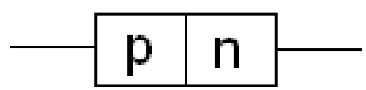
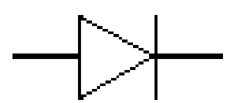
Diodes

Semiconductor Diode

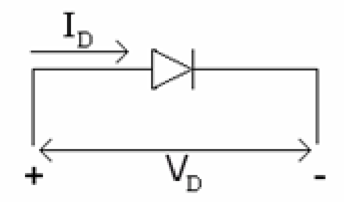
The semiconductor diode is formed by bringing p and n-type materials together (constructed from the same base – Ge or Si)



Anode  Cathode

Diode Symbol

Diode equation



$$I_D = I_s(e^{V_D/nV_T} - 1)$$

where I_s is the reverse saturation current

V_D is the applied forward-bias voltage across the diode

n is an ideality factor which is a function of operating conditions and physical construction; it has a range between 1 &2.

(n=1 will be assumed unless otherwise noted)

$$\mathrm{V_T} = \frac{kT}{q}$$

k is Boltzman constant=1.38×10^{-23} J/K

T is the absolute temperature in Kelvins

q is the electronic charge=$1.6 \times 10^{-19} C$

$V_T \approx 26$ mV at room temperature

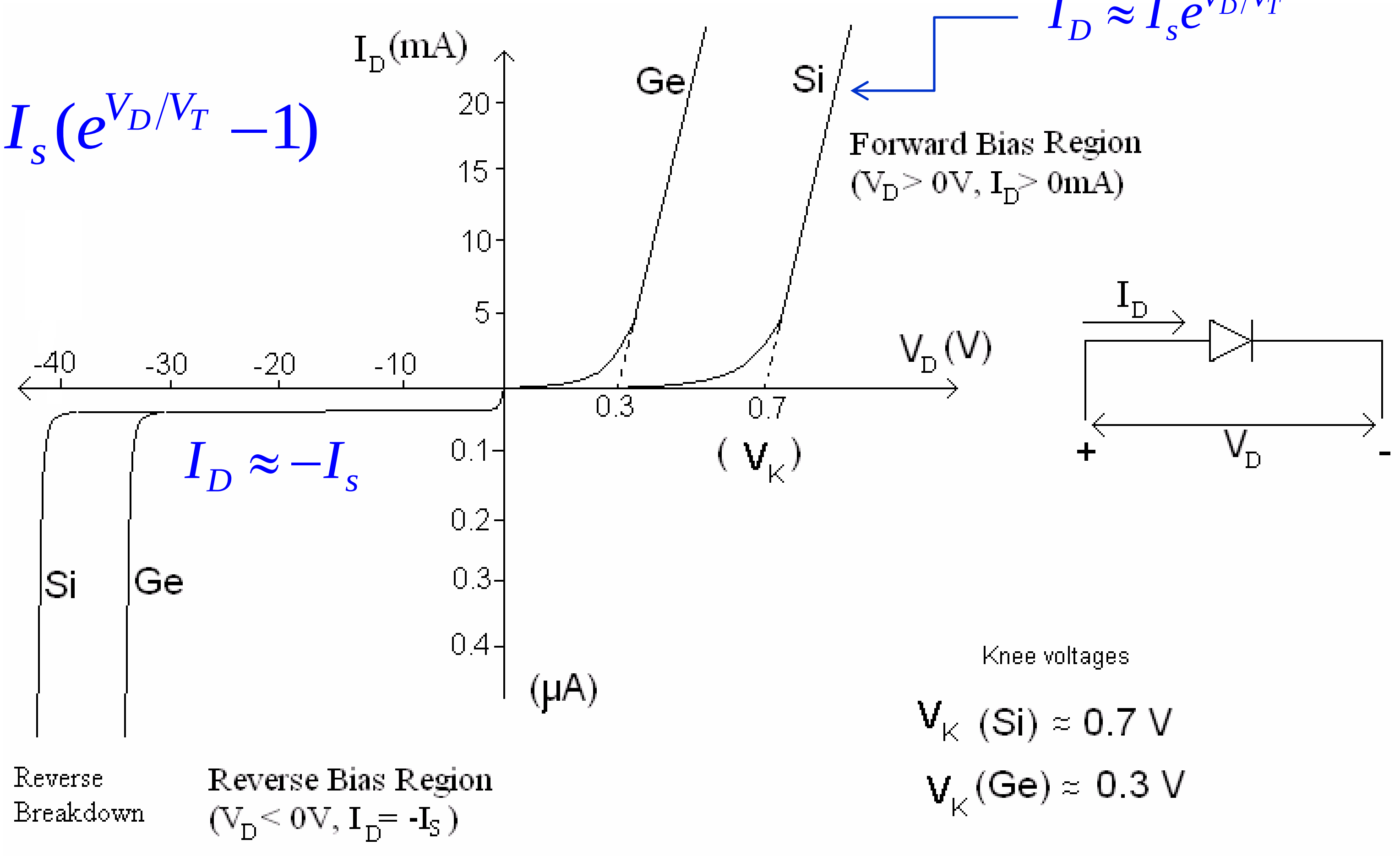
For $V_D > 0$, $I_D \approx I_s e^{V_D/nV_T}$ and for $V_D < 0$, $I_D = -I_s$

V-I characteristic of Diode

$$I_D = I_s(e^{V_D/V_T} - 1)$$

$$I_D \approx I_s e^{V_D/V_T}$$

$$I_D \approx -I_s$$



Temperature Effect

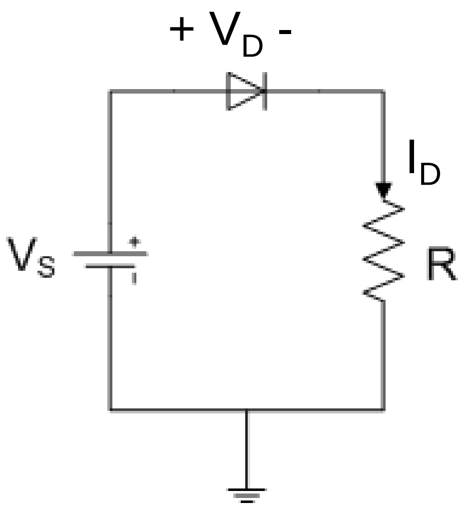
The reverse saturation current I_s approximately doubles for every 10^oC rise in temperature.

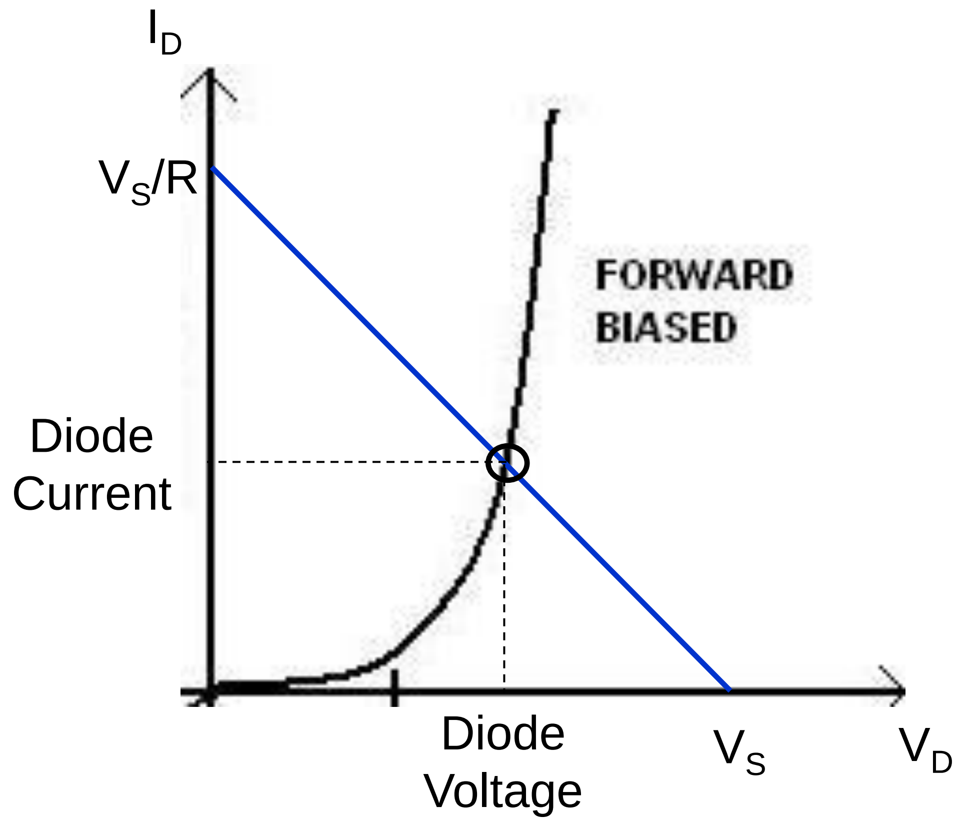
If $I_s = I_{s1}$ at $T = T_1$, then at temperature T_2, I_{s2} is given by,

$$I_{s2} = I_{s1} x\ 2^{(T2 - T1)/10}$$

PIV (Peak Inverse Voltage Rating)

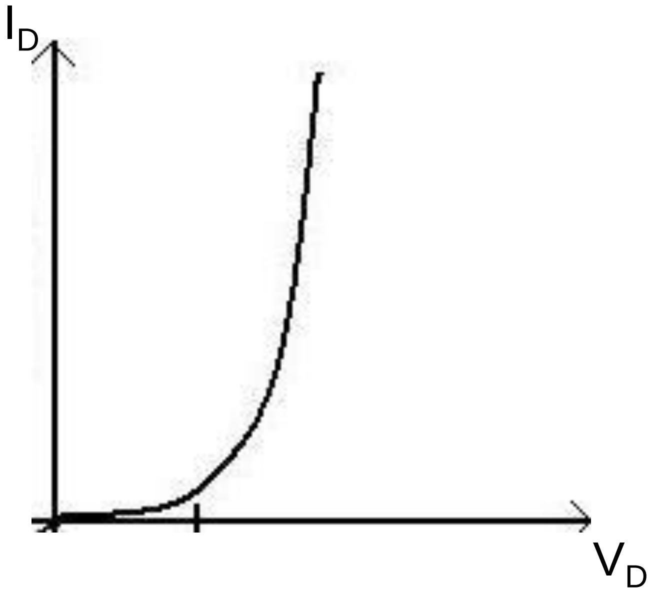
The maximum reverse-bias potential that can be applied to the diode without damaging it or causing it to break down.

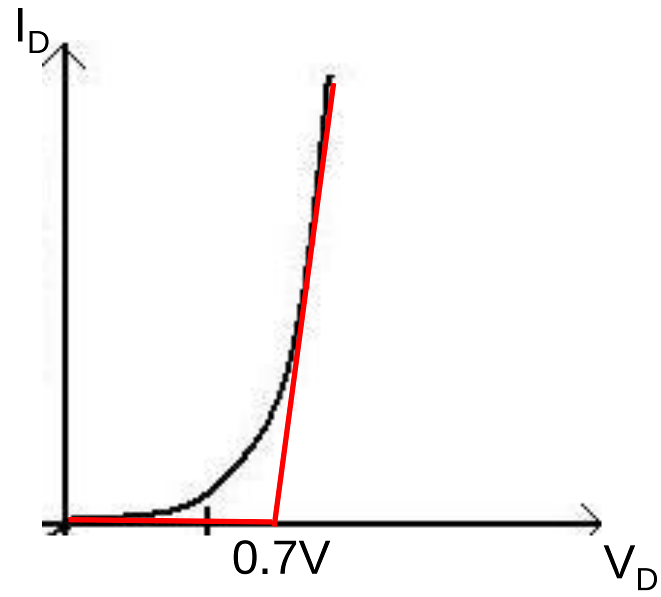


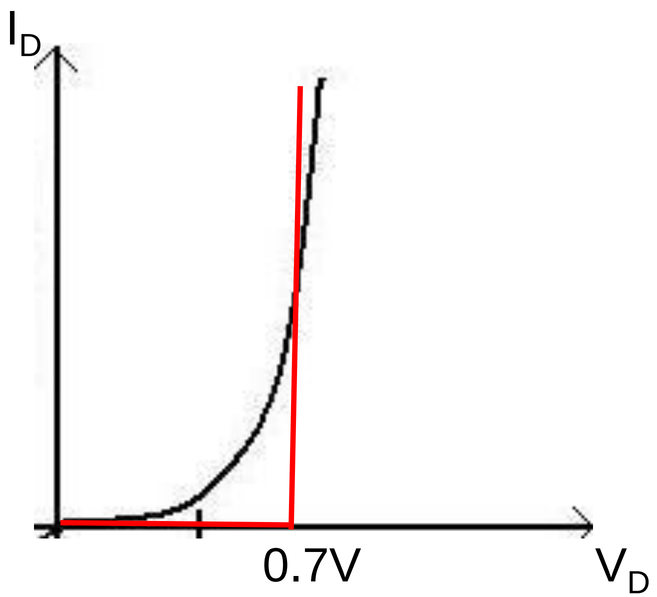


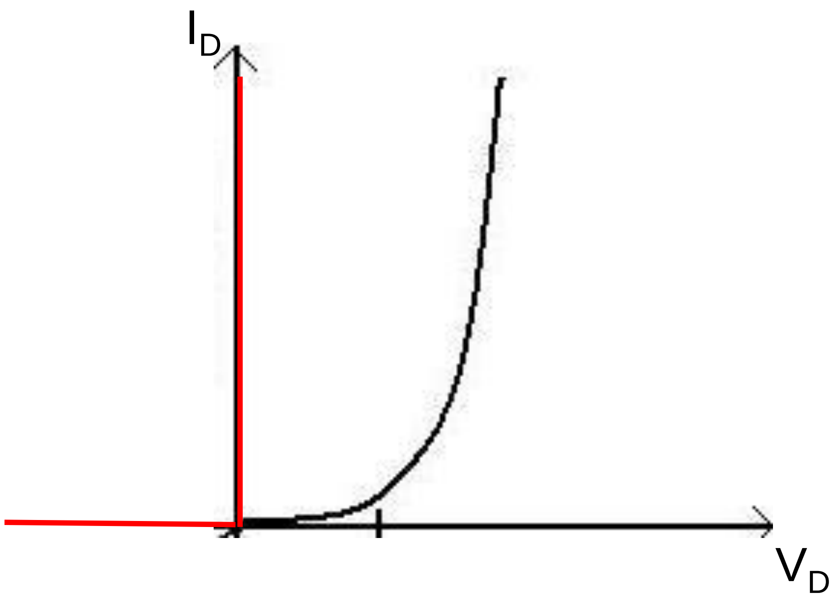
$$I_D = \frac{V_S - V_D}{R}$$

$$I_D = \left(-\frac{1}{R}\right)V_D + \left(\frac{V_S}{R}\right)$$


I_D
V_D

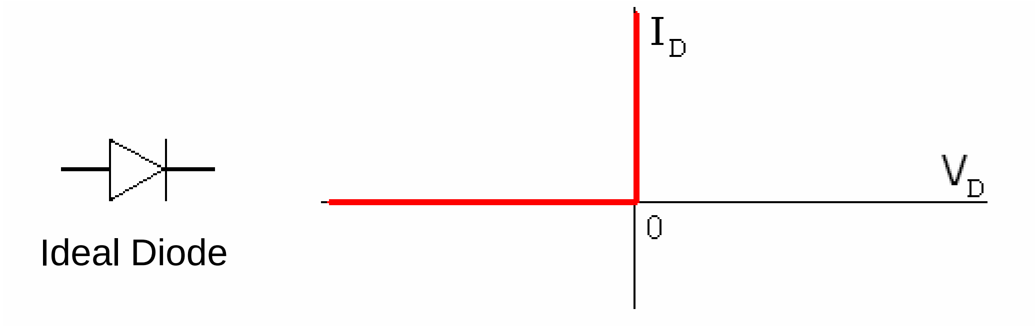

I_D
0.7V
V_D


I_D
0.7V
V_D

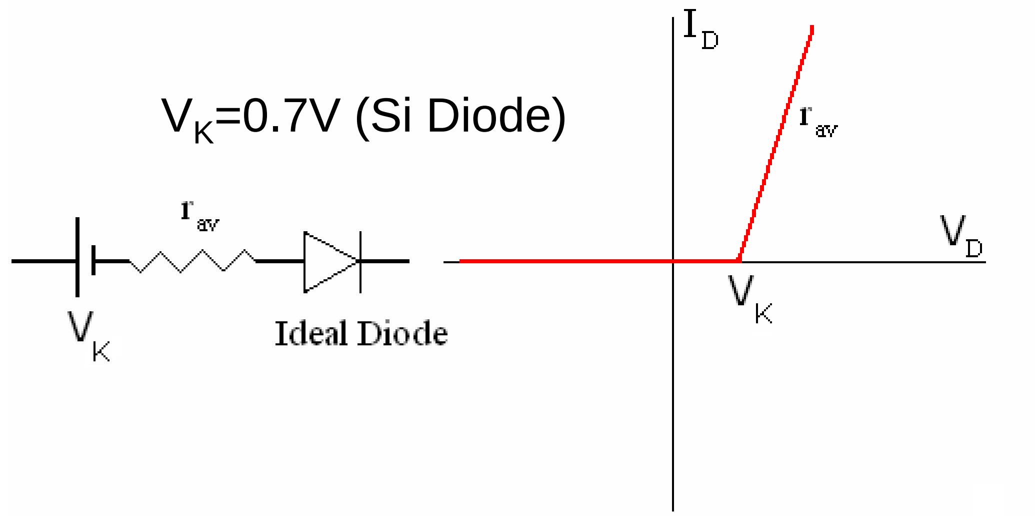

I_D
V_D

Diode Equivalent Circuit

Ideal Diode:



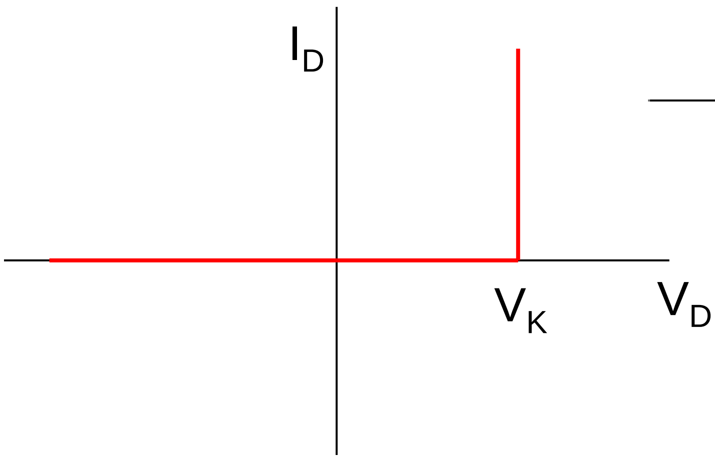
Piecewise Linear Model

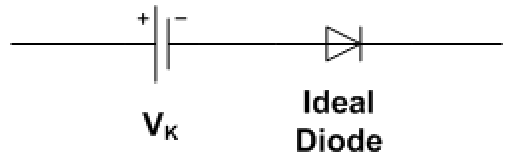


Diode Equivalent Circuit

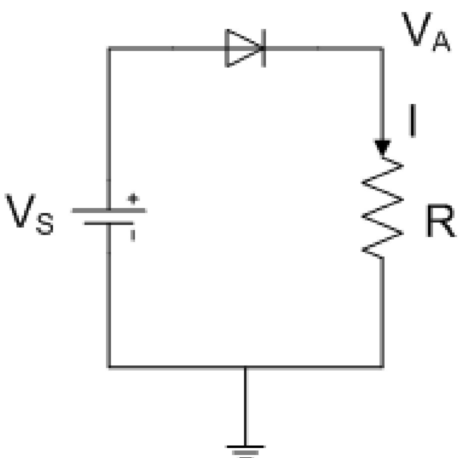
Simple Diode Model Typically Used

Use this for your circuit analysis





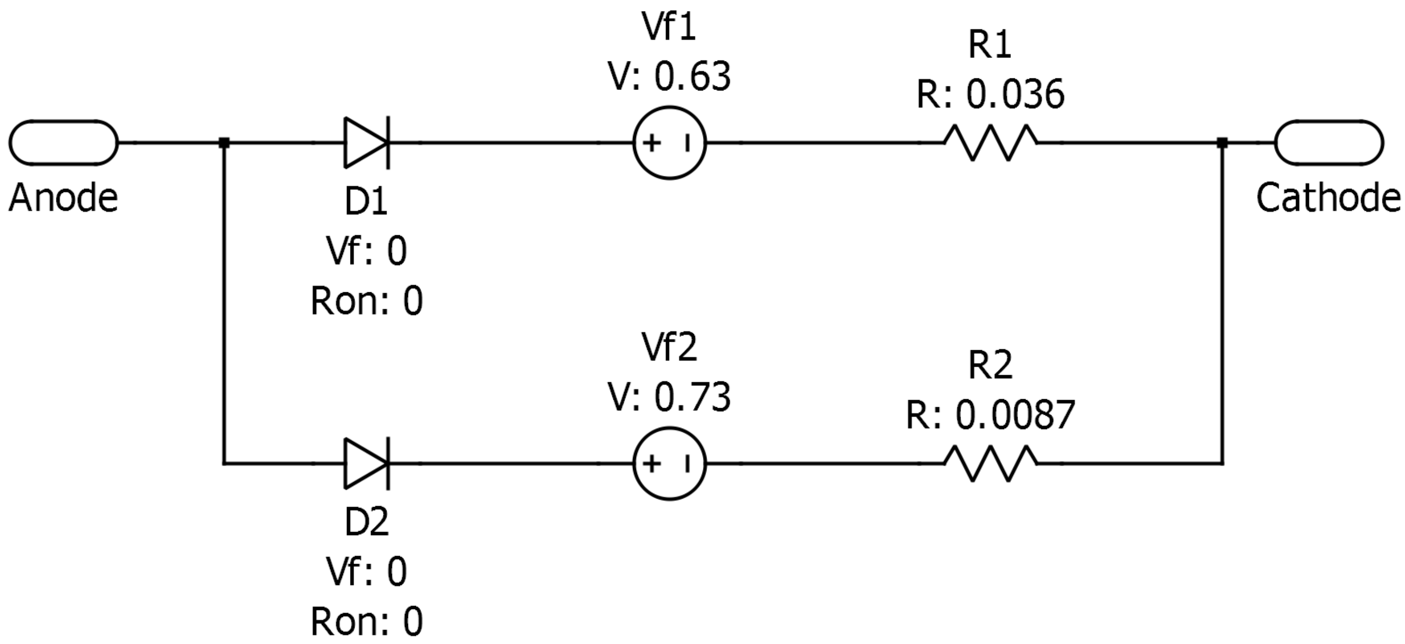
V_K=0.7 V for Si
V_K=0.3 V for Ge



$V_S<V_K$	$I=0$	and	$V_A=0$
$V_S>V_K$	$I=(V_S-V_K)/R$	and	$V_A= V_S-V_K$

V_K=0.7V (Si Diode)

A more complicated model for a diode (Do not use this for your circuit analysis)

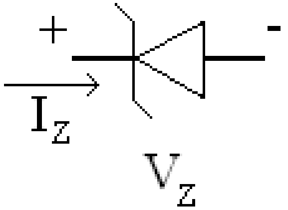


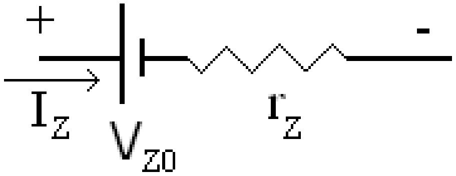
Follows the actual diode characteristics better

Zener Diode

Zener diodes are special diodes manufactured with adequate power dissipation capabilities to operate in the breakdown region.

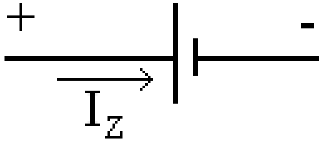
Symbol:





$$V_Z = V_{Z0} + I_Z r_Z$$

Equivalent ckt.

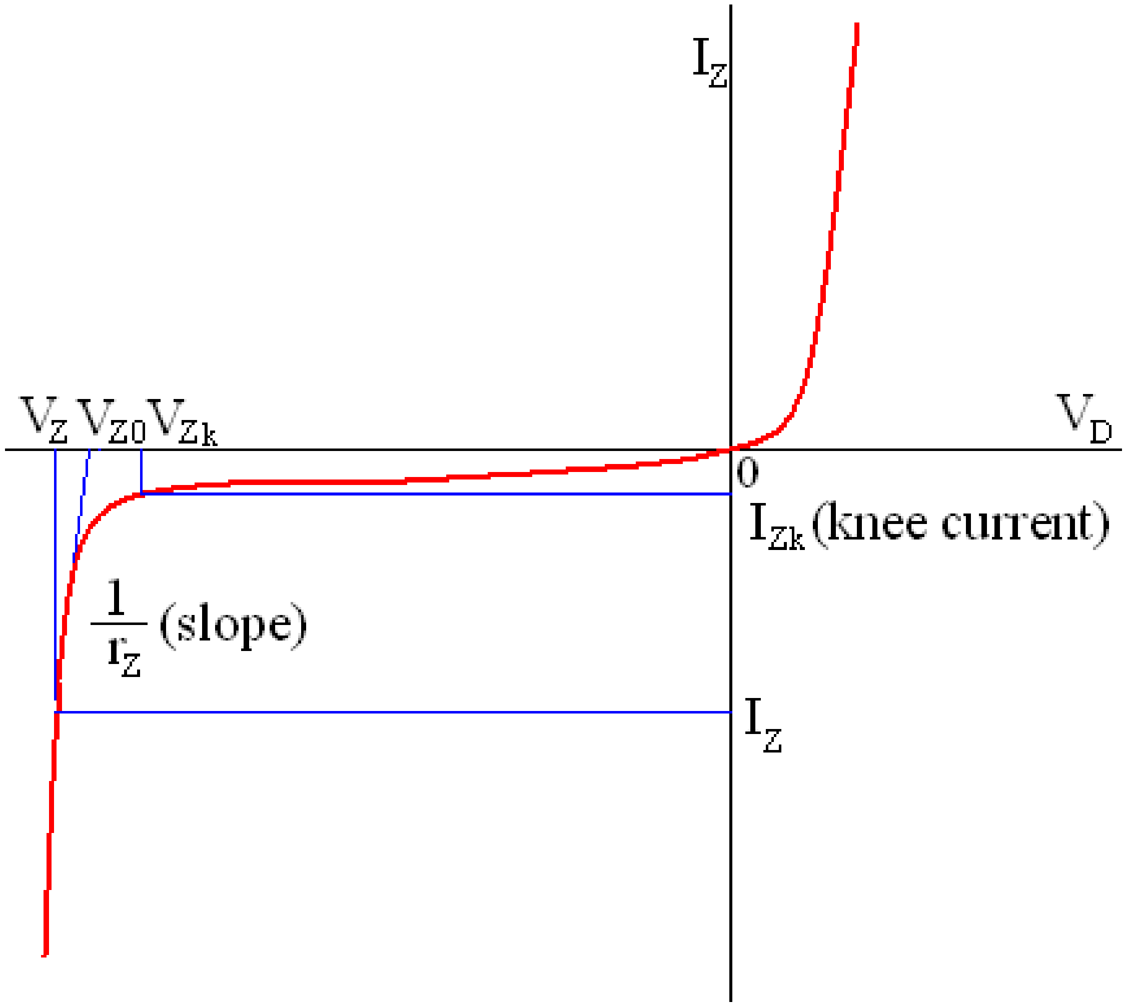


$$V_Z = V_{Z0}$$

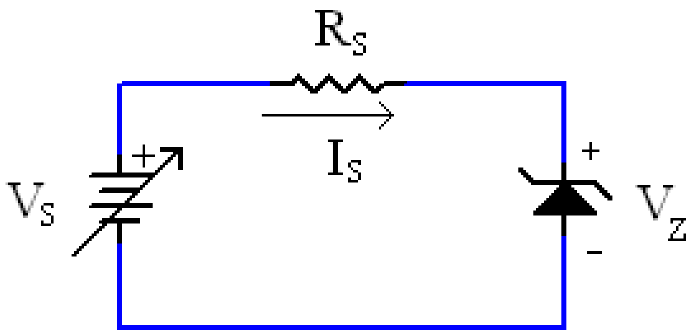
($I_Z r_Z$ is ignored)

Approx. Eq. ckt.

V-I Characteristics of Zener Diode



Zener Regulator

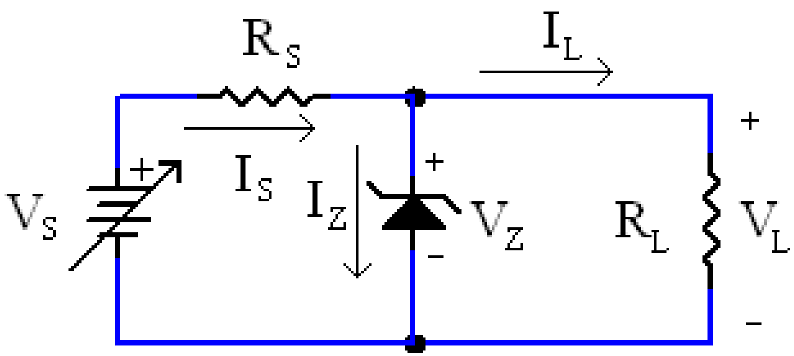


- $V_s > V_z$ for breakdown

- R_s is the current limiting resistance to limit the zener current to less than its maximum rating

$$I_s = (V_s - V_z)/R_s$$

Loaded Zener regulator



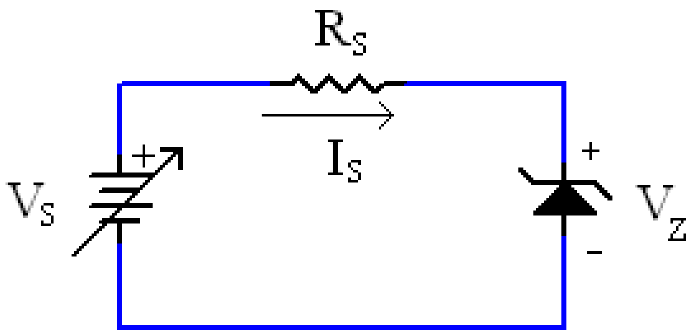
$$I_s = (V_s - V_z)/R_s, \quad I_s = I_z + I_L$$

V_{th} = voltage across zener when it is not in breakdown
$= V_s \times R_L/(R_s+R_L)$

For breakdown, $V_{th} > V_z$

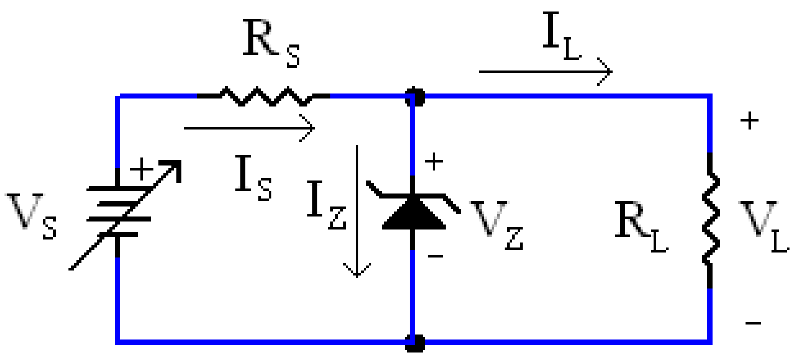
$I_L = V_L/R_L = V_Z/R_L$
$I_z = I_s - I_L$
Power dissipated by zener diode $= V_z I_z$

Zener Regulator



Typically, for a Zener Diode, one would specify the zener voltage V_Z and the maximum power dissipation $P_{Z,max}$ in the zener diode.

Loaded Zener regulator



Additionally, we may also specify the minimum zener current $I_{Z,min}$ that must flow through the zener diode to provide the zener action

$$I_s = (V_s - V_z)/R_s, \quad I_s = I_z + I_L$$