DETAILED SOLUTIONS

MADE EASY

India's Best Institute for IES, GATE & PSUs

Test Centres: Delhi, Hyderabad, Bhopal, Jaipur, Pune, Kolkata

ESE 2025 : Prelims Exam
CLASSROOM TEST SERIES

ELECTRICAL ENGINEERING

Test 12

Section A : BEE + Analog Electronics + Electrical and Electronic Measurements [All Topics]

Section B : Power Electronics and Drives-1 [Part Syllabus]

Section C : Power Systems-2 [Part Syllabus]

ANSWER KEY

1.	(b)	**16.**	(a)	**31.**	(b)	**46.**	(a)	**61.**	(b)
2.	(c)	**17.**	(a)	**32.**	(d)	**47.**	(a)	**62.**	(d)
3.	(c)	**18.**	(c)	**33.**	(b)	**48.**	(a)	**63.**	(a)
4.	(a)	**19.**	(d)	**34.**	(c)	**49.**	(a)	**64.**	(c)
5.	(d)	**20.**	(c)	**35.**	(c)	**50.**	(c)	**65.**	(c)
6.	(b)	**21.**	(c)	**36.**	(b)	**51.**	(d)	**66.**	(b)
7.	(c)	**22.**	(d)	**37.**	(c)	**52.**	(a)	**67.**	(c)
8.	(a)	**23.**	(d)	**38.**	(d)	**53.**	(b)	**68.**	(c)
9.	(c)	**24.**	(c)	**39.**	(d)	**54.**	(a)	**69.**	(b)
10.	(b)	**25.**	(b)	**40.**	(a)	**55.**	(d)	**70.**	(c)
11.	(a)	**26.**	(b)	**41.**	(b)	**56.**	(c)	**71.**	(b)
12.	(c)	**27.**	(b)	**42.**	(b)	**57.**	(a)	**72.**	(d)
13.	(d)	**28.**	(b)	**43.**	(c)	**58.**	(c)	**73.**	(a)
14.	(b)	**29.**	(c)	**44.**	(b)	**59.**	(c)	**74.**	(b)
15.	(a)	**30.**	(c)	**45.**	(d)	**60.**	(c)	**75.**	(d)

DETAILED EXPLANATIONS

Section A : BEE + Analog Electronics + Electrical and Electronic Measurements

1. (b)

Assume, $D \rightarrow \text{OFF}$

Now, when $V_i < 5$ V

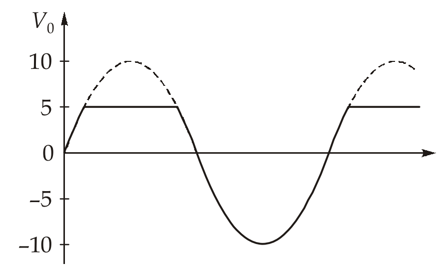
$D \rightarrow \text{OFF}$

$\therefore$ $V_0 = V_i = 10 \sin \omega t$

When $V_i > 5$ V

$D \rightarrow \text{ON}$

$\therefore$ $V_0 = V_B = 5$ volts



2. (c)

Reverse saturation current, I_s doubles for every 10° C rise in temperature

i.e, $$I_{s2} = I_{s1} 2^{\left(\frac{T_2 - T_1}{10}\right)} = I_{s1} 2^{0.1\Delta T} \cong I_{s1}(1+1.07)^{\Delta T}$$

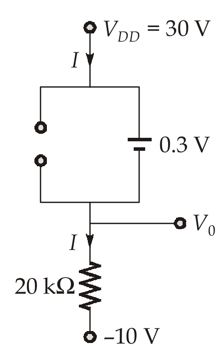
$$= I_{s1}(1+7\%)^{\Delta T}$$

Thus, for every °C rise in temperature, reverse saturation current increases by 7%.

3. (c)

Whenever *Si* and *Ge* diodes are in parallel, the Ge-diode will be ON. First due to lower cut-in voltage of 0.3 V and hence Si-diode will be OFF,

Thus, Ge-diode will be replaced by $V_\gamma = 0.3$ V



By KVL,

$-30 + 0.3 + 20 \times 10^3 I + (-10) = 0$

$\Rightarrow$ $I = 1.985$ mA

and $V_0 = V_{DD} - 0.3$

$= 30 - 0.3 = 29.7$ volts

4. (a)

A clamper circuit basically uses diode, resistor, capacitor and reference voltage.

5. (d)

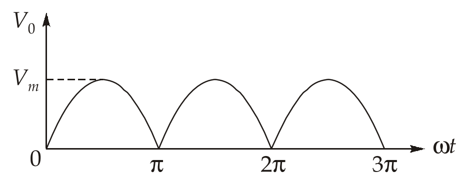
The frequency of oscillations generated by (Astable multivibrator)

$$f = \frac{1}{2RC\ln\left(1+\frac{2R_2}{R_1}\right)} = \frac{1}{2\times10^3\times2\times10^{-6}\ln(1+2)}$$

$$= \frac{10^3}{4\ln(3)} = 227.56 \text{ Hz}$$

6. (b)

- The average output voltage is



$$V_0 = \frac{1}{\pi}\int_0^{\pi} v_m \sin\omega t d(\omega t) = \frac{v_m}{\pi}[-\cos\omega t]_0^{\pi} = \frac{2v_m}{\pi}$$

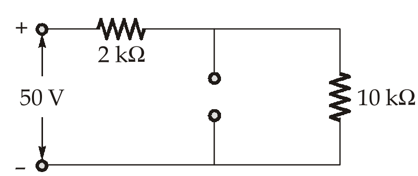
- Recitification efficiency is

$$\eta_{BR} = 2 \times \eta_{\text{HWR}} = 2\times\frac{4}{\pi^2} = \frac{8}{\pi^2} \text{ or } 81\%$$

- Form factor is, $\text{FF} = \frac{\text{Rms value}}{\text{Average value}} = \frac{v_m/\sqrt{2}}{2v_m/\pi} = \frac{\pi}{2\sqrt{2}} = 1.11$

7. (c)

Determination of state of Zener diode,



$$V_{10\ \text{k}\Omega} = 50\times\frac{10}{12} = 41.66 \text{ k}\Omega$$

∴ $V_{10\ \text{k}\Omega} > 40$ V

∴ Zener diode is ON

∴ Voltage across 10 kΩ = 40 V

∴ $V_{2\ \text{k}\Omega} = 50 - 40 = 10$ V

8. (a)

Four types of operating region in BJT are:

Operating Region	J_E	J_C	Application
Forward active	F.B.	R.B.	Amplifier
Saturation	F.B.	F.B.	On-switch
Cut-off	R.B.	R.B.	Off-switch
Reverse active	R.B.	F.B.	Attenuator

9. (c)

$\because$ $$g_m = \frac{2I_D}{V_{GS} - V_t}$$

and $$I_D = \frac{1}{2}K_n'\left(\frac{W}{L}\right)(V_{GS} - V_t)^2$$

$\therefore$ $$V_{GS} - V_t \propto \sqrt{\frac{L}{W}} \quad \text{(Since } I_D \text{ is given as constant)}$$

$\therefore$ $$g_m \propto \sqrt{\frac{W}{L}}$$

$$\frac{g_{m1}}{g_{m2}} = \frac{\sqrt{\left(\frac{W}{L}\right)_1}}{\sqrt{\left(\frac{W}{L}\right)_2}} = \frac{\sqrt{\left(\frac{W}{L}\right)}}{\sqrt{4\left(\frac{W}{L}\right)}} = \frac{1}{2}$$

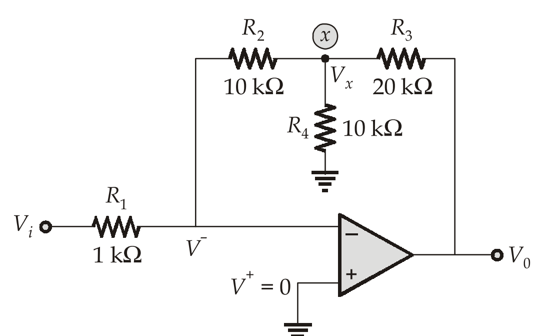
$$\frac{g_{m1}}{g_{m2}} = \frac{1}{2}$$

$$2g_{m1} = g_{m2}$$

$$g_{m2} = 2g_{m1}$$

10. (b)

Redrawing the circuit, it is a T-network op-amp circuit,



The voltage gain of the T-network op-amp is

$$A_V = \frac{V_0}{V_i} = -\frac{R_2}{R_1}\left[1 + \frac{R_3}{R_2} + \frac{R_3}{R_4}\right]$$

$$= -\frac{10}{1}\left[1 + \frac{20}{10} + \frac{20}{10}\right] = -50$$

11. (a)

As output is taken as voltage → Voltage sampling

As input signal given to non-inverting terminal of op-amp → series mixing

$\therefore$ Voltage - series negative feedback.

12. (c)

Input resistance, $r_\pi = \dfrac{V_T}{I_{BQ}}$

Now, $I_{BQ} = I_E - I_C = (2.01 - 2)\text{ mA} = 0.01\text{ mA}$

$$r_\pi = \frac{26\times10^{-3}}{0.01\times10^{-3}} = 2600\ \Omega = 2.6\ \text{k}\Omega$$

13. (d)

$$\text{CMRR} = 20\log\frac{A_d}{A_c}$$

where, $A_d \rightarrow$ differential gain, $A_c \rightarrow$ common mode gain

$\Rightarrow$ $$80 = 20\log\left(\frac{A_d}{1}\right)$$

$\Rightarrow$ $$\frac{A_d}{1} = 10^4$$

$$A_d = 10^4$$

Output, $$V_0 = A_d(V_1 - V_2) + A_c\left(\frac{V_1+V_2}{2}\right)$$

$$= 10^4(0.6-0.4) + 1\left(\frac{0.6+0.4}{2}\right)$$

$$= 2000.5 \approx 2000\text{ Volts}$$

14. (b)

The frequency of the output signal generated by the Colpitts oscillator is

$$f = \frac{1}{2\pi\sqrt{LC_T}}$$

where, $$C_T = \frac{C_1C_2}{C_1+C_2} = \frac{C^2}{2C} = \frac{C}{2} = \frac{0.625}{2}\mu\text{F} = 0.3125\ \mu\text{F}$$

$\therefore$ $$\frac{400}{\pi}\times10^3 = \frac{1}{2\pi\sqrt{L\times0.3125\times10^{-6}}}$$

$\Rightarrow$ $$(800\times10^3)^2 = \frac{1}{L\times0.3125\times10^{-6}}$$

$\Rightarrow$ $$L = \frac{1}{640000\times0.3125} = 5\ \mu\text{H}$$

15. (a)

- Negative feedback decreases the lower cut-off frequency and increases the upper cut-off frequency thereby increasing the bandwidth.

$$f_{Lf} = \frac{f_L}{(1+A\beta)}, \qquad f_{Hf} = f_H(1 + A\beta)$$

$$\Rightarrow \qquad (BW)_f = BW(1 + A\beta)$$

- Fractional change in closed loop gain, with negative feedback

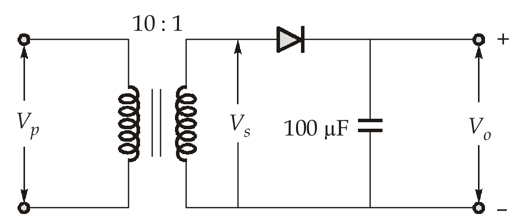
$$\frac{\partial A_f}{A_f} = \frac{1}{(1+A\beta)}\frac{\partial A}{A}$$

where A : closed loop gain without feedback.

16. (a)

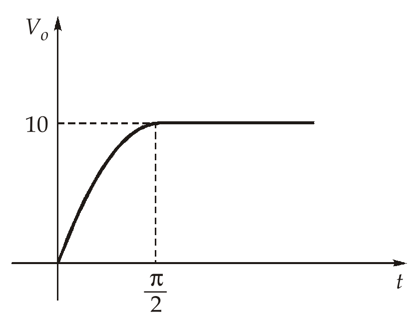
$$\frac{V_p}{V_s} = 10$$

$$\Rightarrow \qquad V_s = 10\sin\omega t$$



Since, there is no discharge path available once the capacitor gets charged. It remain at the same voltage i.e. output remain constant.

$$V_o = 10 \text{ V}$$



17. (a)

Replacing zener diode with ideal voltage source as it is in breakdown region,

KVL :

$$-20 + 5I_1 + 5 = 0$$

$$I_1 = 3 \text{ mA}$$

KCL :

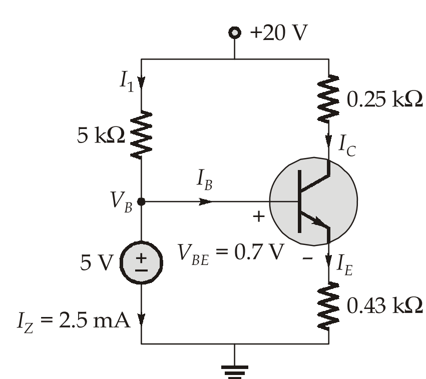
$$I_B + I_2 = I_1$$

$$I_B + 2.5 = 3$$

$$I_B = 0.5 \text{ mA}$$

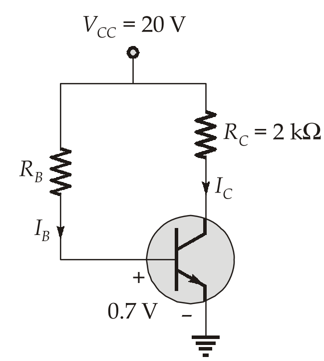
KVL to base-emitter loop

$$-5 + 0.7 + 0.43(1 + \beta)I_B = 0$$



$$-4.3 + 0.43(1 + \beta) \times 0.5 = 0$$
$$\beta = 19$$
$$\therefore \quad \beta = \frac{I_C}{I_B} = 19$$

18. (c)



R_B = 322 kΩ :

KVL to input:

$$-V_{CC} + R_B I_{B1} + V_{BE} = 0$$
$$-20 + 322 I_{B1} + 0.7 = 0$$
$$I_{B1} = 0.06 \text{ mA}$$
$$I_{C1} = \beta I_B = 100 \times 0.06 = 6 \text{ mA}$$

R_B = 386 kΩ :

KVL to input:

$$-20 + 386 I_{B2} + 0.7 = 0$$
$$I_{B2} = 0.05 \text{ mA}$$
$$I_{C2} = \beta I_{B2} = 100 \times 0.05 = 5 \text{ mA}$$

Change in collector current,

$$\Delta I_C = I_{C2} - I_{C1}$$
$$= 5 - 6 = -1 \text{ mA}$$

Negative sign indicates that collector current decreased from its previous value.

19. (d)

- Turn-ON time of transistor is the sum of delay time and rise time.
- Turn-OFF time of the transistor is the sum of storage time and fall time.

20. (c)

The given circuit is a MOSFET basic current mirror

where, $I_1 = I_{D1} = I_{ref}$ = Input current

and $I_{D2} = I_0$ = output current

For a basic MOSFET current mirror

$$\frac{I_0}{I_{ref}} = \frac{(W/L)_2}{(W/L)_1}$$

$$\Rightarrow \quad \frac{I_{D2}}{I_{D1}} = \frac{10}{5}$$

$$\Rightarrow \quad \frac{I_{D2}}{2\text{mA}} = 2$$

$$I_{D2} = 4 \text{ mA}$$

21. **(c)**

$V_i > 6$ V	$4\text{ V} < V_i < 6V$	$V_i < 4$ V
D_1 ON	D_1 OFF	D_2 ON
D_2 OFF	D_2 OFF	D_1 OFF
$V_0 = 6$ V	$V_0 = V_i$	$V_0 = 4$ V

22. **(d)**

minimum conductivity occurs at

electron concentration (n) = $n_i\sqrt{\dfrac{\mu_p}{\mu_n}}$

and hole concentration (p) = $n_i\sqrt{\dfrac{\mu_n}{\mu_p}}$

So, minimum conductivity

$$\sigma = nq\mu_n + pq\mu_p$$

$$= n_i\sqrt{\frac{\mu_p}{\mu_n}}\cdot q\cdot\mu_n + n_i\sqrt{\frac{\mu_n}{\mu_p}}\cdot q\cdot\mu_p$$

$$\sigma = 2n_i q\sqrt{\mu_p\cdot\mu_n}$$

23. **(d)**

Bark Hausen criterion for oscillators

$$A\beta = 1 \angle 0° \text{ or } 360°$$

25. **(b)**

The natural frequency of vibration of the reeds depends upon their weights and dimensions. Since the reeds have different weights and sizes, their natural frequencies of vibration are different. The reeds are arranged in ascending order of natural frequency, the difference in frequecy is usually 0.5 Hz. Thus the natural frequency of first reed may be 47 Hz of the second 47.5 Hz of the next 48 Hz and so on.

27. **(b)**

$$D = \frac{Ll_dE_d}{2dE_a}$$

∴ voltage applied to deflecting plates

$$E_d = \frac{2dE_aD}{Ll_d} = \frac{2\times5\times10^{-3}\times4000\times3\times10^{-2}}{0.3\times2\times10^{-2}} = 200\text{ V}$$

∴ Input voltage required for a deflection of 3 cm

$$= \frac{E_d}{\text{gain}} = \frac{200}{100} = 2\text{ V}$$

28. (b)

$$\text{Resolution} = \frac{1}{10^3} = 0.001$$

$$\text{Sensitivity of DVM} = \text{Resolution} \times (\text{Full-scale value})_{min}$$

$$\therefore \quad \text{Sensitivity} = 0.001 \times 10 \text{ mV} = 0.01 \text{ mV}$$

29. (c)

Signal at X-deflecting plate = $0.4 \times 5 \sin 100\,\pi t = 2 \sin 100\,\pi t$

Signal at Y-deflecting plate = $0.5 \times 4 \cos 100\pi t = 2 \cos 100\pi t = 2 \sin(100\pi t + 90°)$

Since, the signals at X and Y deflecting plates are equal in magnitude but having a phase difference of 90°. Hence, circle will be displayed on CRO screen.

30. (c)

A Megger is used to measure high insulation resistance. Unlike conventional measuring instruments, a megger operates on a principle where the deflection torque is provided by the interaction of magnetic fields, and there is no need for a controlling torque. The pointer comes to rest at a position where the deflection torque is balanced by the resistance of the system itself. Hence, no spring weights are required for controlling torque.

31. (b)

Electrostatic voltmeter operate based on the force between charged plates, which depends on the electrostatic field. The energy density in an electrostatic field is much smaller than in an electromagnetic field. Which means that for the same measurement sensitivity, electrostatic voltmeters need to be physically larger to generate the required force for deflection.

32. (d)

Given,voltmeter range, 0 to 300 V

$$1.5\% \text{ accuracy} = \frac{300 \times 1.5}{100} = 4.5 \text{ V}$$

$$\therefore \text{percentage limiting error} = \frac{4.5}{100} \times 100 = 4.5\%$$

33. (b)

The deflection of a thermo-electric ammeter is

$$\theta = KI^2$$

suppose θ_F is the full scale deflection

$$\therefore \quad \theta_F = K \times (10)^2$$

$$\text{or} \quad \frac{\theta_F}{K} = 100$$

The deflection at half scale is $\dfrac{\theta_F}{2}$

$$\therefore \quad \frac{\theta_F}{K} = KI^2$$

or current required to give half scale deflection

$$I = \left(\frac{\theta_F}{2K}\right)^{1/2} = \left(\frac{100}{2}\right)^{1/2} = 7.07 \text{ A}$$

34. (c)

Deflection, $\theta = 90° = \frac{\pi}{2}\text{rad}$

Final steady deflection, $\theta = \frac{1}{2}\frac{V^2}{K}\frac{dC}{d\theta}$

or rate of change of capacitance

$$\frac{dC}{d\theta} = \frac{2\theta K}{V^2} = \frac{2\times\frac{\pi}{2}\times 2\times 10^{-6}}{(1000)^2} = 6.28 \times 10^{-12} \text{ F/rad} = 6.28 \text{ pF/rad}$$

Change in capacitance when reading from 0 to 1000 V is

$$6.28\times\frac{\pi}{2} = 9.86 \text{ pF}$$

∴ Capacitance when reading 1000 V

$$C = 20 + 9.86 = 29.86 \text{ pF}$$

35. (c)

Advantages of rectifier instruments:

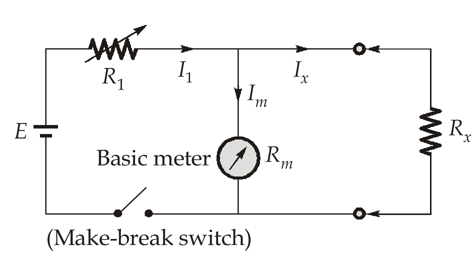
- The frequency range-extends from about 20 Hz to high audio frequency.
- These instruments have a much lower operating current for voltmeters (or higher value of ohm per volts) than other a.c. instruments with the exception of electrostatic and valve voltmeters.
- The have a practically uniform scale for most ranges.
- Their accuracy is about ±5% under normal operating conditions.

36. (b)

An electrodynamometer voltmeter reads the rms value of the applied voltage

$$e_{\text{rms}} = \sqrt{\left(\frac{200}{\sqrt{2}}\right)^2 + \left(\frac{40}{\sqrt{2}}\right)^2 + \left(\frac{30}{\sqrt{2}}\right)^2} = 145.77 \approx 146 \text{ V}$$

37. (c)



The circuit diagram of a shunt type ohmmeter is shown in figure. It consists of a batter in series with an adjustable resistor R_1 and a basic d'Arsonval movement. The unknown resistance is connected across terminals A and B, parallel with the meter. In this circuit it is necessary to having an "off-on" switch to disconnect the battery from the circuit when the instrument is not in use.

38. (d)

There has been improved accuracy of potential transformers with the advent of new materials. There are some modifications in design which leads to smaller total errors.

These are:

- Reduction of magnetizing and loss components.
- Reduction of resistance and leakage reactance.
- Turns compensation.

40. (a)

We have,

$$P_1 + P_2 = 60 \text{ kW} \quad \text{...(i)}$$

Now,

$$\cos\phi = 0.6,$$

$$\sin\phi = \sqrt{1-(0.6)^2} = 0.8$$

$\therefore$

$$\tan\phi = \frac{\sin\phi}{\cos\phi} = \frac{0.8}{0.6} = \frac{4}{3}$$

$$\tan\phi = \sqrt{3}\cdot\frac{P_1 - P_2}{P_1 + P_2}$$

$\therefore$

$$\frac{4}{3} = \sqrt{3}\cdot\frac{P_1 - P_2}{60}$$

$$P_1 - P_2 = \frac{4}{3}\times\frac{60}{\sqrt{3}} = \frac{80}{\sqrt{3}} = 46.2 \quad \text{...(ii)}$$

$$P_1 = 53.1 \text{ kW and } P_2 = 6.9 \text{ kW}$$

Alternate Solution:

Reading of first wattmeter,

$$P_1 \propto \cos(30 - \phi)$$

Reading of second wattmeter,

$$P_2 \propto \cos(30 + \phi)$$

$$\cos\phi = 0.6$$

$\Rightarrow$

$$\phi = 53.13°$$

Therfore,

$$\frac{P_1}{P_2} = \frac{\cos(30-53.13)}{\cos(30+53.13)} = 7.688$$

$\Rightarrow$

$$P_1 - 7.688P_2 = 0 \quad \text{...(i)}$$

Also

$$P_1 + P_2 = 60 \quad \text{...(ii)}$$

On solving equation (i) and (ii),

$$P_1 = 53.1 \text{ kW}$$
$$P_2 = 6.9 \text{ kW}$$

41. (b)

Both the statements are correct and statement-II is not the correct explanation of statement-I.

42. (b)

$$f_H = 20 \text{ kHs : each amplifier}$$
$$\text{B.W.} = \text{upper cut-off frequency}$$

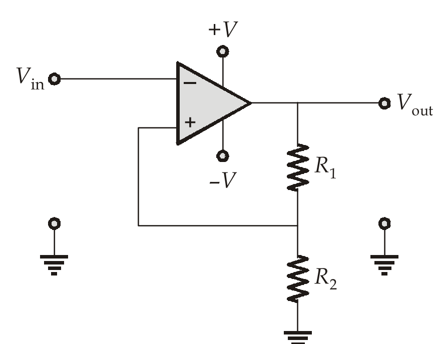
For n-stage cascaded amplifier

$$f_H^* = f_H\sqrt{2^{1/n}-1} = 20\times10^3\sqrt{2^{1/2}-1}$$
$$= 20\times10^3\sqrt{1.414-1} = 20\times10^3\sqrt{0.414}$$
$$\approx 20\times10^3\times0.632 = 12.6 \text{ kHz} \qquad \left[\text{Note}: \sqrt{0.414} = \frac{\sqrt{414}}{\sqrt{1000}} \approx \frac{20}{10\sqrt{10}} = \frac{2}{\sqrt{20}} = 2\times0.316\right]$$

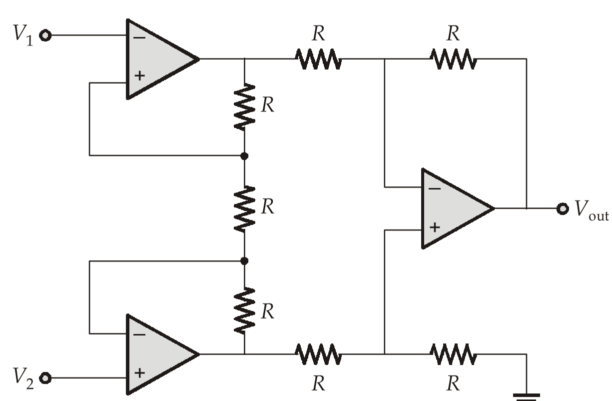
∴ both the statements are correct.

43. (c)

Schmitt trigger circuit : It uses an op-amp based comparator with positive feedback from the output



Instrumentation amplifier :



An instrumentation amplifier contains 3 op-amps. It is employed to amplify low-level signals, rejecting noise and interference signals.

44. (b)

- Cascode amplifier is a multi-stage configuration of CE and CB. This amplifier enhances I/O isolation like there is no straight coupling from the output to input which reduces the miller effect and therefore supplies high bandwidth.
- As the temperature of FET increases, the carrier mobility decreases, so thermal run away is not possible in FET.

45. (d)

A dynamometer type wattmeter has a linear scale while a dynamometer type voltmeter has a non-linear scale.

Section B : Power Electronics and Drives-1

46. (a)

$$i(t) = 5+\frac{12}{1}\sin(2\pi f_0 t+\theta_1)+\frac{12}{2}\sin(4\pi f_0 t+2\theta_1)+\frac{12}{3}\sin(6\pi f_0 t+3\theta_1)$$
$$+\alpha\sin(8\pi f_0 t+4\theta_1)$$

$$I_{\text{rms}} = \sqrt{5^2+\frac{12^2}{2}+\frac{6^2}{2}+\frac{4^2}{2}+\frac{\alpha^2}{2}} = \sqrt{\frac{246+\alpha^2}{2}}$$

$$I_{1\text{ rms}} = \frac{12}{\sqrt{2}}$$

$$\frac{1}{g} = \frac{13}{6\sqrt{2}} = \frac{I_{\text{rms}}}{I_{1\text{rms}}} = \frac{\sqrt{\frac{246+\alpha^2}{2}}}{\frac{12}{\sqrt{2}}} = \frac{\sqrt{246+\alpha^2}}{12}$$

$\Rightarrow$ $$\alpha = 2\sqrt{23}$$

48. (a)

All the statements are correct.

49. (a)

$$i(t) = 8 + \beta\cos(377t + 30°) + \beta\cos(754t + 45°)\text{ A}$$

$$I_{1\text{ rms}} = \frac{\beta}{\sqrt{2}}$$ ($\because$ 377 rad/sec is the fundamental frequency)

Rms current, $$I_{\text{rms}} = \sqrt{8^2+\frac{\beta^2}{2}+\frac{\beta^2}{2}}$$

$\Rightarrow$ $$I_{\text{rms}} = \sqrt{64+\beta^2}$$

$$g = \frac{I_{1rms}}{I_{rms}} = \frac{\beta/\sqrt{2}}{\sqrt{64+\beta^2}} = \frac{3}{5\sqrt{2}}$$

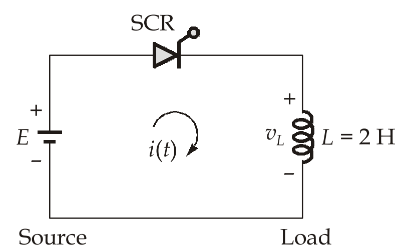
$$\Rightarrow \quad \frac{5\beta}{3} = \sqrt{64+\beta^2}$$

$$\Rightarrow \quad \frac{25}{9}\beta^2 = 64 + \beta^2$$

$$\Rightarrow \quad \frac{16}{9}\beta^2 = 64$$

$$\Rightarrow \quad \beta = 6 \text{ A}$$

50. (c)



When SCR → ON

By KVL,
$$E = L\frac{di}{dt} = v_L$$

$$\Rightarrow \quad di = \frac{E}{L}dt$$

$$\int_0^{I_L} d_i = \int_0^{t_{g\min}} \frac{E}{L}dt$$

$$\Rightarrow \quad I_L = \frac{E}{L}t_{g\min}$$

$$\Rightarrow \quad t_{g\min} = \frac{L \cdot I_L}{E} = \frac{200\times10^{-3}\times 2}{400} = 1 \text{ msec}$$

51. (d)

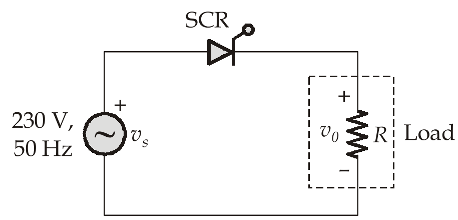
$$V_S = L\left(\frac{di}{dt}\right)$$

$$\left(\frac{di}{dt}\right)_{max} = \frac{V_S}{L} = \frac{240}{4.8\times10^{-6}} = 50 \text{ A/}\mu\text{sec}$$

We have,
$$\left(\frac{dv}{dt}\right)_{max} = R_s\left(\frac{di}{dt}\right)_{max} = 6 \times 50 = 300 \text{ V/}\mu\text{sec}$$

52. (a)

$$P_0 = \frac{V_{0r}^2}{R} = 132.25$$



But,
$$V_{0r} = \frac{v_m}{\sqrt{2T_0}}\left[(\pi-\alpha)+\frac{1}{2}\sin 2\alpha\right]^{1/2}$$

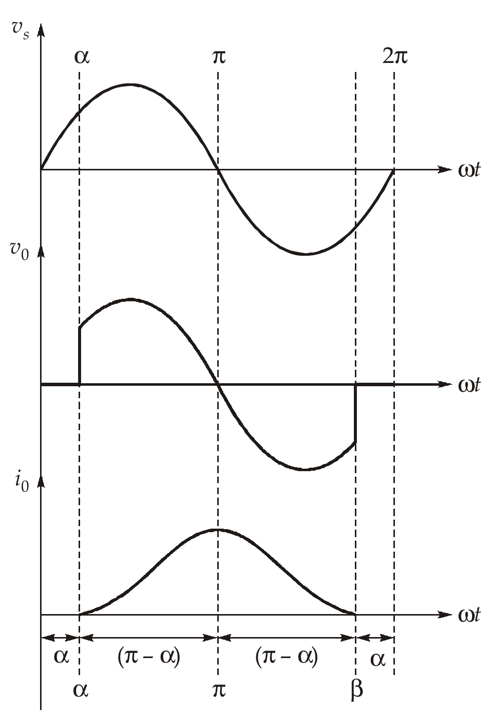
$$= \frac{230\sqrt{2}}{\sqrt{2\times 2\pi}}\left[\left(\pi-\frac{\pi}{2}\right)+\frac{1}{2}\sin 2\times\frac{\pi}{2}\right]^{1/2}$$

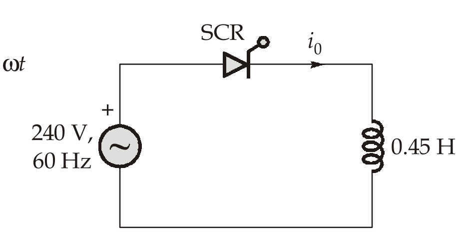
$$= \frac{115\sqrt{2}}{\sqrt{\pi}}\times\sqrt{\frac{\pi}{2}} = 115\text{ V}$$

$\therefore$
$$P_0 = \frac{V_{0r}^2}{R} = 132.25 = \frac{115^2}{R}$$

$\Rightarrow$
$$R = 100\ \Omega$$

53. (b)





How much time the inductor will take to store the energy, the same time it will take to release the stored energy,

$\therefore$ Extinction angle, $\beta = \alpha + (\pi - \alpha) + (\pi - \alpha)$

$$= 2\pi - \alpha$$

$$= 2\pi - \frac{\pi}{4} = \frac{7\pi}{4} \text{ radian}$$

$$= 1\frac{3}{4}\pi$$

54. (a)

$$I_{on} = \frac{4I_0}{n\pi}$$

$\Rightarrow$ $$\hat{I}_{05} = \frac{4 \times 10}{5\pi} = \frac{8}{\pi} \text{A}$$

RMS value, $$I_{05} = \frac{8}{\pi\sqrt{2}} = \frac{4\sqrt{2}}{\pi} = 1.8 \text{ A}$$

55. (d)

$$I_0 = \frac{V_0 - E}{R}$$

$\Rightarrow$ $$V_0 = E + I_0 R$$

$$\frac{2V_m}{\pi}\cos\alpha = E + I_0 R$$

$$\frac{2\sqrt{2} \times 240}{\pi}\cos\alpha = 150 + 25 \times 0.7$$

$\Rightarrow$ $$\alpha = \cos^{-1}(0.7752)$$

56. (c)

$$V_{ph} = 230 \text{ V}$$

$$f = 50 \text{ Hz}$$

$\Rightarrow$ $$\omega = 2\pi f = 2\pi \times 50 = 100\pi \text{ rad/sec}$$

$$V_{mL} = \sqrt{6}\, V_{ph} = \sqrt{6} \times 230$$

Peak value of circulating current is

$$i_{peak} = \frac{\sqrt{3} V_{mL}}{\omega L}(1 - \sin\alpha_1)$$

$$= \frac{\sqrt{3} \times \sqrt{6} \times 230}{100\pi \times 15 \times 10^{-3}}(1 - \sin 30°) = 103.54 \text{ A}$$

57. (a)

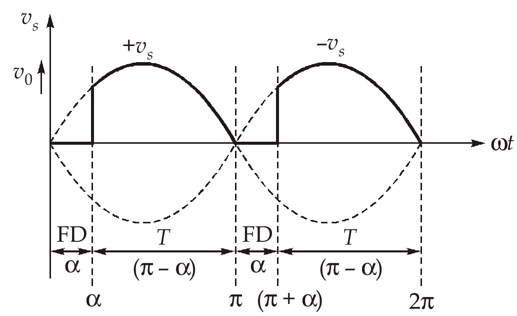
PIV of thyristor in three phase full bridge converter is v_{mL}

$$= \sqrt{3}\, v_{mph} = \sqrt{3} \times \sqrt{2} V_{ph}$$

$$= \sqrt{6} \times 230 = 563.38 \text{ volts}$$

58. (c)

Output voltage waveform for 1-ϕ half controlled rectifier with FD is shown below



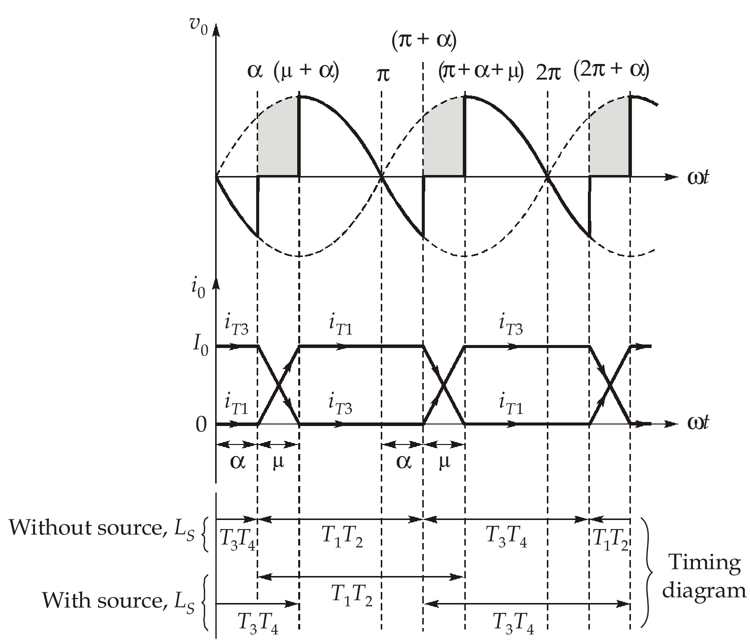
The FD conducts two times in 1 cycle

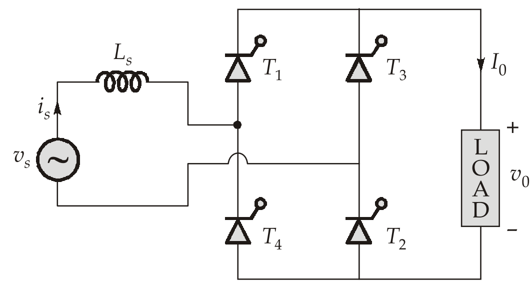
∴ Fraction of cycle for FD conduction

$$= \frac{2\alpha}{2\pi} = \frac{2\pi/4}{2\pi} = \frac{1}{4} = 0.25$$

59. (c)

For 2-pulse converter





(1-ϕ full bridge 2 pulse converter)

Exchange of load current between the power semiconductor devices occurs during overlap period.

- This reduces the net output voltage (average as well as rms).
- All the thyristors are in on-state during overlap period.
- Conduction angle of each thyristor is now increased by 'μ' radians per 2π radians.

Section C : Power Systems-2

62. (d)

Both the statements are correct.

63. (a)

$$X_0 = X_s + 2X_m = 5X_2 = 5 \times 0.05 = 0.25 \quad ...(i)$$

$$X_2 = X_s - X_m = 0.05 \quad ...(ii)$$

Solving (i) and (ii),

$$X_s = \frac{7}{60} \text{p.u.}$$

and $$X_m = \frac{1}{15} \text{p.u.}$$

66. (b)

In three-phase system, the p.u. values can also be obtained from per phase base quantities.

67. (c)

For the fully transposed transmission line

Positive sequence impedance,

$$Z_1 = Z_s - Z_m$$

Negative sequence impedance,

$$Z_2 = Z_s - Z_m$$

Zero sequence impedance,

$$Z_0 = Z_s + 2Z_m + 3Z_n$$

where, Z_s = Self impedance/phase

Z_m = Mutual impedance/phase

If the system voltages are unbalanced, we have a neutral current I_n flowing through the neutral (ground) having impedance Z_n.

From above,

- Positive and negative sequence impedance are equal.
- Zero sequence impedance is much larger than the positive or negative sequence impedance.

∴ Statement (II) is true and statement (I) is false.

69. (b)

$$X_2 = 66\% \text{ of } X_1 \qquad (\because \text{ reduction by } 34\%)$$

$$\Rightarrow \quad X_2 = 0.66X_1$$

and $$V_2 = 1.15 \text{ of } V_1$$

$$\Rightarrow \quad V_2 = 1.15\ V_1$$

$$P_{max2} = \frac{V_2^2}{X_2} = \frac{(1.15V_1)^2}{(0.66X_1)}$$

$$= \frac{(1.15)^2}{0.66} \times P_{max1} \qquad \left(\because P_{max1} = \frac{V_1^2}{X_1}\right)$$

$$\frac{P_{max2}}{P_{max1}} = 2.004$$

i.e., $$P_{max2} = 200.4\ P_{max1}$$

% increasing in the steady state stability limit

$$= \frac{P_{max2} - P_{max1}}{P_{max1}} \times 100$$

$$= \frac{2.004P_{max1} - P_{max1}}{P_{max1}} \times 100 = 100.38\%$$

70. (c)

Admittance of non-shunt branch,

$$y_{NS} = \frac{1}{j0.2} = -j5 \text{ p.u.}$$

$$\therefore \quad [Y_{bus}]_{new} = j\begin{bmatrix} -10 & 2 & 4 \\ 2 & -8 & 2 \\ 4 & 2 & -13 \end{bmatrix} + \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & -1 \\ 0 & -1 & 1 \end{bmatrix}(-j5)$$

$$= j\begin{bmatrix} -10 & 2 & 4 \\ 2 & -13 & 7 \\ 4 & 7 & -18 \end{bmatrix}$$

Here, $$Y_{11} = -j10 \text{ p.u, the old value}$$

$$Y_{23} = j7 \text{ p.u.}$$

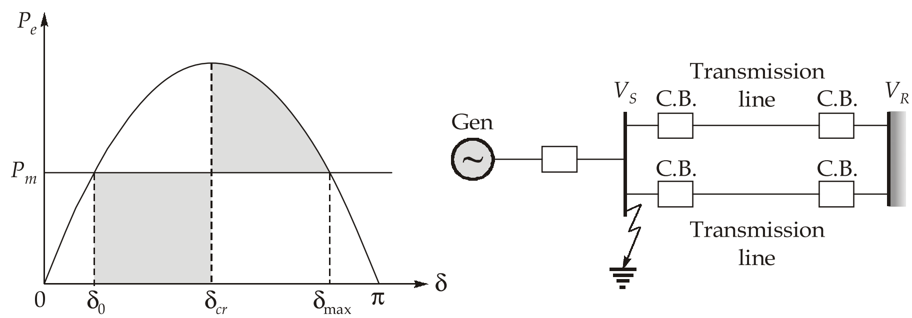
$$\therefore \quad \% \text{ change in } Y_{23} = \frac{j7 - j2}{j2} \times 100 = 250\%$$

$$Y_{33} = -j18 \text{ p.u.}$$

$$\% \text{ change in } Y_{33} = \frac{(-j18)-(-j13)}{-j13} \times 100 = 38.5\%$$

71. (b)

When 3-ϕ fault occurs at sending end bus no power flows through the system and after fault clearance the normal operating conditions are maintained,

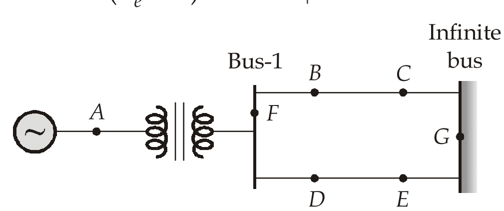


72. (d)

During the fault ($\delta_0 \le \delta \le \delta_{cr}$)

Electrical power output, $P_e = 0$

Electrical power output will be zero ($P_e = 0$) for a 3-ϕ fault at locations A, B, C, D, E, F and G



i.e. for a 3-ϕ fault at far ends (sending or receiving end), $P_e = 0$. For other than these above locations,

$$P_e \neq 0$$

Also, for any unsymmetrical fault at any location of any power system,

$$P_e \neq 0$$

73. (a)

Common base, $S_B = 500$ MVA

Machine-1 :

$$H_{1\,old} = 6 \text{ MJ/MVA on 300 MVA}$$

$$H_{1\,new} = \frac{H_{1old} S_{old}}{S_B} = \frac{6 \times 300}{500} = 3.6 \text{ MJ/MVA}$$

Machine-2 :

$$H_{2\,old} = 3 \text{ MJ/MVA on 500 MVA}$$

Since machines are coherent unit

$$\therefore \quad H_{eq} = H_1 + H_2$$
$$= 3.6 + 3 = 6.6 \text{ MJ/MVA}$$

Basic swing equation for coherent unit

$$\frac{2H_{eq}}{\omega_s}\frac{d^2\delta}{dt^2} = (P_{m\,eq} - P_{e\,eq})_{\text{p.u.}} \quad \text{.... on 500 MVA}$$

$$\Rightarrow \quad \frac{2\times 6.6}{\omega_s}\frac{d^2\delta}{dt^2} = (P_{m\,eq} - P_{e\,eq})_{\text{p.u.}}$$

$$\Rightarrow \quad \frac{13.2}{\omega_s}\frac{d^2\delta}{dt^2} = (P_{m\,eq} - P_{e\,eq})_{\text{p.u.}} \quad \text{.... on 500 MVA}$$

74. (b)

For SLG fault:

Fault current is 3 times the sequence currents,

i.e., $I_f = 3I_{af}^{(1)} = 3I_{af}^{(2)} + 3I_{af}^{(0)}$

75. (d)

❍❍❍❍