Numerical on Zener Diode

Q1. For the circuit shown in Fig.1 (i), find : (i) the output voltage (ii) the voltage drop across series resistance (iii) the current through zener diode.

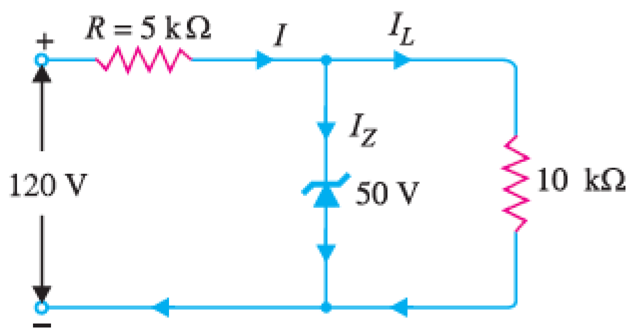

Fig.1 (i)

Solution :

If you remove the zener diode in Fig. 1, the voltage V across the open-circuit is given by :

$$V = \frac{R_L\ E_i}{R + R_L} = \frac{10 \times 120}{5 + 10} = 80\text{ V}$$

Since voltage across zener diode is greater than VZ (= 50 V), the zener is in the "on" state. It can, therefore, be represented by a battery of 50 V as shown in Fig. 1 (ii).

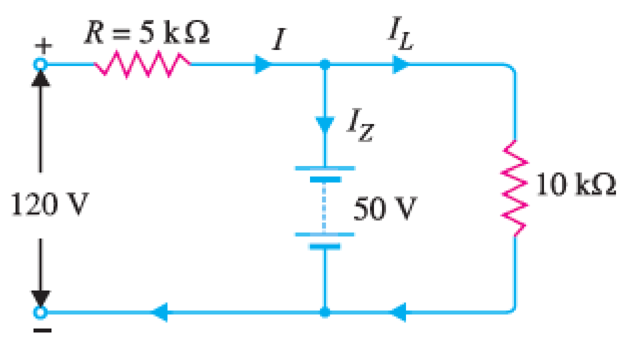

Fig. 1(ii)

(i) Referring to Fig. 1 (ii),

Output voltage $= V_Z = 50$ V

(ii) Voltage drop across R = Input voltage $- V_Z = 120 - 50 = 70$ V

Load current, $I_L = V_Z/R_L = 50 \text{ V}/10 \text{ k}\Omega = 5$ mA

Current through R, $I = \dfrac{70 \text{ V}}{5 \text{ k}\Omega} = 14$ mA

(iii)

Applying Kirchhoff's first law, $I = I_L + I_Z$

$\therefore$ Zener current, $I_Z = I - I_L = 14 - 5 = 9$ mA

Q2. For the circuit shown in Fig. 2 (i),find the maximum and minimum values of zener diode current.

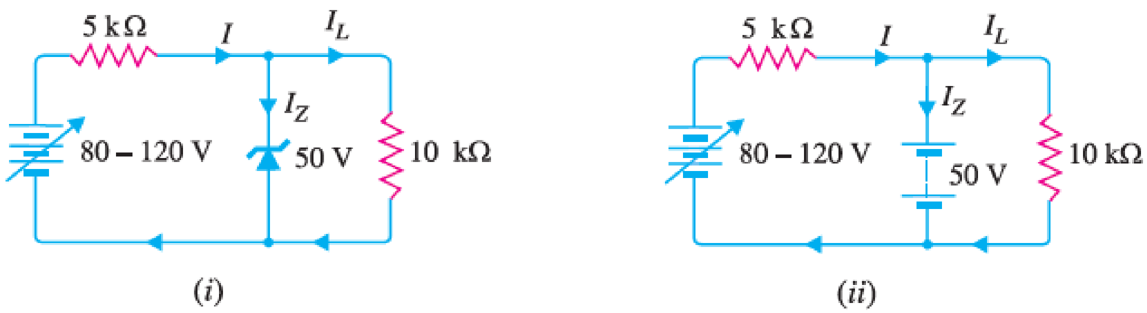

Fig.2

Solution :

The first step is to determine the state of the zener diode. It is easy to see that for the given range of voltages (80 − 120 V), the voltage across the zener is greater than VZ (= 50 V). Hence the zener diode will be in the "on" state for this range of applied voltages. Consequently, it can be replaced by a battery of 50 V as shown in Fig. 2(ii).

Maximum zener current: The zener will conduct maximum current when the input voltage is maximum i.e. 120 V. Under such conditions :

Voltage across 5 kΩ $= 120 - 50 = 70$ V

Current through 5 kΩ, $I = \dfrac{70 \text{ V}}{5 \text{ k}\Omega} = 14$ mA

Load current, $I_L = \dfrac{50 \text{ V}}{10 \text{ k}\Omega} = 5$ mA

Applying Kirchhoff's first law, $I = I_L + I_Z$

$\therefore$ Zener current, $I_Z = I - I_L = 14 - 5 = 9$ mA

Minimum Zener current: The zener will conduct minimum current when the input voltage is minimum i.e. 80 V. Under such conditions, we have,

$$\text{Voltage across } 5\text{ k}\Omega = 80 - 50 = 30\text{ V}$$

$$\text{Current through } 5\text{ k}\Omega,\ I = \frac{30\text{ V}}{5\text{ k}\Omega} = 6\text{ mA}$$

$$\text{Load current, } I_L = 5\text{ mA}$$

$$\therefore \quad \text{Zener current, } I_Z = I - I_L = 6 - 5 = \mathbf{1\text{ mA}}$$

Q3. A 7.2 V zener is used in the circuit shown in Fig. 3 and the load current is to vary from 12 to 100 mA. Find the value of series resistance R to maintain a voltage of 7.2 V across the load. The input voltage is constant at 12V and the minimum zener current is 10 mA.

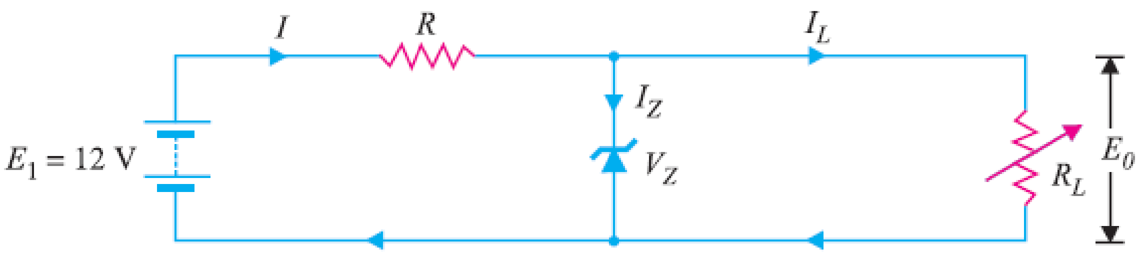

Fig. 3

Solution :

$$E_i = 12\text{ V}; \quad V_Z = 7.2\text{ V}$$

$$R = \frac{E_i - E_0}{I_Z + I_L}$$

The voltage across R is to remain constant at 12 − 7.2 = 4.8 V as the load current changes from 12 to 100 mA. The minimum zener current will occur when the load current is maximum.

$$\therefore \quad R = \frac{E_i - E_0}{(I_Z)_{min} + (I_L)_{max}} = \frac{12\text{ V} - 7.2\text{ V}}{(10 + 100)\text{ mA}} = \frac{4.8\text{ V}}{110\text{ mA}} = \mathbf{43.5\ \Omega}$$

If R = 43.5 Ω is inserted in the circuit, the output voltage will remain constant over the regulating range. As the load current IL decreases, the zener current IZ will increase to such a value that IZ + IL = 110 mA.

Note that if load resistance is open-circuited, then IL = 0 and zener current becomes 110 mA.

Q4. The zener diode shown in Fig. 4 has VZ = 18 V. The voltage across the load stays at 18 V as long as IZ is maintained between 200 mA and 2 A.

Find the value of series resistance R so that E0 remains 18 V while input voltage Ei is free to vary between 22 V to 28V.

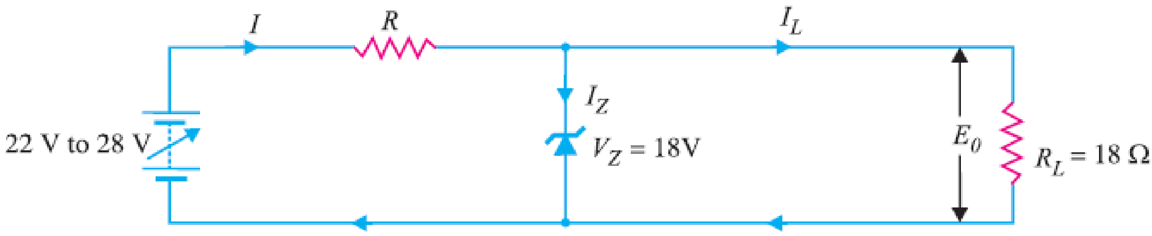

Fig. 4

Solution : The zener current will be minimum (i.e. 200 mA) when the input voltage is minimum (i.e. 22 V). The load current stays at constant value IL = VZ / RL = 18 V/18 Ω = 1 A = 1000 mA.

$$\therefore \quad R = \frac{E_i - E_0}{(I_Z)_{min} + (I_L)_{max}} = \frac{(22-18)\text{ V}}{(200+1000)\text{ mA}} = \frac{4\text{ V}}{1200\text{ mA}} = 3.33\ \Omega$$

Q5. A 10-V zener diode is used to regulate the voltage across a variable load resistor [See fig.5]. The input voltage varies between 13 V and 16 V and the load current varies between 10 mA and 85 mA. The minimum zener current is 15 mA. Calculate the value of series resistance R.

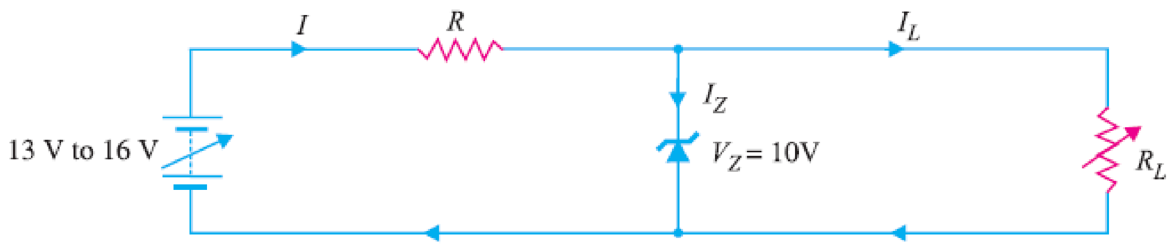

Fig. 5

Solution :

The zener will conduct minimum current (i.e. 15 mA) when input voltage is minimum (i.e. 13 V).

$$\therefore \quad R = \frac{E_i - E_0}{(I_Z)_{min} + (I_L)_{max}} = \frac{(13-10)\text{ V}}{(15+85)\text{ mA}} = \frac{3\text{ V}}{100\text{ mA}} = 30\ \Omega$$

Q6. The circuit of Fig. 6 uses two zener diodes, each rated at 15 V, 200 mA. If the circuit is connected to a 45-volt unregulated supply, determine :(i) The regulated output voltage (ii) The value of series resistance R.

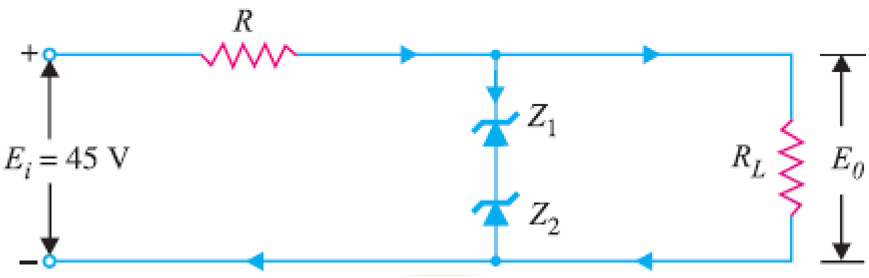

Fig. 6

Solution :

When the desired regulated output voltage is higher than the rated voltage of the zener, two or more zeners are connected in series as shown in Fig. 6. However, in such circuits, care must be taken to select those zeners that have the same current rating.

$$\text{Current rating of each zener, } I_Z = 200 \text{ mA}$$

$$\text{Voltage rating of each zener, } V_Z = 15 \text{ V}$$

$$\text{Input voltage, } E_i = 45 \text{ V}$$

(i) $$\text{Regulated output voltage, } E_0 = 15 + 15 = \mathbf{30\ V}$$

(ii) $$\text{Series resistance, } R = \frac{E_i - E_0}{I_Z} = \frac{45 - 30}{200 \text{ mA}} = \frac{15 \text{ V}}{200 \text{ mA}} = \mathbf{75\ \Omega}$$