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Experiment 5

Aim:

Zener diode as a voltage regulator using line regulation.

Tools and Apparatus:

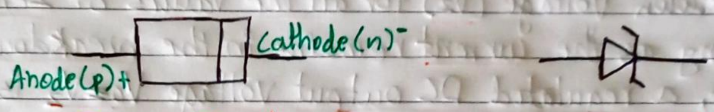
- http://vlabs.iitkgp.ernet.in/be/exp10/index.html#
- Zener Diode, Resistors, Multimeter, DC Voltage Source

Theory and Design:

- **Zener Diode:**

→ A zener diode is a special kind of diode which permits current to flow in the forward direction like a standard diode, but it will also allow it to flow in the reverse direction when the voltage is above the breakdown voltage or "zener voltage".

→ Zener diodes are designed so that their breakdown voltage is much lower.



Zener Diode Symbol

→ In a standard diode, the Zener voltage is high, and the diode is permanently damaged if a reverse current above that value is allowed to pass through it.

→ In the reverse bias direction, there is practically no reverse current flow until the breakdown voltage is reached.

→ When this occurs there is a sharp increase in reverse current.

→ Varying amount of reverse current can pass through the Zener diode without damaging it.

→ The breakdown voltage or Zener Voltage (V_Z) across the diode remains relatively constant.

Zener diode as a Voltage Regulator:

→ A voltage regulator is an electronic circuit that provides a stable DC voltage independent of the load current, temperature and AC line voltage variations.

→ A zener diode of breakdown voltage (V_Z) is reverse connected to an input voltage source (V_S) across a load resistance (R_L) and a series resistor (R_S).

→ The voltage across the Zener diode will remain steady at its breakdown voltage (V_Z) for all the values of zener current (I_Z) as long as the current remains in the breakdown region.

→ Hence, a regulated DC output voltage $V_O = V_Z$ is obtained across R_L, whenever the input voltage remains within a minimum and maximum voltage.

→ There are 2 types of regulations:

① Line Regulation: Series resistance (R_S) and Load resistance (R_L) are fixed, only input voltage (V_S) is changing. Output Voltage (V_O) remains the same, as long as the input voltage is maintained above a minimum value.

② Load Regulation: Input Voltage (V_S) is fixed and the Load resistance (R_L) is varying. Output voltage remains the same, as long as the load resistance is maintained above a minimum value.

- **Line Regulation:** R_L is constant, V_s varies, V_s must be sufficiently large to turn the Zener Diode ON.

$$V_L = V_Z = \frac{V_{s\,min} \times R_L}{(R_s + R_L)}$$

So, the minimum turn-on voltage ($V_{s\,min}$) is:

$$\boxed{V_{s_{min}} = \frac{V_Z \times (R_s + R_L)}{R_L}}$$

The maximum value of V_s is limited by the maximum zener current ($I_{Z\,max}$)

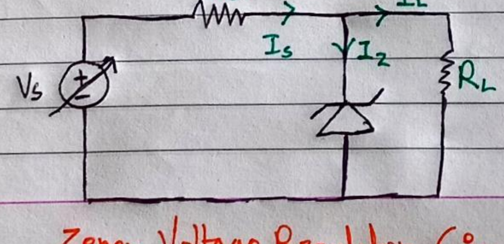
$$I_{R_{max}} = I_{Z_{max}} + I_L$$

I_L is fixed at $\frac{V_Z}{R_L}$, since, $V_L = V_Z$

So maximum V_s is $\boxed{V_{s_{max}} = V_{R_{max}} + V_Z}$ OR $\boxed{V_{s_{max}} = I_{R_{max}} \times R + V_Z}$

$\boxed{\text{For } V_s < V_Z : V_o = V_s}$

$\boxed{\text{For } V_s > V_Z : V_o = V_s - I_s \times R_s}$



Zener Voltage Regulator Circuit

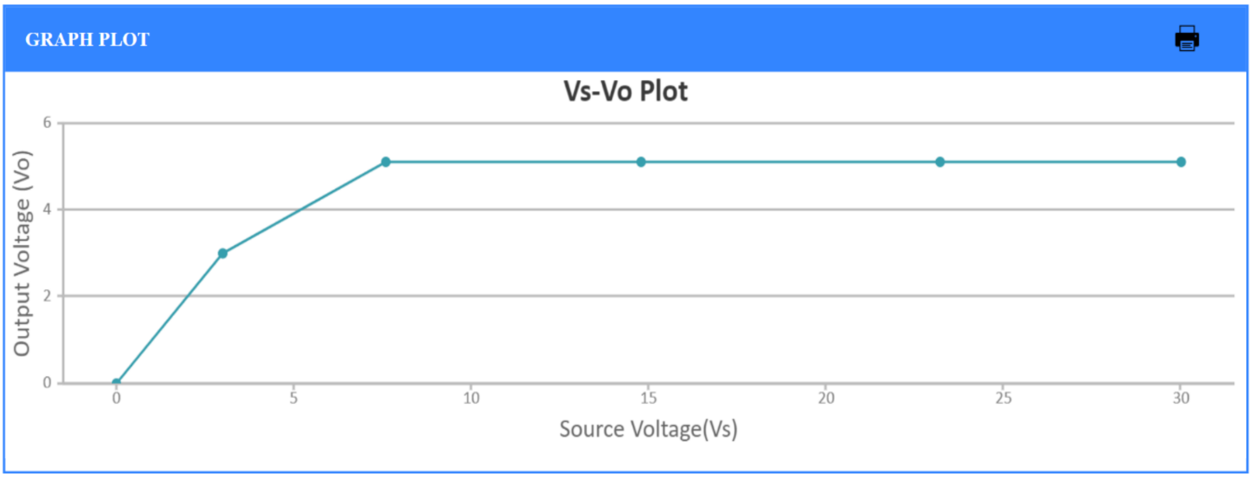
Simulation Results:

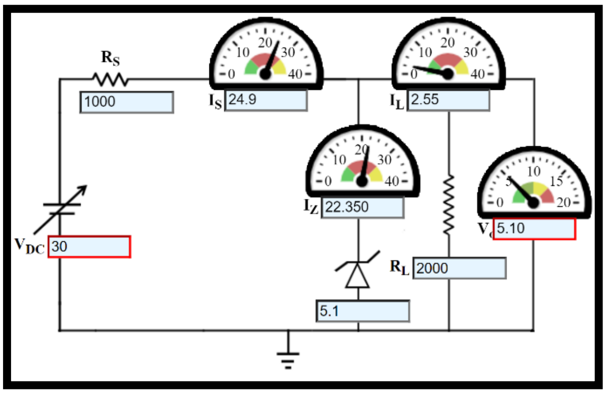
1. **Zener Voltage (V_Z) = 5.1V**
   Series Resistance (R_S) = 1kΩ
   Load Resistance (R_L) = 2kΩ

EXPERIMENTAL TABLE

Zener Voltage(V_Z): 5.1 V
Series Resistance(R_S): 1 KΩ
Load Resistance (R_L): 2 KΩ

Serial No.	Unregulated supply voltage(V_S) V	Load Current(I_L) mAmp	Zener Current(I_Z) mAmp	Regulated Output Voltage(V_O) V	% Voltage Regulation
1	0	2.55	0	0	NaN
2	3	2.55	0	3	100
3	7.6	2.55	-0.050	5.10	71.4
4	14.8	2.55	7.150	5.10	35.7
5	23.2	2.55	15.550	5.10	21.7
6	30	2.55	22.350	5.10	16.7





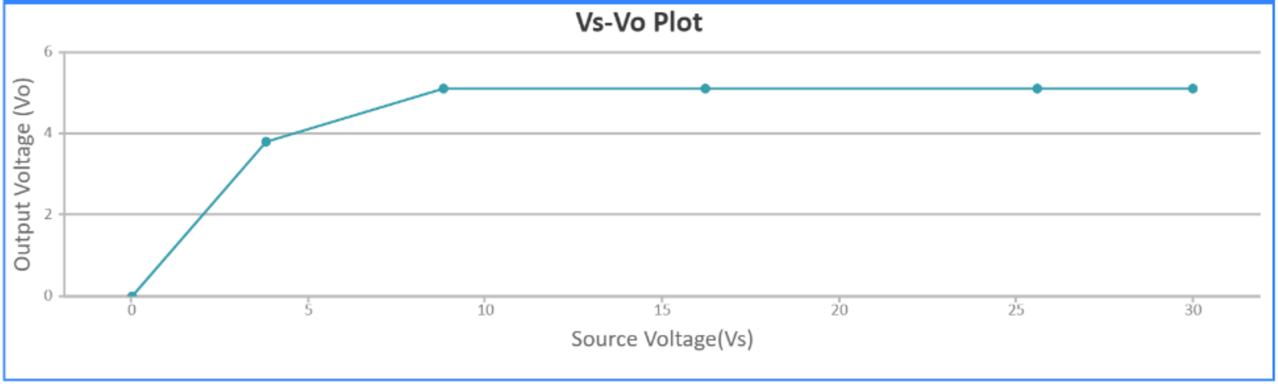
2. **Zener Voltage (V_Z) = 5.1V**
   Series Resistance (R_S) = 1kΩ
   Load Resistance (R_L) = 5kΩ

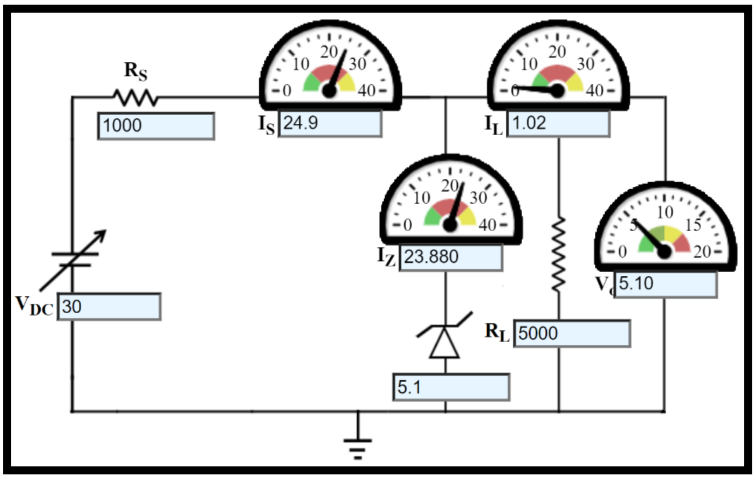
EXPERIMENTAL TABLE

Zener Voltage(V_Z): 5.1 V
Series Resistance(R_S): 1 KΩ
Load Resistance (R_L): 5 KΩ

Serial No.	Unregulated supply voltage(V_S) V	Load Current(I_L) mAmp	Zener Current(I_Z) mAmp	Regulated Output Voltage(V_O) V	% Voltage Regulation
1	0	1.02	0	0	NaN
2	3.8	1.02	0	3.8	100
3	8.8	1.02	2.680	5.10	62.5
4	16.2	1.02	10.080	5.10	31.3
5	25.6	1.02	19.480	5.10	20.0
6	30	1.02	23.880	5.10	16.7

GRAPH PLOT





Conclusion:

1. For constant value of Zener Voltage (**V_z = 5.1V)** and varying values of V_S and R_L
    a. Output Voltage is constant, **V_O = 5.1V**

2. For constant value of **V_z = 5.1V** and varying values of V_S
    a. **R_L = 2kΩ**
        i. Load current is constant, **I_L = 2.55A**
    b. **R_L = 5kΩ**
        i. Load current is constant, **I_L = 1.02A**

Inferences:

1. For all values of Source Voltage greater than Zener Voltage, Output Voltage is constant and is equal to Zener Voltage.
2. If Source Voltage is less than Zener Voltage, Output Voltage will be equal to Source Voltage.
3. To get a straight line graph of constant voltage always keep Source Voltage greater than Zener Voltage.
4. **$I_S = I_L + I_Z$**
    a. I_S and I_Z are regulated in such a way that I_L remains constant for a constant value of R_L and therefore V_O remains the same.
    b. If R_L changes then all current values change accordingly (Inversely Proportional) and therefore V_O still remains the same.