Problem 3-1

V_m = 170 V, R = 10 Ω, f = 60 Hz

From Eq. (3-21), $V_d = 0.6366\ V_m = 0.6366 \times 170 = 113.32$ V

Problem 3-5

R = 100 Ω, V_s = 280 V, f = 60 Hz

$V_m = 280 \times \sqrt{2}/\sqrt{3} = 228.6$ V

From Eq. (3-40), $V_{dc} = 1.6542 \times 228.6 = 378.15$ V

Problem 3-7

V_{dc} = 400 V, R = 10 Ω

From Eq. (3-21), $V_{dc} = 400 = 0.6366\ V_m$ or $V_m = 628.34$ V

The rms phase voltage is $V_s = V_m/\sqrt{2} = 628.34/\sqrt{2} = 444.3$ V

$I_{dc} = V_{dc}/R = 400/10 = 40$ A

Diodes:

Peak current, $I_p = 628.34/10 = 62.834$ A

Average current, $I_d = I_{dc}/2 = 40/2 = 20$ A

RMS current, $I_R = 62.834/2 = 31.417$ A

Transformer:

RMS voltage, $V_s = V_m/\sqrt{2} = 444.3$ V

RMS current, $I_s = I_m/\sqrt{2} = 44.43$ A

Volt-amp, VI = 444.3 x 44.43 = 19.74 kVA

$P_{dc} = (0.6366\ V_m)^2/R$ and $P_{ac} = V_s I_s = V_m^2/2R$

TUF = $P_{dc}/P_{ac} = 0.6366^2 \times 2 = 0.8105$ and the de-rating factor of the transformer is 1/TUF = 1.2338.

Problem 3-9

V_m = 170 V, f = 60 Hz, R = 15 Ω and ω = 2πf = 377 rad/s

From Eq. (3-22), the output voltage is

$$v_L(t) = \frac{2V_m}{\pi} - \frac{4V_m}{3\pi}\cos(2\omega t) - \frac{4V_m}{15\pi}\cos(4\omega t) - \frac{4V_m}{35\pi}\cos(6\omega t) - ..\infty$$

The load impedance, $Z = R + j(n\omega L) = \sqrt{R^2 + (n\omega L)^2}\angle\theta_n$

and $\theta_n = \tan^{-1}(n\omega L/R)$

and the load current is given by

$$i_L(t) = I_{dc} - \frac{4V_m}{\pi\sqrt{R^2 + (n\omega L)^2}}\left[\frac{1}{3}\cos(2\omega t - \theta_2) - \frac{1}{15}\cos(4\omega t - \theta_4) - \frac{1}{35}\cos(6\omega t - \theta_6) - ..\infty\right]$$

where $I_{dc} = \frac{V_{dc}}{R} = \frac{2V_m}{\pi R}$

The rms value of the ripple current is

$$I_{ac}^2 = \frac{(4V_m)^2}{2\pi^2[R^2 + (2\omega L)^2]}\left(\frac{1}{3}\right)^2 + \frac{(4V_m)^2}{2\pi^2[R^2 + (4\omega L)^2]}\left(\frac{1}{15}\right)^2 + \frac{(4V_m)^2}{2\pi^2[R^2 + (6\omega L)^2]}\left(\frac{1}{35}\right)^2 + ..\infty$$

Considering only the lowest order harmonic (n = 2) and neglecting others,

$$I_{ac} = \frac{4V_m}{\sqrt{2}\pi\sqrt{R^2 + (2\omega L)^2}}\left(\frac{1}{3}\right)$$

Using the value of I_{dc} and after simplification, the ripple factor is

$$RF = \frac{I_{ac}}{I_{dc}} = \frac{0.481}{\sqrt{1 + (2\omega L/R)^2}} = 0.04$$

$0.481^2 = 0.04^2\,[1 + (2 \times 377\ L/15)^2]$ or L = 238.4 mH

Problem 3-11

E = 20 V, I_{dc} = 10 A, V_p = 120 V, $V_s = V_p/n$ = 120/2 = 60 V

$V_m = \sqrt{2}\, V_s = \sqrt{2} \times 60$ = 84.85 V

(i) From Eq. (3-17), $\alpha = \sin^{-1}(20/84.85) = 15.15^\circ$ or 0.264 rad

$\beta = 180 - 15.15 = 164.85^\circ$

The conduction angle is $\delta = \beta - \alpha = 164.85 - 15.15 = 149.7^\circ$

(ii) Equation (3-18) gives the resistance R as

$$R = \frac{1}{2\pi I_{dc}}\left[2V_m \cos\alpha + 2\alpha E - \pi E\right]$$

$$R = \frac{1}{2\pi \times 10}\left[2 \times 84.85 \times \cos 15.15^\circ + 2 \times 20 \times 0.264 - \pi \times 20\right] = 1.793\ \Omega$$

(iii) Equation (3-19) gives the rms battery current I_{rms} as

$$I_{rms}^2 = \frac{1}{2\pi R^2}\left[\left(\frac{V_m^2}{2} + E^2\right)\times(\pi - 2\alpha) + \frac{V_m^2}{2}\sin 2\alpha - 4V_m E\cos\alpha\right] = 272.6$$

or $I_{rms} = \sqrt{272.6}$ = 16.51 A

The power rating of R is $P_R = 16.51^2 \times 1.793$ = 488.8 W

(iv) The power delivered P_{dc} to the battery is

$P_{dc} = E\, I_{dc} = 20 \times 10 = 200$ W

$h\, P_{dc} = 100$ or $h = 200/P_{dc} = 200/200 = 1$ hr

(v) The rectifier efficiency η is

$$\eta = \frac{P_{dc}}{P_{dc} + P_R} = \frac{200}{200 + 488.8} = 29\%$$

(vi) The peak inverse voltage PIV of the diode is

PIV = V_m + E = 84.85 + 20 = 104.85 V

Problem 3-15

RF = 5%, R = 200 Ω, and f = 60 Hz

(a) For a half-wave rectifier, the frequency of output ripple voltage is the same as the supply frequency. Thus, the constant 4 in Eq. (3-62) should be changed to 2.

Solving for C_e in Eq. (3-62),

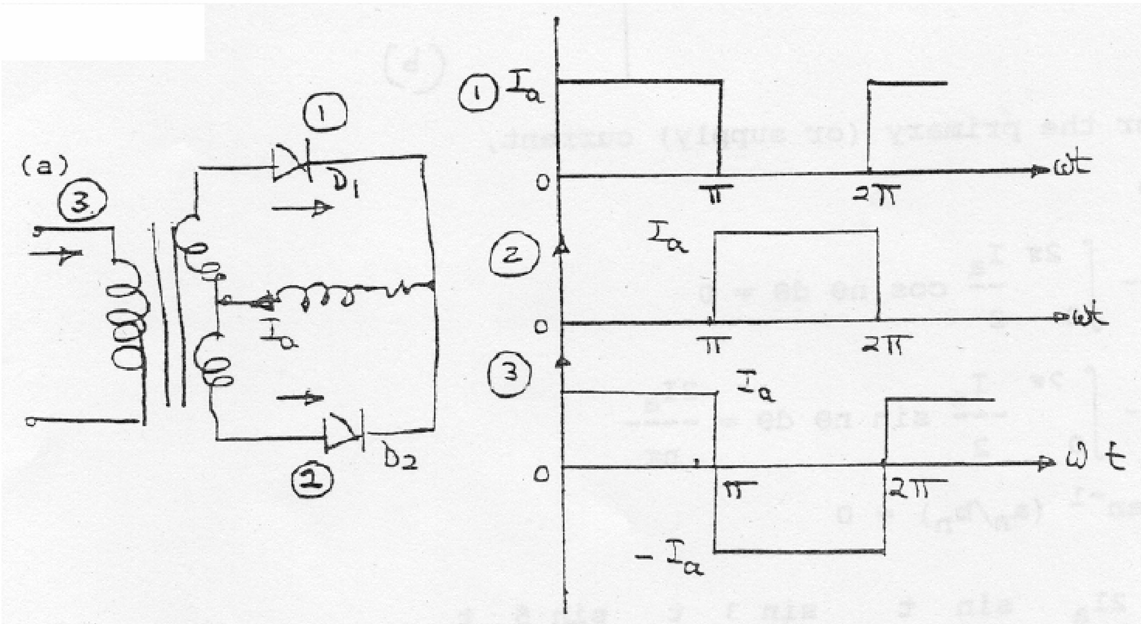
$$C_e = \frac{1}{2\times 60\times 200}\left[1+\frac{1}{\sqrt{2}\times 0.05}\right] = 630.92\ \mu\text{F}$$

(b) From Eq. (3-61), the average load voltage V_{dc} is

$$V_{dc} = 169.7 - \frac{169.7}{2\times 60\times 200\times 415.46\times 10^{-6}} = 169.7 - 22.42 = 147.28\text{ V}$$

Problem 3-21

(a)



(b) For the primary (or supply) current: From Eq. (3-23), the primary current is

$$i_s(t) = \frac{4I_a}{\pi}\left[\frac{\sin\omega t}{1} + \frac{\sin 3\omega t}{3} + \frac{\sin 5\omega t}{5} + ..\infty\right]$$

$I_1 = 4I_a/(\pi\sqrt{2})$

The rms current is $I_s = I_a$. PF = $I_1/I_s = 2\sqrt{2}/\pi = 0.9$ and $HF = \sqrt{(I_s/I_1)^2 - 1} =$ 0.4834.

(c) For the rectifier input (or secondary) current:

$a_o/2 = I_a/2$

$$a_n = \frac{1}{\pi}\int_0^{\pi} I_a \cos(n\theta)\, d\theta = 0$$

$$b_n = \frac{1}{\pi}\int_0^{\pi} I_a \sin(n\theta)\, d\theta = \frac{I_a}{n\pi}(1 - \cos n\theta)$$

$\varphi_n = \tan^{-1}(a_n/b_n) = 0$

$C_n = \sqrt{(a_n^2 + b_n^2)}$ and $I_1 = C_1/\sqrt{2} = \sqrt{2}I_a/\pi$

and $I_s = I_a/\sqrt{2}$

PF = $I_1/I_s = 2/\pi = 0.6366$ and $HF = \sqrt{(I_s/I_1)^2 - 1}$ = 1.211