Diode Characteristics

Resistance level of the diode

As operating point of a diode moves from one region to another the resistance of the diode will also change due to the nonlinear shape of the characteristics curve. The type of applied voltage or signal defined the resistance level.

DC or Static Resistance

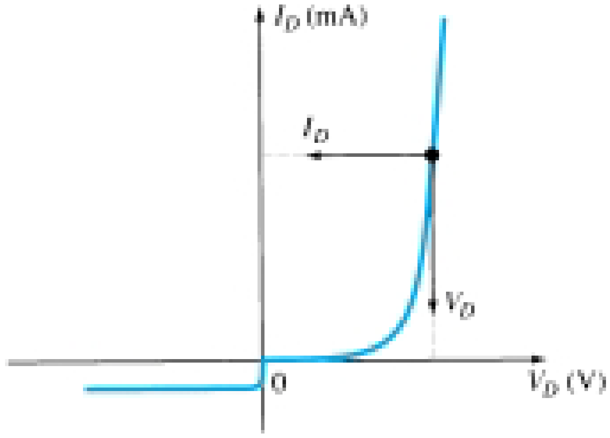


Fig. 8.1. Determining the dc resistance of a diode at a particular operating point.

The DC resistance (R_D) of diode at the operating point can be found simply by finding the corresponding level of V_D and I_D. The DC resistance levels at the knee and below will be greater than the resistance levels obtained for the vertical rise section.

$$R_D = \frac{V_D}{I_D}$$

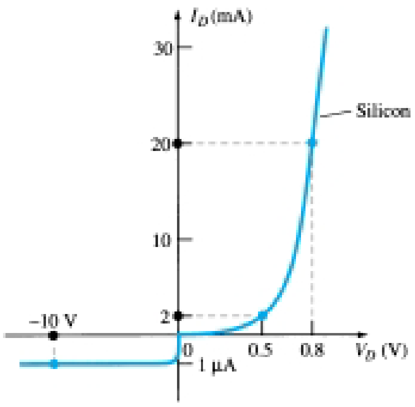


Fig. Example 8.1

Example

Determine the dc resistance levels for the diode of the figure shown if

(a) I_D=0.2mA

(b) I_D=5mA

(c) V_D=-10V

Solution

(a) At I_D=0.2mA V_D=0.5V from the curve

$$R_D = \frac{V_D}{I_D} = \frac{0.5}{0.2\times10^{-3}} = 2.5k\Omega$$

(b) At I_D=20mA V_D=0.8V from the curve

$$R_D = \frac{V_D}{I_D} = \frac{0.8}{20\times10^{-3}} = 40\Omega$$

(c) At V_D=-10V I_D =-1µA from the curve

$$R_D = \frac{V_D}{I_D} = \frac{10}{1\times10^{-6}} = 10M\Omega$$

AC (Dynamic Resistance)

If a sinusoidal rather than dc input is applied, the varying input will move the instantaneous operating point up and down region of the characteristics and thus define a specific change in current and voltage. The ac resistance (r_d) can be define as

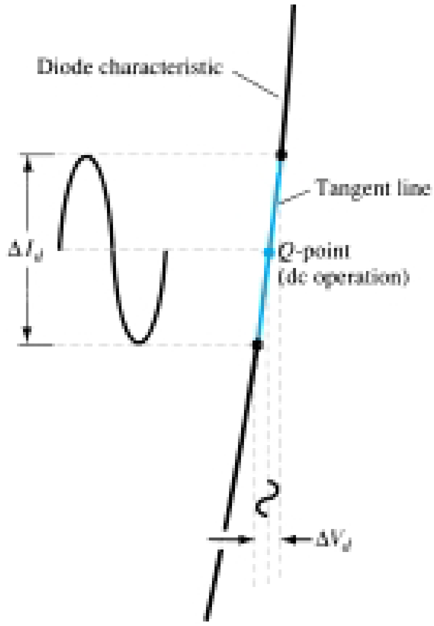


Fig. 8.3, Defining the dynamic or ac resistance.

$$r_d = \frac{\Delta v}{\Delta i} = \frac{dv}{di}$$

$$g_d = \frac{di}{dv}$$

$$I_D = I_s\left(\exp(\frac{eV}{kT}) - 1\right)$$

$$= I_s \exp(\frac{eV}{kT}) - I_s$$

$$g_d = \frac{di}{dv} = \frac{d\left(I_s \exp(\frac{eV}{kT}) - I_s\right)}{dv} = \frac{e}{kT} I_s \exp(\frac{eV}{kT})$$

$$I_D = I_s \exp(\frac{eV}{kT}) - I_s$$

$$\cong I_s \exp(\frac{eV}{kT})$$

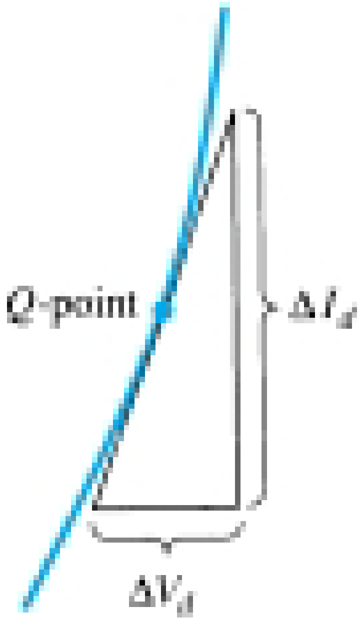


Fig. 8.4, Determining the ac resistance at a Q-point.

$$g_d = \frac{e}{kT} I_D = 38.7 I_D$$

$$rd = \frac{1}{38.7 I_D} = \frac{26mV}{I_D}$$

Example

Determine the ac resistance levels for the diode if I_D=13mA

Solution

$$rd = \frac{26mV}{I_D} = \frac{26}{13} = 2\Omega$$

Diode equivalent circuit

The equivalent circuit means that, the device symbol can be removed from a schematic and the equivalent circuit inserted in its place without affecting the actual behavior of the system. The result is often a network that can be solved using traditional circuit analysis techniques.

- Ideal diode

Ideal diode conducts current in forward biasing and act like an open circuit like an open circuit in the reverse biasing. The characteristics of an ideal diode are those of a switch that can conduct current in only one direction.

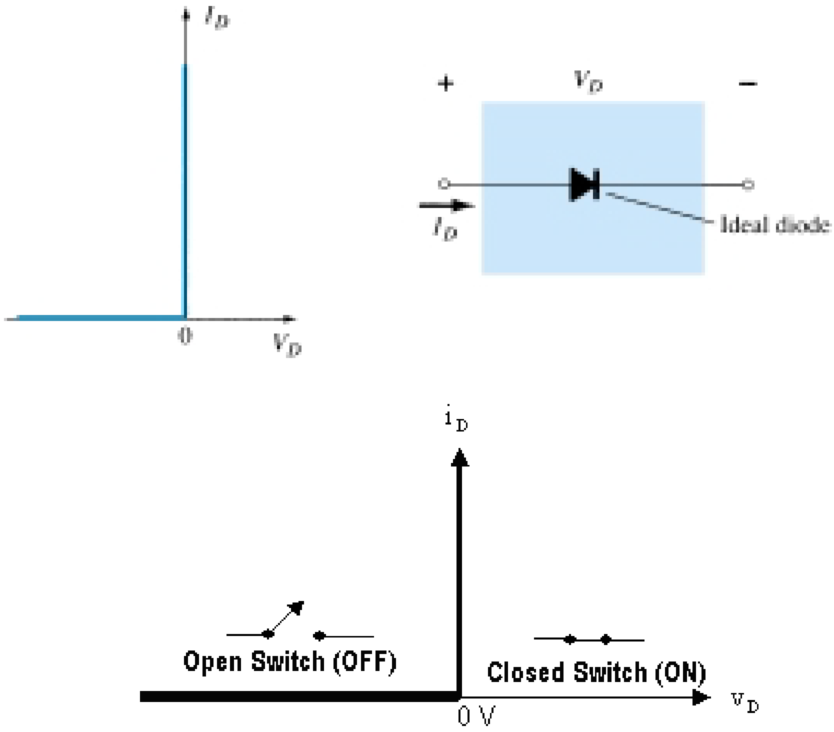
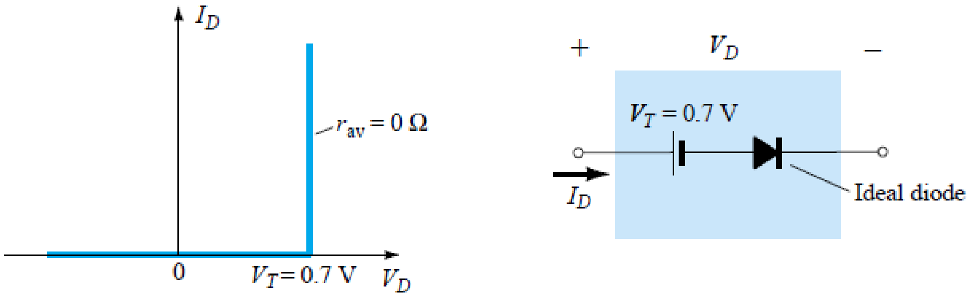


Fig. 8.5. Ideal diode and its characteristics.

Approximate equivalent model

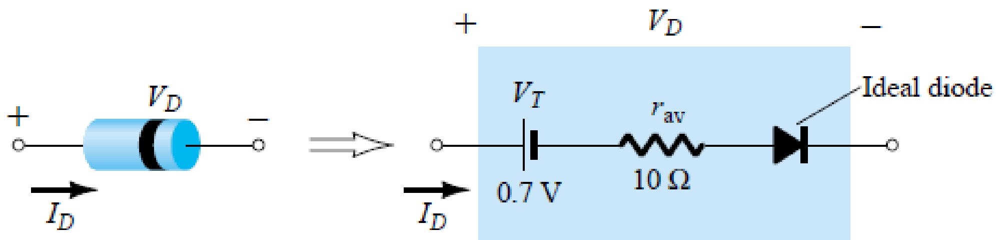


Fib. 8,7 Simplified equivalent circuit for the silicon semiconductor diode.

In this case, the practical diode is modeled by an ideal diode and a voltage source. The magnitude of the voltage source is usually equal to the forward voltage drop across the diode. The voltage drop across the diode remains the same regardless the current through it when it conducts.

- Piecewise Linear Model

The simplest possible piecewise linear model of a diode is obtained by using two straight lines to approximate its voltage-current characteristic. However, the point should be on the right-hand side of the current axis (y-axis) as shown. In this figure, line (1) corresponds to the OFF state of the diode, line (2). The intersection of the two lines on the



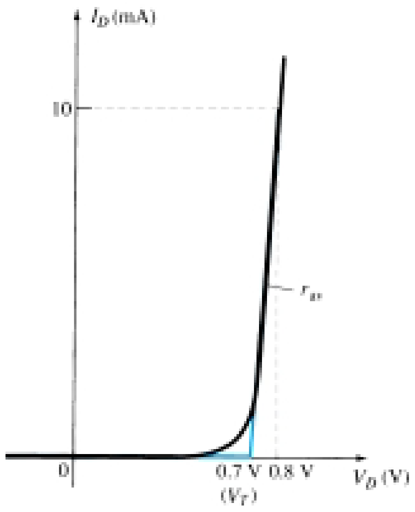


Fig.8.8. Defining the piecewise-linear equivalent circuit using straight-line segments to approximate the characteristic curve.

voltage axis is taken to be the forward voltage drop of the diode for this model. From the slope of the line (2), we can compute the resistance that must be included in series with the diode model. According to this model, the voltage drop across the diode must exceed V_{DO} for the diode to begin conducting.

Series Diode Configurations with DC Inputs

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= 0.7 V for silicon and V_D= 0.3 V for germanium.

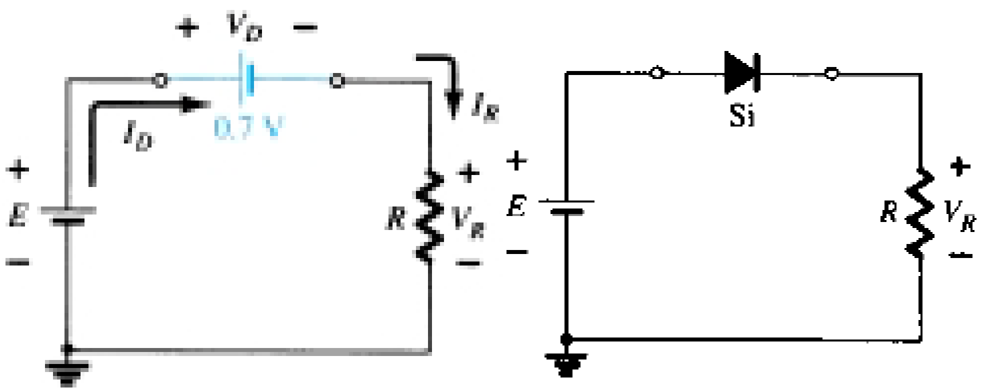


Fig.9.1 Series diode configuration and Substituting the equivalent model for the "on" diode

- If a diode in the on-state place 0.7 V ***or*** 0.3 V drop across the diode

$$E - I_D R_s - V_D = 0$$

$$E - I_D R_s - 0.7 = 0$$

$$I_D = \frac{E - 0.7}{R_s}$$

- If a diode (has been reversed) is the off state place an open circuit across the diode

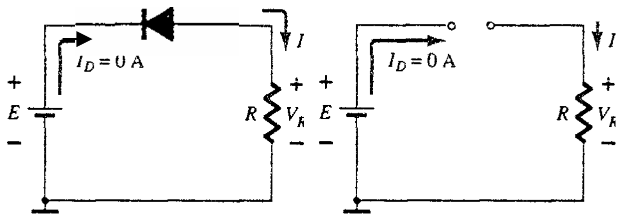


Fig. 9.2 Reversing the diode

$$E - I_D R_s - V_D = 0$$

$$I_D = 0$$

$$E - V_D = 0 \qquad E = V_D$$

Example 9.1

Determine (a)V_D,I_D,V_R and (b) if the diode reversed V_D,I_D,V_R. For E=8V, R_s=2.2k

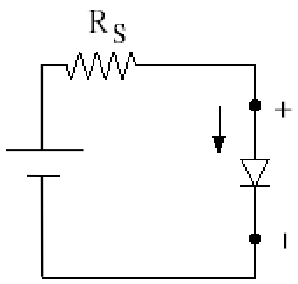


Fig. 9.3 Example 9.1

Solution

(a) For forward bias V_D=0.7V

$$I_D = \frac{E - 0.7}{R_s} = \frac{8 - 0.7}{2.2k} = 3.3mA$$

$$V_R = 8 - 0.7 = 7.3V$$

(b) For reverse bias V_D=8V

I_D=0

V_R=0

Notes

- An open circuit can have voltage a cross its terminals but the current is always **0A**
- A short circuit has **0V** voltage drop a cross its terminals but the current is limited surrounding networks.

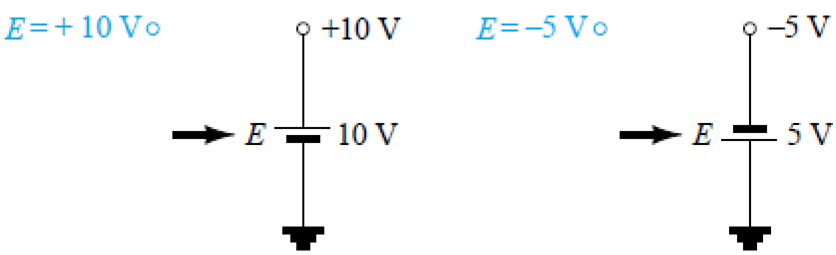


Fig. 9.4 Source notation.

Example 9.2

Determine V_R, I_D

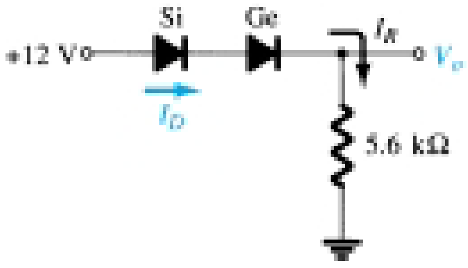


Fig. 9.4 Example 9.2

Solution

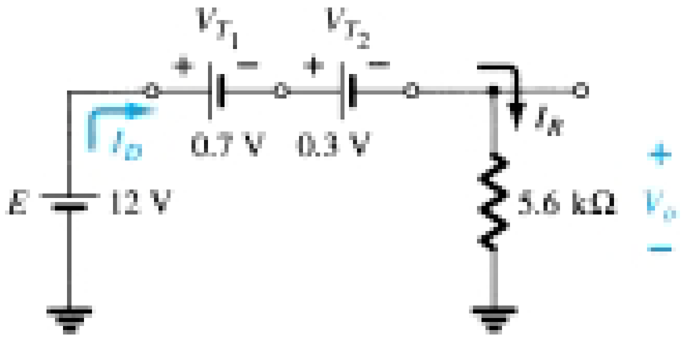


Fig. 9.5 Determining the unknown quantities for Example 9.2

$$E - I_D R_s - V_{D1} - V_{D2} = 0$$

$$12 - I_D 5.6k - 0.7 - 0.3 = 0$$

$$I_D = \frac{E - 0.7 - 0.3}{R_s}$$

$$= \frac{12 - 0.7 - 0.3}{5.6k} = 1.96mA$$

$$V_R = I_D R_s$$
$$= 1.96 \times 5.6 = 11V$$

Example 9.3

Determine I_D, V_1, V_2, V_o.

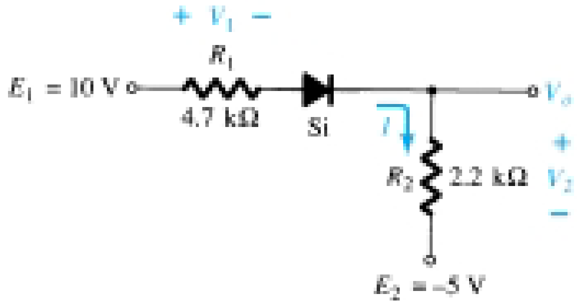


Fig. 9.6 Example 9.3

Solution

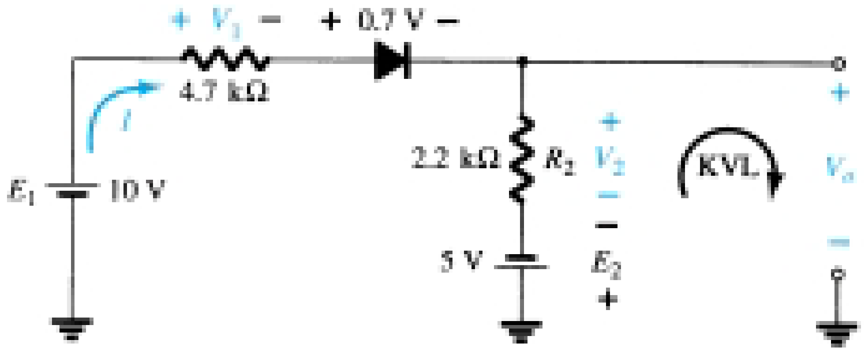


Fig. 9.7 Determining the unknown quantities for Example 9.3

$$E_1 - I_D R_s - V_D - I_D R + E_2 = 0$$

$$10 - I_D 4.7k - 0.7 - I_D 2.2k + 5 = 0$$

$$I_D = \frac{15 - 0.7}{(4.7 + 2.2)k} = 2.07mA$$

$$V_1 = I_D R_s = 2.07 \times 4.7 = 9.73V$$

$$V_2 = I_D R = 2.07 \times 2.2 = 4.55V$$

$$-E_2 + I_D R - Vo = 0 \qquad Vo = -5 + 4.55 = -0.45V$$

Parallel and Series-Parallel Diode Configurations

Example 9.4

Determine V_O, I, I_{D1}, I_{D2}.

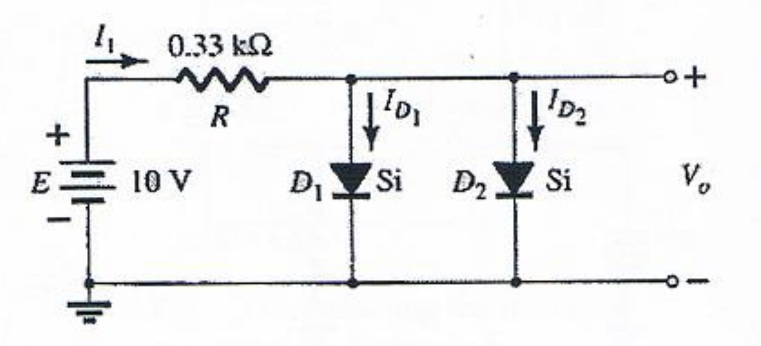


Fig. 9.8 Example 9.4

Solution

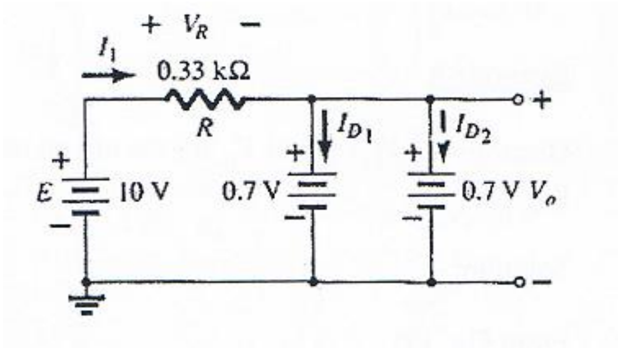


Fig. 9.9 Determining the unknown quantities for Example 9.4

V_o=0.7V

$$E - IRs - V_{D1} = 0 \qquad 10 - I0.33k - 0.7 = 0$$

$$I = \frac{10-0.7}{0.33k}$$
$$= 28.18mA$$

Diodes of similar characteristics

$$I_{D1} = I_{D2} = \frac{I}{2} = 14.9mA$$

Example 9.5

Determine I

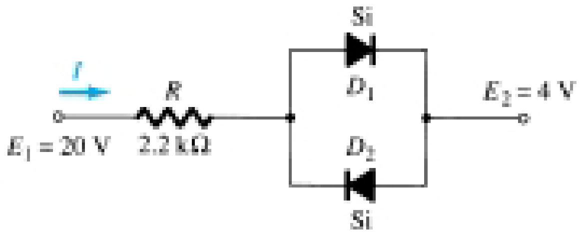


Fig. 9.10 Example 9.5

Solution

$$E_1 - I_D R_s - V_D - E_2 = 0 \qquad\qquad 20 - I_D 2.4k - 0.7 - 4 = 0$$

$$I_D = \frac{16 - 0.7}{2.4k} = 6.8mA$$

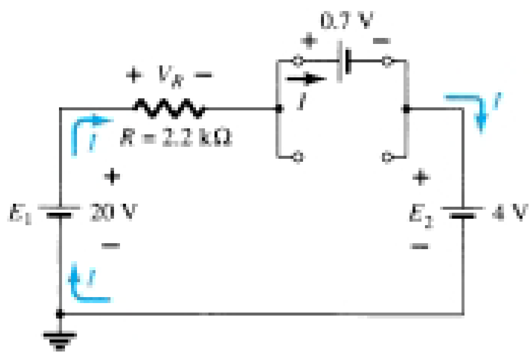


Fig. 9.11 Determining the unknown quantities for Example 9.5

Example 9.6

Determine V_o

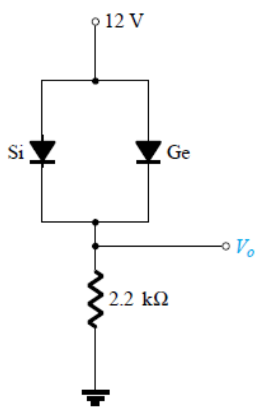


Fig. 9.12 Example 9.6

Solution

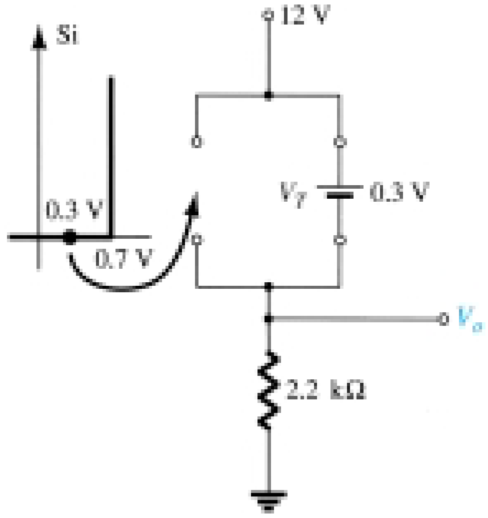


Fig. 9.13 Determining the unknown quantities for Example 9.6

The applied voltage will turn both diodes. But the voltage across parallel elements must be the same, when the supply turned on it will increase from 0-12V over a period time (ms).

At the instant during the rise that 0.3V is established a cross Ge diode it will turn on maintain a level 0.3V, the silicon diode remains open circuit

$$Vo = 12 - 0.3 = 11.7V$$

Example 9.7

Determine I_1,I_2 and I_D.

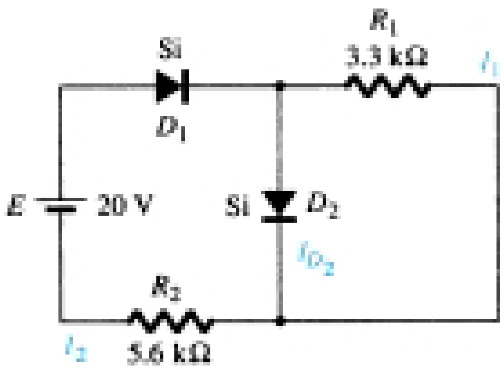


Fig. 9.14 Example 9.7

Solution

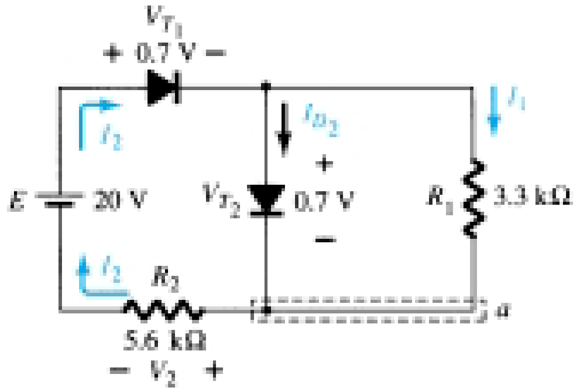


Fig. 9.15 Determining the unknown quantities for Example 9.7

$$I_1 = \frac{V_{D2}}{3.3k}$$

$$= \frac{0.7}{3.3k}$$

$$= 0.212mA$$

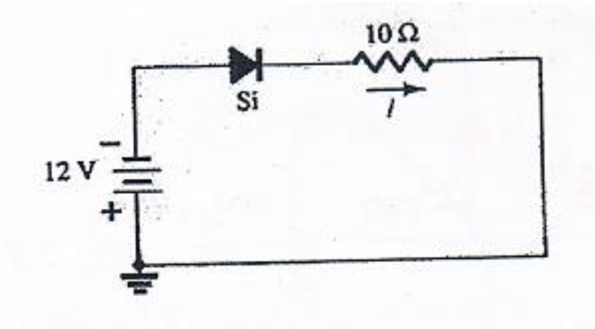
$$E_1 - 0.7 - 0.7 - I_2(5.6k) = 0$$

$$I_2 = I_{D2} + I_1$$

$$I_{D2} = I_2 - I_1 = 3.32 - 0.212 = 3.108mA$$

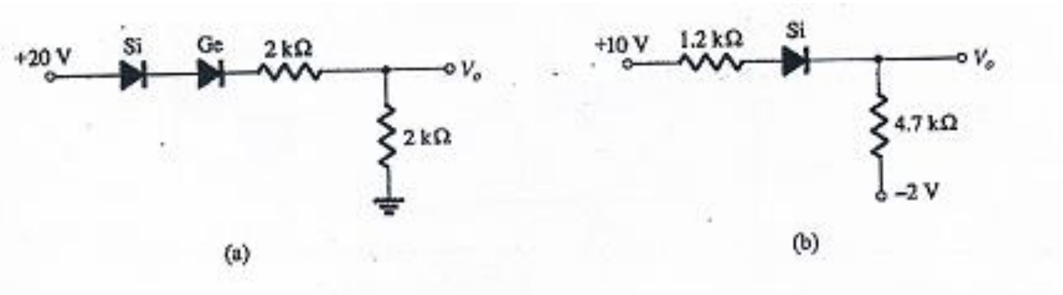
Problems

Q1: Determine the current I for the configuration of the figure using the approximation equivalent model for the diode.



(Ans:I_{DQ}=0A)

Q2: Determine the voltage V_o for each configuration of the figure



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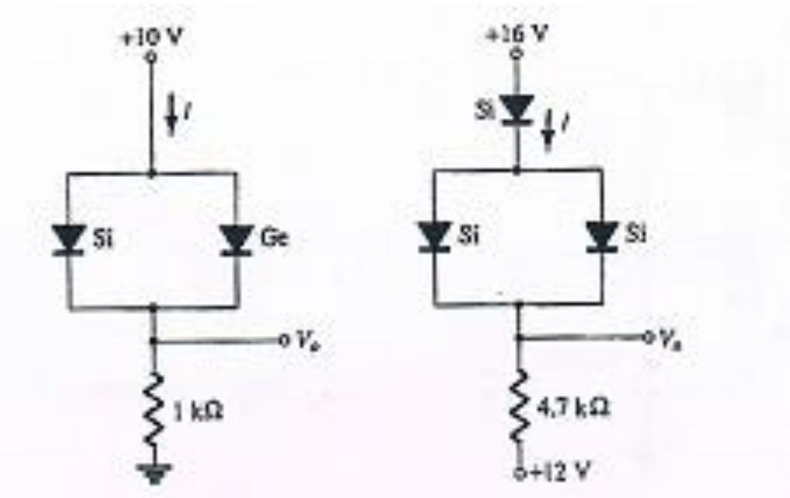
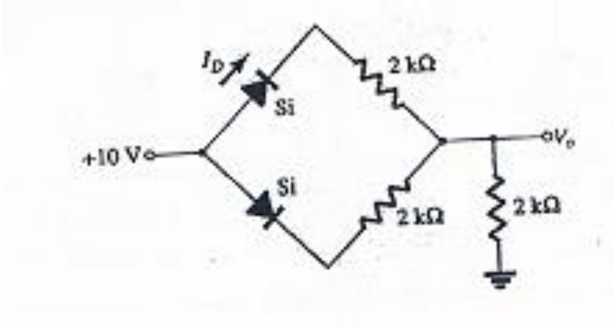
(Ans:9.5V, 7V)

Q3: Determine V_o and I for each configuration of the figure



.(Ans:(a) 9.7V, 9.7 mA, (b) 14.6V, 0.553 mA)

Q4: Determine V_o and I for each configuration of the figure



(Ans: 6.2V, 1.55mA)

Q5: Determine *Vo* and *ID* for the networks