S.No. : 01 PT_EE_A+B_250819

Power Electronics

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CLASS TEST 2019-2020

ELECTRICAL ENGINEERING

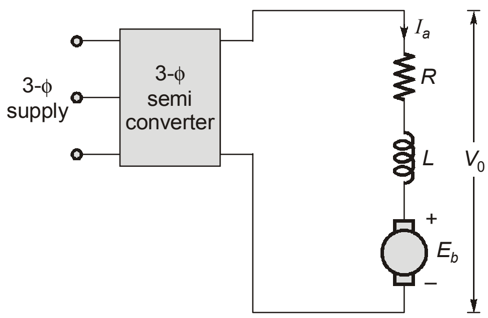
Date of Test : 25/08/2019

ANSWER KEY ➤ Power Electronics

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

Detailed Explanations

1. (b)



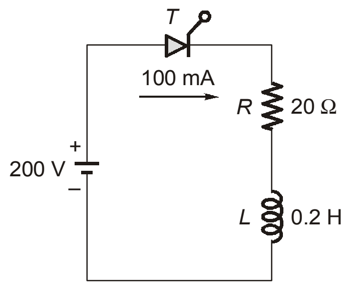
$$V_0 = I_0 R + E_b$$

If I_0 is droped to zero then,

$$V_0 = E_b$$

When I_0 drops to zero, at that instance of time, voltage assumes a value equal to the instantaneous value of the motor back emf.

2. (b)



$$I = \frac{V_s}{R}\left(1 - e^{-t/\tau}\right)$$

or, $$I = I_L = \frac{200}{20}\left(1 - e^{-t/0.01}\right)$$

$\Rightarrow$ $$100 \times 10^{-3} = \frac{200}{20}\left(1 - e^{-t/0.01}\right)$$

$$\left[\because \tau = \frac{L}{R} = \frac{0.2}{20} = 0.01\,s\right]$$

or, $$e^{-t/0.01} = 1 - 0.01$$

or, $$e^{-t/0.01} = 0.99$$

or, $$t = -\ln(0.99) \times 0.01$$

or, $$t = 1.0050 \times 10^{-4}\text{ s}$$

or, $$t = 100.5\ \mu s$$

4. (b)

As in the output the even and 3rd and multiple of 3rd harmonics are absent so, lowest order harmonics is 5th harmonics.

So, frequency of 5th harmonics

$= 5 \times$ fundamental frequency

$= 5 \times 60 = 300$ Hz

5. (b)

During overlapping period, number of conducting Thyristors are:

for $1 - \phi \rightarrow 4$ Thyristors

for $3 - \phi \rightarrow 3$ Thyristors

6. (a)

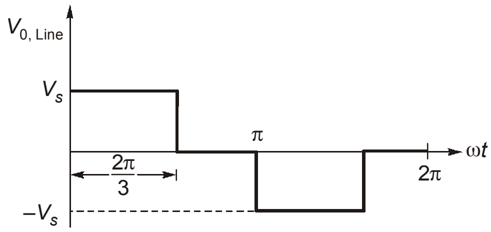
Effective on period of a voltage commutated chopper is

$$T'_{on} = T_{on} + \frac{2V_s}{I_0}C = (800 \times 10^{-6}) + \left(\frac{2 \times 220}{80} \times 50 \times 10^{-6}\right)$$

$$T'_{on} = 1.075 \times 10^{-3} \text{ s.}$$

7. (b)

The output waveform of line voltage is



$$V_{0,\text{rms, line}} = \sqrt{\frac{1}{\pi}\int_0^{\frac{2\pi}{3}} V_s^2 d\omega t} = V_s\sqrt{\left(\frac{1}{\pi}\right)\left(\frac{2\pi}{3}\right)} = V_s\sqrt{\frac{2}{3}}$$

$$V_{0,\text{rms, line}} = 440\sqrt{\frac{2}{3}} = 359.25 \text{ V}$$

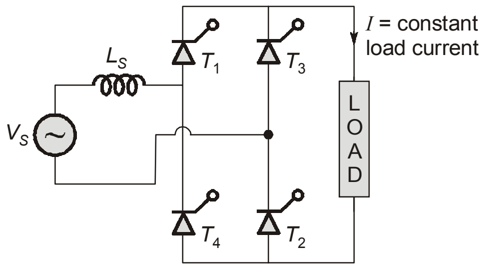
8. (d)

AC input current waveform is not smooth in single-phase diode rectifier with capacitive filter. Presence of an inductor makes the current waveform smoother.

10. (b)

$$\left(\frac{di}{dt}\right)_{\max} = \frac{V_m}{L} = \frac{230\sqrt{2}}{20\,\mu\text{H}} = 16.26 \text{ A/}\mu\text{ sec}$$

11. (b)



The dc load current, is given by

$$I_0 = \frac{V_m}{\omega L_s}[\cos\alpha - \cos(\alpha + \mu)]$$

Let μ_1 be the overlap angle for firing angle α_1, then

$$I_0 = \frac{V_m}{\omega L_s}[\cos\alpha - \cos(\alpha + \mu)] = \frac{V_m}{\omega L_s}[\cos\alpha_1 - \cos(\alpha_1 + \mu_1)]$$

or, $$\cos\alpha - \cos(\alpha + \mu) = \cos\alpha_1 - \cos(\alpha_1 + \mu_1)$$

or, $\cos 0 - \cos(15°) = \cos 30° - \cos(30° + \mu_1)$

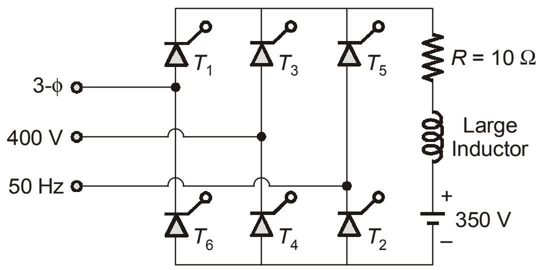
or, $0.0341 = 0.866 - \cos(30° + \mu_1)$

or, $\cos(30° + \mu_1) = 0.8319$

or, $30° + \mu_1 = 33.7°$

or, $\mu_1 = 3.7°$

12. (c)



For firing advance angle of 60°, $\alpha = 180° - 60° = 120°$

Average output voltage, $V_0 = \dfrac{3V_{mL}}{\pi}\cos\alpha$

$\therefore$ $V_0 = \dfrac{3\sqrt{2}\,400}{\pi}\cos(120)°$

or, $V_0 = -270.09$ V

As V_0 is negative, this converter is operating as line-commutated inverter. The polarity of load Emf E must be reversed.

Now, $V_0 = -E + I_0 R$

or, $-270.09 = -350 + I_0(10)$

$\therefore$ Load current, $I_0 = 7.991$ A

Rms value of load current, $I_{0,\text{rms}} = I_0 = 7.991$ A

Power delivered by the battery to the ac source through the line commutated inverter is:

$P_0 = V_0 I_0 = -270.09 \times 7.991$

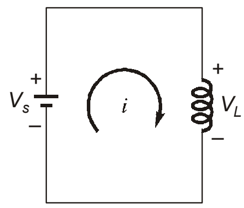
$P_0 = -2158.289$ W

$\simeq$ $P_0 = -2158$ W

Negative sign indicates that the power is delivered from load to source.

13. (b)

During on period of switch, the circuit behaves as

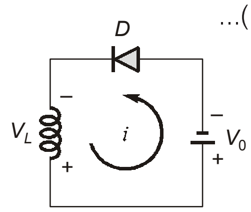


$\therefore$ $V_S = V_L = L\dfrac{di}{dt}$

or, $V_S = L\dfrac{\Delta I}{dt}$

or, $V_S(T_{on}) = L\Delta I$ ...(i)

During off period, the circuit behaves as shown below,



$\therefore$ $-V_L + V_0 = 0$

or, $V_0 = V_L = L\dfrac{di}{dt}$

or, $V_0(T_{off}) = L\Delta I$ ...(ii)

Equating both the equations.

$$V_0 = V_s \frac{T_{on}}{T_{off}}$$

$$V_0 = \frac{V_s\left(\frac{T_{on}}{T}\right)}{\left(\frac{T-T_{on}}{T}\right)}$$

or,
$$V_0 = V_s\left(\frac{\alpha}{1-\alpha}\right)$$

$\therefore$ When $\alpha < 0.5$ the circuit operates as a step down chopper. In case $\alpha > 0.5$, this circuit operates as stepup chopper.

14. (d)

RMS value of fundamental component of load voltage

$$= V_{on} = \frac{4V_s}{n\pi\sqrt{2}}$$

$\therefore$
$$V_{01} = \frac{4V_s}{\pi\sqrt{2}} = \frac{4\times 230}{\pi\sqrt{2}} = 207.1 \text{ V}$$

RMS value of fundamental current,

$$I_{01} = \frac{V_{01}}{Z_1}$$

Now,
$$Z_n = \sqrt{\left[R^2 + \left(n\omega L - \frac{1}{n\omega C}\right)^2\right]}$$

$\therefore$
$$Z_1 = \sqrt{\left[R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2\right]}$$

or,
$$Z_1 = \sqrt{1^2 + (6-7)^2}$$

or,
$$Z_1 = \sqrt{2}\,\Omega$$

$\therefore$
$$I_{01} = \frac{207.1}{\sqrt{2}} A$$

Phase angle,
$$\phi_n = \tan^{-1}\frac{\left[n\omega L - \frac{1}{n\omega C}\right]}{R} \text{ degree}$$

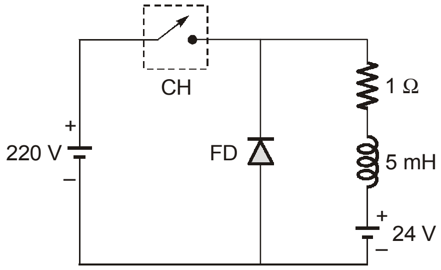
$\therefore$
$$\phi_1 = \tan^{-1}\frac{(6-7)}{1} = -45°$$

$\therefore$ The fundamental component of current i_{01} as function of time is

$$i_{01} = \sqrt{2} I_{01}\sin(\omega t - \phi_1)$$

or,
$$i_{01} = 207.1 \sin(\omega t + 45°) \text{ A}$$

15. (b)



The limit of continuous current conduction is reached at duty cycle,

$$\delta' = \frac{T_a}{T} ln\left[1 + m\left(e^{T/T_a} - 1\right)\right]$$

Here, $$m = \frac{E}{V_s}$$

$$T_a = \frac{L}{R} = \frac{5\times10^{-3}}{1} = 5\times10^{-3} s.$$

Also, $$m = \frac{24}{220} = 0.11$$

$\therefore$ $$\delta' = \left(\frac{5\times10^{-3}}{2000\times10^{-6}}\right) ln\left[1 + 0.11\left(e^{\frac{2000\times10^{-6}}{5\times10^{-3}}} - 1\right)\right] = 2.5\, ln(1.0541)$$

$$\delta' = 0.13$$

If duty cycle is less than this value, then load current will be discontinuous.

16. (d)

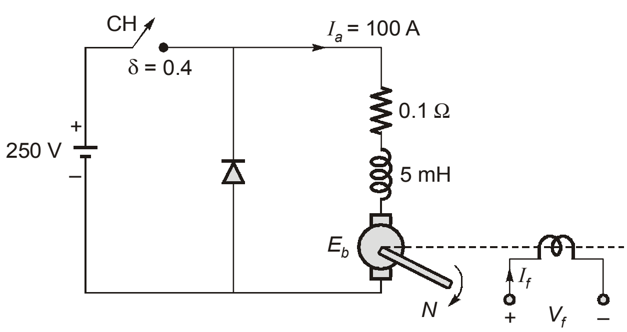
Fourier analysis of line voltage is,

$$V_{ab} = \sum_{n=6K\pm1}^{\infty} \frac{3V_s}{n\pi} \sin n\left(\omega t + \frac{\pi}{3}\right)$$

$$V_{L-L(\text{fundamental})} = \frac{3V_s}{\pi} \sin\left(\omega t + \frac{\pi}{3}\right)$$

$$V_{rms} = \frac{3V_s}{\sqrt{2}\pi} = 0.6752\, V_s = 0.6752 \times 180 = 121.543 \text{ V}$$

17. (c)



Back emf at 2100 rpm is $E_b = V_t - I_a R_a$

$= 220 - 100 \times 0.1$

$= 210$ V

Back emf constant $= \frac{210}{2100} = 0.1$ V/rpm

duty ratio $= 0.4$

$\Rightarrow$ V applied is $= 250 \times 0.4 = 100$ V

As torque is same

$\Rightarrow$ I_a = constant

$\Rightarrow$ Back emf $= 100 - 100 \times 0.1 = 90$ V

$\therefore$ speed $= \frac{90}{0.1} = 900$ rpm

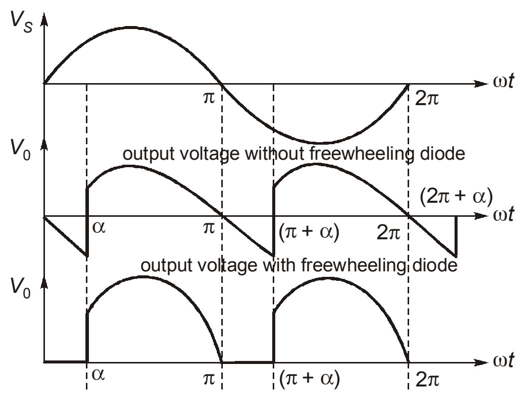
18. (c)

$$\alpha = \text{common base current gain}$$
$$I_{CBO} = \text{common base leakage current}$$
$$I_C = \alpha I_E + I_{CBO}$$
$$I_{C1} = \alpha_1 I_a + I_{CBO1}$$
$$I_{C2} = \alpha_2 I_K + I_{CBO2}$$
$$I_a = I_{C1} + I_{C2}$$
$$I_a = \alpha_1 I_a + I_{CBO1} + \alpha_2 I_K + I_{CBO2}$$

In the above equation substituting,

$$I_K = I_g + I_a$$
$$I_a = \alpha_1 I_a + I_{CBO1} + \alpha_2 (I_g + I_a) + I_{CBO2}$$
$$I_a = \frac{\alpha_2 I_g + I_{CBO1} + I_{CBO2}}{1-(\alpha_1+\alpha_2)}$$

19. (a)



Without free wheeling diode (FD):

$$V_o = \frac{2V_m}{\pi}\cos\alpha$$
$$= \frac{2\times 220\sqrt{2}}{\pi}\cos 25°$$
$$= 179.51 \text{ V}$$

With FD:

$$V_o = \frac{V_m}{\pi}(1+\cos\alpha)$$
$$= \frac{220\sqrt{2}}{\pi}(1+\cos 25°) = 188.79 \text{ V}$$

The difference in the output voltage is,

$$\Delta V_o = 188.79 - 179.51 = 9.28 \text{ V}$$

20. (b)

Equation of the straight line $= y = mx + c$

$$i = \left(\frac{60}{1.1}\right)v + c$$

Now, Current i = 0 A at v = 1.0 Volt

$$\therefore \quad c = \frac{-60}{1.1}$$

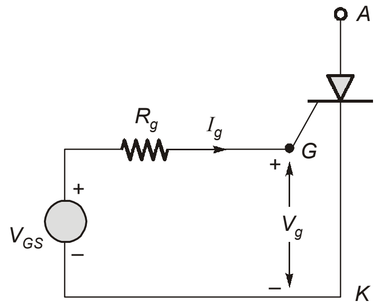
∴ The equation becomes

$$i = \frac{60}{1.1}v - \frac{60}{1.1}$$
$$v = \left(\frac{1.1}{60}i + 1\right)$$

The mean power loss will be half the instantaneous power loss over the half cycle when the current is flowing.

$$\text{Mean power (for } i = 39.6 \text{ A)} = \frac{VI}{2} = \frac{39.6\left[1+\left(\frac{1.1}{60}\right)39.6\right]}{2} = 34.17 \text{ W}$$

21. (c)



Applying KVL in the loop:

$$-V_{GS} + I_g R_g + V_g = 0$$

$$V_{GS} = R_g I_g + V_g$$

$$V_{GS} = R_g I_g + (1.5 + 8 I_g)$$

$$12 = (R_g + 8) I_g + 1.5 \qquad \text{...(i)}$$

Peak power loss in the gate

$$= V_g I_g = 5\ W \qquad \text{(Given)}$$

$$5 = (1.5 + 8 I_g) I_g$$

$$8 I_g^2 + 1.5 I_g - 5 = 0$$

$$I_g = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{-1.5 \pm \sqrt{(1.5)^2 - 4 \times 8 \times (-5)}}{16}$$

$$I_g = 0.7\text{ A} \qquad (\text{Neglecting } I_g = -0.889\text{ A})$$

Substituting the value of I_g in equation (i),

$$12 = (R_g + 8)\, 0.7 + 1.5$$

$$R_g = 7\ \Omega$$

22. (d)

The source current for a 3-phase full converter is given by

$$i_s(t) = \sum_{n=1,3,5}^{\infty} \frac{4I_0}{n\pi} \sin\frac{n\pi}{3} \sin(n\omega t - n\alpha)$$

rms value of fundamental current,

$$I_{s1} = \frac{\left(\frac{4I_0}{\pi} \sin\frac{\pi}{3}\right)}{\sqrt{2}} = \frac{\sqrt{6}}{\pi} I_0$$

rms value of source current,

$$I_s = I_0 \sqrt{\frac{2}{3}}$$

$$\text{current distortion factor} = \frac{I_{s1}}{I_s} = \frac{\frac{\sqrt{6}}{\pi} I_0}{I_0 \sqrt{\frac{2}{3}}} = 0.955$$

23. (d)

Let, V_1 = Output of buck converter = Input of boost converter

$$V_1 = 10\, D_1$$

$$\text{Output of boost converter} = 30\text{ V} = \frac{V_1}{1 - D_2}$$

$$30 = \frac{10 D_1}{1 - D_2}$$

or $\quad 3 - 3 D_2 = D_1$

or $\quad D_1 + 3 D_2 = 3$

24. (c)

For proper turn on $\quad I_A \geq I_L$

$$I_A = \frac{1}{L}\int V\,dt + \frac{V}{R}$$

$$I_A = \frac{V}{L}t + \frac{V}{R}$$

or $$\frac{V}{L}t + \frac{V}{R} \geq 5 \times 10^{-3}$$

or $$\frac{50}{L} \times 5 \times 10^{-6} + \frac{50}{50 \times 10^{3}} \geq 5 \times 10^{-3}$$

or $$\frac{250 \times 10^{-6}}{L} \geq 4 \times 10^{-3}$$

or $$L \leq \frac{250 \times 10^{-6}}{4 \times 10^{-3}}$$

or $$L \leq 0.0625 \text{ H}$$

$$L = 0.0625 \text{ H}$$

25. (b)

For proper commutation the circuit should be under damped.

$$\frac{1}{LC} - \left(\frac{R}{2L}\right)^2 > 0$$

or $$R < \sqrt{\frac{4L}{C}}$$

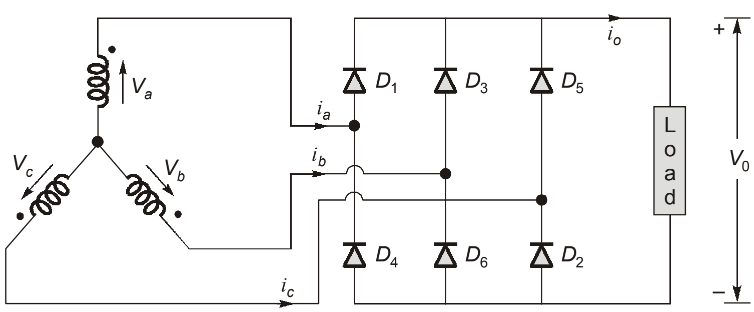
$$R < \sqrt{\frac{4 \times 20 \times 10^{-6}}{50 \times 10^{-6}}}$$

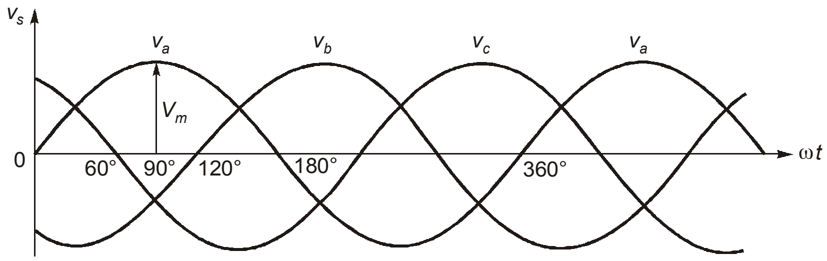
$$R < 1.26\ \Omega$$

Option (b) is the only value which is less than 1.26 Ω

$\therefore \quad R_L = 1\ \Omega$

26. (a)





$$V_A = V_m \sin\omega t$$

Phase A will get maximum voltage at $\omega t = 90°$. At this instant

$$V_0 = V_A - V_B$$

$$V_0 = V_m \sin\omega t - V_m \sin(\omega t - 120°)$$

$$= V_m - V_m \sin(-30°) \qquad [\because \ \omega t = 90°]$$

$$V_0 = 1.5\, V_m$$

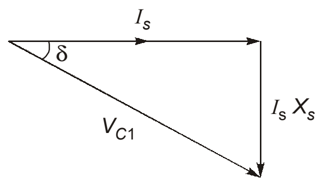
27. (c)

$$P = V_s I_s \text{ p.f.}$$

$$5 \times 10^3 = 220 \times I_s \times 1$$

$$I_s = 22.72 \text{ A}$$

$$\tan\delta = \frac{I_s X_s}{V_s}$$



$$\delta = \tan^{-1}\left(\frac{I_s X_s}{V_s}\right)$$

$$\delta = \tan^{-1}\left(\frac{22.72 \times 2\pi \times 50 \times 5 \times 10^{-3}}{220}\right)$$

$$\delta = 9.21°$$

28. (b)

$$V_r = 4 \text{ V}$$

$$V_c = 6 \text{ V}$$

$$\text{Total pulse width} = 2d$$

$$\frac{2d}{N} = \left(1 - \frac{V_r}{V_c}\right)\frac{\pi}{N}$$

(Where N is number of pulses per half cycle)

$$2d = \left(1 - \frac{V_r}{V_C}\right)\pi$$

$$2d = \left(1 - \frac{4}{6}\right)180° = 60°$$

29. (d)

The amplitude of n^{th} harmonic of the two pulse waveform is

$$V_m = \frac{8V_s}{n\pi} \sin n\gamma . \sin\frac{nd}{2}$$

Peak value of fundamental voltage component

$$V_1 = \frac{8V_S}{\pi} \cdot \sin\frac{d}{2} \cdot \sin\gamma$$

$$V_S = 300 \text{ V},\ N = 2\ ,\ \gamma = 56°$$

$$\gamma = \frac{\pi - 2d}{N+1} + \frac{d}{N}$$

(we known)

$$\left(\frac{\pi}{180}\right)56° = \frac{\pi - 2d}{3} + \frac{d}{2}$$

or $$d = 24°$$

Hence

$$V_1 = \frac{8 \times 300}{\pi} \cdot \sin\frac{24°}{2} \cdot \sin 56° = 131.67 \text{ V}$$

30. (c)

To obtain the average value of the periodic waveform,

$$I_{\text{average}} = \frac{\text{Area under the curve}}{\text{Total time period}}$$

$$= \frac{\left(\frac{1}{2} \times 5 \times 10\right) + (10 \times 10) + \left(\frac{1}{2} \times 5 \times 10\right)}{30}$$

$$I_{\text{avg}} = 5 \text{ A}$$

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