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POWER ELECTRONICS

ELECTRICAL ENGINEERING

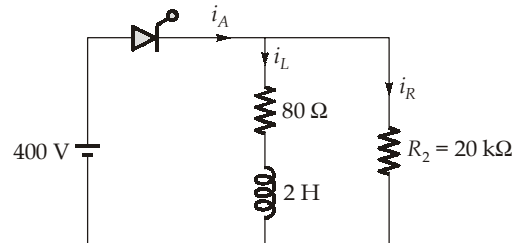
Date of Test : 07/09/2026

ANSWER KEY ➤

1. (b)	7. (a)	13. (a)	19. (c)	25. (d)
2. (c)	8. (a)	14. (a)	20. (d)	26. (b)
3. (a)	9. (a)	15. (b)	21. (c)	27. (a)
4. (c)	10. (d)	16. (a)	22. (b)	28. (d)
5. (a)	11. (a)	17. (b)	23. (b)	29. (b)
6. (d)	12. (b)	18. (a)	24. (d)	30. (d)

DETAILED EXPLANATIONS

1. (b)



Current through 20 kΩ resistor,

$$i_R = \frac{400}{20 \times 10^3} = 0.02 \text{ A}$$

Current through inductor,

$$\begin{aligned} i_L &= \frac{V}{R_1} (1 - e^{-R_1/Lt}) = \frac{200}{40} (1 - e^{-40t}) \\ &= 5(1 - e^{-40t}) \\ i_A &= i_R + i_L \\ &= 0.02 + 5(1 - e^{-40t}) \end{aligned}$$

To turn on $i_A \geq$ latching current,

$$\begin{aligned} 0.02 + 5(1 - e^{-40t}) &= 60 \text{ mA} \\ T &= 200 \text{ μsec} \end{aligned}$$

2. (c)

Using relation,

$$\cos \alpha - \cos(\alpha + \mu) = \text{constant} \quad \dots(1)$$

$$\alpha = 35^\circ, \quad \mu = 4^\circ$$

$$K = \cos 35^\circ - \cos(35 + 4^\circ) = 0.042$$

At $\alpha = 0^\circ$

Let,

$$\mu = \mu_0$$

$$K = \cos 0^\circ - \cos(0 + \mu_0)$$

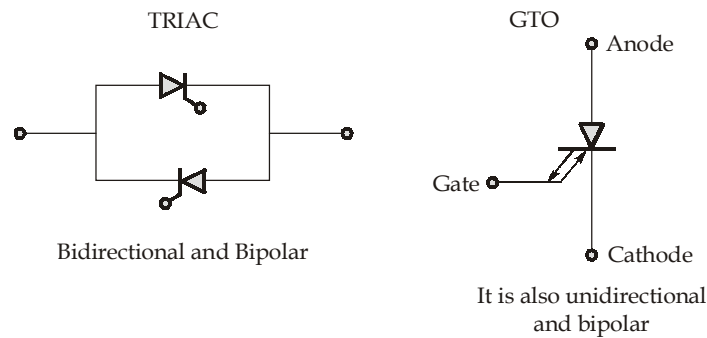
$$0.042 = 1 - \cos \mu_0$$

$$\cos \mu_0 = 0.958$$

$$\mu_0 = 16.66^\circ$$

$$\text{Inductive voltage regulation} = \frac{1 - \cos \mu_0}{2} = 0.0209$$

3. (a)



4. (c)

Due to absence of minority carrier reverse recover time of schottky diode is in nanosecond. It is used in SMPS.

5. (a)

The source is a 'cosine' function. So capacitor charges to its maximum value instantaneously as switch is closed at $t = 0$. So diode conducts for 0° .

6. (d)

$$\text{Average load current} = \frac{12 + 16}{2} = 14 \text{ A}$$

$$\text{Average load voltage} = V_0 = I_0 R = 14 \times 10 = 140 \text{ V}$$

$$V_0 = \alpha V_s$$

Since the chopper is step down or type-A,

$$140 = \alpha 200$$

$$\alpha = \frac{140}{200} = 0.7$$

$$\frac{T_{\text{on}}}{T_{\text{on}} + T_{\text{off}}} = 0.7$$

$$0.3 T_{\text{on}} = 0.7 T_{\text{off}}$$

$$\frac{T_{\text{on}}}{T_{\text{off}}} = 2.33$$

7. (a)

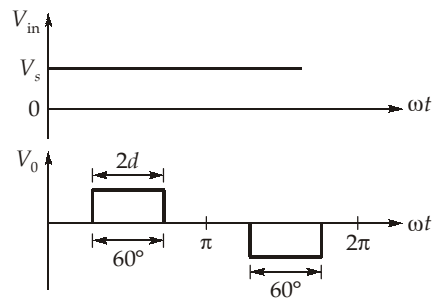
In 6 pulse thyristor, frequency components available on supply side current are

$f_s, (6K \pm 1) f_s$ where $K = 1, 2, 3, 4, \dots$

60, 300, 420, 660

Lowest frequency component is 60.

8. (a)

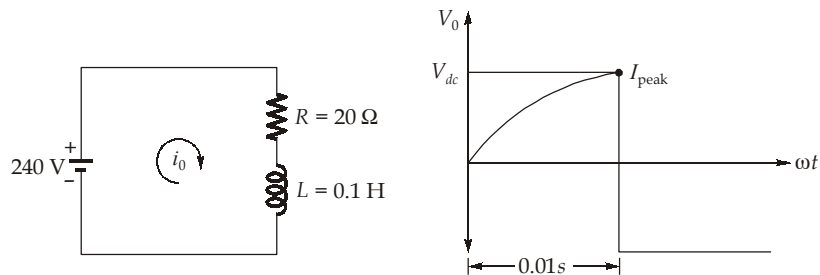


$$V_{or} = V_s \sqrt{\frac{2d}{\pi}}$$

$$V_{0\text{ rms}} = 600 \sqrt{\frac{60^\circ}{180^\circ}} = 346.4 \text{ V}$$

9. (a)

During the positive half cycle the circuit is,



$$i(t) = \frac{V_s}{R} (1 - e^{-t/\tau}) = \frac{240}{20} \left(1 - e^{-\frac{0.01 \times 20}{0.1}} \right)$$

$$i_{(0.01)} = 10.37 \text{ A}$$

10. (d)

In the output phase voltage the even, third and multiples of 3rd harmonics are absent. So, lowest order harmonics are 5th harmonics,

$$\text{Fourier series, } V_R = \sum_{n=6k \pm 1} \frac{2V_s}{n\pi} \sin n\omega t$$

So, frequency of 5th harmonis = 5 × fundamental frequency = 5 × 50 = 250 Hz

11. (a)

The main thyristor is turned off when i_c is,

$$i_c = I_p \sin \omega t = I_0$$

$$\omega t = \sin^{-1} \left(\frac{I_0}{I_p} \right)$$

Peak value of current through capacitor,

$$I_p = V_s \sqrt{\frac{C}{L}} = 230 \times \sqrt{\frac{20 \times 10^{-6}}{5 \times 10^{-6}}} = 460 \text{ A}$$

$$\omega t = \sin^{-1}\left(\frac{300}{460}\right) = 40.70^\circ$$

$$\begin{aligned} \text{Voltage across main thyristor} &= V_s \cos \omega t \\ &= 230 \times \cos 40.70^\circ \\ &= 174.37 \text{ V} \end{aligned}$$

12. (b)

The power loss,

$$\begin{aligned} P &= \frac{1}{T} \int_0^3 V_s(t) i_s(t) dt \\ &= \frac{1}{T} \int_0^3 \left(\frac{200}{3} t \right) \left(\frac{600}{3} t \right) dt = \frac{40000}{3T} \int_0^3 t^2 dt \\ P &= \frac{40000}{3T} \left[\frac{t^3}{3} \right]_0^3 \end{aligned}$$

Where T is in μsec

$$\Rightarrow T = \frac{1}{50} \times 10^6 = 20000$$

$$\text{So, } P = \frac{40000}{3 \times 20000} \left[\frac{3^3}{3} \right]$$

$$P = 6 \text{ Watt average power loss}$$

13. (a)

$$\text{Given, } \frac{V_{dc}}{2} = 96$$

$$V_{dc} = 192 \text{ V}$$

Rms value of the fundamental voltage in the output,

$$V_{01} = \frac{2V_s}{\sqrt{2\pi}} = \frac{2 \times 192}{\sqrt{2\pi}} = 86.43 \text{ V}$$

Fundamental power in the output,

$$= \frac{(V_{01})^2}{R} = \frac{(86.43)^2}{5} = 1494 \text{ W}$$

14. (a)

Fourier expression of output voltage is,

$$V_{0,n} = \sum_{n=1,3,5}^{\infty} \frac{2V_{dc}}{n\pi} \sin n\omega t \text{ V}$$

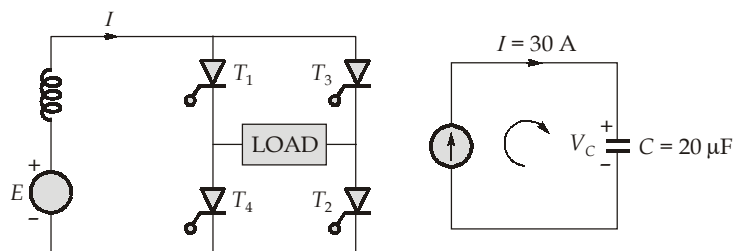
Harmonic factor for 3rd harmonic

$$\text{H.F.} = \frac{V_{3, \text{rms}}}{V_{1, \text{rms}}}$$

$$\begin{aligned} \text{H.F.} &= \frac{V_{3, \text{rms}}}{V_{1, \text{rms}}} = \frac{\frac{2 \times 48}{\sqrt{2} \times 3\pi}}{\frac{2 \times 48}{\sqrt{2} \pi}} \times 100 \\ &= \frac{1}{3} \times 100 = 33.33\% \end{aligned}$$

15. (b)

During the on period of T_1 and T_2 the circuit behaves as



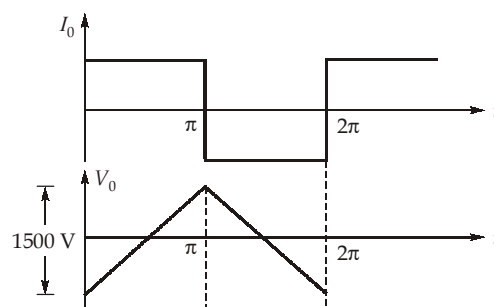
$$V_C = \frac{1}{C} \int_0^{t_{\text{on}}} i dt$$

$$V_C = \frac{30}{20 \times 10^{-6}} T_{\text{on}}$$

Where,

$$T_{\text{on}} = \frac{1}{2f} = \frac{1}{2 \times 500} = 1 \times 10^{-3} \text{ s}$$

$$V_C = \frac{30}{20 \times 10^{-6}} \times 1 \times 10^{-3} = 1500 \text{ V}$$



Peak to peak of output voltage is 1500 V.

The reverse voltage that appears across thyristor is 750 V.

16. (a)

To eliminate the 5th harmonic content,

$$2d = \frac{2\pi}{5}$$

$$d = \frac{\pi}{5} = 36^\circ$$

The 7th harmonic rms value is,

$$V_{07 \text{ (rms)}} = \frac{4V_S}{7\pi\sqrt{2}} \sin \frac{7\pi}{2} \sin(7 \times 36^\circ)$$

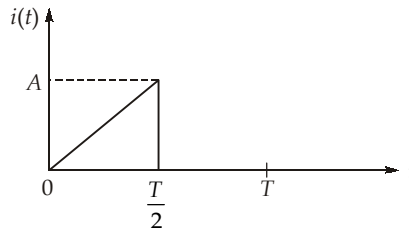
$$= 0.122 V_S$$

17. (b)

$$\text{Average ON state loss} = I_{\text{rms}}^2 R_{\text{ON}}$$

Where, $I_{\text{rms}} \rightarrow$ rms value current,

$R_{\text{ON}} \rightarrow$ On state resistance of MOSFET



$$i(t) = \frac{A}{T/2} t = \frac{2A}{T} t$$

$$i_{\text{rms}} = \sqrt{\frac{1}{T} \int_0^{T/2} [i(t)]^2 dt} = \sqrt{\frac{1}{T} \int_0^{T/2} \frac{4A^2}{T^2} t^2 dt}$$

$$= \sqrt{\frac{1}{T} \times \frac{4A^2}{T^2} \left(\frac{t^3}{3} \right)_0^{T/2}} = \sqrt{\frac{1}{T} \times \frac{4A^2}{T^2} \times \frac{T^3}{8 \times 3}} = \frac{A}{\sqrt{6}}$$

$$\text{Average ON state loss} = \left(\frac{15}{\sqrt{6}} \right)^2 \times 0.25 = 9.375 \text{ W}$$

18. (a)

$$\text{Gate-cathode characteristic slope} = \frac{V_g}{I_g}$$

Where,

$V_g =$ Allowable voltage across SCR

$I_g =$ Allowable current across SCR

$$\frac{V_g}{I_g} = 120$$

$$V_g = 120 I_g \quad \dots(i)$$

Allowable gate power dissipation = 0.4 watt

$$V_g I_g = 0.4 \text{ Watt}$$

Put value of ' V_g ' from equation (i)

$$(120 I_g) I_g = 0.4$$

$$I_g = \sqrt{\frac{0.4}{120}} A = 0.0577 A$$

$$V_g = 120 \times 0.0577 = 6.92 V$$

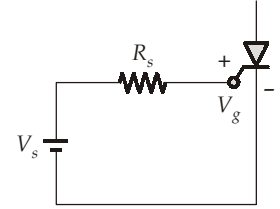
We know,

$$V_s = V_g + R_s I_g$$

$$20 = 6.928 + 0.0577 R_s$$

$$0.0577 R_s = 13.071$$

$$R_s = 226.54 \Omega$$



19. (c)

The diode will start conducting at an angle θ_1 , where

$$\theta_1 = \sin^{-1} \frac{E}{(V_s)_{\max}} = \sin^{-1} \frac{120}{230 \times \sqrt{2}} = 21.64^\circ$$

Average value of charging current,

$$I_{0 \text{ avg}} = \frac{1}{2\pi R} [2V_m \cos \theta_1 - E(\pi - 2\theta_1)]$$

$$= \frac{1}{2\pi \times 10} \left[2 \times 230 \times \sqrt{2} \times \cos 21.64^\circ - 120 \left(\pi - \frac{2 \times 21.64^\circ \times \pi}{180} \right) \right]$$

$$= 5.071 A$$

Power delivered to battery

$$= EI_{0 \text{ avg}} = 120 \times 5.071 = 608.52 W$$

(Power delivered to battery) $\times$ (Charging time in hours) = Battery capacity

$$(608.52) \times \text{charging time} = 8850 \text{ Wh}$$

$$\text{Charging time} = \frac{8850}{608.52} \text{ hours} = 14.54 \text{ hours}$$

20. (d)

For 1- ϕ semiconverter,

$$\text{Supply rms current, } I_{\text{rms}} = I_{dc} \left[\frac{\pi - \alpha}{\pi} \right]^{1/2} = I_{dc} \left[\frac{\pi - \pi/4}{\pi} \right]^{1/2} = 0.866 I_{dc}$$

The rms value of the supply fundamental component of input current

$$I_{\text{rms}, 1} = \frac{2\sqrt{2}}{\pi} I_{dc} \cos\left(\frac{\alpha}{2}\right)$$

$$= \frac{2\sqrt{2}}{\pi} I_{dc} \cos\left(\frac{\pi}{4 \times 2}\right) = 0.83178 I_{dc}$$

$$\text{Harmonic factor (Hf)} = \left[\left(\frac{I_{\text{rms}}}{I_{\text{rms}, 1}} \right)^2 - 1 \right]^{1/2} = \left[\left(\frac{0.866 I_{dc}}{0.83178 I_{dc}} \right)^2 - 1 \right]^{1/2} = 28.98\%$$

21. (c)

Case-I,

$$T_j = 110^\circ \text{C}, \quad T_s = 80^\circ \text{C}$$

$$P_{av1} = \frac{110 - 80}{0.16 + 0.05} = 142.85 \text{ W}$$

Case-II,

$$T_j = 110^\circ \text{C}, \quad T_s = 50^\circ \text{C}$$

$$P_{av2} = \frac{110 - 50}{0.16 + 0.05} = 285.71 \text{ W}$$

Thyristor rating is proportional to the square root of average power loss

$$\% \text{ increase in rating} = \frac{\sqrt{285.71} - \sqrt{142.85}}{\sqrt{142.85}} \times 100 = 41.42\%$$

22. (b)

For Buck-converter

$$\text{Average output voltage} = DV_s$$

Where,

$$D = \text{Duty ratio},$$

$$V_s = \text{input voltage}$$

$$V_s = 40 \text{ V},$$

$$V_0 = 16 \text{ V}$$

$$f = 20 \text{ kHz}$$

$$16 = D \times 40$$

$$D = \frac{16}{40} = 0.4$$

Peak to peak ripple current,

$$\Delta I_L = \frac{V_s D(1-D)}{Lf}$$

$$0.8 = \frac{40 \times 0.4 \times 0.6}{L \times 20 \times 10^3}$$

$$L = 600 \mu\text{H}$$

23. (b)

$$V_s = 250 \text{ V},$$

$$V_0 = 625 \text{ V}$$

For boost converter,

$$V_0 = \frac{V_s}{1-D}$$

$$625 = \frac{250}{1-D}$$

 $\Rightarrow$

$$D = 0.6$$

$$I_{L \min} = I_L - \frac{\Delta I_L}{2} = \frac{3125}{250} - \frac{250 \times 0.6}{2 \times 10 \times 10^{-3} \times 25 \times 10^3}$$

$$= 12.2 \text{ A} > 0$$

It is operating in continuous conduction,

Now

$$I_0 = \frac{3125}{625} = 5 \text{ A}$$

$$\frac{V_0}{V_s} = \frac{I_s}{I_0} = \frac{1}{1-D}$$

$$\Rightarrow I_s = \frac{I_0}{1-D} = \frac{5}{1-0.6} = 12.5 \text{ A}$$

$$R_{in} = \frac{V_s}{I_s} = \frac{250}{12.5} = 20 \Omega$$

24. (d)

Output voltage (V_0) = 36 V

Input voltage (V_s) = 24 V

For Buck-boost converter

$$V_0 = \frac{DV_s}{1-D}$$

$$36 = \frac{24D}{1-D}$$

$$\Rightarrow 36 - 36D = 24D$$

$$60D = 36$$

$$\Rightarrow D = 0.6$$

$$\Delta I_L = \frac{DV_s}{Lf}$$

At the boundary,

$$I_{Lavg} - \frac{\Delta I_L}{2} = 0$$

$$\frac{I_0}{1-D} = \frac{\Delta I_L}{2}$$

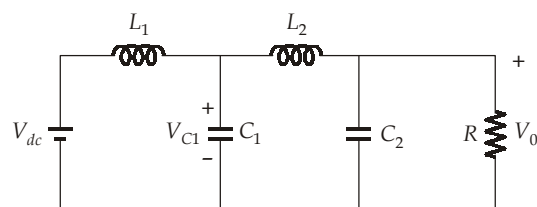
$$\frac{144/36}{1-0.6} = \frac{0.6 \times 24}{2 \times 20 \times 10^{-3} \times L}$$

$$L = \frac{0.4}{4} \times \frac{0.6 \times 24}{2 \times 20 \times 10^{-3}} = 36 \mu\text{H}$$

$$\left[I_{Lavg} = \frac{I_0}{1-D} \right]$$

25. (d)

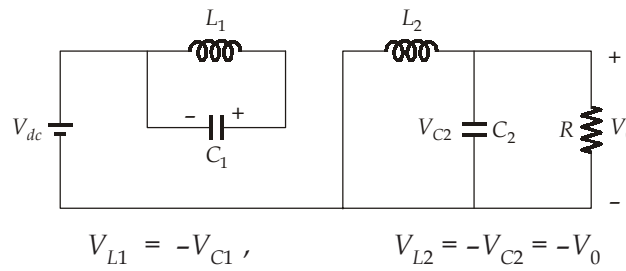
For ON period:



$$V_{L1} = (V_{dc} - V_{c1})$$

$$V_{L2} = (V_0 - V_{c2})$$

For OFF-period



Now, for inductor ' L_1 '

$$(V_L)_{\text{avg}} = 0$$

$$(V_{dc} - V_{C1})DT - V_{C1}(1 - D)T = 0$$

$$V_{C1} = DV_{dc}$$

Similarly for inductor ' L_2 '

$$(V_{C1} - V_0)DT - V_0(1 - D)T = 0$$

$$V_0 = DV_{C1} = D^2V_{dc}$$

So,

$$V_0 = D^2V_{dc} = (0.75)^2 \times 80 \text{ V} = 45 \text{ V}$$

26. (b)

$$P_{\text{avg}} = I_{\text{rms}}^2 \cdot R_{\text{ON}}$$

$$R_{\text{ON}} = 0.15 \, \Omega \text{ and } I_{\text{rms}} = \sqrt{\frac{1}{2\pi} \int_0^\pi 10t \, dt} = \frac{10}{\sqrt{6}}$$

$$P_{\text{avg}} = \frac{100}{6} \times 0.15 = 2.50 \text{ W}$$

27. (a)

For 1- ϕ full bridge inverter

$$V_{dc} = 60 \text{ V}, \quad R = 12 \, \Omega$$

$$V_{01 \text{ rms}} = \frac{2\sqrt{2} V_{dc}}{\pi} = \frac{2\sqrt{2}}{\pi} \times 60 = 54.046 \text{ V}$$

$$\text{Power} = \frac{V_{01 \text{ rms}}^2}{R} = \frac{(54.046)^2}{12} = 243.41 \text{ W}$$

28. (d)

Pole voltage, phase voltage,

$$V_{\text{pole}} = V_R \rightarrow \text{quasi square wave } 2d = \frac{2\pi}{3} \text{ rad}$$

$$n = 6K \pm 1 = 1, 5, 7, 11, 13 \dots$$

Line voltage $\rightarrow$ 6 step :

$$n = 6K \pm 1 = 1, 5, 7, 11, 13 \dots$$

29. (b)

Average output voltage of the converter,

$$V_0 = \frac{3V_{mL}}{\pi} \cos \alpha$$

Load current, $I_0 = 20 \text{ A}$
 Back emf, $E_b = 180 \text{ V}$
 $R_a = 1 \Omega$

Applying KVL,

$$V_0 - 1 \times I_0 - 180 = 0$$

$$V_0 = 180 + 1 \times 20 = 200 \text{ V}$$

Now, $\frac{3V_{mL}}{\pi} \cos \alpha = 200$

$$\frac{3 \times 400 \times \sqrt{2}}{3.14} \times \cos \alpha = 200$$

$$\cos \alpha = 0.37$$

$$\alpha = 68.28^\circ$$

30. (d)

$$V_i = 200\sqrt{2} \sin(120\pi t) \text{ V}$$

$$i_i = \left(20\sqrt{2} \sin\left(120\pi t - \frac{\pi}{3}\right) + 10\sqrt{2} \sin\left(360\pi t + \frac{\pi}{4}\right) \right) + 4\sqrt{2} \sin\left(840\pi t - \frac{\pi}{6}\right) \text{ A}$$

Fundamental component of input voltage,

$$(V_i)_1 = 200\sqrt{2} \sin(120\pi t) \text{ V}$$

$$(V_i)_{\text{rms}} = 200 \text{ V}$$

Fundamental component of current,

$$(i_L)_{1, \text{rms}} = \frac{20\sqrt{2}}{\sqrt{2}} = 20$$

Phase difference between the two components

$$\phi_1 = \frac{\pi}{3}$$

Active power due to fundamental component

$$P_1 = (V_i)_{1, \text{rms}} \times (i_i)_{1, \text{rms}} \cos \phi_1$$

$$P_1 = 200 \times 20 \times \cos\left(\frac{\pi}{3}\right) = 2000 \text{ W}$$

rms value of input voltage = 200 V

$$\begin{aligned} \text{rms value of current} &= \sqrt{\left(\frac{20\sqrt{2}}{\sqrt{2}}\right)^2 + \left(\frac{10\sqrt{2}}{\sqrt{2}}\right)^2 + \left(\frac{4\sqrt{2}}{\sqrt{2}}\right)^2} = \sqrt{400 + 100 + 16} = \sqrt{516} \\ &= 22.71 \text{ A} \end{aligned}$$

Let input power factor $\cos \phi$

$$200 \times 22.71 \times \cos \phi = 2000$$

$$\cos \phi = \frac{10}{22.71} = 0.44$$

