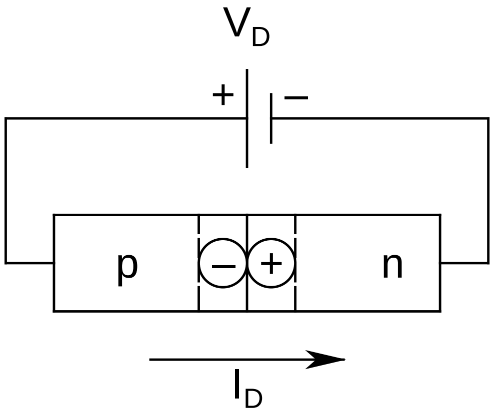
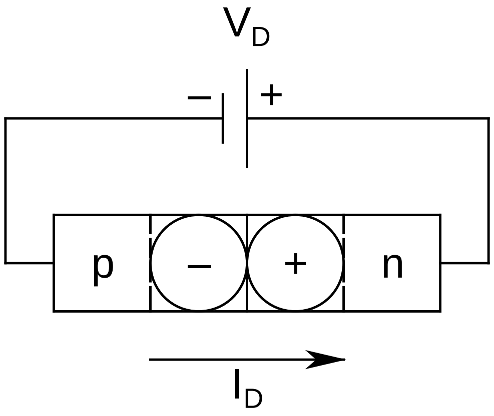
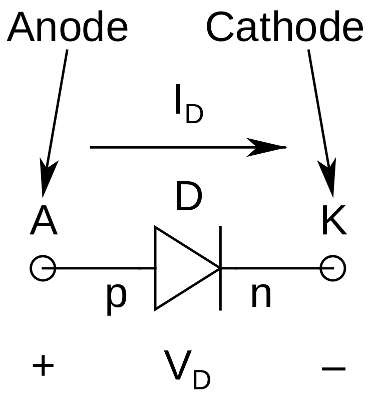
Diode Under Bias



Forward Bias:
p-side positive
w.r.t. n-side



Reverse Bias:
n-side positive
w.r.t. p-side



Symbol and
current-voltage
convention

Voltage and Current Conventions:

V_D: 0 (Equilibrium), Positive (Forward Bias), Negative (Reverse Bias)

I_D: p to n (Positive), n to p (Negative)

- ***Forward Bias*** (***V_D positive***):
  - ***p positive w.r.t. n***
  - ***Depletion region width***$\downarrow$
  - ***Electric field across MJ***$\downarrow$
    - ***Barrier height*** $(V_0 - V_D)\downarrow$
  - ***Injection of holes from p to n and electrons from n to p***$\uparrow\uparrow$ (***thermionic emission***)
    - ***Diffusion component***$\uparrow\uparrow$ ***while drift current remains more or less same***
  - ***Net current from p to n*** (***can be large***)
    - Known as ***forward current*** (***I_D positive***)

- ***Reverse Bias*** (***V_D negative***):
  - ***p negative w.r.t. n***
  - ***Depletion region width*** ↑
  - ***Electric field across MJ*** ↑
    - ***Barrier height (V_0 + $|V_D|$)*** ↑
  - ***Injection of holes from p to n and electrons from n to p*** ↓↓ (known as ***carrier extraction***)
    - ***Diffusion component*** ↓↓ ***while drift current remains more or less same***
  - ***Net current from n to p*** (***miniscule***!)
    - Known as ***reverse current*** (***I_D negative***)

More on Forward & Reverse Currents

- ***Injection of carriers***: Inj $\propto$ exp[– BH/V_T)
  - BH: ***Barrier Height***
  - V_T (= kT/q): ***Thermal Voltage*** [26 mV at room temperature (300 K)]
- ***Under equilibrium***:
  - Inj $\propto$ exp(–V_0/V_T)
  - ***Exactly balanced by the opposing drift component*** $\Rightarrow$ ***net current = 0***

- ***Under forward bias***:
  - ***BH reduces to $(V_0 - V_D)$***
  - ***Inj that creates current flow*** $\propto \exp(V_D/V_T)$
  - Note the ***exponential dependence***
    - ***Possibility of large injection for large V_D***
  - ***Drift component remains more or less same***, since it is ***dependent on the minority carriers***
  - ***Current increases exponentially with V_D***
  - ***V_D can never equal or exceed V_0***
    - ***Thermodynamically untenable situation***

- ***Under reverse bias***:
  - ***Inj↓↓ due to negative V_D***
  - ***Drift component remains same***
    - Function of ***minority carriers*** available on the two sides, which is a ***constant*** (***function only of temperature***)
  - ***Current becomes small and independent of bias***
- In ***forward bias***, ***both injection components*** create ***current from p to n***
- In ***reverse bias***, ***both minority carrier drift components*** create ***current from n to p***

Current-Voltage Characteristic

- $I_D = I_0[\exp(V_D/V_T) - 1]$
  - I_0: ***Reverse Saturation Current*** (~ nA-fA)
- In ***equilibrium***: $V_D = 0 \Rightarrow I_D = 0$
- Under ***forward bias***: ***V_D positive***
  - I_D ***positive*** (***flows from p to n***) (~ mA)
  - For $V_D > 4V_T$ (~ 100 mV at 300 K):
    - $I_D \approx I_0[\exp(V_D/V_T)]$ (***A True Exponent***)

- Under ***reverse bias***: ***V_D negative***
  - I_D ***negative*** (***flows from n to p***)
  - For $|V_D| > 4V_T$:
    - $I_D \approx -I_0$ (note the ***negative sign***)
    - ***Extremely small***, almost negligible
- ***Depending on V_D, the ratio of the forward current to the reverse current can range from 5 to 14 orders of magnitude***!
- ***Primary applications***:
  - ***Rectification*** and various types of ***waveshaping***

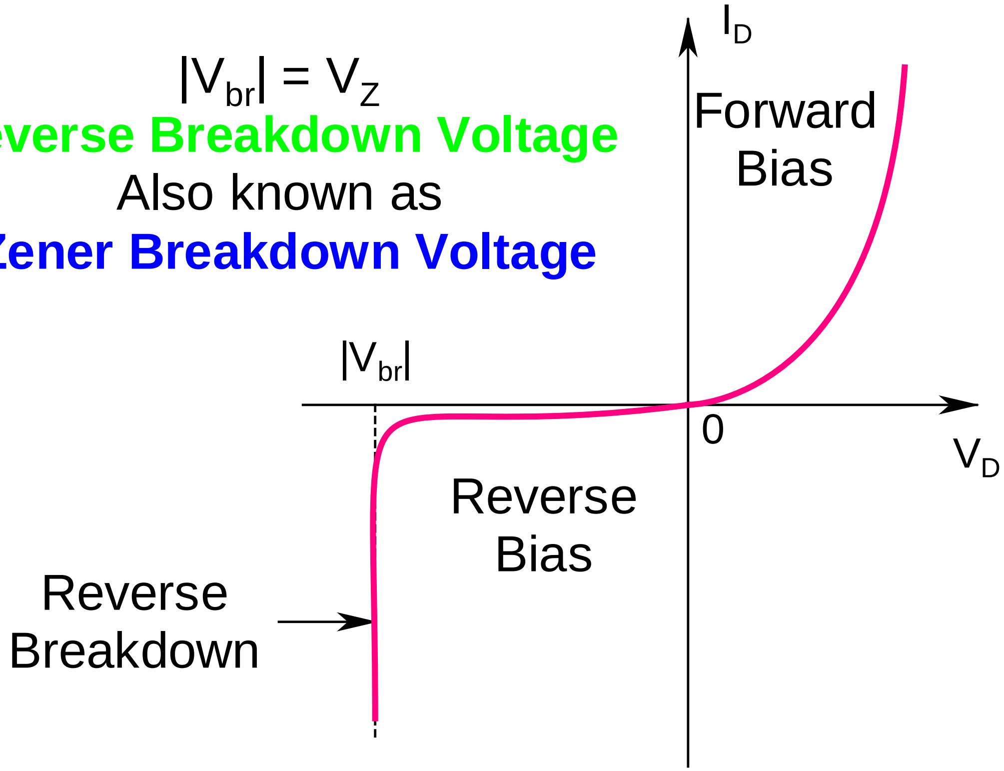
Complete I-V Characteristic

$|V_{br}| = V_Z$

Reverse Breakdown Voltage

Also known as

Zener Breakdown Voltage



Note that the forward and reverse current scales are not same