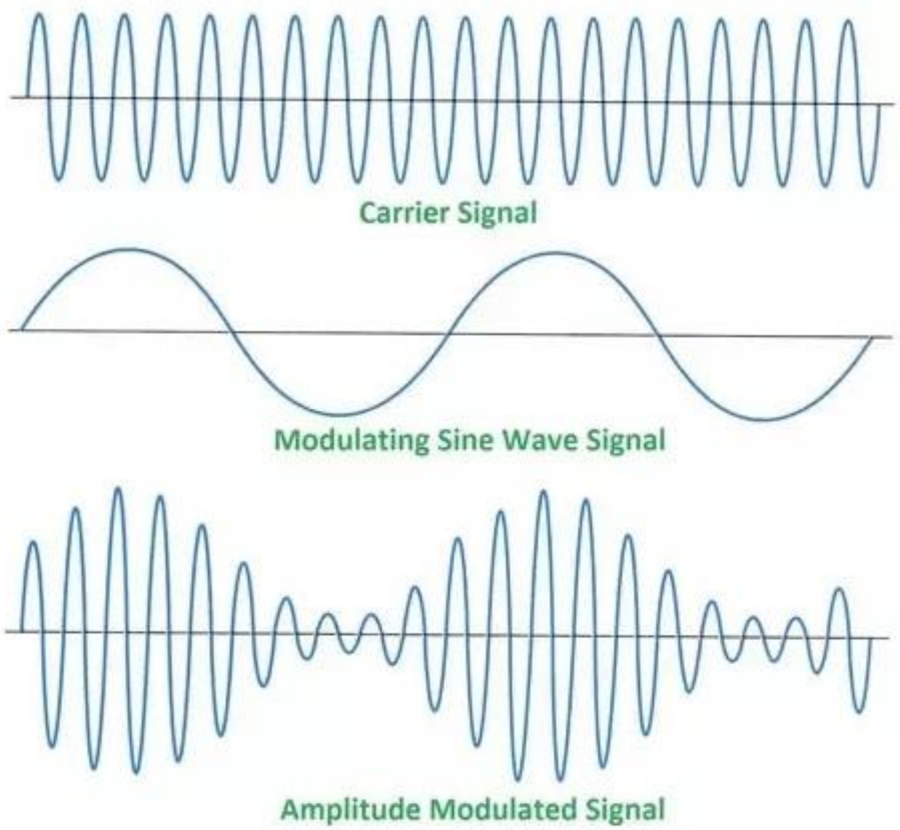


Crystal radios ..

- Antenna : A long wire strung up to the highest point for picking up radio signals
- Ground : A piece of wire that is connected to earthed objects such as metal pipes
- Resonant circuit : the coil and capacitor form a resonant circuit; this allows the radio to select the signal we would like to hear
- Demodulator : the diode converts the modulated RF signal into audio
- Earphones : the high impedance earphone converts the electrical audio signal into audible sounds

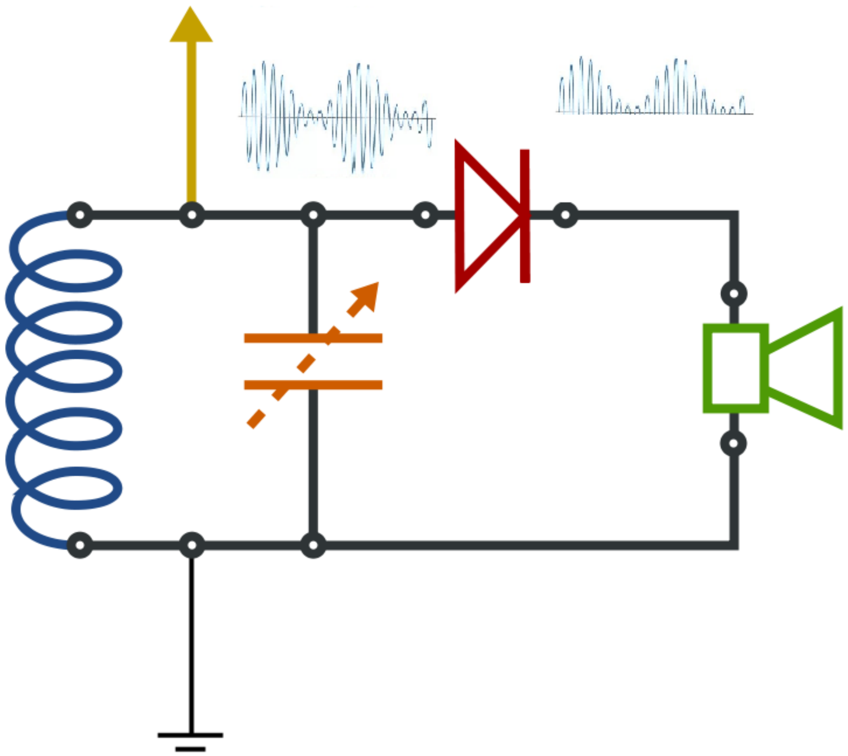
How do crystal radios work ?

- Crystal radios detect Amplitude Modulated (AM) signals
- The radio station is equipped with modulators which mix audio signals and radio waves; they merely vary the amplitude of a radio wave according to frequency



How do crystal radios work …?

- The resonant circuit only allows signals of one frequency to be received; Unwanted signals are grounded
- The selected signal is sent to the diode, usually germanium, which rectifies it to pulsating dc
- Pulsating DC is fed to the earphones, which convert the electrical energy into sound



Thank you!

Questions and Comments in the chat box!