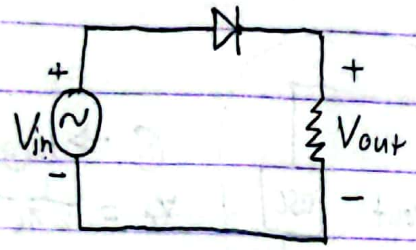
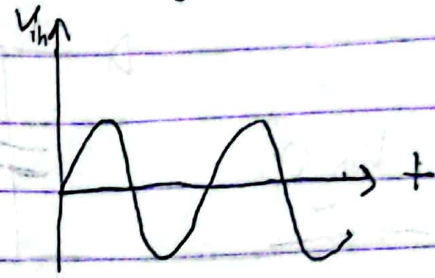
Rectifiers:

* It is a circuit that converts AC to DC.
* All electronic devices operates on DC current but current from the power ~~supl~~ supply is AC so here rectifiers are used to convert AC to DC.
* High voltage DC is more efficient than ~~low~~ high voltage ~~DC~~ AC.

W-5(L-9)(V-2)

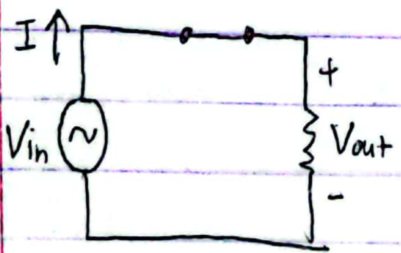


Waveform graph of V_{in},



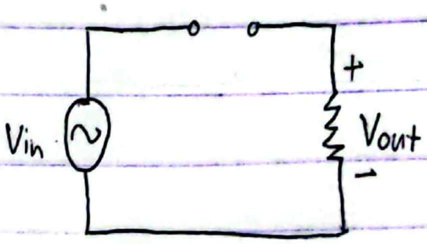
* Halfwave rectifier

For +ve cycle,

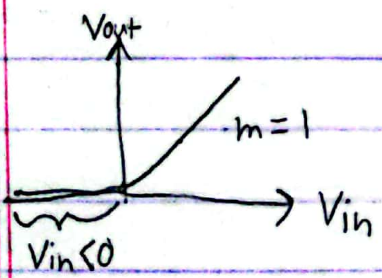


$V_{in} = V_{out}$

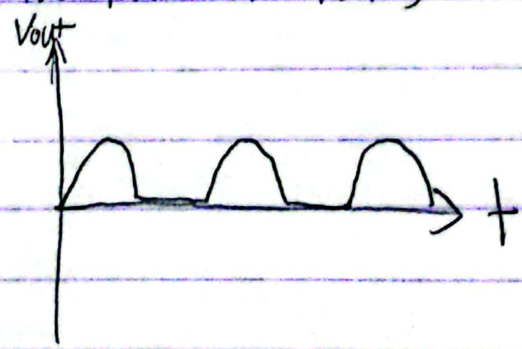
For -ve cycle,



$V_{out} = 0$



Wave form of V_{out},

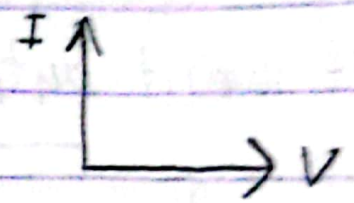


* There is no power loss in halfwave rectifier, as current is 0 during negative cycle.

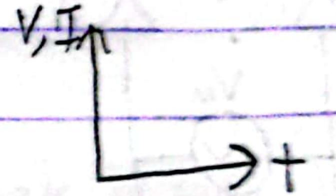
Types of Graphs for this course:

1. IV Graphs / IV - Characteristics

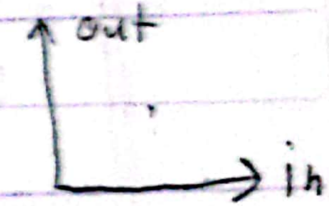
- We do it for devices



2. Waveform Graphs (V or I vs t)



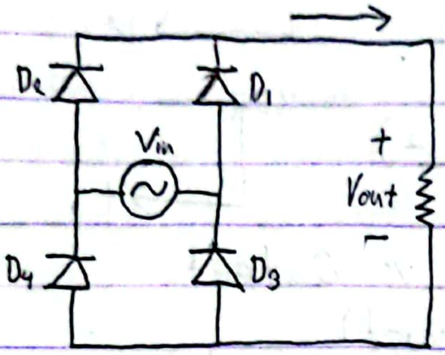
3. Transfer Characteristics (Input vs Output)



- ~~I~~ We do it for circuits (2-port)
- (2-port) means comparision between out and In ~~B~~ quantit~~y~~ies.
- V_{out} Vs V_{in} is called Voltage transfer characteristics (VTC).
- I_{out} Vs I_{in} " " Current " " (CTC).
- V_{out} Vs I_{in} and I_{out} Vs V_{in} is just called TC.

Full Wave Rectifiers:

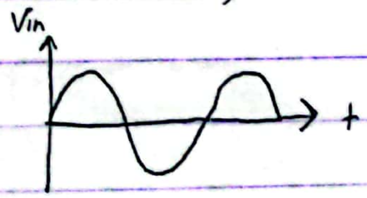
* We don't want output to have 2 polarities.



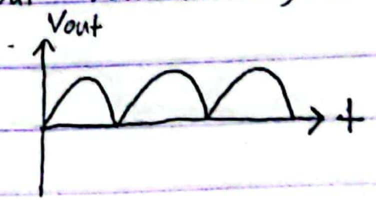
• No matter what cycle (+ve or −ve) it is current will flow in 1 direction only.

* If −(~)+ then, current will go through D_1 and return through D_4.
* If +(~)− then, current will go through D_2 and return through D_3.

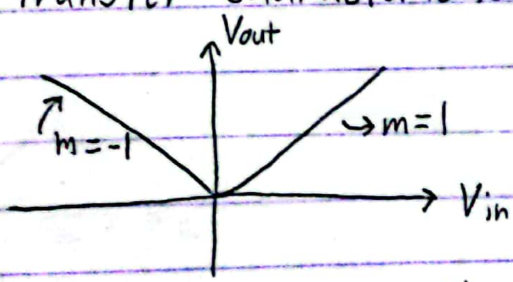
* V_{in} waveform,



* V_{out} waveform,



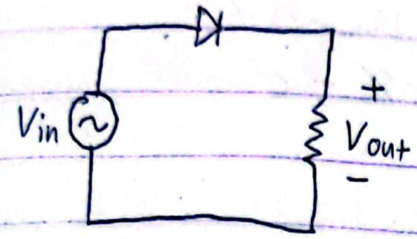
* Full wave Rectifier also called Bridge Rectifier.
* Voltage Transfer Characteristics (VTC),



* Here all diodes ~~as~~ are considered ideal.

Rectifiers with Real Diodes:

* Half wave rectifiers:

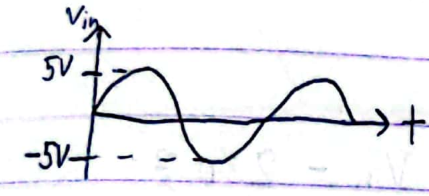


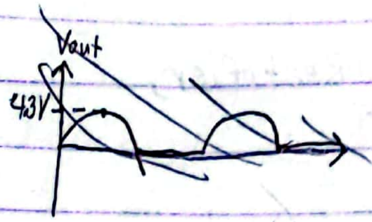
$I_D = I_S(e^{V_D/V_T} - 1)$

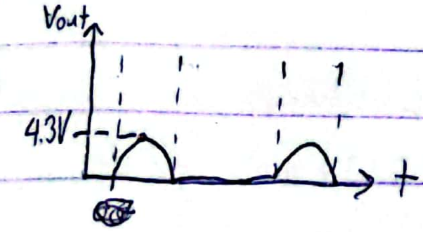
↓

CVD model (0.7V)

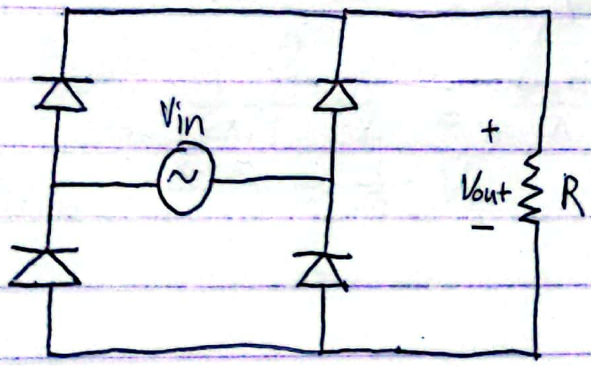
• Peak Voltage, $V_P = V_{in} - 0.7V$



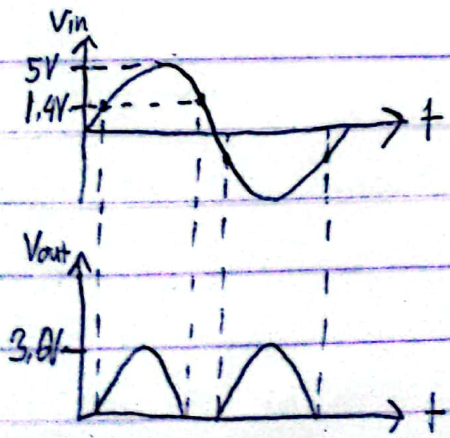




* Full wave rectifiers:



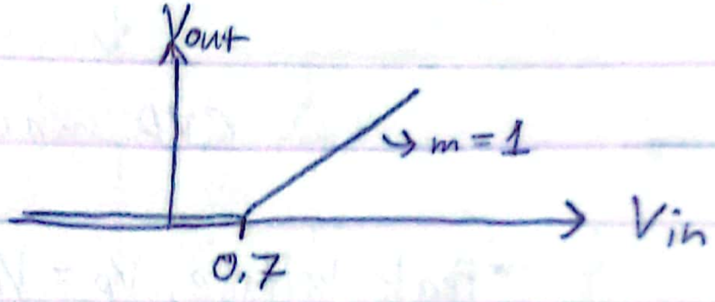
• It will turn ON when $V_{in} \geq 2 \times 0.7 = 1.4V$. Because 2 diode are ON in each cycle.



• Peak Voltage, $V_P = V_{in} - 2 \times 0.7$
$= V_{in} - 1.4V$

Transfer Characteristics with Real Diodes:

* Half Wave Rectifier,

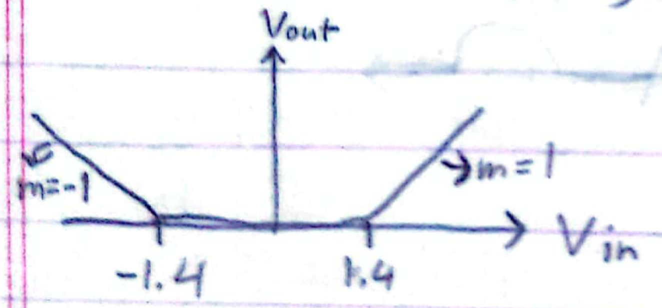


V_p $\qquad$ V_m

$$V_{out} = V_{in} - 0.7$$

$$y = x - c$$

* Full Wave Rectifier,



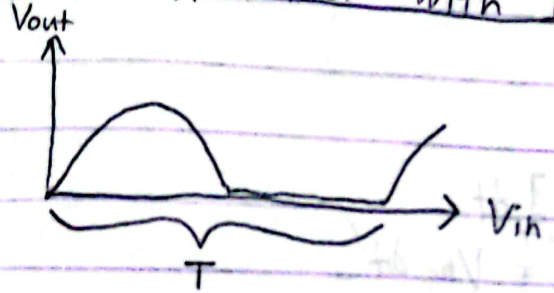
V_{D0}

$$V_{out} = V_{in} - 2 \times 0.7$$

* Average Value/DC Value of a periodic signal is the area divided by time period.

$$V_{Avg} = \frac{1}{T}\int_0^T V(t)\,dt \quad , \; T = \text{Time period.}$$

* <u>Half Wave Rectifier with Ideal diode:</u>

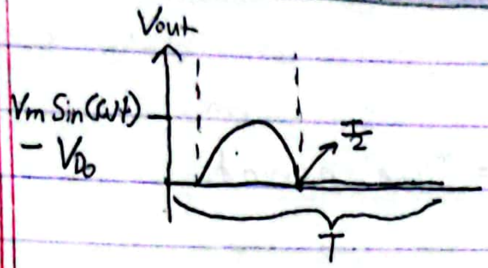


$$V_{in} = V_{max}\,\sin(\omega t)$$
$$= V_{max}\,\sin(2\pi f t)$$

$$\text{Area} = \int_0^T V_{out}(t)\,dt$$
$$= \int_0^{T/2} V_{out}(t)\,dt + \int_{T/2}^{T} \cancel{V_{out}}(t)\,dt$$
$$= \int_0^{T/2} V_m \sin(\omega t)\,dt$$
$$= \left[-V_m \frac{\cos \omega t}{\omega}\right]_0^{T/2} \quad , \; \omega = \frac{2\pi}{T}$$
$$= V_m \cdot \frac{1}{\omega}\left[-\cos\left(\frac{\omega T}{2}\right) + \cos(0)\right] \quad , \; \frac{\omega T}{2} = \pi \; , \; \cos \pi = -1$$
$$= V_m \cdot \frac{1}{\omega} \cdot 2$$
$$= V_m \cdot \frac{1}{2\pi/T} \cdot 2 = \frac{V_m T}{\pi}$$

$$\therefore \; V_{Avg} = \frac{\text{Area}}{T} = \frac{1}{\pi} V_m$$

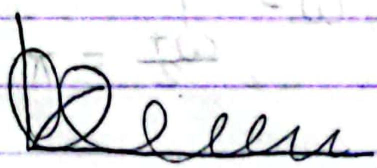
* Half wave rectifier with Real diode:

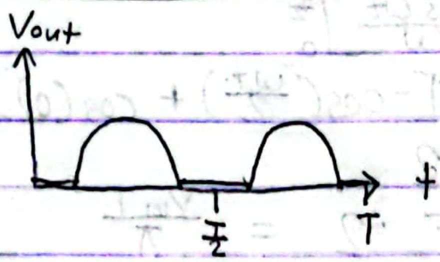


V_{D0} = diode activation voltage (0.7V)

$$V_{Avg} = \frac{1}{T}\int_0^T V_{out}(t)\,dt$$
$$= \frac{1}{T}\int_0^{T/2} V_{out}(t)\,dt$$
$$= \frac{1}{T}\int_0^{T/2} [V_m \sin(\omega t) - V_{D0}]\,dt$$
$$= \frac{1}{T}\left[\int_0^{T/2} V_m \sin(\omega t) - \int_{T/2}^{T} V_{D0}\,dt\right.$$
$$= \frac{1}{T}\left[\frac{T}{\pi}V_m - V_{D0}\frac{T}{2}\right]$$
$$= \frac{1}{\pi}V_m - \frac{1}{2}V_{D0}$$

* Full wave rectifier with Real Diode:

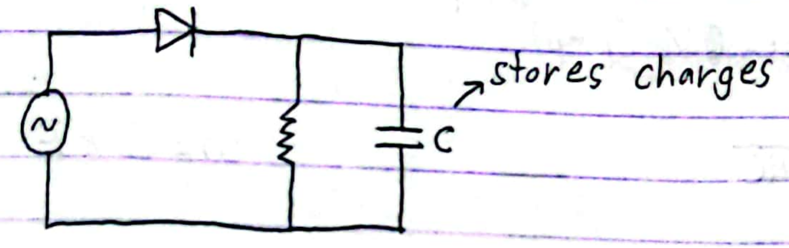


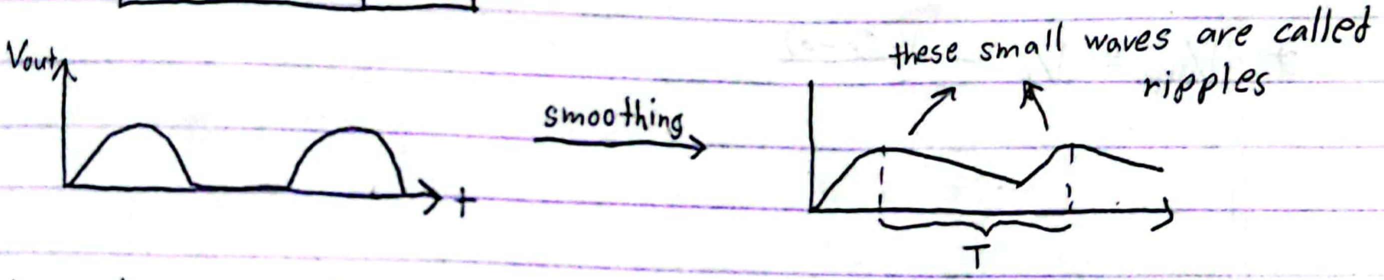


$$V_{out}(t) = V_m \sin(\omega t) - 2V_{D0}$$
$$\text{Area} = \int_0^T V_{out}(t)\,dt$$
$$= 2\int_0^{T/2} V_{out}(t)\,dt$$
$$= 2\int_0^{T/2} [V_m \sin(\omega t) - 2V_{D0}]\,dt$$
$$= 2\left[\frac{T}{\pi}V_m - 2V_{D0}\cdot\frac{T}{2}\right]$$
$$\therefore V_{Avg} = \frac{\text{Area}}{T}$$
$$= \frac{2}{\pi}V_m - 2V_{D0}$$

* $V_{Avg} = \frac{2}{\pi}V_m$, for FWR with Ideal Diode.

* Rectifiers convert a AC signal to Pulsating DC Signal.
* But we need to smooth these pulsating signal in order to make them actual DC current and it is done using a capacitor.





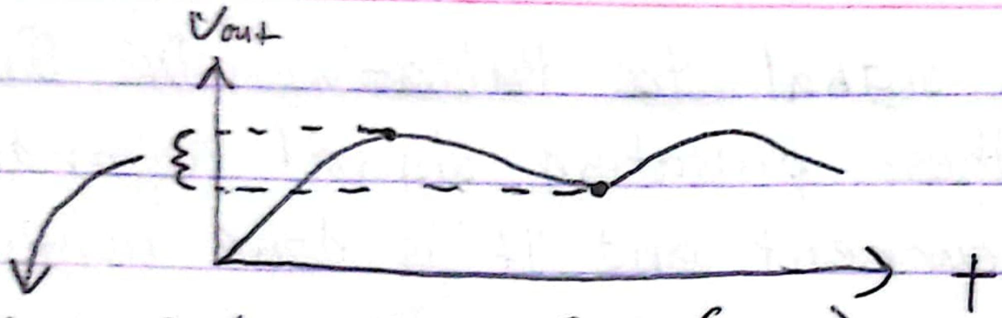
* Higher the capacitance of the capacitor more ~~of~~ smoothing will occur (higher capacitance will discharge more slowly).

W-5 (L-10)(V-3)

* Time period of the ripple (T_r) is equal to the time period of the signal (T_s), $T_r = T_s$, $\therefore f_r = f_s = \frac{1}{T_s}$, for half wave rectifier.

* For Full wave rectifier, $T_r = \frac{1}{2} T_s$, $\therefore f_r = 2 f_s$

*



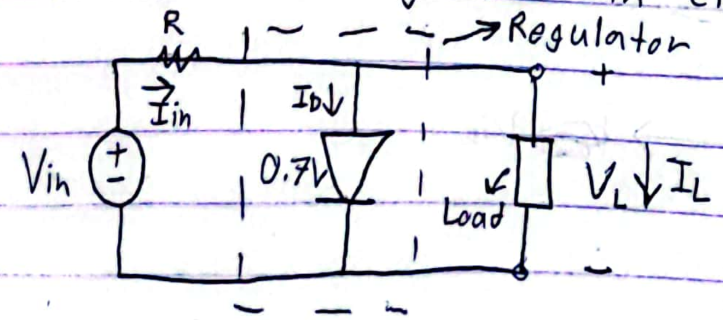
Peak to Peak Voltage, $V_r(p-p)$

* $V_r(p-p) = \frac{V_p}{f_r \times RC}$ $\omega = 2\pi f$

* $V_{avg} = V_p - \frac{V_r(p-p)}{2}$

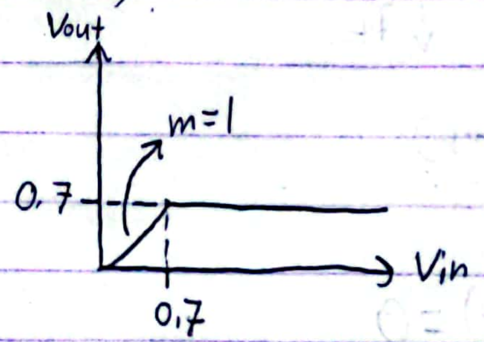
Regulators:

* It is used to further smooth the DC Voltage.
* Diode is used as regulator in circuits.



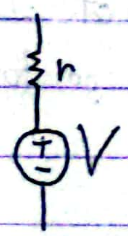
* $V_L = V_{in} - RI$

* For CVD

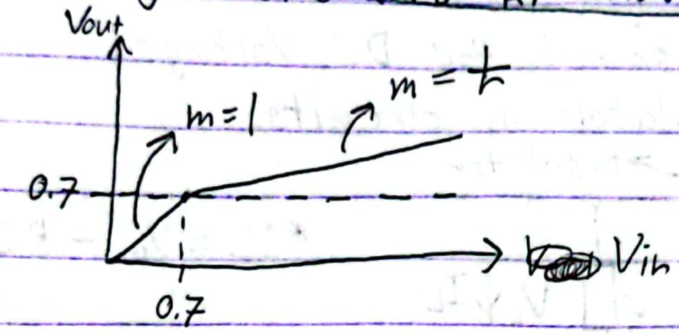


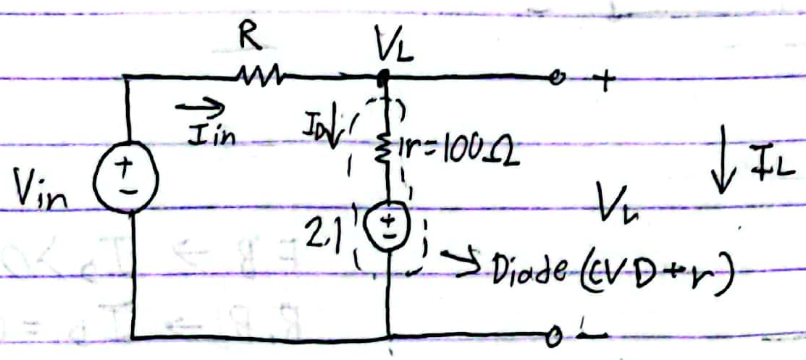
F.B → $I_D > 0$
R.B → $I_D = 0$

* The Diode needs to be in Forward Bias to act as a Voltage Regulator.
* Because if the diode is in R.B the Voltage across the load would flactuate if the Vin flactuates.
* The value of I_L needs to be low and I_D needs to be high for the diode to ~~be~~ stay in F.B.
* Vin should be high also, for the above reason.
* Multiple diodes can be connected in series to each other in order to ~~in~~ increase Voltage across the load(V_L)
* Regulator Equivalent Circuit:



Real Regulators (CVD + r model diode):





$$V_L\left(\frac{1}{R}+\frac{1}{r}\right) - V_{in}\left(\frac{1}{R}\right) - 2.1\left(\frac{1}{r}\right) = 0$$

$$V_L = \left(\frac{r}{r+R}\right)V_{in} + 2.1 \quad \text{—— (1)}$$

* From eqn-(1), It is visible that V_L depends on $\left(\frac{r}{r+R}\right)$ and V_{in}, but V_{in} is not constant so $\left(\frac{r}{r+R}\right)$ is what mainly keeps V_L constant.
* $\left(\frac{r}{r+R}\right)$ needs to be very small to maintain a constant V_L. To do this the value of r needs to be small and the value of R needs to be big.
* However, keeping R big may cause problems because it will decrease the value of I_{in} which inturn may lower I_D and the diode ~~mar~~ go to R.B.

Performance Measure:

① Line Regulation

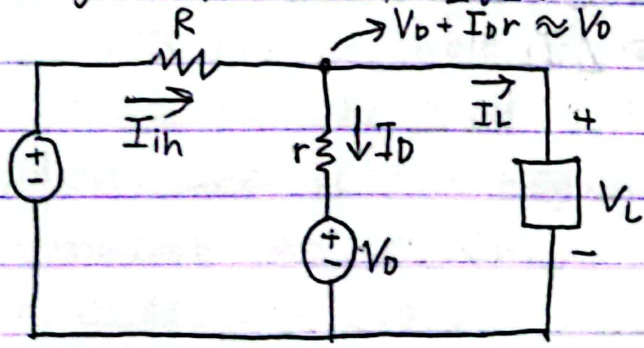
② Load "

* Line Regulation:

- It measures the change in Load Voltage (ΔV_L) if V_{in} changes by 1V.
- If the regulator is good ΔV_L would be very small.

* Load Regulation:

- It measures the change in Load Voltage ~~Current~~ (ΔV_L ~~ΔI~~) if I_L changes by 1 mA.
- Good regulator = small ΔV_L.



* For the above circuit,
* Line Regulation eqn,

$$\frac{\Delta V_L}{\Delta V_{in}} = \frac{r}{R+r}$$

* Load Regulation eqn,

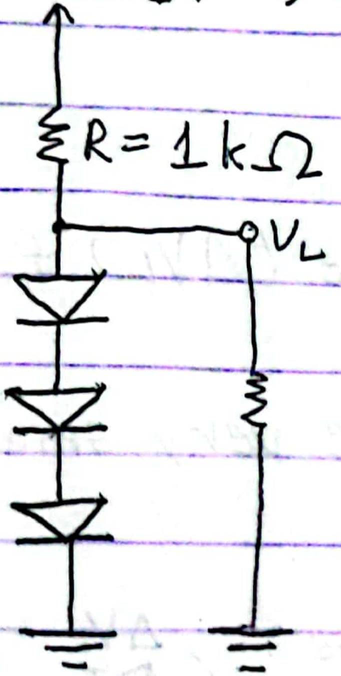
$$\frac{\Delta V_L}{\Delta I_L} = -\frac{Rr}{R+r}$$

* **Example:**

Each Diode res $= 3.2\,\Omega$, $V_D = 0.7V$

Calc Line and Load regulation.

$10 \pm 1\,V \rightarrow 9V \sim 11V$



Line Regulation,

$$\frac{\Delta V_L}{\Delta V_{in}} = \frac{r}{R+r} = \frac{3 \times 3.2}{1000 + 3 \times 3.2}$$

$$= 9.5 \times 10^{-3}$$

$$\therefore \Delta V_L = 9.5 \times 10^{-3} \times \Delta V_{in}$$

$$I_L = \frac{V_L}{R_L} = \frac{2.1}{1000} = \Delta I_L = 2.1\,mA$$

Load Regulation,

$$\frac{\Delta V_L}{\Delta I_L} = -\frac{Rr}{R+r} = \frac{-1000 \times 3 \times 3.3}{1000 + 3 \times 3.3} = -9.51$$

$$\therefore \Delta V_L = -9.51 \times \Delta I_L$$