- A fluctuating d.c voltage may result in an erratic operation of electronic devices & circuits.
e.g. It may cause a frequency shift in an oscillator, change of calibration in instruments, distortion in the o/p of power amplifiers etc.
- In order to avoid fluctuations, a voltage regulator ckt is used.
- A voltage regulator is connected between the filter & the load.
- Its function is to maintain a constant o/p d.c vtg inspite of a.c i/p vtg fluctuations or changes in load resistance values.

* Voltage Regulation -

An ideal voltage regulator will maintain a constant dc output voltage regardless of changes in either its input voltage or its load current demand.
e.g. consider +5Vdc regulator shown in next fig.
- A change in the regulator i/p voltage shown as ΔV_s in fig a) would not appear at the regular o/p.
- It may be carefully noted that ΔV_s could be either a change in steady-state (dc) value of V_s or could be some ripple voltage.
- In either case, the change in V_L for the ideal regulator would be 0V.
- We have assumed that the value of i/p vtg to the vtg regulator (V_s) does not decrease below the value required to maintain the operation of vtg regulator.

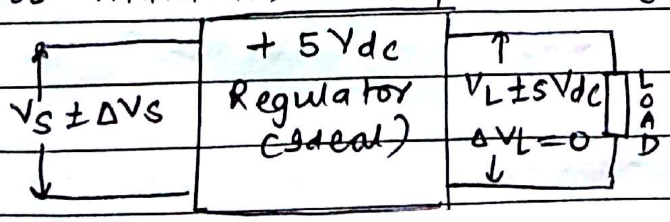

fig a)

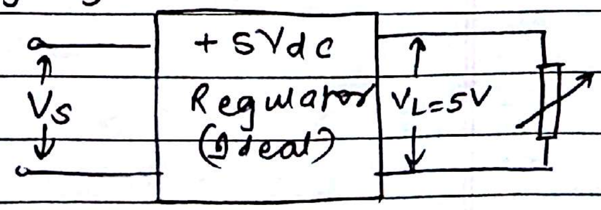

fig b)

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- As a thumb rule, a regulator cannot have 5Vdc o/p if the i/p is less than 5Vdc.
- Fig a) & b) shows how an ideal voltage regulator would respond to a change in load current demand.
- The ideal voltage regulator maintains a constant o/p vtg (ie $\Delta V_L = 0$) despite the changes in load current demand.
- Accordingly, we have two ways of specifying the quality of regulation for a voltage regulator.
  (1) Line Regulation (2) Load Regulation.

(1) Line Regulation -

In actual practice, a change in i/p vtg to a voltage regulator will cause a change in its o/p or load voltage.

- The line regulation rating of a voltage regulator indicates the change in o/p vtg that will occur per unit change in the i/p voltage.
- The line regulation of a voltage regulator is given by,

$$\boxed{\text{Line Regulation} = \frac{\Delta V_L}{\Delta V_S}}$$

where ΔV_L = the change in o/p vtg usually in mV or μV

ΔV_S = the change in i/p vtg in volts

- The line Regulation is expressed as (V/V) or ($\mu V/V$)

② **Load Regulation** -

In practice, the voltage regulator will also experience a slight change in o/p vtg when there is a change in load current demand.

- The load regulation indicates the change in o/p vtg that will occur per unit change in load current.
- Mathematically, the load regulation may be expressed as

$$\boxed{\text{Load Regulation} = \frac{V_{NL} - V_{FL}}{\Delta I_L}}$$

where V_{NL} = No load o/p vtg
V_{FL} = full load o/p vtg
ΔI_L = the change in load current demand

- The load regulation of a voltage regulator is expressed in terms of $\mu V/\mu A$

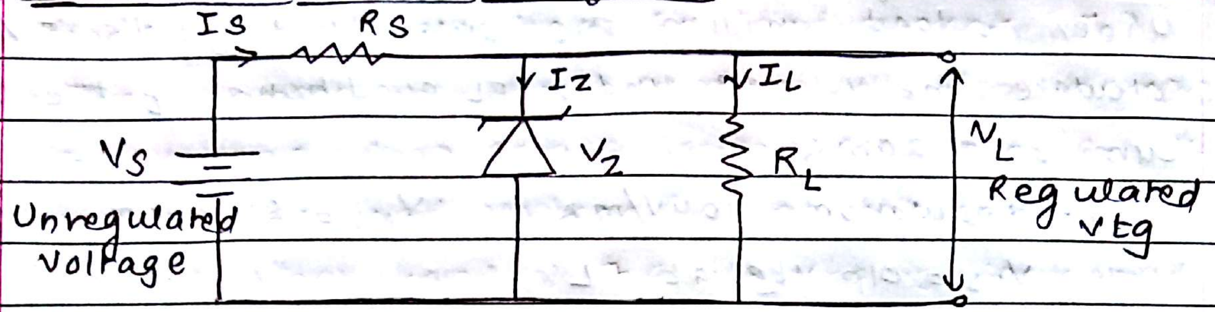
- Line/load regulation values should be lower for the better quality of regulation.

- Voltage Regulation is expressed as the ability of the regulator to maintain a constant o/p vtg inspite of a.c. i/p vtg fluctuations & changes in load resistance.

$$\boxed{\%\ \text{regulation} = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100}$$

where V_{NL} = No load vtg
V_{FL} = Full load vtg

* Zener Diode shunt Regulator -



- Above fig shows a circuit of zener diode shunt regulator.
- since the zener is connected in parallel (or shunt) with the load, therefore the circuit is known as shunt Regulator.
- A resistance (R_s) is connected in series with zener to limit current in the circuit.
- Therefore the resistance R_s is also known as series current limiting resistor.
- The o/p vtg (V_L) is taken across the load resistance (R_L).
- for proper operation, the i/p vtg (V_s) must be greater than the zener voltage (V_Z).
- This ensures that zener operates in the reverse breakdown region,
- The i/p current (i.e current through the limiting resistor) is given by the relation

$$\boxed{I_s = \frac{V_s - V_Z}{R_s}}$$

where V_s = d.c i/p vtg to the regulator ckt
V_Z = zener voltage

- Ideal zener diode acts as a constant voltage source of voltage (V_Z).
- A practical zener diode has a finite value of resistance called zener resistance (r_Z).

- Because of the zener resistance, there is a vtg drop across it which is equal to $I_Z \cdot r_Z$.
- Therefore the voltage across the terminals of the zener diode (which is equal to load voltage),

$$V_L = V_Z + I_Z \cdot r_Z$$

- If zener resistance is negligible, then load vtg

$$V_L = V_Z$$

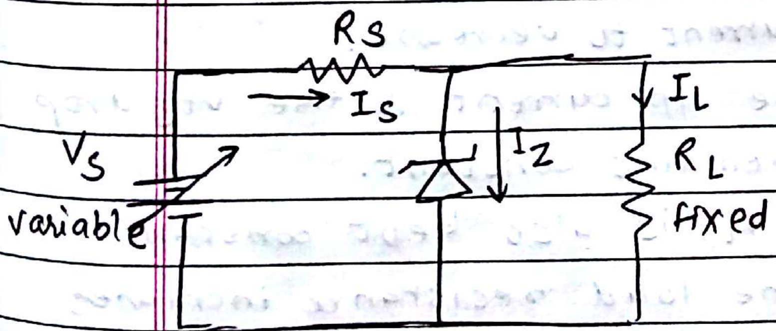
& the current through the load resistance is given by the relation, $I_L = \frac{V_L}{R_L}$

- i/p current is the sum of zener current & load current ie $\boxed{I_S = I_Z + I_L}$ or $\boxed{I_Z = I_S - I_L}$

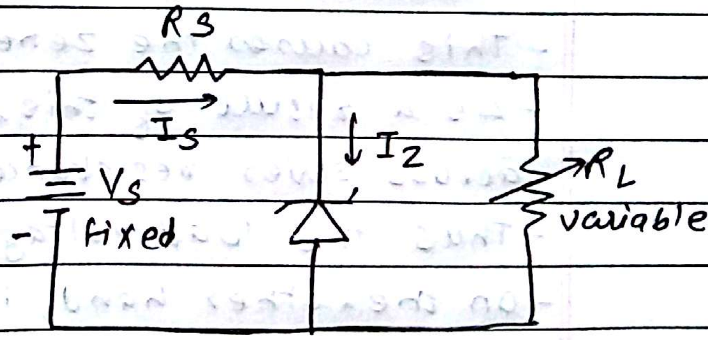
* **Working of Zener diode shunt Regulator :-**

It may be explained under the two levels namely regulation with varying i/p vtg & regulation with varying load resistance.

① **Regulation with varying i/p vtg :-** consider the regulator circuit as shown in fig a). Here the load resistor (R_L) is kept fixed & the i/p voltage (V_S) series within the limits.



a) varying i/p vtg



b) varying load resistance

- As the i/p voltage increases, the i/p current (I_S) also increases. This increases the current through zener diode, without affecting the load current (I_L).

- The increase in input current will also increase the voltage drop across series resistance (R_s), thereby keeping the load voltage (V_L) as constant.
- On the other hand, if the i/p vtg is decreased, the i/p ~~chann~~ current also decreases.
- As a result of this the current through zener will also decrease.
- Consequently, the voltage drop across series resistance will be reduced.
- Thus the load voltage (V_L) & load current (I_L) remains constant.

2. Regulation with varying load Resistance -

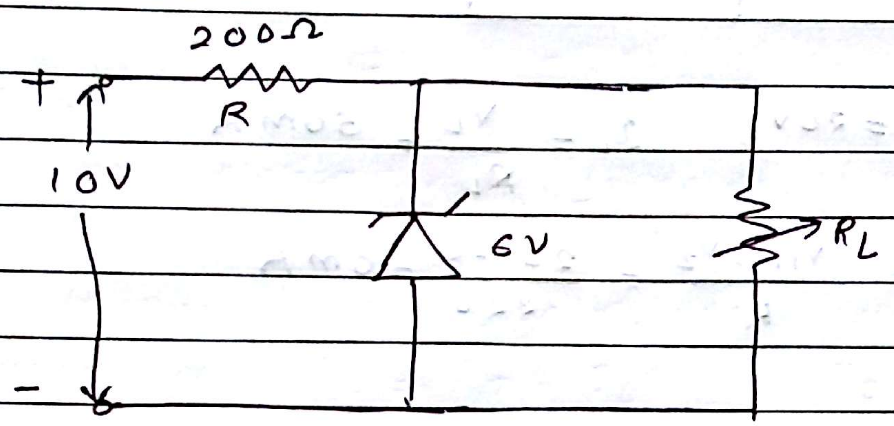
- consider the regulator ckt in fig b)
- Here the i/p vtg (V_s) is kept fixed & the load resistance (R_L) varies.
- The variation of load resistance changes the current (I_L) through it, thereby changing voltage (V_L) across it.
- When the load resistance decreases, the load current increases.
- This causes the zener current to decrease.
- As a result of this, the i/p current & the vtg drop across series resistance remains constant.
- Thus the load voltage (V_L) is also kept constant.
- On the other hand, if the load resistance increases the load current decreases.
- As a result of this, the zener current increases.
- This again keeps the value of i/p current & vtg

drop across series resistance as constant.

- Thus the load voltage remains constant.

Numericals

Ex1) For the given circuit, find I, I_Z, I_L for $R_L = 300\Omega$ & $R_L = 100\Omega$



Sol^n (a) for $R_L = 100\Omega$

$$I_L = \frac{V_Z}{R_L} = \frac{6}{100} = 0.06A \text{ or } 60mA$$

$$I = \frac{V_{in} - V_Z}{R} = \frac{10-6}{200} = 20mA$$

$$I_Z = I - I_L = 20 - 60mA = -40mA$$

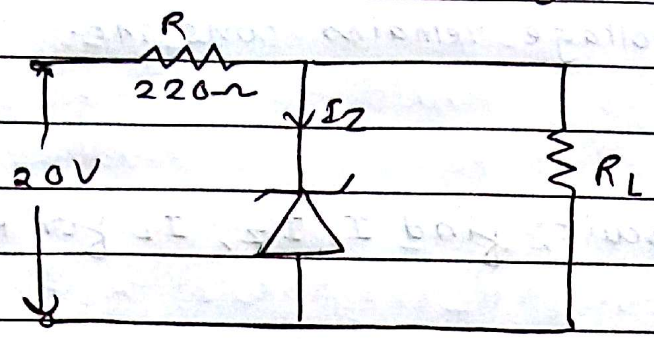
(b) for $R_L = 300\Omega$

$$I_L = \frac{V_Z}{R_L} = \frac{6}{300} = 20mA$$

$$I = \frac{V_{in} - V_Z}{R} = \frac{10-6}{200} = 20mA$$

$$I_Z = I - I_L = 0mA$$

Ex 2) Determine V_L, I_L, I_Z & I_R for N/W shown



$V_Z = 20V$

$P_{Z max} = 400mW$

$R_L = 400\Omega$

Soln

1) $V_L = V_Z = 20V$, $I_L = \frac{V_L}{R_L} = 50mA$

$I_R = \frac{V_{in} - V_Z}{R} = \frac{20-20}{220} = 0mA$

- If R_L ↑ses, I_L ↓ses. As a result of this I_Z ↑ses. This again keeps the value of i/p c/n & v/g drop across series resistance as constant. Thus the load v/g 'V_L' remains constant.

→ Optimum value of c/n Limiting Resistor

- When i/p v/g is minimum & load c/n is maximum, sufficient c/n must be supplied to keep zener diode within its breakdown region.
- when i/p v/g is maximum & load c/n is minimum the zener c/n must not ↑se the maximum rated value.

$$R_{s(min)} = \frac{V_{s(max)} - V_Z}{I_{Z(max)} + I_{L(min)}}$$

$$R_{s(max)} = \frac{V_{s(min)} - V_Z}{I_{Z(min)} + I_{L(max)}}$$

'R_s' should be $R_{s(min)} < R_s < R_{s(max)}$

→ Advantages

- Very simple ckt
- low cost & requires only 2 or 3 components.

→ Disadvantages

- Poor efficiency for heavy load.
- DC o/p v/g slightly changes due to Zener Resistance.
- o/p v/g is not adjustable because $V_o = V_Z$.

→ Application

- Used in emitter follower regulator.
- Used with small load c/n range over which the o/p DC v/g remains constant.