

Tutorial (Problems from Ch. 3)



Abdullah M. Noman

Q 3-1

- 3-1. The half-wave rectifier circuit of Fig. 3-1a has $v_s(t) = 170 \sin(377t)$ V and a load resistance $R = 15 \Omega$. Determine (a) the average load current, (b) the rms load current, (c) the power absorbed by the load, (d) the apparent power supplied by the source, and (e) the power factor of the circuit.

(a)

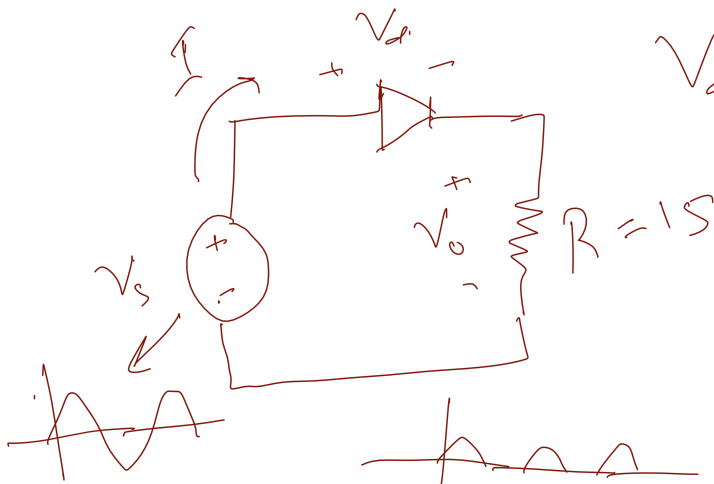
Solution is on the Board

$$V = IR$$

$$\Rightarrow I = \frac{V}{R}$$

$$V_{avg} \rightarrow V_0 = \frac{V_m}{\pi} = \frac{170}{\pi} = 54.11 \text{ V}$$

$$\rightarrow I_0 = \frac{V_0}{R} = \frac{54.11}{15} = 3.61 \text{ A}$$



$$(b) V_{rms} = \frac{V_m}{2} = \frac{170}{2} = 85 \text{ V}$$

$$V_s = \underbrace{170}_{V_m} \sin(\underbrace{377t}_{\omega = 2\pi f}) \text{ V}$$

$$I_{rms} = \frac{V_{rms}}{R} = \frac{85}{15} = 5.67 \text{ A}$$

$$(c) P = I_{rms}^2 R = (5.67)^2 \times 15 = 481.67 \text{ W}$$

$$(d) \quad S = I_{rms} V_{rms} = 5.67 \times 120.21 = 681.2 \text{ VA}$$

$$V_{rms} = \frac{V_m}{\sqrt{2}} = \frac{170}{\sqrt{2}} = \underline{\underline{120.21 \text{ V}}}$$

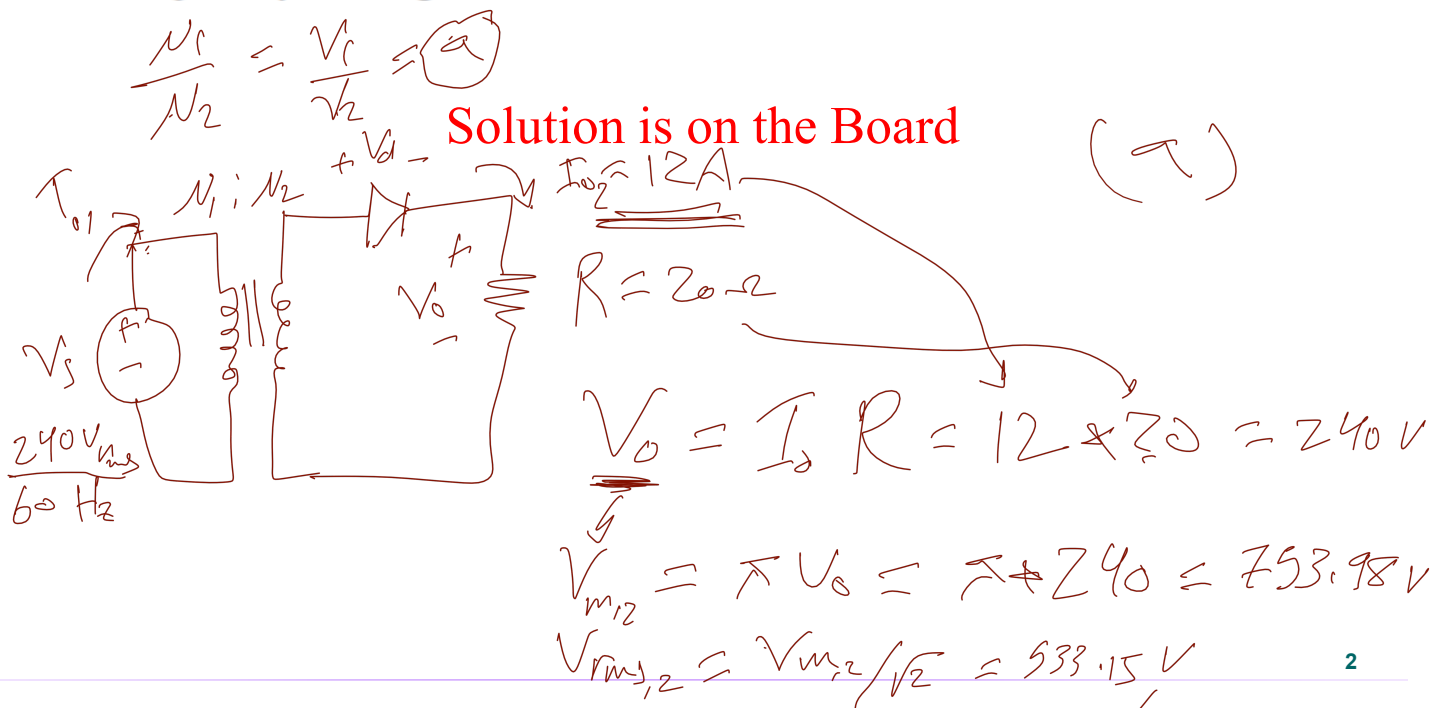
$$I_{rms} = 5.67 \text{ A}$$

$$PF = \frac{P}{S} = \frac{481.67}{681.2} = \underline{\underline{0.707}}$$

$\cos(\theta)$

Q 3-2

- 3-2. The half-wave rectifier circuit of Fig. 3-1a has a transformer inserted between the source and the remainder of the circuit. The source is 240 V rms at 60 Hz, and the load resistor is $20\ \Omega$. (a) Determine the required turns ratio of the transformer such that the average load current is 12 A. (b) Determine the average current in the primary winding of the transformer.



$$a = \frac{N_1}{N_2} = \frac{V_{rms1}}{V_{rms2}} = \frac{240}{533.15} = \underline{\underline{0.45}}$$

(b)

$$a = \frac{V_1}{V_2} = \frac{I_2}{I_1} \quad 12 \text{ A}$$

$$\Rightarrow I_1 = \frac{I_2}{a} = \frac{12}{0.45} \quad A = 26.67 \text{ A}$$

Q 3-5

- 3-5. A half-wave rectifier has a source of 120 V rms at 60 Hz and an RL load with $R = 10\ \Omega$ and $L = 15\text{ mH}$. Determine (a) an expression for load current, (b) the average current, (c) the power absorbed by the resistor, and (d) the power factor.

$$V_{s_{rms}} = 120\text{ V}_{rms}$$

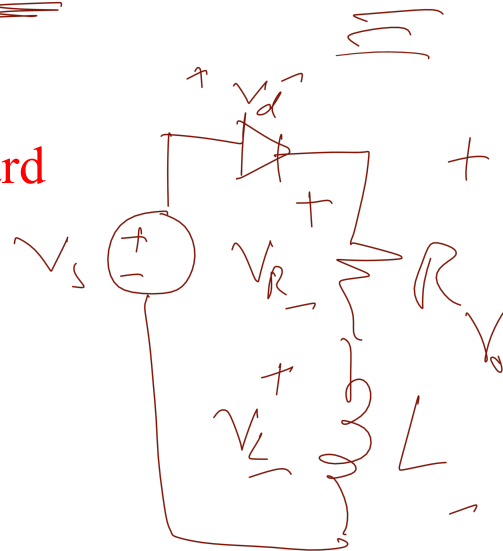
$$f = 60\text{ Hz}$$

$$R = 10\ \Omega$$

$$L = 15\text{ mH}$$

$$= 15 \times 10^{-3}\text{ H}$$

Solution is on the Board



(a) $f = 60 \text{ Hz}$, $V_{\text{rms}} = 120 \text{ V}$, $L = 15 \text{ mH}$, $R = 10 \Omega$

$$\omega = 2\pi f = 2\pi \cdot 60 = 377 \text{ rad/s}$$

$$V_m = V_{rms} \cdot \sqrt{2} = 120 \sqrt{2} = 169.7 \text{ V}$$

$$Z = \sqrt{R^2 + (\omega L)^2} = \sqrt{10^2 + (377 \cdot 0.015)^2} = 11.48 \, \Omega$$

$$\theta = \tan^{-1} \left(\frac{WL}{R} \right) = \tan^{-1} \left(\frac{377 \times 0.015}{10} \right) = \boxed{0.514} \text{ rad} \quad (29.5^\circ)$$

$\swarrow$ WT $\searrow$ s
 $\swarrow$ rad/s $\searrow$ s

$$\frac{WL}{R} = \frac{377 \times 0.015}{10} = 0.5655 \text{ rad}$$

$$i(\omega t) = \frac{V_m}{Z} \left[\sin(\omega t - \theta) + \sin(\theta) e^{-\frac{\omega t}{\tau}} \right]$$

$$= \frac{169.7}{11.48} \left[\sin(\omega t - 0.514) + \sin(0.514) e^{-\frac{\omega t}{0.5655}} \right]$$

$$i(\beta) = 0$$

$$\cancel{14.75} \left[\sin(\omega t - 0.514) + 0.492 e^{-\frac{\omega t}{0.5655}} \right] = 0$$

$$\sin(\omega t - 0.514) + 0.492 e^{-\frac{\omega t}{0.5655}} = 0$$

$$\omega t = \beta$$

$$I(\beta) = 0.1 \sin^2$$

$$\underline{\underline{\beta = \omega t}} \Rightarrow \underline{\underline{\beta = 3.61 \text{ rad}}} \quad \underline{\underline{(206.8^\circ)}}$$

$$I_0 = \frac{1}{2\pi} \int_0^{\beta} I(\omega t) d(\omega t)$$

$$\Rightarrow \frac{1}{2\pi} \int_0^{3.61} 14.78 \left[\sin(\omega t - 0.519) + 0.492 e^{\frac{-\omega t}{0.585}} \right] d\omega t$$

$$\Rightarrow 3.86 \text{ A}$$

$$I(\omega t)$$

$$P = I_{rms}^2 R$$

3.61

$$I_{rms} = \sqrt{\frac{1}{2\pi} \int_0^{2\pi} i^2(\omega t) d\omega t} \approx \underline{\underline{6.02 \text{ A}}}$$

$$P = (6.02)^2 \times 10 = \underline{\underline{362.4 \text{ W}}}$$

$$Pf = \frac{P}{V_s I_s} = \frac{362.4}{120 \times 6.02} = 0.502$$

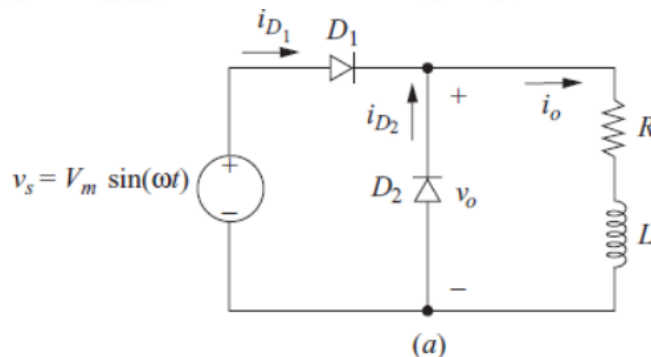
Q 3-9

- 3-9. A half-wave rectifier of Fig. 3-5a has a 120 V rms, 60 Hz ac source. The load is a series inductance, resistance, and dc source, with $L = 120$ mH, $R = 12\ \Omega$, and $V_{dc} = 48$ V. Determine (a) the power absorbed by the dc voltage source, (b) the power absorbed by the resistance, and (c) the power factor.

Solution is on the Board

Q 3-15

- 3-15. The half-wave rectifier with a freewheeling diode (Fig. 3-7a) has $R = 4 \Omega$ and a source with $V_m = 50 \text{ V}$ at 60 Hz. (a) Determine a value of L such that the amplitude of the first ac current term in the Fourier series is less than 5 percent of the dc current. (b) Verify your results with PSpice, and determine the peak-to-peak current.



Given,

The Fourier series for the half-wave rectified sine wave for the voltage across the load is

$$v(t) = \frac{V_m}{\pi} + \frac{V_m}{2} \sin(\omega_0 t) - \sum_{n=2,4,6,\dots}^{\infty} \frac{2V_m}{(n^2 - 1)\pi} \cos(n\omega_0 t)$$

Solution is on the Board

Q 3-17

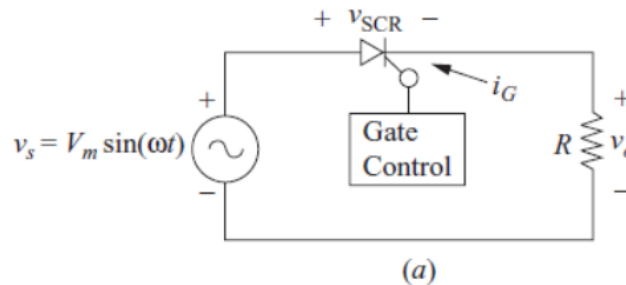
3-17. A half-wave rectifier with a capacitor filter has $V_m = 200$ V, $R = 1$ k Ω , $C = 1000$ μ F, and $\omega = 377$. (a) Determine the ratio of the RC time constant to the period of the input sine wave. What is the significance of this ratio? (b) Determine the peak-to-peak ripple voltage using the exact equations. (c) Determine the ripple using the approximate formula in Eq. (3-51).

Solution is on the Board

Q 3-23

3-23. Show that the controlled half-wave rectifier with a resistive load in Fig. 3-13a has a power factor of

$$\text{pf} = \sqrt{\frac{1}{2} - \frac{\alpha}{2\pi} + \frac{\sin(2\alpha)}{4\pi}}$$



Solution is on the Board