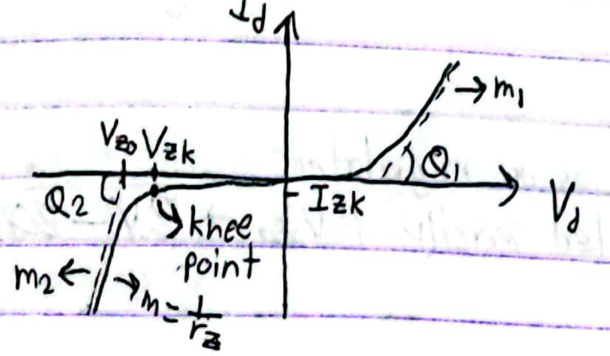
Breakdown Region:

* In reality current does flow in the opposite direction of a diode but it is really small i.e. $10^{-9} \sim 10^{-12}$ A
* At a certain negative voltage, current starts to flow through a diode just like it does when the diode is on this ~~voltage~~ voltage is known as Breakdown region.



$Q_2 > Q_1$

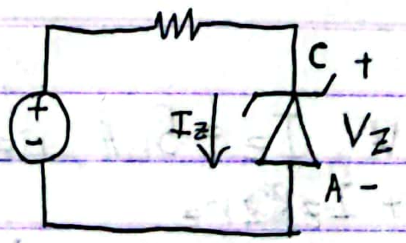
$\tan Q_2 > \tan Q_1$

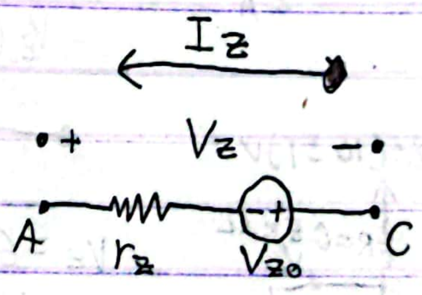
$m_2 > m_1$

$\frac{1}{r_2} > \frac{1}{r_1}$

$r_2 < r_1$

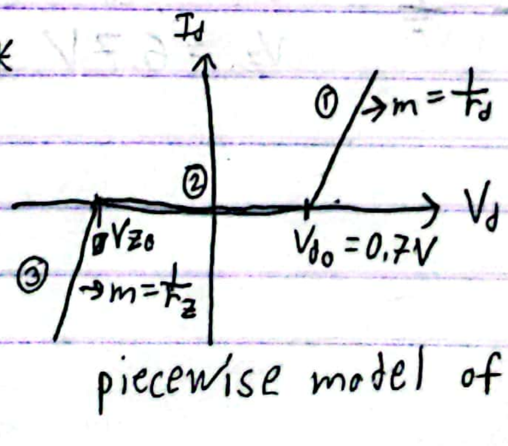
* Normal diodes ~~are~~ become unusable if it goes to breakdown region once.
* ~~Zenar~~ Zener diodes can be used in the breakdown region.
* These diodes are better regulators because the value of r is smaller as $r_2 < r_1$.
* Zener diode symbol,



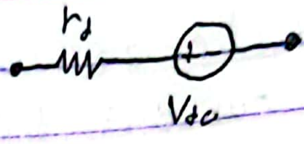


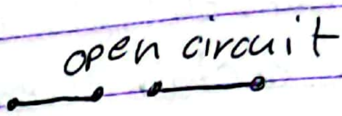
$$\boxed{V_z = V_{z0} + I_z r_z}$$

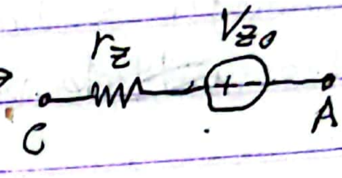
*



piecewise model of zener diode

- region - ① : $I_d > 0 \rightarrow$ ON $\rightarrow$ 

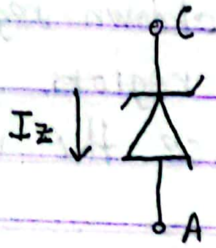
- region - ② : $-I_{ZK} \leq I_d < 0 \rightarrow$ OFF $\rightarrow$ 

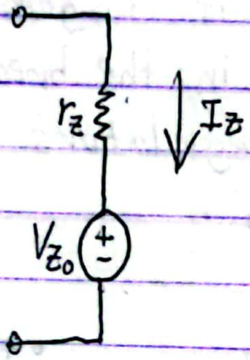
- region - ③ : $I_d < -I_{ZK} \rightarrow$ Breakdown Region $\rightarrow$ 

* Why use zener diode :

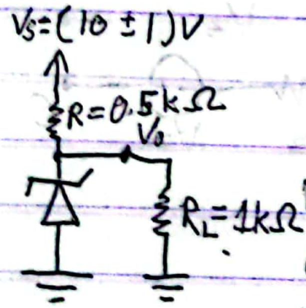
- $r_Z < r_d \rightarrow$ works better as a regulator
- V_{Z0} can be controlled easily ($V_{Z0} \rightarrow 2V - 200V$)

* Example:





$I_Z > I_{ZK}$



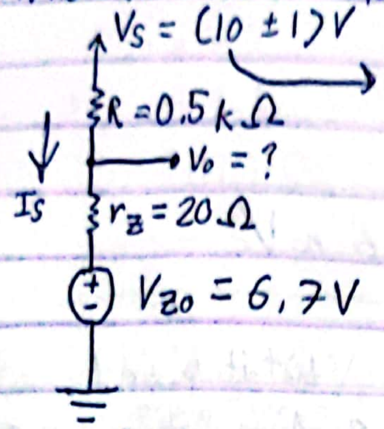
$V_Z = 6.8V$, $I_Z = 5mA$, $r_Z = 20\Omega$, $I_{ZK} = 0.2mA$

$V_Z = V_{Z0} + I_Z r_Z$

$6.8 = V_{Z0} + (5 \times 10^{-3} \times 20)$

$V_{Z0} = 6.7V$

① Find V_o with no load and V_s at it's nominal value.



$$I_s = \frac{10-6.7}{500+20} = 6.34 \times 10^{-3} A$$
$$= 6.34 \, mA$$

$I_{ZK} = 0.2 mA$ (I_s should be greater than I_{ZK})

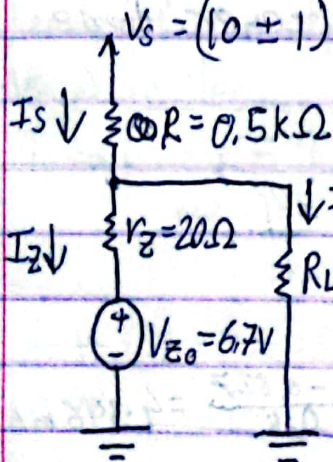
$$V_o = V_{Z0} + I_s r_z$$
$$= 6.7 + 6.34 \times 10^{-3} \times 20$$
$$= 6.827 V$$

② $\pm 1V$ change in $V_s \rightarrow \Delta V_o = ?$

$$\frac{\Delta V_o}{\Delta V_s} = \frac{r_z}{R + r_z} = \frac{20}{500+20} = \frac{2}{52} = 0.038 \; V/V = 38 \, mV/V$$

$\Delta V_o = \Delta V_s \times 38 \; mV/V = \pm 38 \, mV/V$ (~~Load~~ Line regulation)

③



$$V_o = 6.827 V$$
$$I_L = \frac{V_o}{R_L}$$
$$= \frac{6.827}{2000}$$
$$= 3.413 \, mA$$

~~Line~~ Load Regulation $\rightarrow \frac{\Delta V_o}{\Delta I_L} = \frac{-R r_z}{R + r_z} = \frac{-500 \times 20}{500 + 20}$

$$\frac{\Delta V_o}{\Delta I_L} = -19.27 \; V/A = -19.23 \; mV/mA$$

$$\Delta V_o = 3.413 \times -19.23 = -65.632 \; mV$$

(4) $R_L = 0.5\,k\Omega$

$I_L = \frac{V_o}{R_L} = \frac{6.827}{0.5} = 13.654\ mA$

$\Delta I_L = 13.654\ mA$

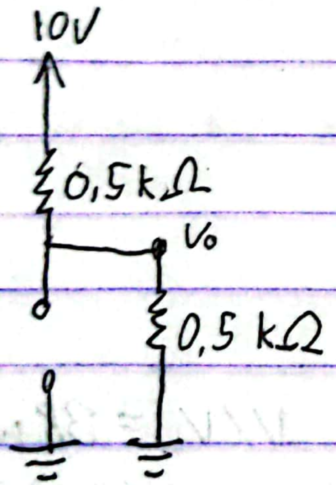
$\frac{\Delta V_o}{\Delta I_L} = -19.23\ mV/mA$

$\Delta V_o = 13.654 \times -19.23 = 262.566\ mV$

$I_S = I_Z + I_L$

$6.36 = I_Z + 13.654$

$I_Z = -7.35\ mA$ [$I_Z > I_{ZK} = 0.2mA$ but it is not, so the zener diode will be off]



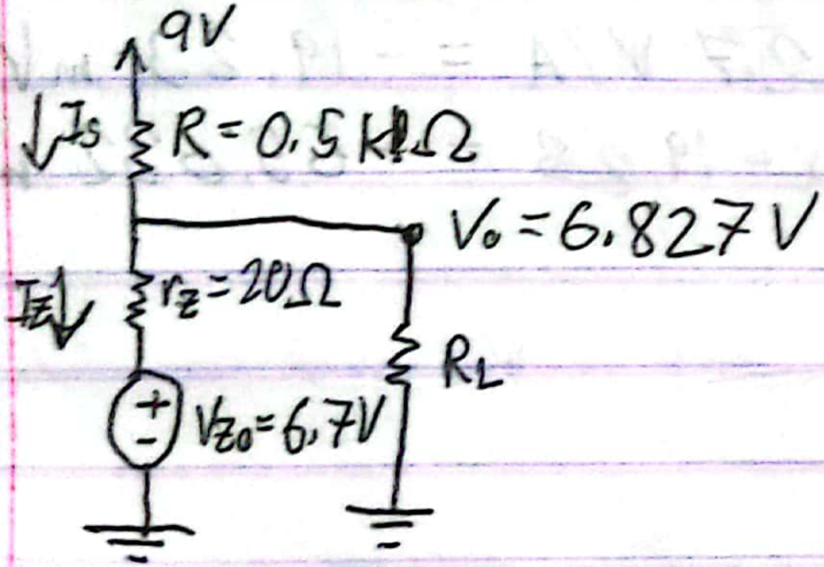
$V_o = 10 \times \frac{0.5}{0.5+0.5}$

$V_o = 5V$

* Load resistance should be kept big for zener diode to work.

(5) Minimum possible Load resistance value = ?

- $V_s \rightarrow$ min
- $I_Z = I_{ZK}$



$I_s = \cancel{6.34\,mA}\ \frac{9-6.827}{0.5} = 4.346\,mA$

$I_s = I_Z + I_L$

$I_L = \cancel{6.34}^{\,4.346} - 0.2 = \cancel{6.14}^{\,4.146}\,mA$

$R_L = \frac{V_o}{I_L} = \frac{6.827}{4.146} = 1.6466\,k\Omega$

* ~~II~~ The output voltage (V_o) is constant because zener diode's purpose is to give a constant output voltage.