Ch-2: Diode Applications

2.2 LOAD-LINE ANALYSIS

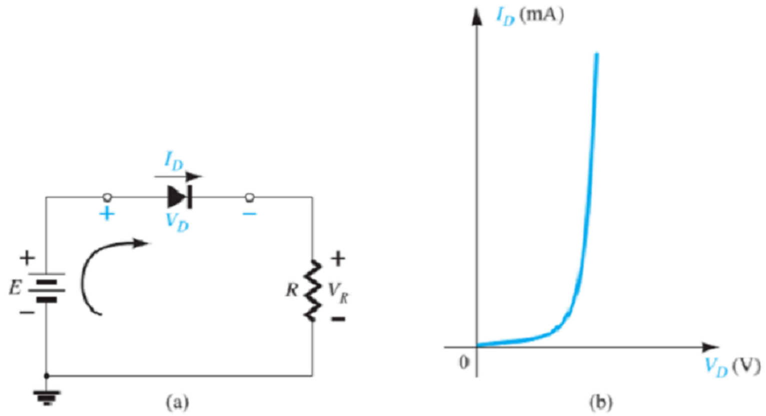


FIG. 2.1

Series diode configuration: (a) circuit; (b) characteristics.

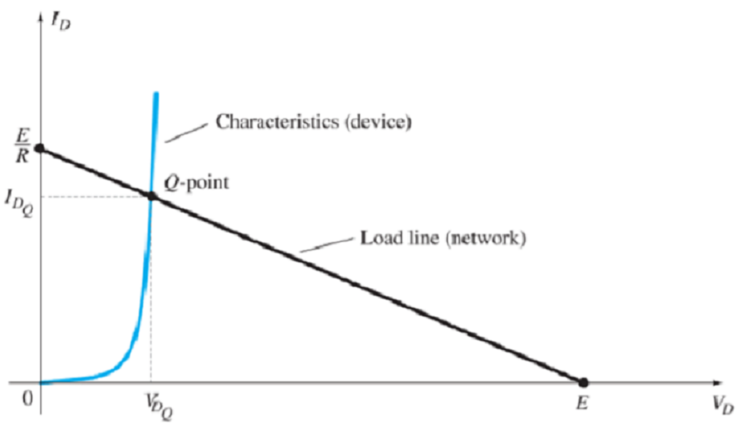


FIG. 2.2

Drawing the load line and finding the point of operation.

$$+E - V_D - V_R = 0$$

or
$$\boxed{E = V_D + I_D R} \tag{2.1}$$

$$\begin{aligned} E &= V_D + I_D R \\ &= 0\,\text{V} + I_D R \end{aligned}$$

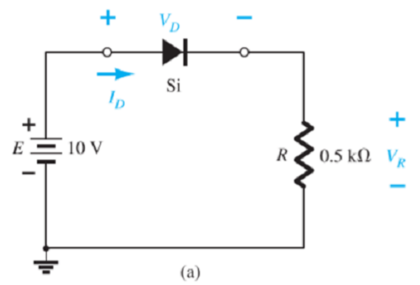
and
$$\boxed{I_D = \frac{E}{R}\bigg|_{V_D = 0\,\text{V}}} \tag{2.2}$$

$$\begin{aligned} E &= V_D + I_D R \\ &= V_D + (0\,\text{A})R \end{aligned}$$

and
$$\boxed{V_D = E\big|_{I_D = 0\,\text{A}}} \tag{2.3}$$

The point of operation is usually called the *quiescent point* (abbreviated "*Q*-point") to reflect its "still, unmoving" qualities as defined by a dc network.

EXAMPLE 2.1 For the series diode configuration of Fig. 2.3a, employing the diode characteristics of Fig. 2.3b, determine: a. V_{D_Q} and I_{D_Q}. b. V_R.



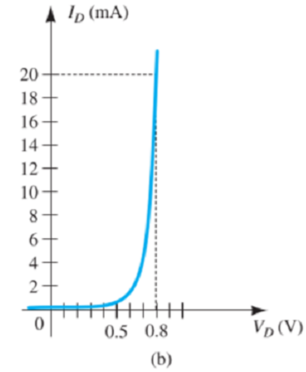


FIG. 2.3
(a) Circuit; (b) characteristics.

Solution:

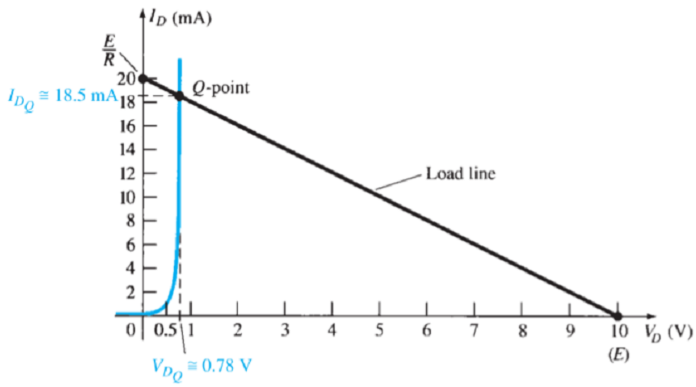


FIG. 2.4
Solution to Example 2.1.

Using the Q-point values, the dc resistance for Example 2.1 is

$$R_D = \frac{V_{D_Q}}{I_{D_Q}} = \frac{0.78\text{ V}}{18.5\text{ mA}} = 42.16\ \Omega$$

An equivalent network (for these operating conditions only) can then be drawn as shown in Fig. 2.5.

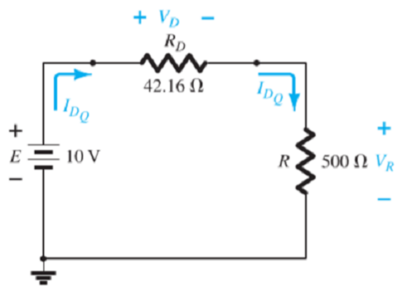


FIG. 2.5
Network quivalent to Fig. 2.4.

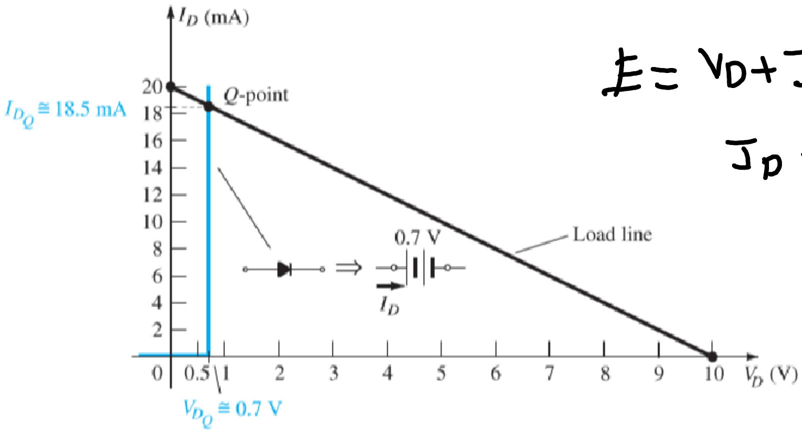
The current

$$I_D = \frac{E}{R_D + R} = \frac{10\text{ V}}{42.16\ \Omega + 500\ \Omega} = \frac{10\text{ V}}{542.16\ \Omega} \cong \mathbf{18.5\ mA}$$

and $$V_R = \frac{RE}{R_D + R} = \frac{(500\ \Omega)(10\text{ V})}{42.16\ \Omega + 500\ \Omega} = \mathbf{9.22\ V}$$

EXAMPLE 2.2 Repeat Example 2.1 using the approximate equivalent model for the silicon semiconductor diode.

Solution: The resulting Q-point is $V_{D_Q} = \mathbf{0.7\ V}$ $I_{D_Q} = \mathbf{18.5\ mA}$



$E = V_D + I_D . R$

$I_D = \dfrac{E - V_D}{R} = \dfrac{10 - 0.7}{0.5k}$

$= \underline{18.6mA}$

FIG. 2.6
Solution to Example 2.1 using the diode approximate model.

For this situation the dc resistance of the Q-point is

$$R_D = \frac{V_{D_Q}}{I_{D_Q}} = \frac{0.7\ \text{V}}{18.5\ \text{mA}} = 37.84\ \Omega$$

which is still relatively close to that obtained for the full characteristics.

EXAMPLE 2.3 Repeat Example 2.1 using the ideal diode model.

Solution: As shown in Fig. 2.7, the load line is the same, but the ideal characteristics now intersect the load line on the vertical axis. The Q-point is therefore defined by

$$V_{D_Q} = \mathbf{0\ V}$$
$$I_{D_Q} = \mathbf{20\ mA}$$

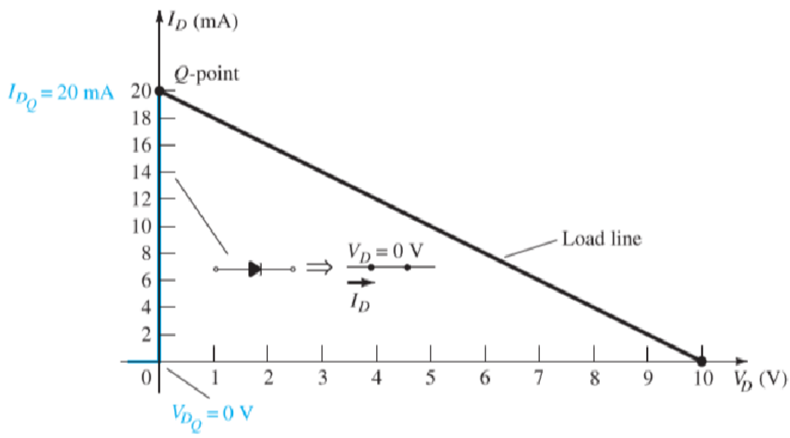


FIG. 2.7
Solution to Example 2.1 using the ideal diode model.

$$R_D = \frac{V_{D_Q}}{I_{D_Q}} = \frac{0\ \text{V}}{20\ \text{mA}} = 0\ \Omega \text{ (or a short-circuit equivalent)}$$

2.3 SERIES DIODE CONFIGURATIONS

For all the analysis to follow in this chapter it is assumed that

The forward resistance of the diode is usually so small compared to the other series elements of the network that it can be ignored.

In general, a diode is in the "on" state if the current established by the applied sources is such that its direction matches that of the arrow in the diode symbol, and $V_D \geq 0.7$ V for silicon, $V_D \geq 0.3$ V for germanium, and $V_D \geq 1.2$ V for gallium arsenide.

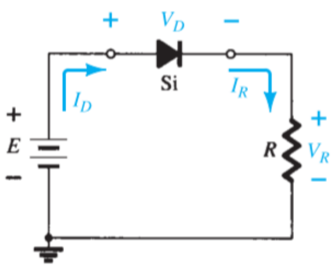
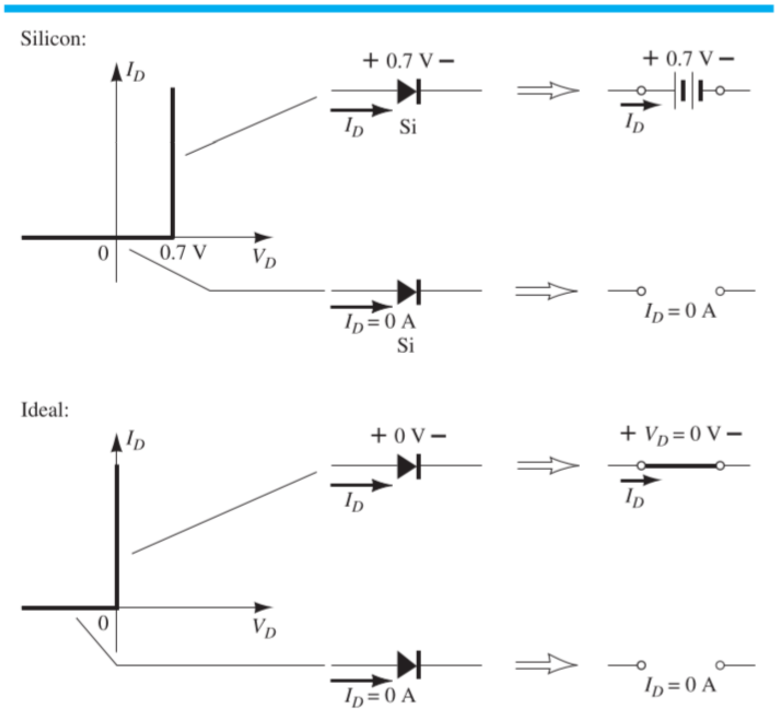


FIG. 2.8
Series diode configuration.

TABLE 2.1
Approximate and Ideal Semiconductor Diode Models.



EXAMPLE 2.4 For the series diode configuration of Fig. 2.13, determine V_D, V_R, and I_D.

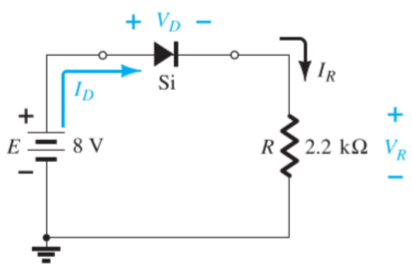


FIG. 2.13
Circuit for Example 2.4.

Solution: Since the applied voltage establishes a current in the clockwise direction to match the arrow of the symbol and the diode is in the "on" state,

$$V_D = \mathbf{0.7\ V}$$

$$V_R = E - V_D = 8\text{ V} - 0.7\text{ V} = \mathbf{7.3\ V}$$

$$I_D = I_R = \frac{V_R}{R} = \frac{7.3\text{ V}}{2.2\text{ k}\Omega} \cong \mathbf{3.32\ mA}$$

EXAMPLE 2.5 Repeat Example 2.4 with the diode reversed.

Solution: The result is the network of Fig. 2.14, where $I_D = \mathbf{0\ A}$ due to the open circuit. Since $V_R = I_R R$, we have $V_R = (0)R = \mathbf{0\ V}$. Applying Kirchhoff's voltage law around the closed loop yields

$$E - V_D - V_R = 0$$

and

$$V_D = E - V_R = E - 0 = E = 8\ \text{V}$$

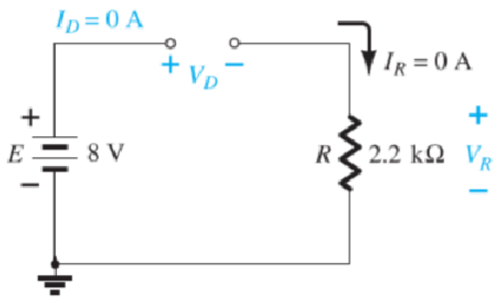


FIG. 2.14
Determining the unknown quantities for Example 2.5.

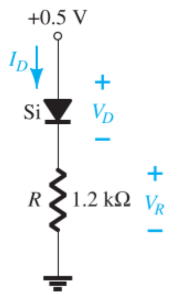


FIG. 2.16
Series diode circuit for Example 2.6.

EXAMPLE 2.6 For the series diode configuration of Fig. 2.16, determine V_D, V_R, and I_D.

Solution: establishing the open-circuit equivalent as the appropriate approximation, as shown in Fig. 2.18. The resulting voltage and current levels are therefore the following:

$$I_D = \mathbf{0\ A}$$

$$V_R = I_R R = I_D R = (0\ \text{A})\,1.2\ \text{k}\Omega = \mathbf{0\ V}$$

and

$$V_D = E = \mathbf{0.5\ V}$$

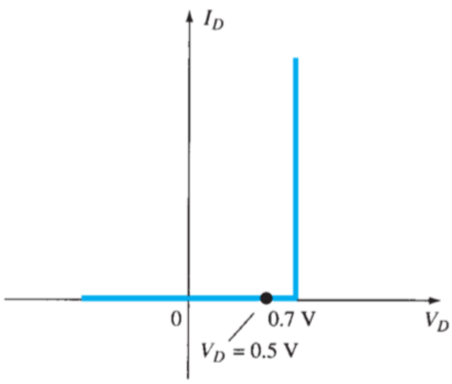


FIG. 2.17
Operating point with E = 0.5 V.

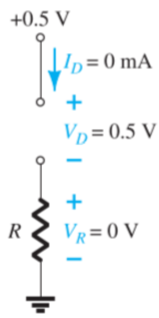


FIG. 2.18
Determining I_D, V_R, and V_D for the circuit of Fig. 2.16.

Example 2.8. Determine I_D, V_{D2}, V_o,

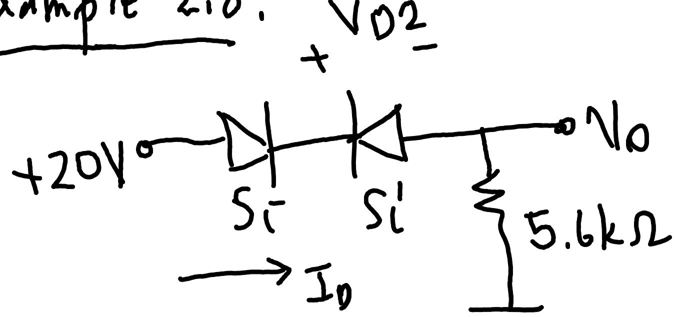


Fig 2.24

Example 2.9. Determine I, V_1, V_2, V_o

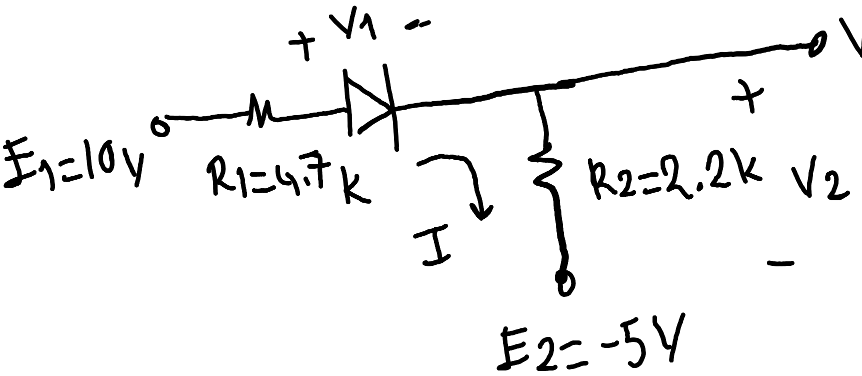


Fig 2.25.

2.4. Parallel and Series-Parallel Configurations:

Example 2.10.

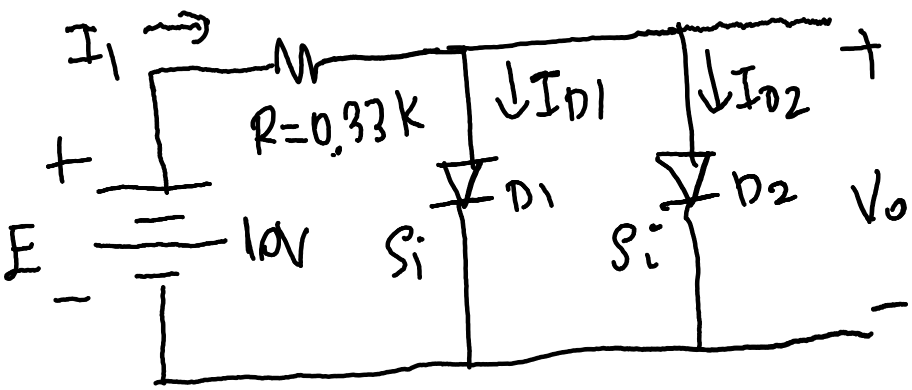


Fig 2.28

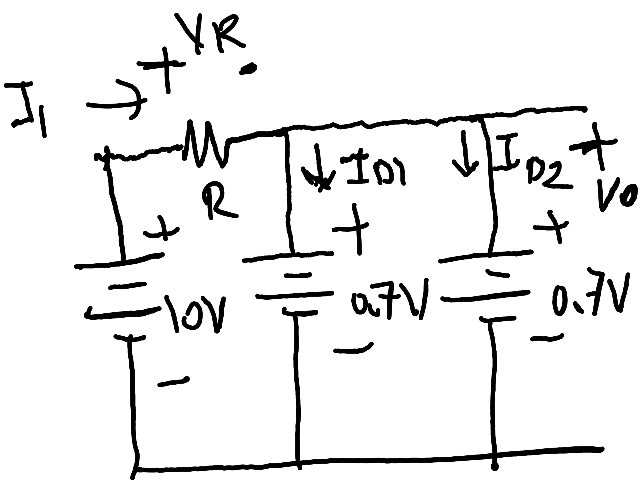
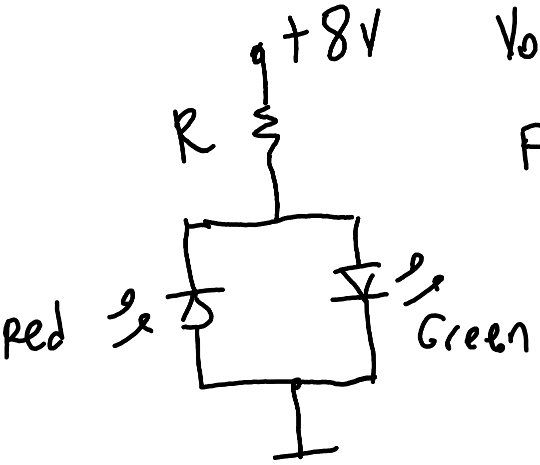


Fig 2.29

$$I_1 = \frac{E - V_0}{R} = \frac{10 - 0.7}{0.33k} = 28.1818 \text{ mA}$$

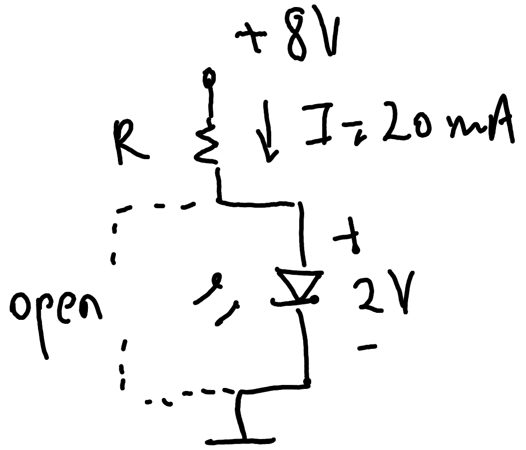
$$I_{D1} = I_{D2} = \frac{I_1}{2} = 14.0909 \text{ mA}$$

Example 2.11. For both LED average turn-on voltage $V_{ON} = 2V$.



Find R that ensures flowing of 20mA thru the 'on' diode.

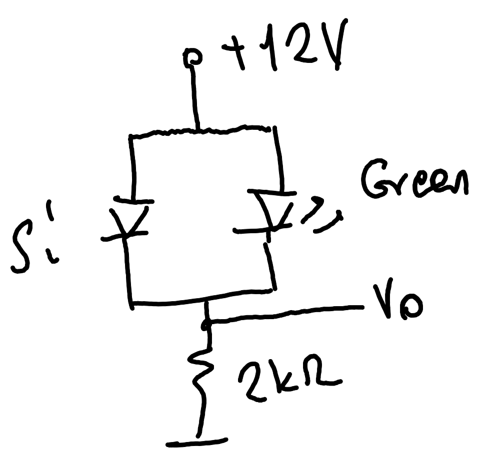
Solution: Red LED is off, Green is on. Thus the equivalent circuit will look like as follows. Thus, we can write by KVL,



$$8 = R\,(20\text{mA}) + 2V$$

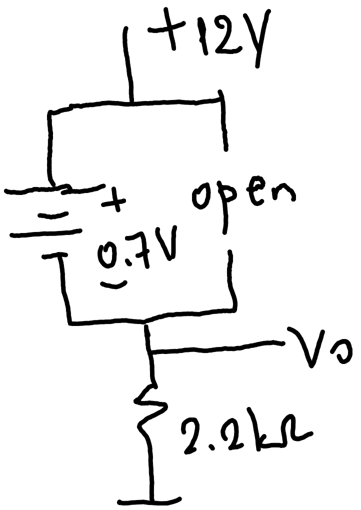
$$R = \frac{8-2}{20 \text{ mA}} = \frac{6}{20 \text{ mA}} = 300\,\Omega = 0.3k$$

Example 2.12. Determine V_o.



Solution: Si diode has small on voltage and its voltage is more quickly reached than LED which has 2V on voltage. LED will be off since the voltage of parallel branches can not be different.

Thus, the equivalent circuit will look like as follows:



Thus, $V_o = 12 - 0.7 = \underline{11.3\,V}$.

Example 2.13. Determine I_1, I_2, I_{D2}.

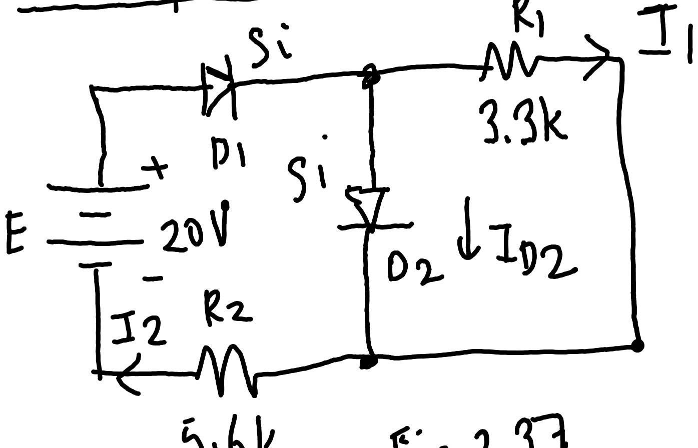


Fig 2.37.

Both diodes will be 'on'.

Using KVL, we can write the loop equation as,

$$-E + V_{D1} + V_{D2} + R_2 I_2 = 0$$

$$I_2 = \frac{E - V_{D1} - V_{D2}}{R_2} = \frac{20 - 0.7 - 0.7}{5.6k}$$

$$\underline{I_2 = 3.32\,mA}.$$

$$I_1 = \frac{V_{D2}}{R_1} = \frac{0.7}{3.3k} = \underline{0.21\,mA}$$

$$I_{D2} = I_2 - I_1 = 3.32 - 0.21 = \underline{3.11\,mA}$$

2.5. AND/OR Gates