Rectifiers :
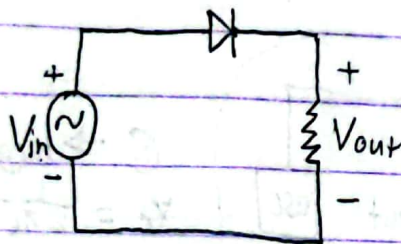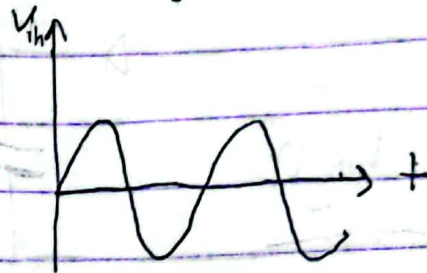
* "It is a circuit that converts AC to DC.
* All electronic devices operates on DC current but current from the power supl supply is AC so here rectifiers are used to convert AC to DC.
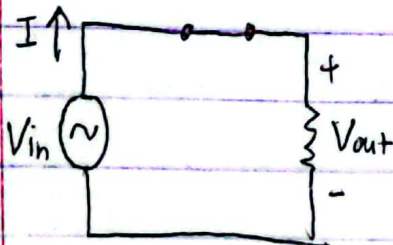* High voltage DC is more efficient than ~~low~~ high voltage DC. AC.
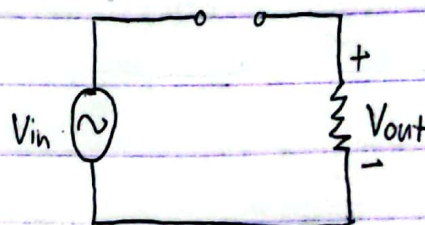
W-5(L-9)(V-2)

Waveform graph of V_{in},

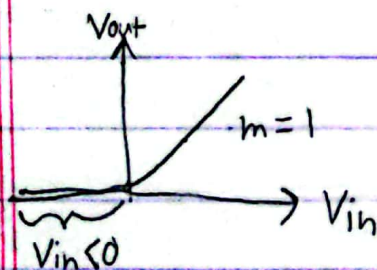* Halfwave rectifier

For +ve cycle,

$V_{in} = V_{out}$

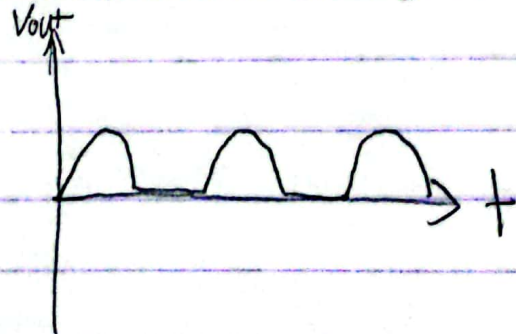For -ve cycle,

$V_{out} = 0$

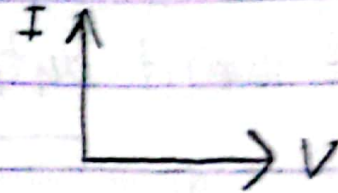Wave form of V_{out},

$m=1$

$V_{in} < 0$

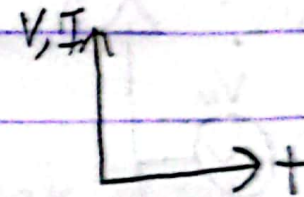* There is no power loss in halfwave rectifier, as current is 0 during negative cycle.

Types of Graphs for this course!

1. IV Graphs / IV - Characteristics
   - We do it for devices

   $I \uparrow$
   $\rightarrow V$

2. Waveform Graphs (V or I vs t)

   $V, I \uparrow$
   $\rightarrow t$

3. Transfer Characteristics (Input vs Output)
   - I We do it for circuits (2-port)

   $\uparrow$ out
   $\rightarrow$ in

   - (2-port) means comparision between out and In & quantityies.
   - V_{out} Vs V_{in} is called Voltage transfer characteristics (VTC).
   - I_{out} Vs I_{in} " " Current " " (ICTC).
   - V_{out} Vs I_{in} and I_{out} Vs V_{in} is just called TC.
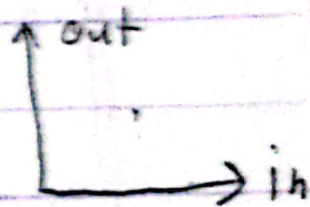
Full Wave Rectifiers:
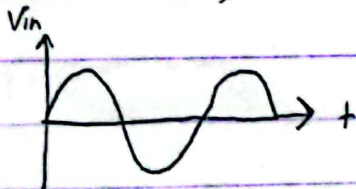
* We don't want output to have 2 polarities.
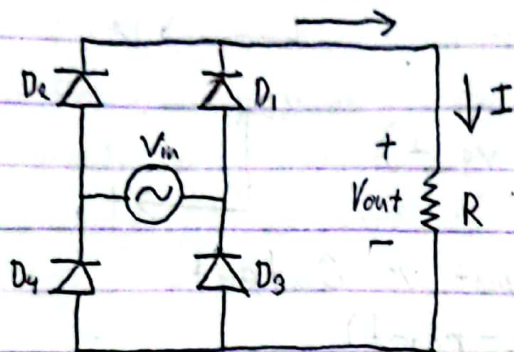
• No matter what cycle (+ve or -ve) it is current will flow in 1 direction only.

* If $\overset{-}{\underset{}{\sim}}{}^{+}$ then, current will go through D_1 and return through D_4.

* If $\overset{+}{\underset{}{\sim}}{}^{-}$ then, current will go through D_2 and return through D_3.

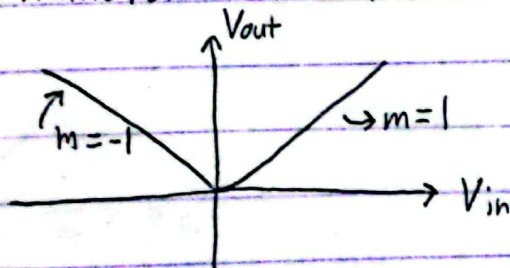* V_{in} waveform,

* V_{out} waveform,
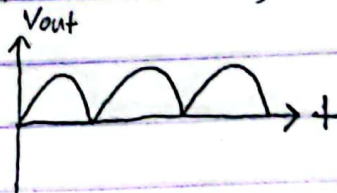
* Full wave Rectifier also called Bridge Rectifier.
* Voltage Transfer Characteristics (VTC),

* Here all diodes as are considered ideal.

Rectifiers with Real Diodes:

* Half wave rectifiers:
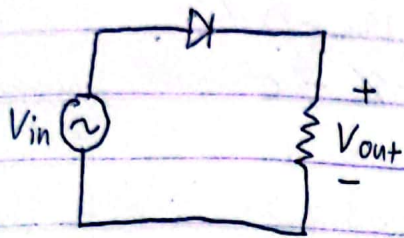
$$I_D = I_S \left(e^{\frac{V_D}{V_T}} - 1 \right)$$

$$\downarrow$$

CVD model (0.7V)

• Peak Voltage, $V_P = V_{in} - 0.7V$
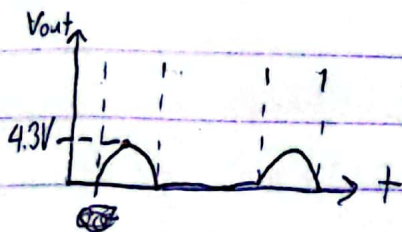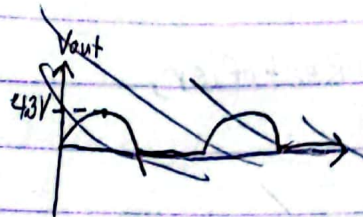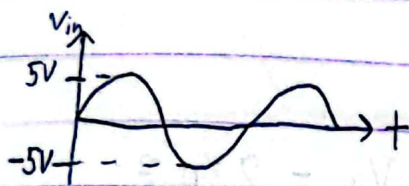
* Full wave rectifiers:
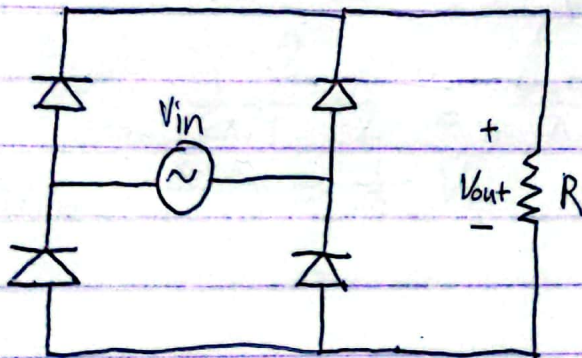
• It will turn ON when $V_{in} \geq 2 \times 0.7 = 1.4V$. Because 2 diode are ON in each cycle.
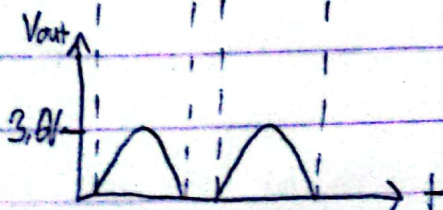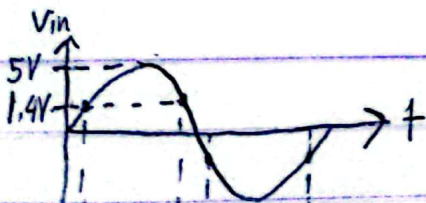
• Peak Voltage $V_P = V_{in} - 2 \times 0.7$
$$= V_{in} - 1.4V$$

#* Transfer Characteristics with Real Diodes:

* Half Wave Rectifier,

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

where V_P and V_M point to V_{out} and V_{in} respectively

$$y = x - c$$

* Full Wave Rectifier,

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

V_{DD}

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

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

* **Half Wave Rectifier with Ideal diode:**
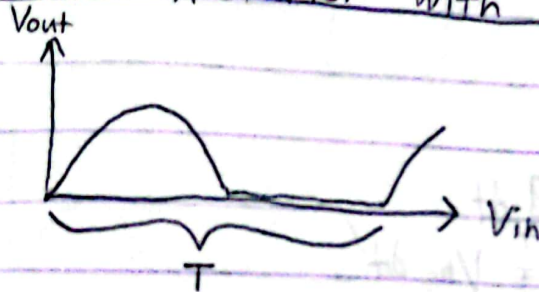
$$V_{in} = V_{max} \sin(\omega t)$$
$$= V_{max} \sin(2\pi f t)$$

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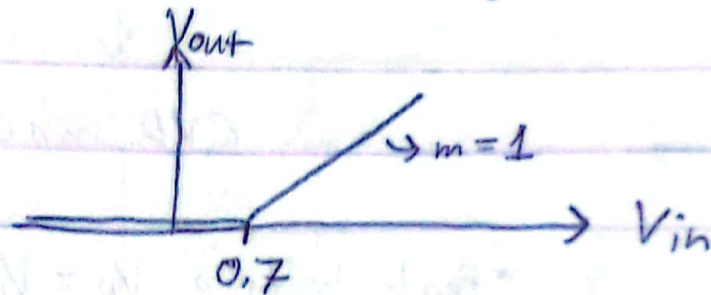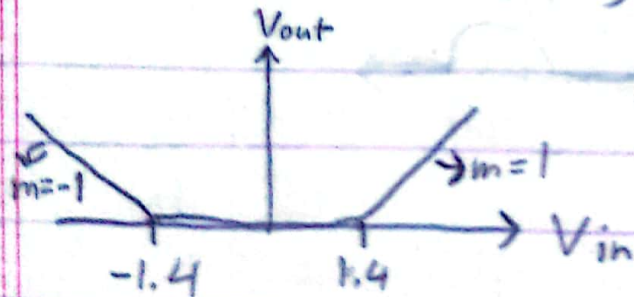&= V_m \cdot \frac{1}{\omega} \left[-\cos\left(\frac{\omega T}{2}\right) + \cos(0) \right] \\
&= V_m \cdot \frac{1}{\omega} \cdot 2 \\
&= V_m \cdot \frac{1}{2\pi/T} \cdot 2 = \frac{V_m T}{\pi}
\end{aligned}
$$

$$\omega = \frac{2\pi}{T}$$
$$\frac{\omega T}{2} = \pi \quad , \quad \cos \pi = -1$$

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

* Half wave rectifier with Real diode:

V_{D_0} = diode activation
voltage (0.7 V)
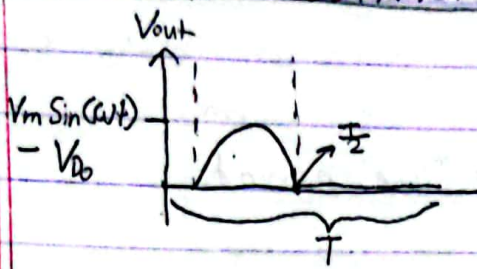
$$V_{AVG} = \frac{1}{T} \int_0^T V_{out}(t)\, dt$$

$$= \frac{1}{T} \int_0^{\frac{T}{2}} V_{out}(t)\, dt$$

$$= \frac{1}{T} \int_0^{\frac{T}{2}} [V_m \sin(\omega t) - V_{D_0}]\, dt$$

$$= \frac{1}{T} \left[\int_0^{\frac{T}{2}} V_m \sin(\omega t) - \int_{\frac{T}{2}}^T V_{D_0}\, dt \right]$$

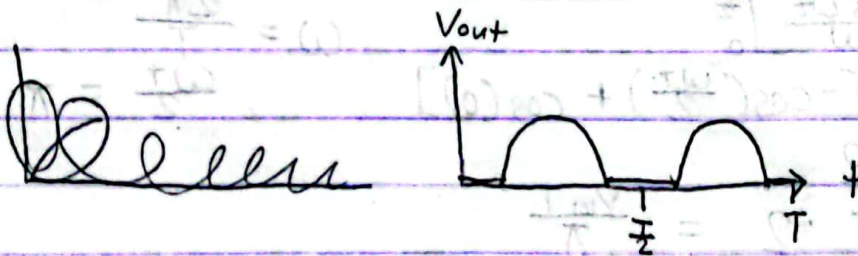$$= \frac{1}{T} \left[\frac{T}{\pi} V_m - V_{D_0} \frac{T}{2} \right]$$

$$= \frac{1}{\pi} V_m - \frac{1}{2} V_{D_0}$$

* Full wave rectifier with Real Diode:

$$V_{out}(t) = V_m \sin(\omega t) - 2 V_{D_0}$$

$$Area = \int_0^T V_{out}(t)\, dt$$

$$= 2 \int_0^{\frac{T}{2}} V_{out}(t)\, dt$$

$$= 2 \int_0^{\frac{T}{2}} [V_m \sin(\omega t) - 2 V_{D_0}]\, dt$$

$$= 2 \left[\frac{T}{\pi} V_m - 2 V_{D_0} \cdot \frac{T}{2} \right]$$

$$\therefore V_{AVG} = \frac{Area}{T}$$

$$= \frac{2}{\pi} V_m - 2 V_{D_0}$$

* $V_{AVG} = \frac{2}{\pi} V_m$, 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.

→ stores charges

smoothing →

these small waves are called ripples
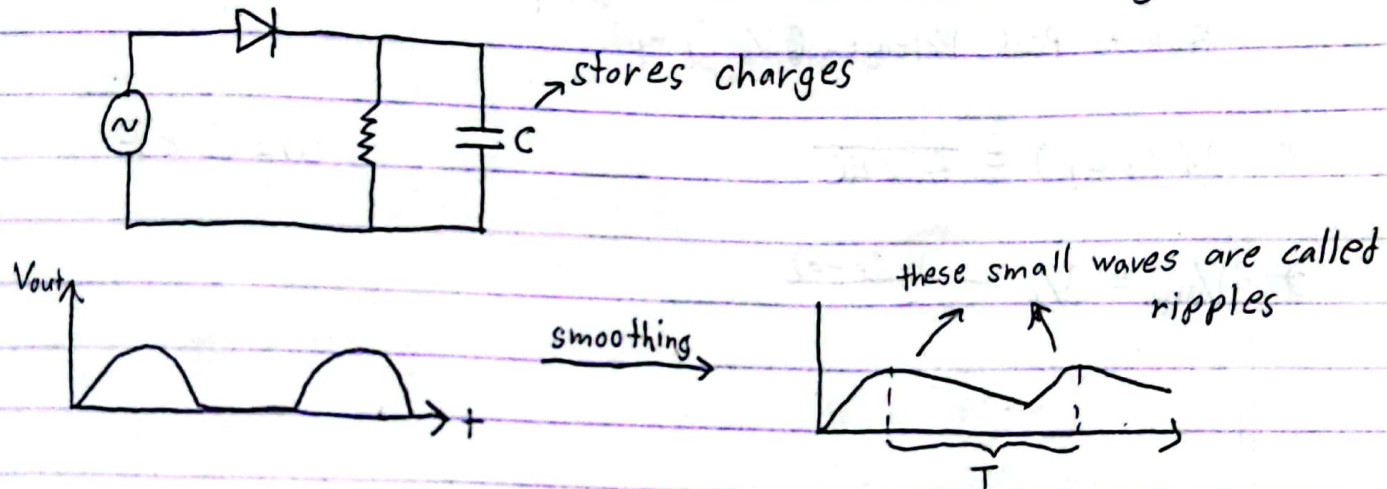
* Higher the capacitance of the capacitor more of smoothing will occur (higher capacitance will discharge more slowly).

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

* Time 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, $T_r = \frac{1}{2} T_s$, $\therefore f_r = 2 f_s$

$*$

V_{out}

Peak to Peak Voltage, @ $V_r (p-p)$
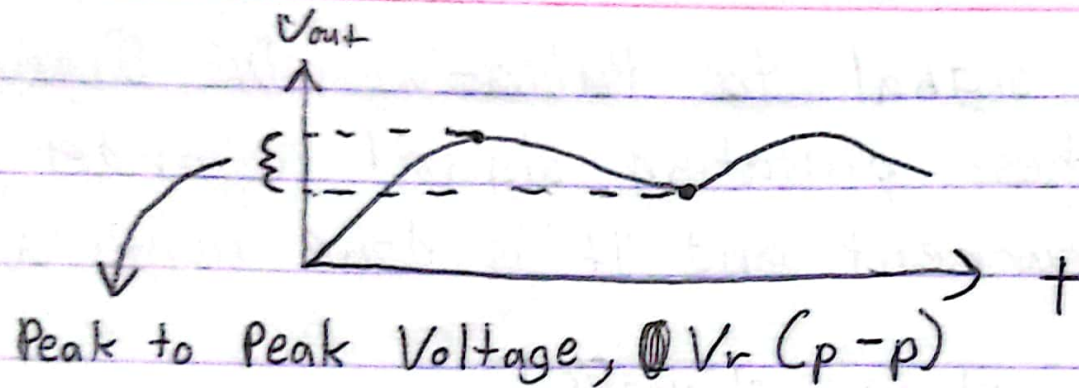
$*$ $V_r(p-p) = \dfrac{V_p}{f_r \times RC}$

$\omega = 2\pi f$

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

Regulators:

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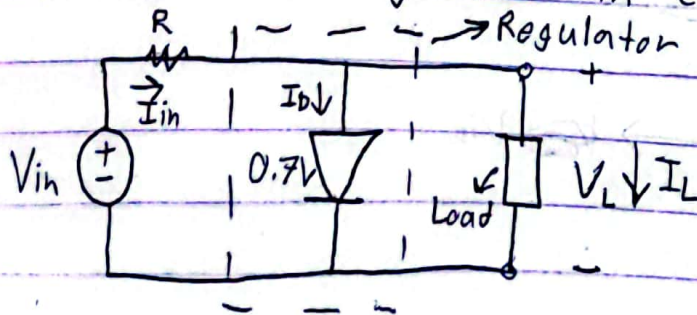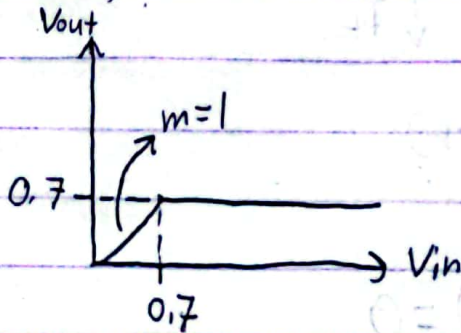

$$* \; V_L = V_{in} - RI$$

* For CVD

$$F.B \rightarrow I_b > 0$$
$$R.B \rightarrow I_D = 0$$

* 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 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 increase Voltage across the load(V_L)
* Regulator Equivalent Circuit:
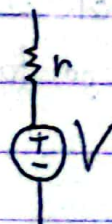
Real Regulators (CVD + r model diode):
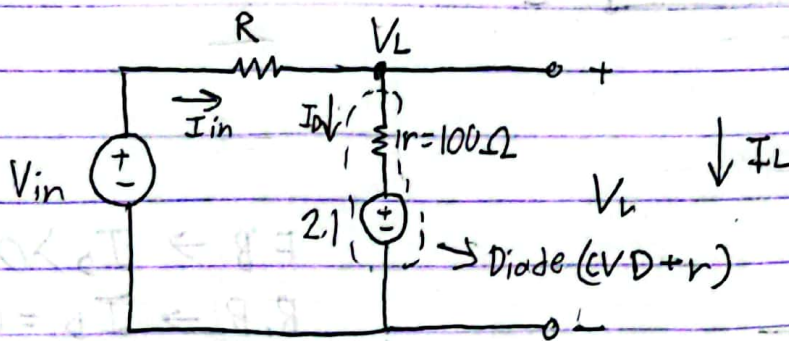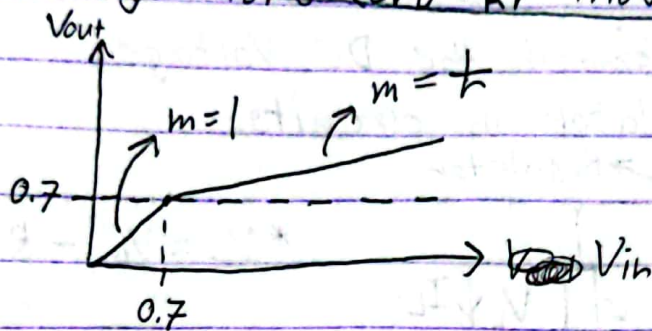
$$V_L\left(\tfrac{1}{R} + \tfrac{1}{r}\right) - V_{in}\left(\tfrac{1}{R}\right) - 2.1\left(\tfrac{1}{r}\right) = 0$$

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

* From eqn-①, It is visible that V_L depends on $\left(\tfrac{r}{r+R}\right)$ and V_{in}, but V_{in} is not constant so $\left(\tfrac{r}{r+R}\right)$ is what mainly keeps V_L constant.

* $\left(\tfrac{r}{r+R}\right)$ 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 may go to R.B.
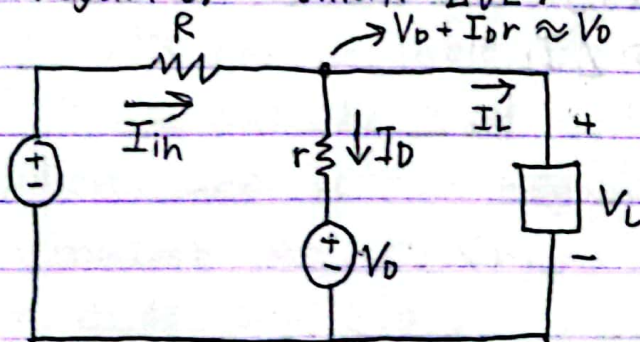
Performance Measure:

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 $\overset{\text{Voltage}}{\cancel{\text{Current}}}$ $\left(\frac{\Delta V_L}{\cancel{\Delta I}}\right)$ if I_L changes by 1 mA.
- Good regulator = small ΔV_L.

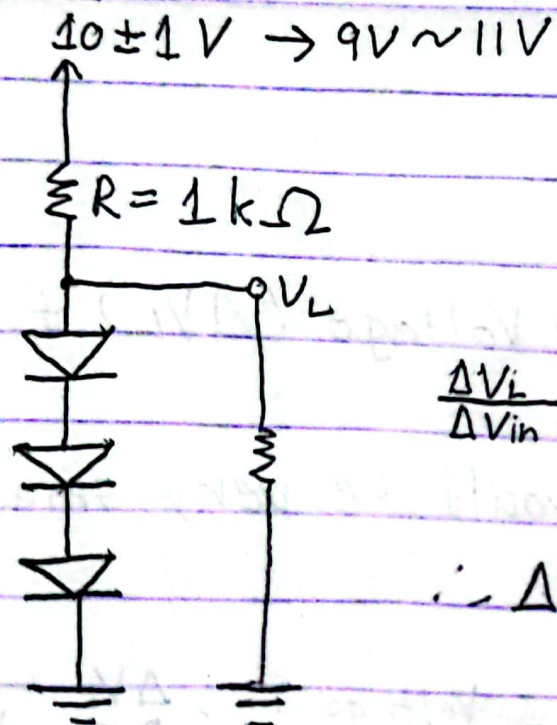## * For the above circuit,

* 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:**

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

$R = 1k\Omega$

$\circ V_L$

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

Calc Line and Load regulation.

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,

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

$$\therefore \Delta V_L = -9.51 \times \cancel{2.1 mA} \Delta I_L$$