Diode Application

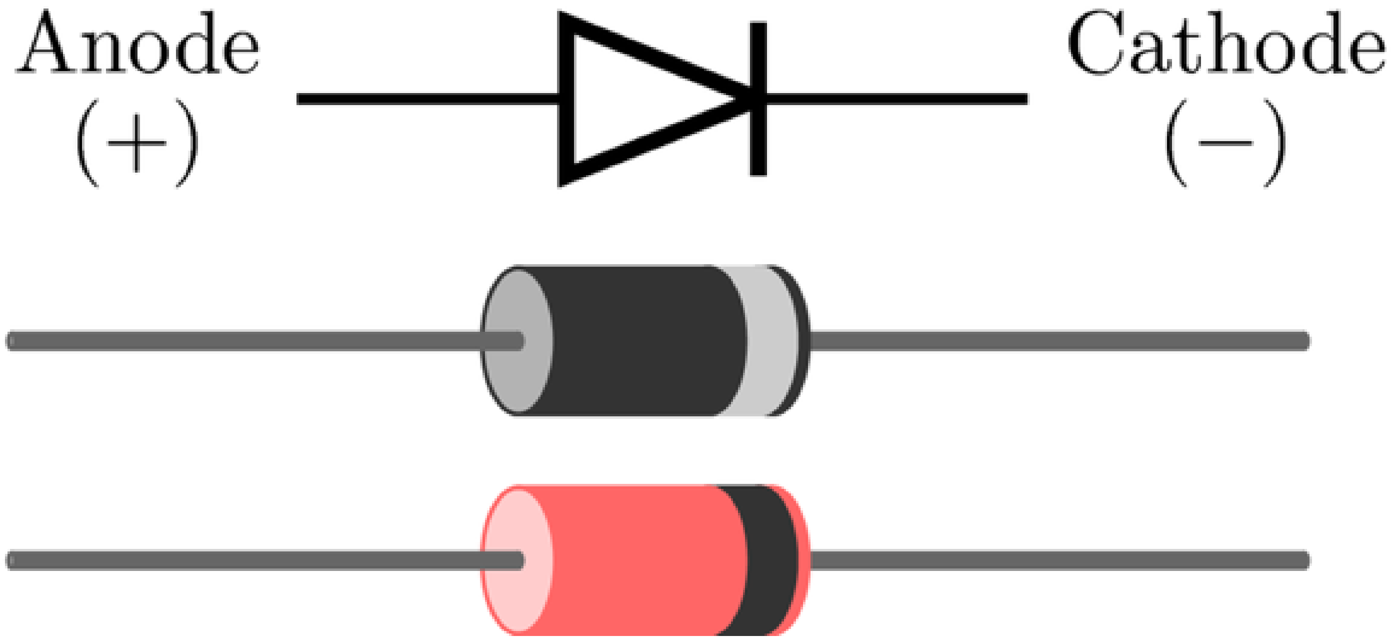
Dr Mohammad Abdur Rashid

Readings

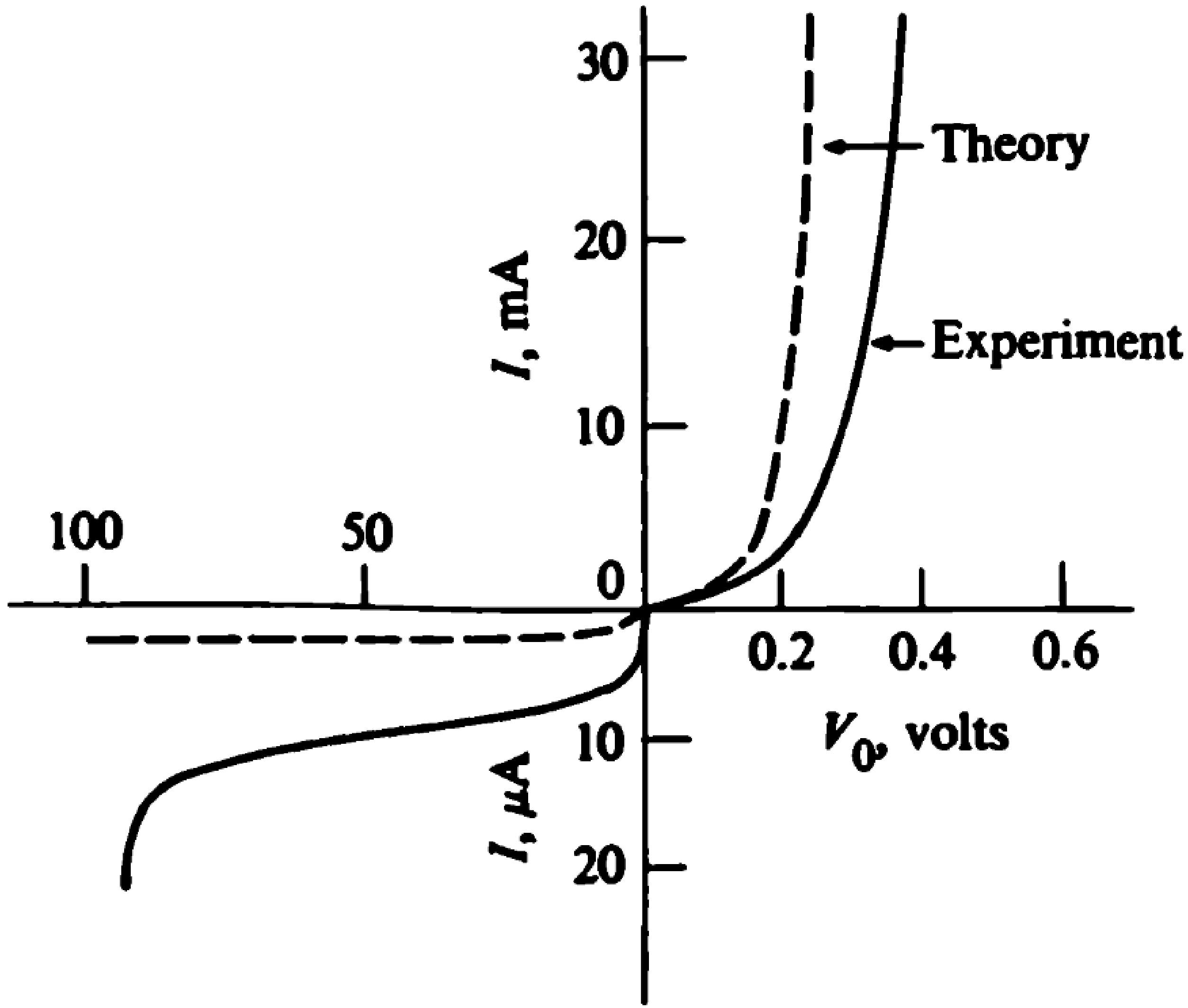
Electronic Devices and Circuit Theory
– Boylestad, Nashelsky

Chapter 2: Diode Applications

Diode



Current versus voltage characteristics

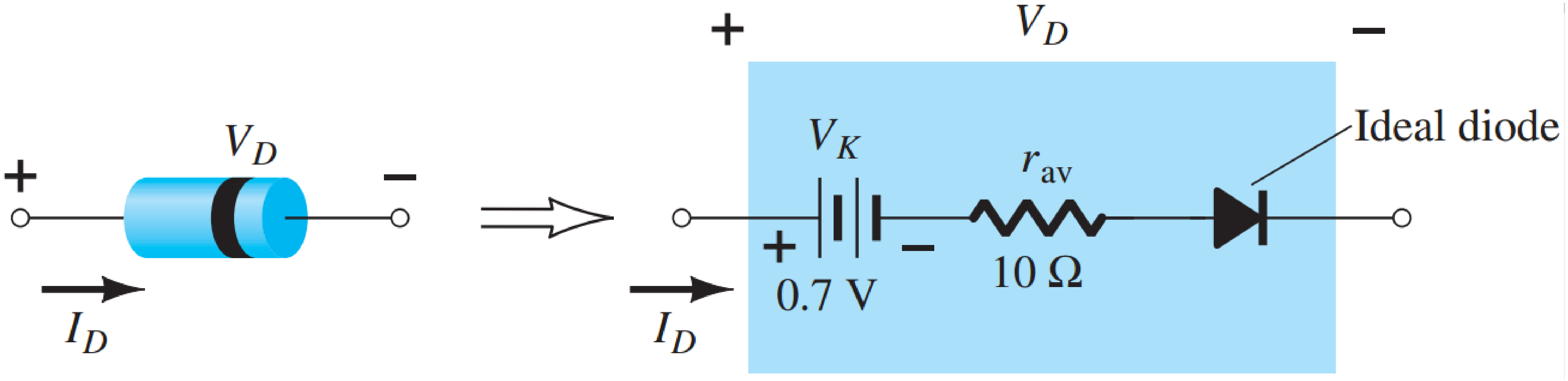


Elementary Solid State Physics – Ali Omar

LED residential and commercial lighting

Electronic Devices and Circuit Theory – Boylestad, Nashelsky

Diode symbol



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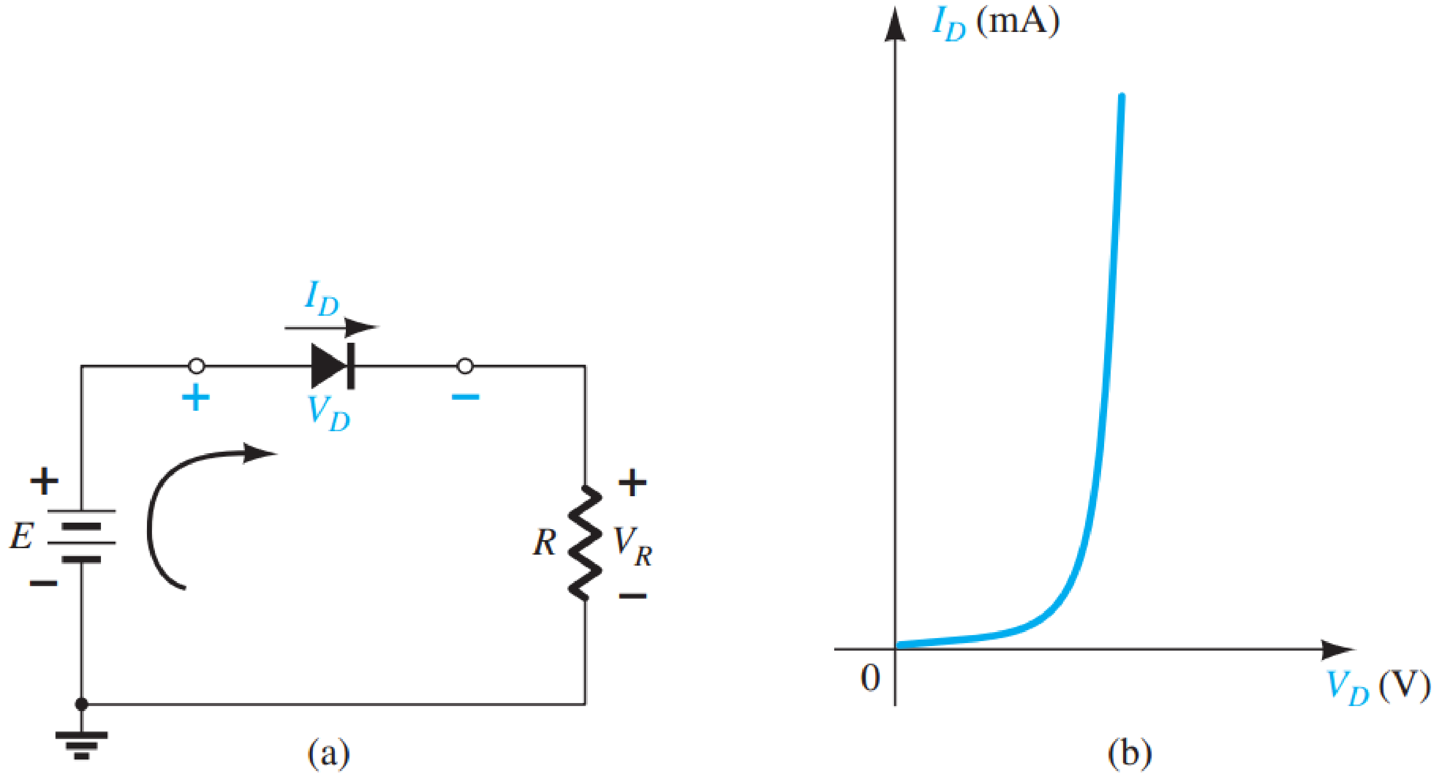
Load-line analysis



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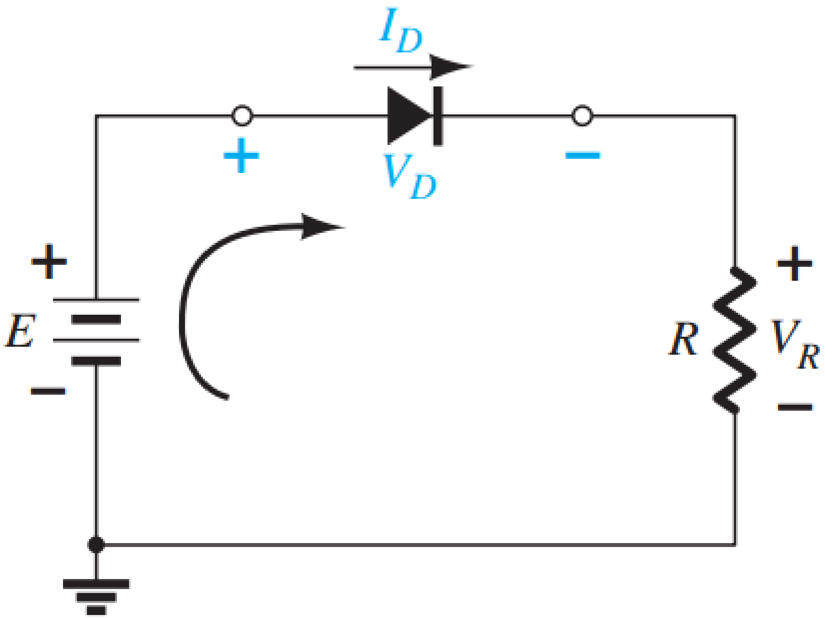
Series diode configuration: (a) circuit; (b) characteristics.

Note

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.

Applying Kirchhoff's voltage law

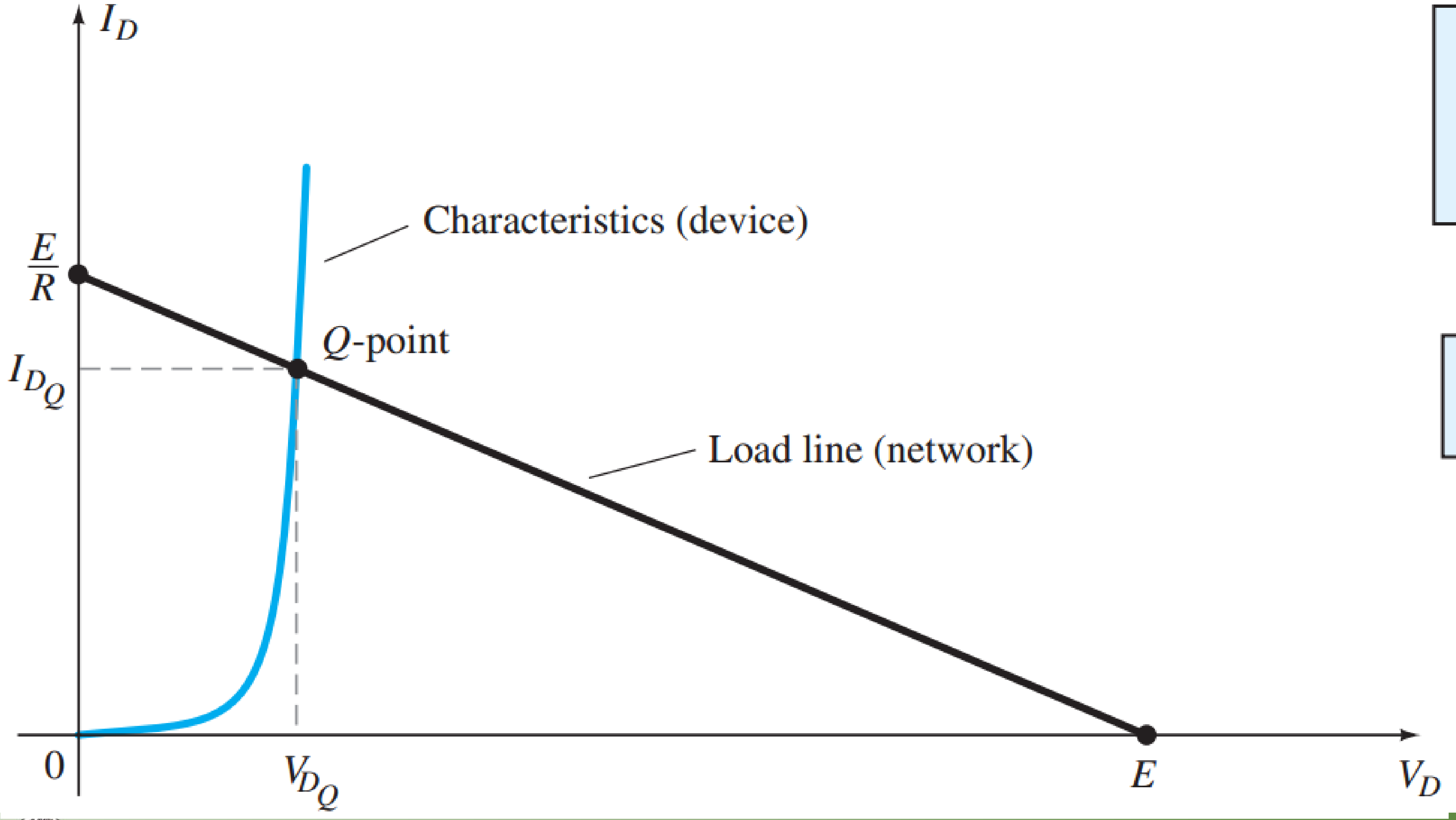


$$E = V_D + I_D R$$

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

$$V_D = E\big|_{I_D = 0\,\text{A}}$$

Load line and point of operation

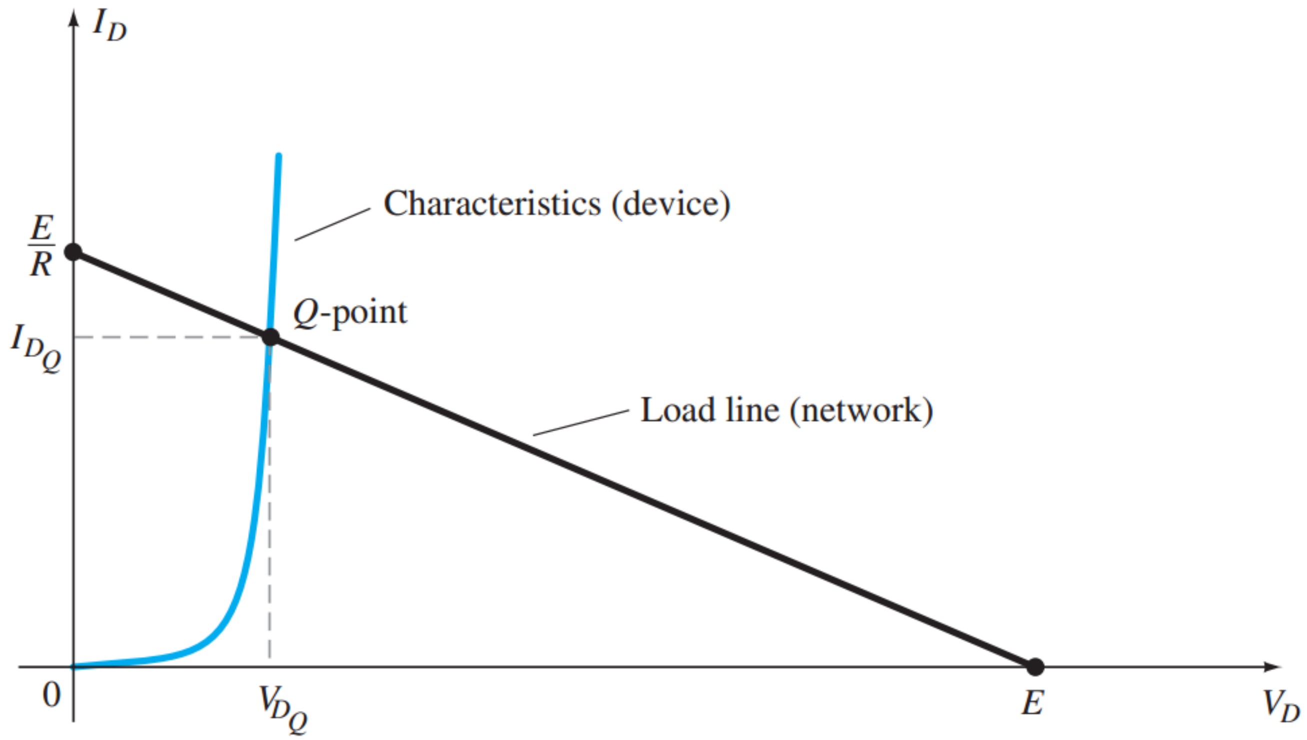


$$I_D = \frac{E}{R}\bigg|_{V_D=0\text{ V}}$$

$$V_D = E\big|_{I_D=0\text{ A}}$$

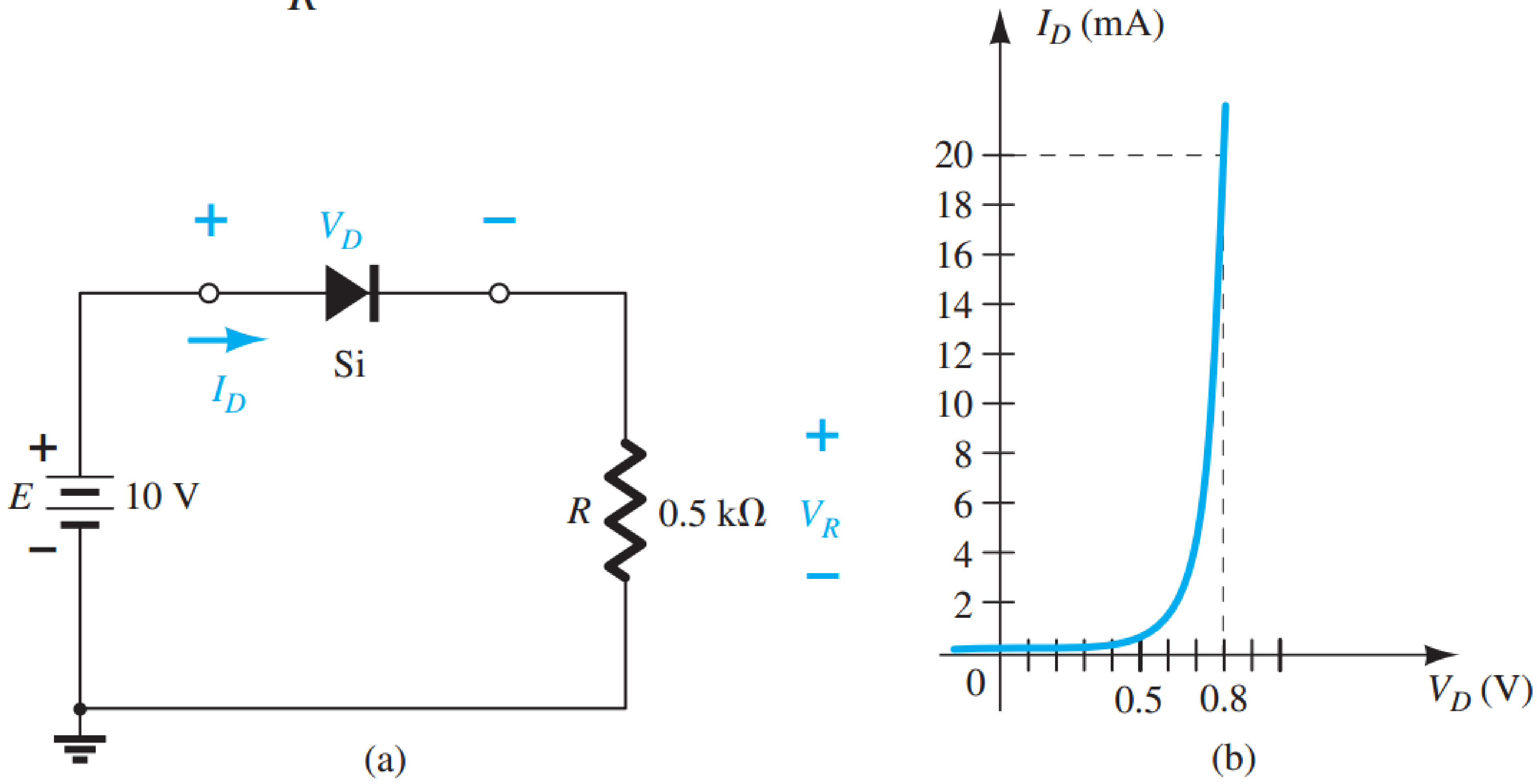
Q-point

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.



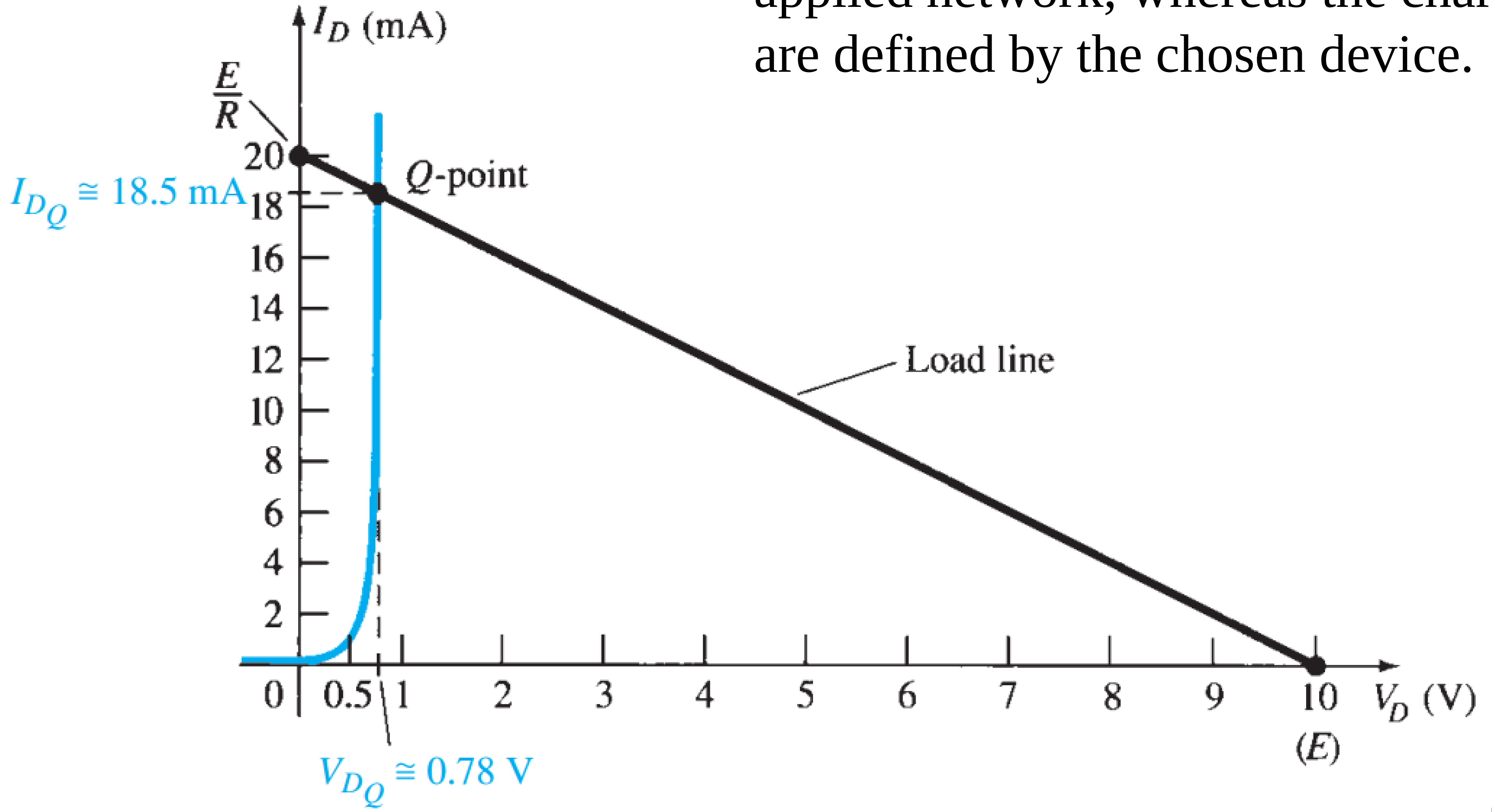
Determine: a. V_{D_Q} and I_{D_Q}.

b. V_R.



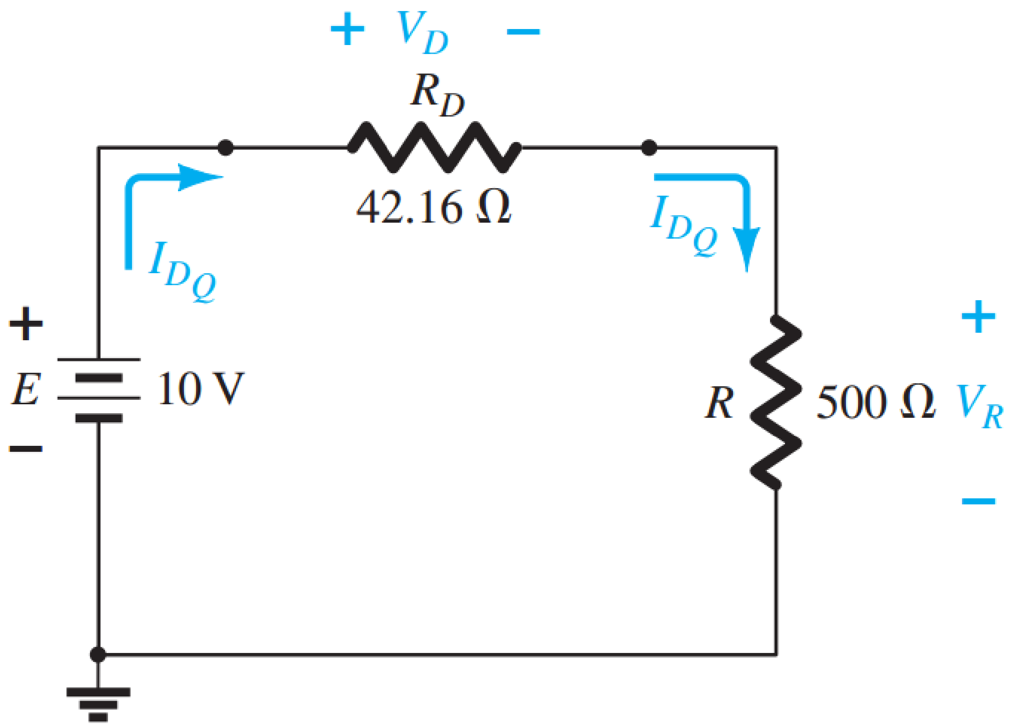
(a) Circuit; (b) characteristics.

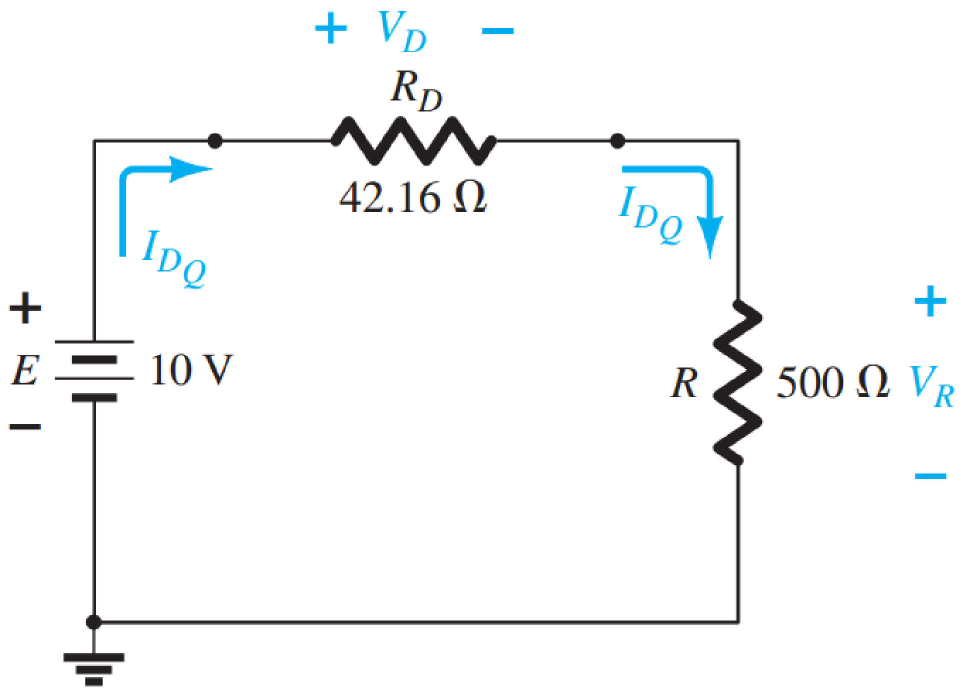
The load line is determined solely by the applied network, whereas the characteristics are defined by the chosen device.



Using the *Q*-point values, the dc resistance

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

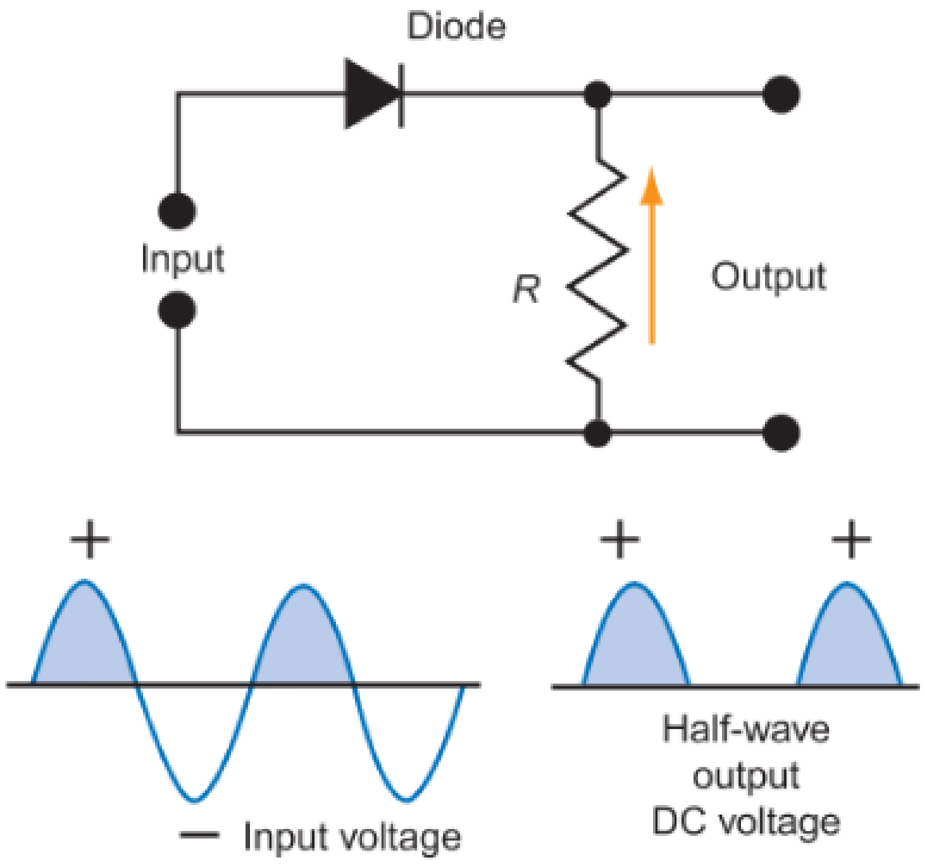




$$I_D = \frac{E}{R_D + R} = \frac{10\text{ V}}{42.16\ \Omega + 500\ \Omega} = \frac{10\text{ V}}{542.16\ \Omega} \cong \mathbf{18.5\ mA}$$

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

Half-wave rectifier



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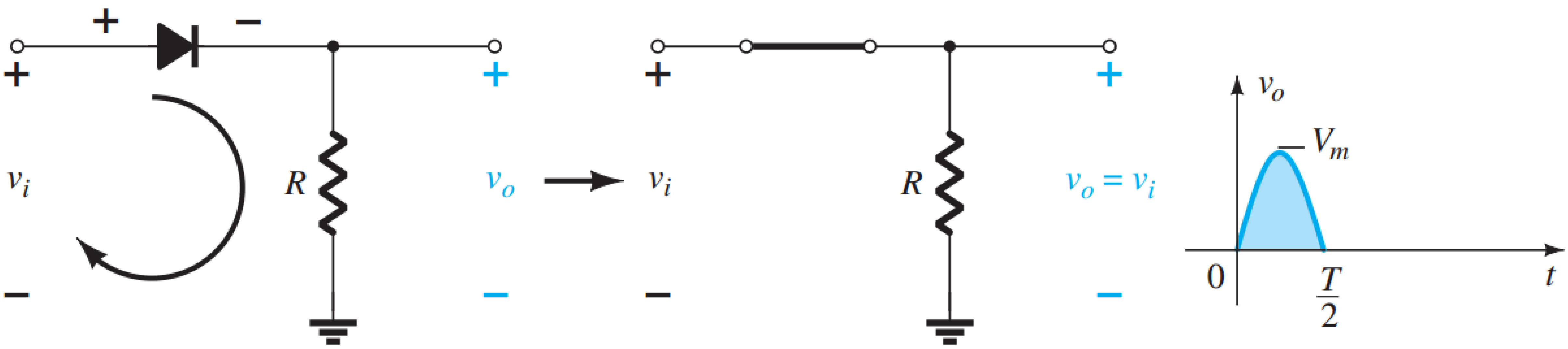
Half-wave rectifier



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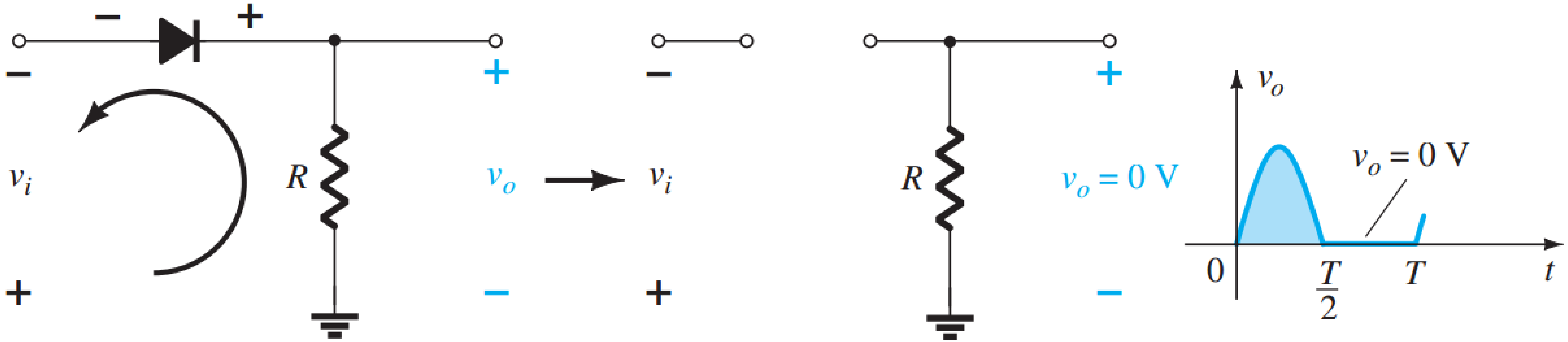
Half-wave rectifier



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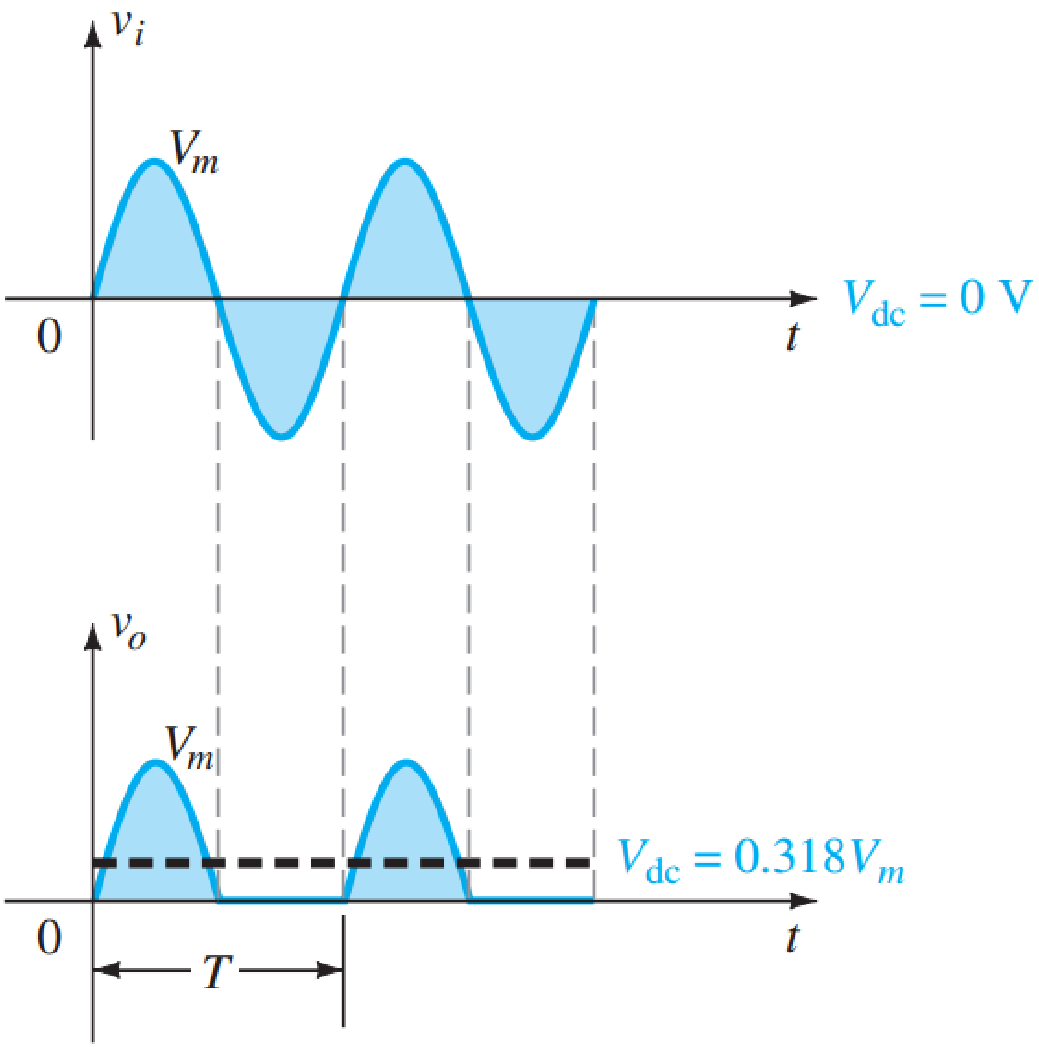
Half-wave rectified signal



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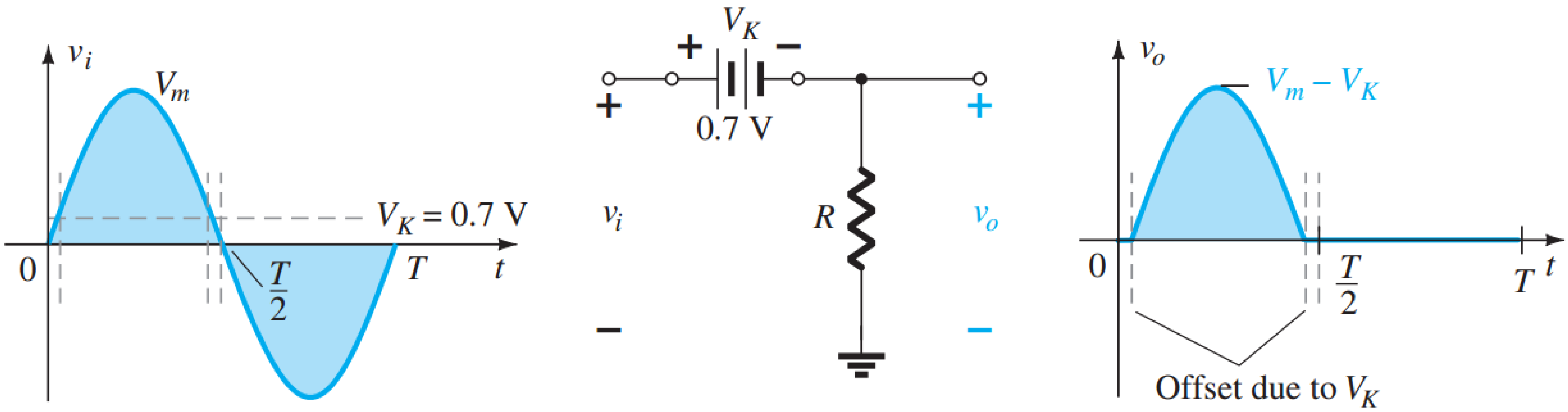
Half-wave rectified signal



$$V_{dc} \cong 0.318(V_m - V_K)$$

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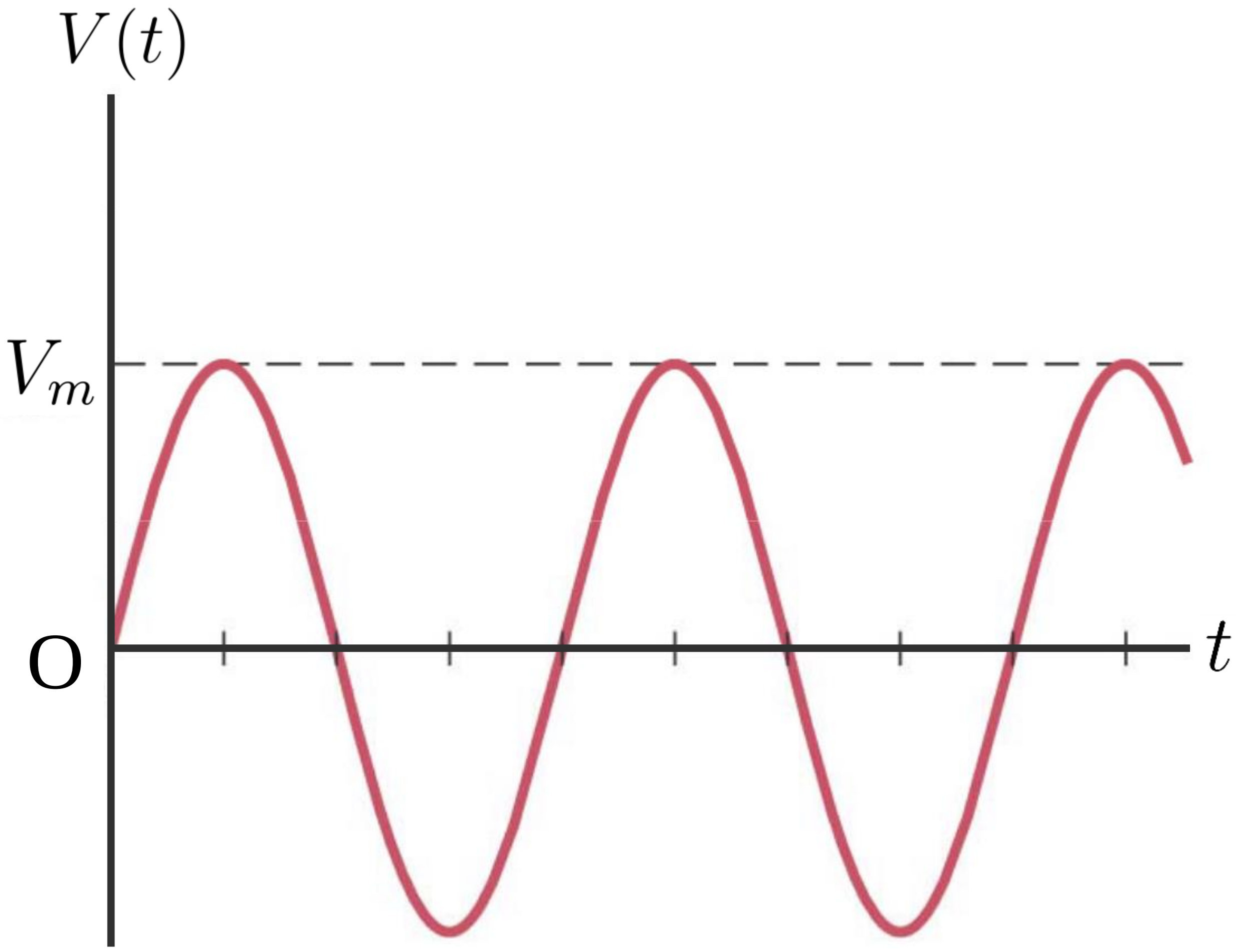
Alternating current (AC)

$$V(t) = V_m \sin(\omega t)$$



Average of $V(t)$ over time T

$$\overline{V} = \frac{1}{T}\int_0^T V(t)\mathrm{d}t$$

$$V(t) = V_m \sin(\omega t)$$

$$\begin{aligned}
\overline{V} &= \frac{V_m}{T}\int_0^T \sin(\omega t)\mathrm{d}t \\
&= \frac{V_m}{T}\left[-\frac{\cos(\omega t)}{\omega}\right]_0^T \\
&= \frac{V_m}{\omega T}\{-\cos(\omega T) + \cos 0\} \\
&= \frac{V_m}{2\pi}\{-\cos(2\pi) + \cos 0\} \\
&= \frac{V_m}{2\pi}(-1+1) \\
&= 0.
\end{aligned}$$

Average of $V(t)$ over time $T/2$

$$V_{\text{avg}} = \frac{1}{T/2}\int_0^{T/2} V(t)\mathrm{d}t$$

$$V(t) = V_m \sin(\omega t)$$

$$\begin{aligned}
V_{\text{avg}} &= \frac{2V_m}{T}\int_0^{T/2} \sin(\omega t)\mathrm{d}t \\
&= \frac{2V_m}{T}\left[-\frac{\cos(\omega t)}{\omega}\right]_0^{T/2} \\
&= \frac{2V_m}{\omega T}\{-\cos(\omega T/2) + \cos 0\} \\
&= \frac{2V_m}{2\pi}\{-\cos(\pi) + \cos 0\} \\
&= \frac{2}{\pi}V_m \\
&\approx 0.637\, V_m .
\end{aligned}$$

The RMS value of *V*(*t*)

The term "RMS" stands for "Root-Mean-Squared", also called the effective or heating value of alternating current, is equivalent to a DC voltage that would provide the same amount of heat generation in a resistor as the AC voltage would if applied to that same resistor.

RMS is not an "Average" voltage, and its mathematical relationship to peak voltage varies depending on the type of waveform.

$$V_{\mathrm{rms}} = \left[\frac{1}{T}\int_0^T V^2(t)\mathrm{d}t\right]^{1/2}$$

The RMS value of *V*(*t*)

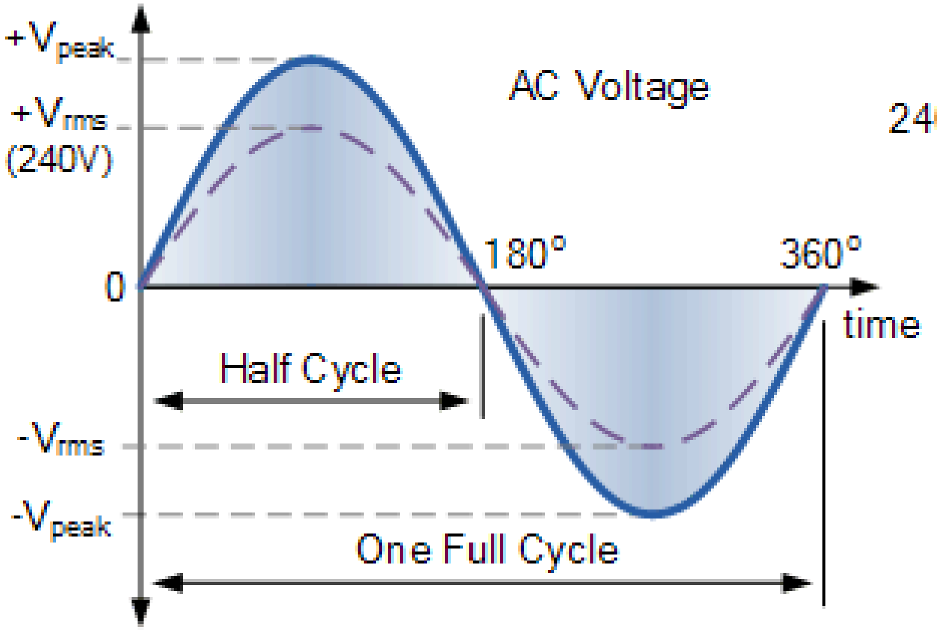
$$
\begin{aligned}
V_{\mathrm{rms}}^2 &= \frac{V_m^2}{T}\int_0^T \sin^2(\omega t)\mathrm{d}t \\
&= \frac{V_m^2}{2T}\int_0^T 2\sin^2(\omega t)\mathrm{d}t \\
&= \frac{V_m^2}{2T}\int_0^T \{1-\cos(2\omega t)\}\,\mathrm{d}t \\
&= \frac{V_m^2}{T2}\int_0^T \mathrm{d}t - \frac{V_m^2}{T}\int_0^T \cos(2\omega t)\mathrm{d}t \\
&= \frac{V_m^2}{2T}\Big[T\Big]_0^T - \frac{V_m^2}{2T}\left[\frac{\sin(2\omega t)}{2\omega}\right]_0^T
\end{aligned}
$$

The RMS value of *V*(*t*)

$$
\begin{aligned}
V_{\text{rms}}^2 &= \frac{V_m^2}{2} - \frac{V_m^2}{4\omega T}\left\{\sin(2\omega T) - \sin(0)\right\} \\
&= \frac{V_m^2}{2} - \frac{V_m^2}{4\omega T}\left\{\sin(4\pi) - \sin(0)\right\} \\
&= \frac{V_m^2}{2} - \frac{V_m^2}{4\omega T}(0 - 0) \\
&= \frac{V_m^2}{2}.
\end{aligned}
$$

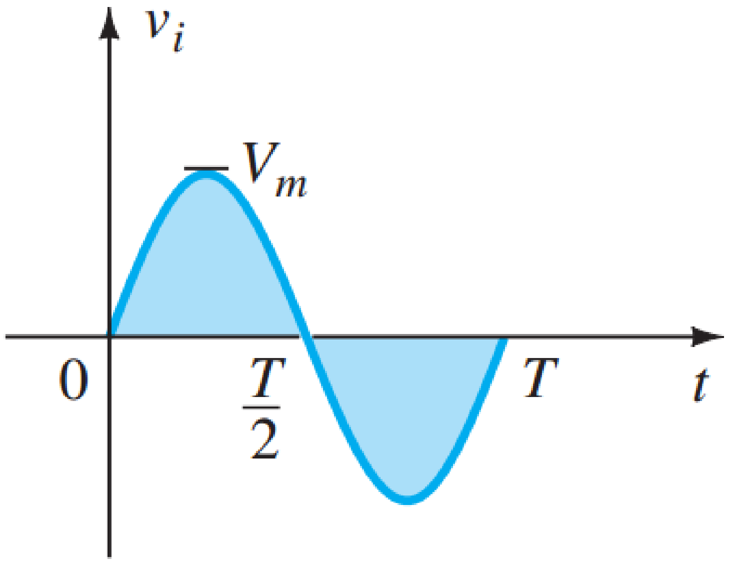
$$
V_{\text{rms}} = \frac{V_m}{\sqrt{2}} \approx 0.707\, V_m
$$

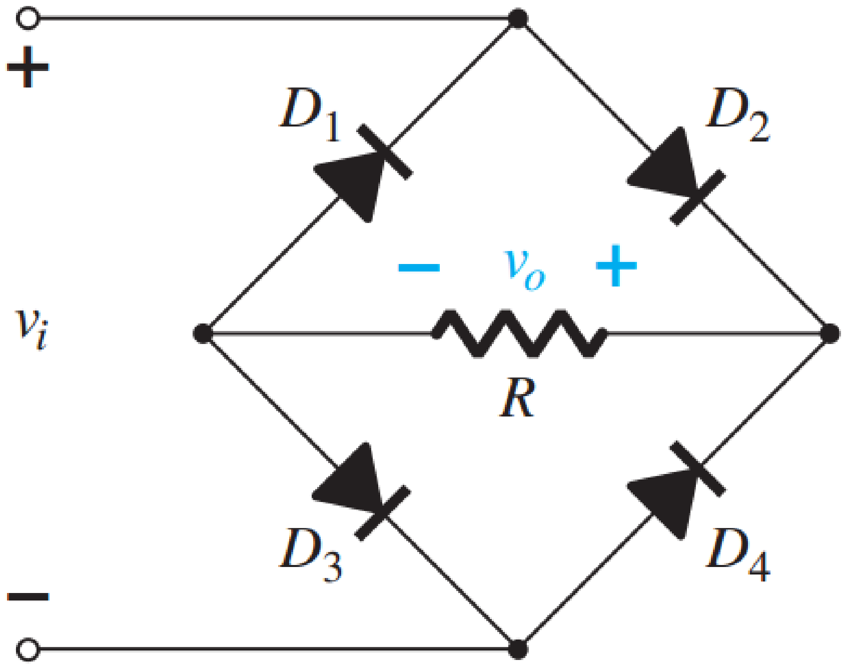
The RMS and peak value of AC voltage



$$V_{\mathrm{rms}} = \frac{V_m}{\sqrt{2}} \approx 0.707\, V_m$$

Full-wave rectified signal





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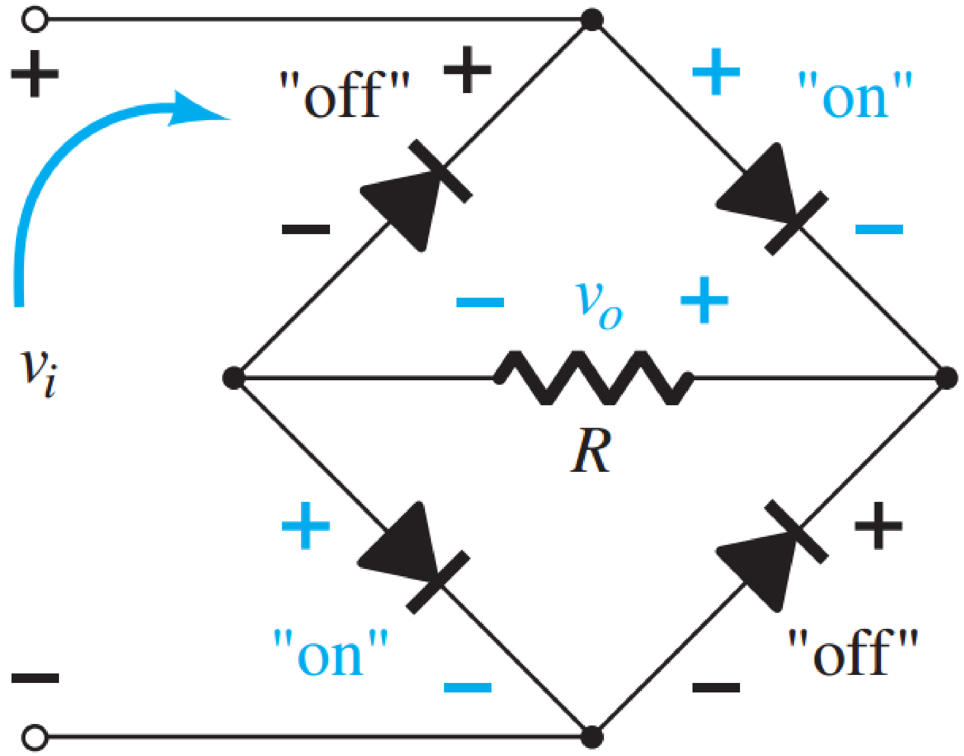
Full-wave rectified signal



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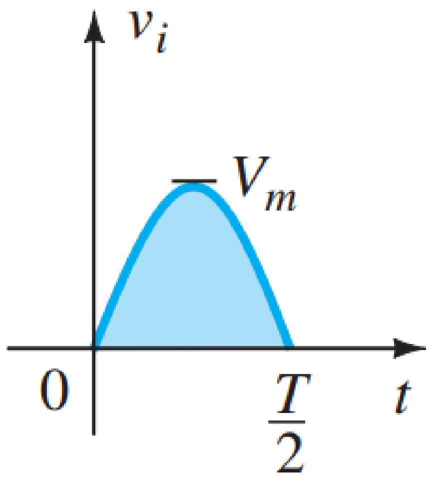
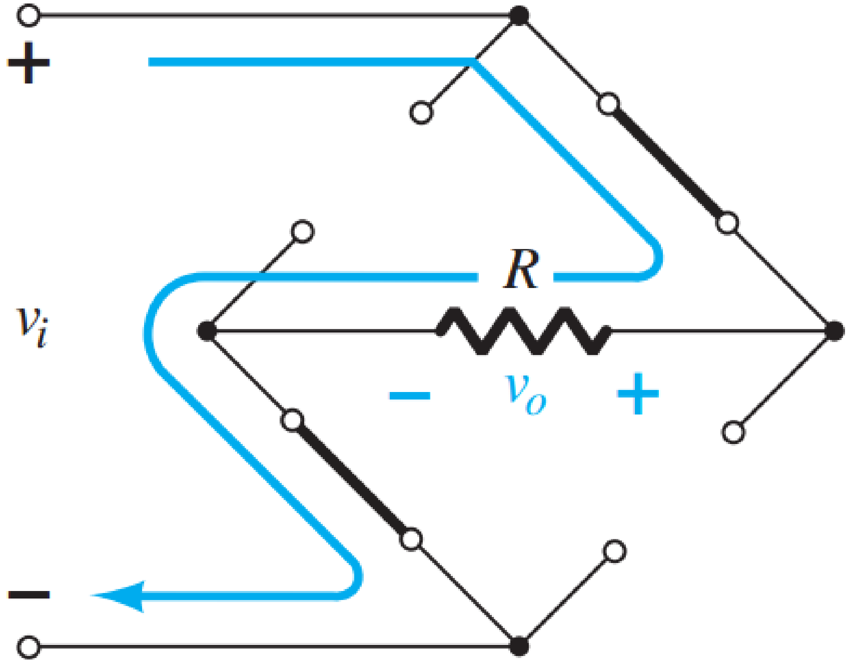
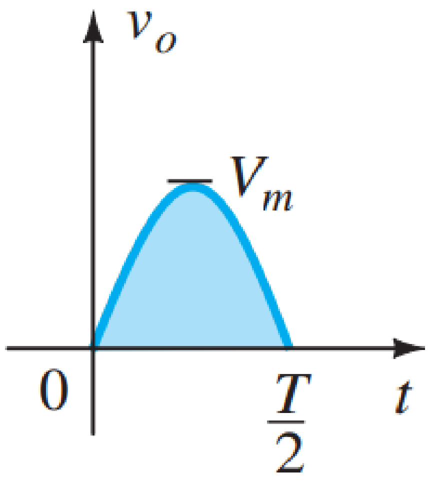
Full-wave rectified signal







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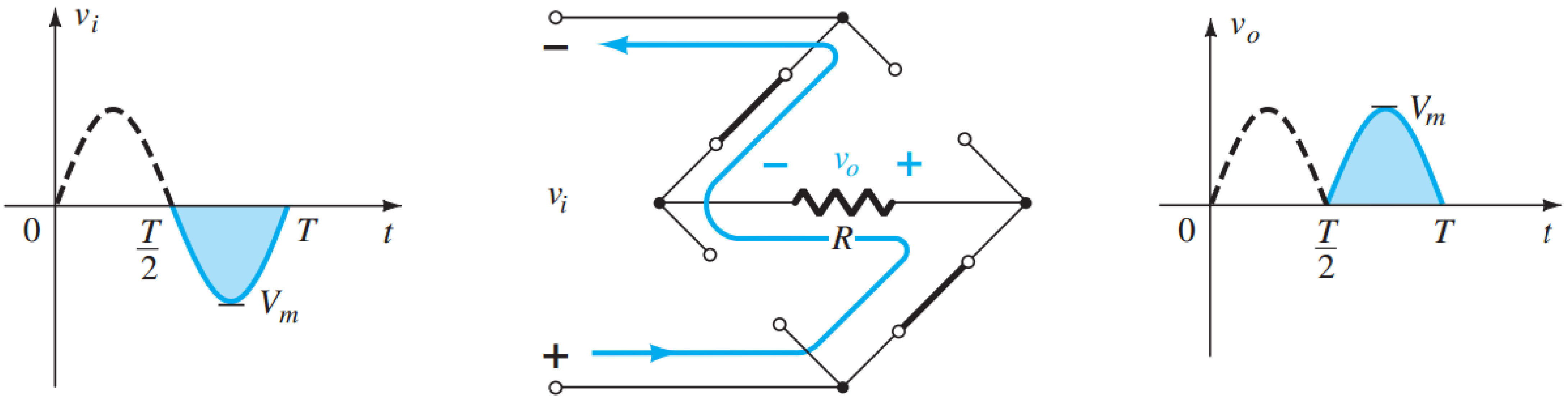
Full-wave rectified signal



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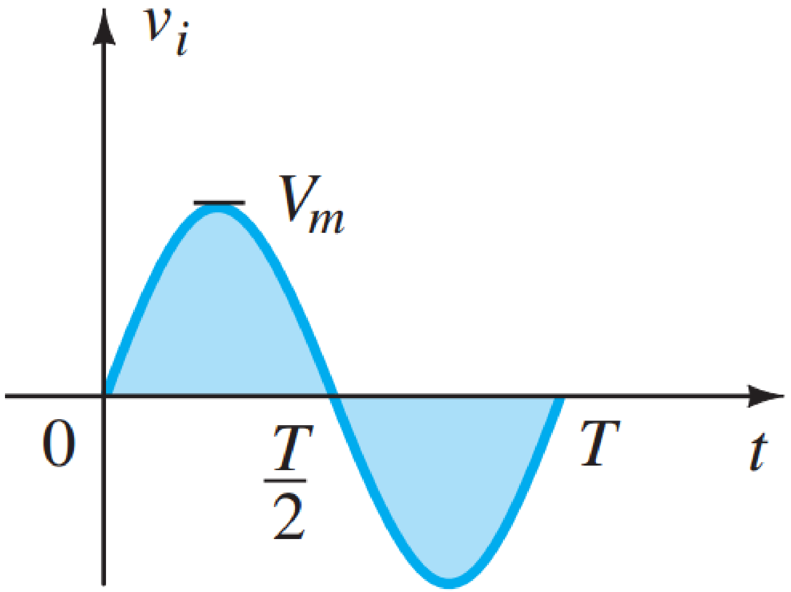

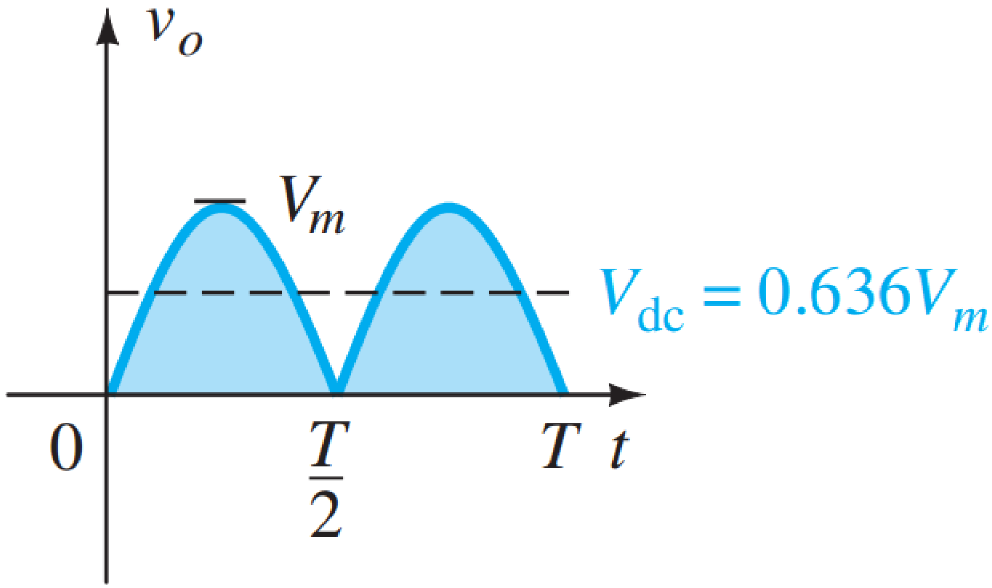

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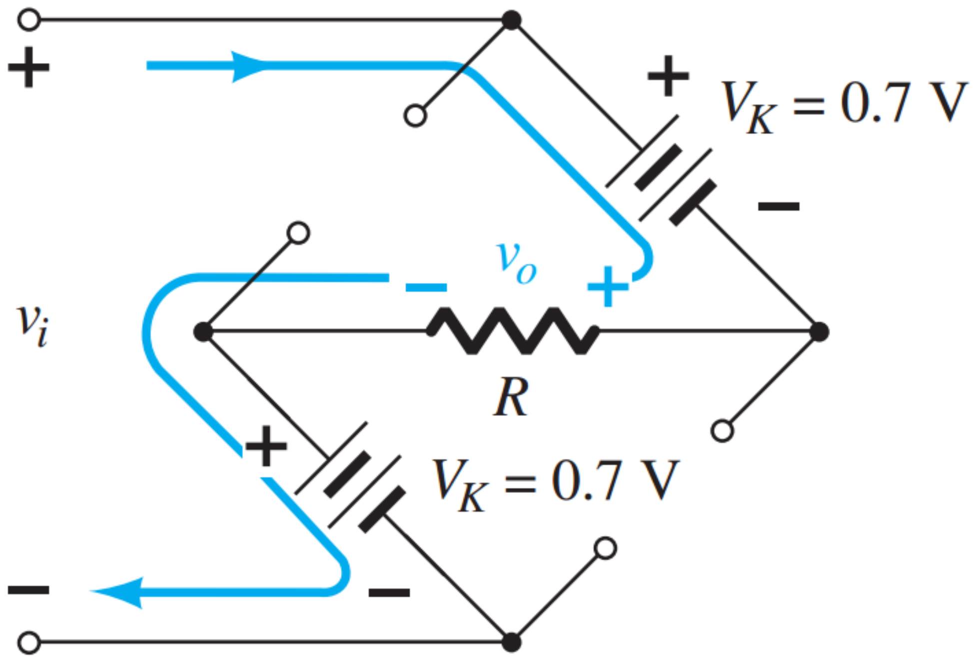
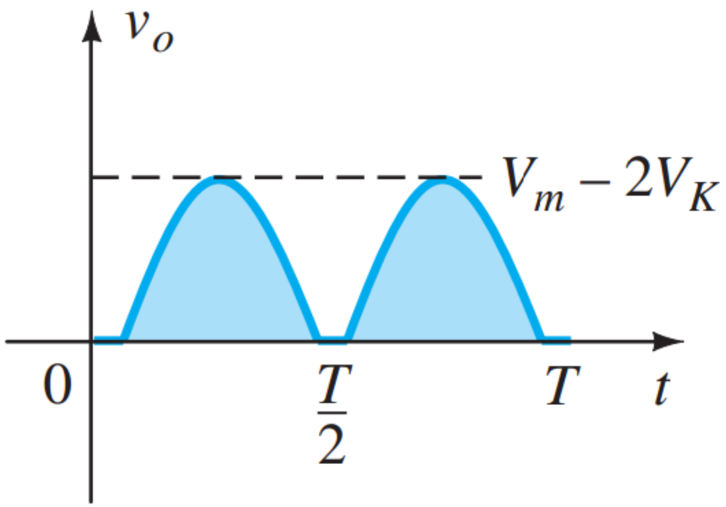
$$V_{dc} = 0.636\ V_m \quad \text{full-wave}$$

Full-wave rectified signal





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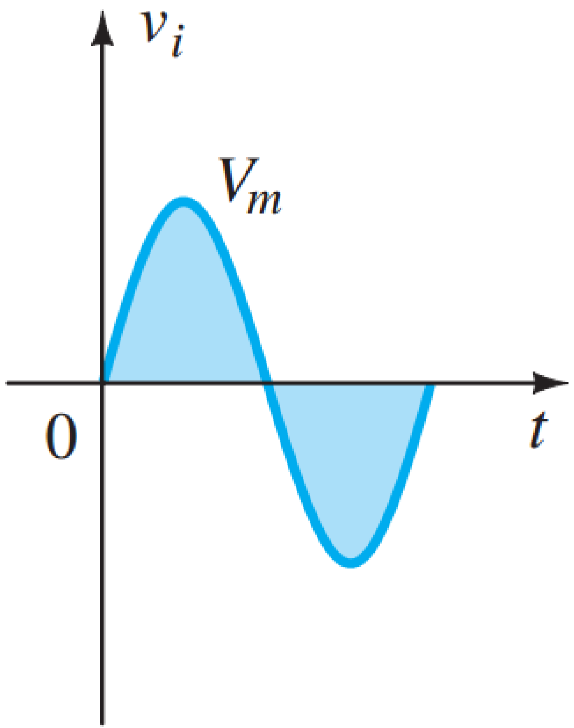
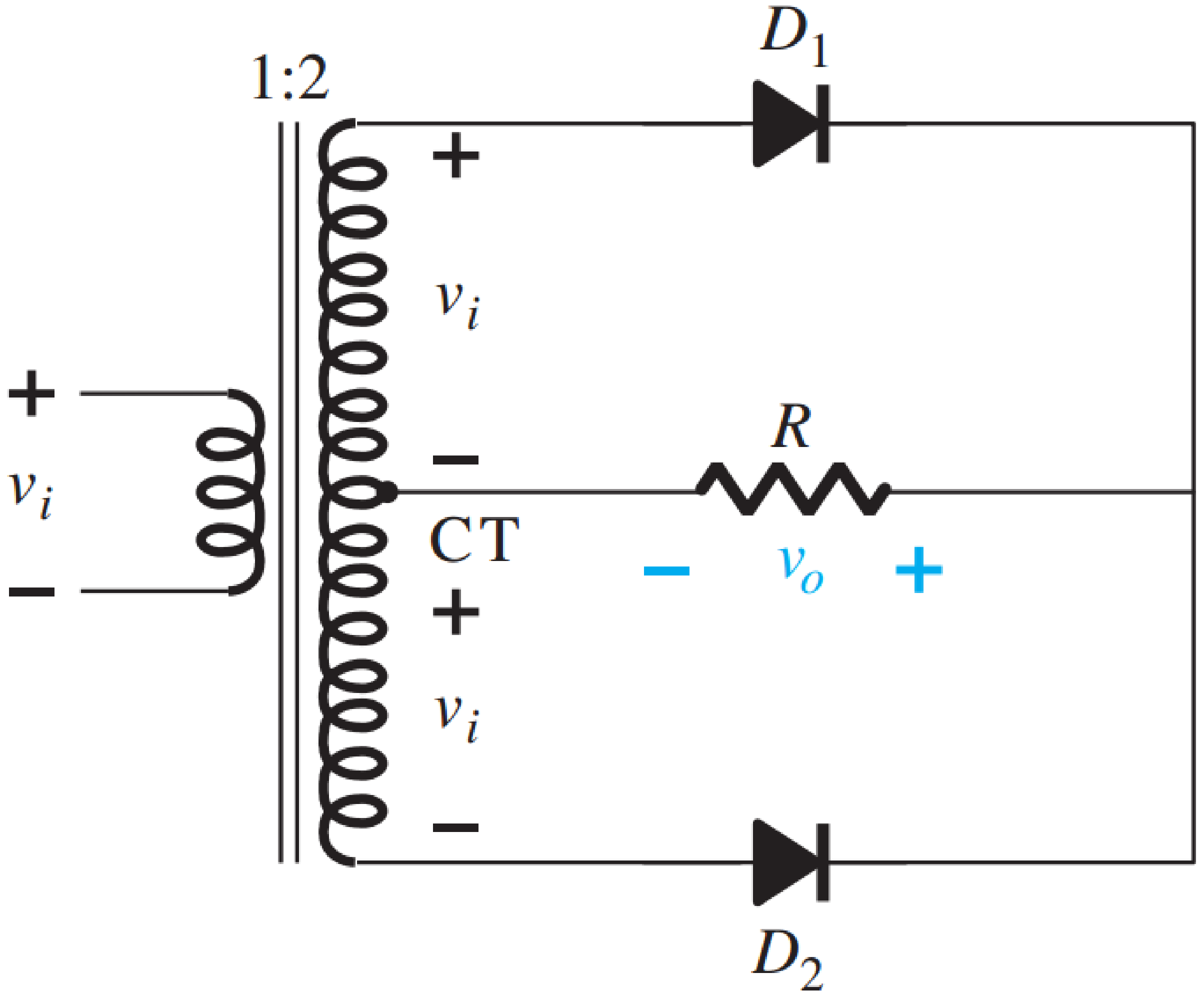
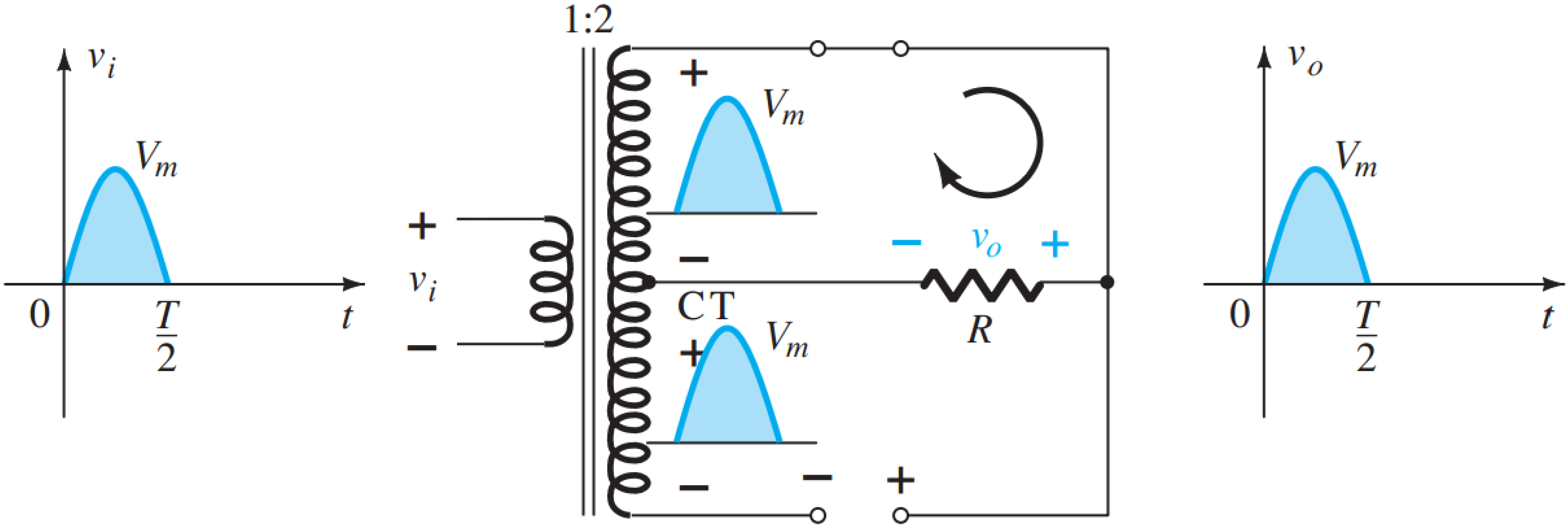
$$V_{dc} \cong 0.636(V_m - 2V_K)$$

Center-tapped transformer full-wave rectifier





Network conditions for the positive region of input voltage



Network conditions for the negative region of input voltage