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ESE 2024 : Prelims Exam
CLASSROOM TEST SERIES

E & T ENGINEERING

Test 12

Section A : Advanced Communication + Electronic Measurements and Instrumentation

Section B : Signals and Systems-1 + Basic Electrical Engineering-1

Section C : Analog & Digital Communication Systems-2

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

Detailed Explanation
Section A : Advanced Communication + Electronic Measurements and Instrumentation

1. (d)

$$2\gamma = 120°$$

$\because$ At each reflection, skew ray change its path by 2γ.

$$\gamma = 60°$$

We know that acceptance angle for skew rays,

$$\theta_A = \sin^{-1}\left[\frac{\sqrt{n_1^2 - n_2^2}}{n_0 \cos\gamma}\right]$$

$$45° = \sin^{-1}\left[\frac{\sqrt{n_1^2 - n_2^2}}{(1.2)\cos 60°}\right]$$

$$\sin 45° = \frac{\sqrt{n_1^2 - n_2^2}}{1.2 \times 0.5}$$

$$\sqrt{n_1^2 - n_2^2} = \frac{1}{\sqrt{2}} \times 1.2 \times 0.5$$

$$\sqrt{n_1^2 - n_2^2} = 0.42 = \text{N.A}$$

Hence, numerical aperture of the fiber is 0.42.

2. (b)

We know that, to achieve single mode condition, V-number of the fiber should be in the range of $0 \le V \le 2.405$.

Consider, $V = 2.405$ at $\lambda = \lambda_c$

$$\lambda_c = \frac{2\pi}{2.405} a(N.A)$$

where a = core radius = 40 μm

$$\text{NA} = \text{Numerical aperture} = \sqrt{n_1^2 - n_2^2} = n_1\sqrt{1 - \left(\frac{n_2}{n_1}\right)^2}$$

$$\text{NA} = 1.5\sqrt{1 - (0.8)^2}$$

$$= 1.5 \times 0.6 = 0.9$$

$$\lambda_c = \frac{2\pi}{2.405} \times 40 \times 0.9 \times 10^{-6}\,\text{m}$$

For simplification $2.405 \approx 2.4$

$$\lambda_c = \frac{2\pi}{2.4} \times 40 \times 0.9 \times 10^{-6}\,\text{m}$$

$$\lambda_c = 30\,\pi\,\mu\text{m}$$

For any λ less than $\lambda_c = 30\pi$ μm, multimode propagation will exist.

Hence, option (b) is correct.

3. (b)

We have,

$$n_1 = 1.5;\ n_2 = 1.2$$

$$B_{T(\max)} = 0.1 \text{ Mbps}$$

$$B_{T(\max)} = \frac{0.2}{\sigma_s}$$

where, σ_s = RMS pulse broadening due to intermodal dispersion on the link.

$$0.1 \times 10^6 = \frac{0.2}{\sigma_s}$$

$$\sigma_s = \frac{0.2}{0.1\times10^6} = 2\times10^{-6} \text{ sec}$$

$$\sigma_s = \frac{Ln_1\Delta}{2\sqrt{3}\,c}$$

$$2 \times 10^{-6} = \frac{L\times1.5\Delta}{2\sqrt{3}\times3\times10^8} \qquad \because\ \Delta = \frac{n_1-n_2}{n_1} = \frac{1.5-1.2}{1.5}$$

$$L = \frac{2\times10^{-6}\times2\sqrt{3}\times3\times10^8}{1.5\times\frac{(1.5-1.2)}{1.5}}$$

$$L = \frac{2\times10^{-6}\times2\sqrt{3}\times3\times10^8}{0.3} = 40\sqrt{3}\times100$$

$$L \approx 7000 \text{ m} = 7 \text{ km}$$

4. (c)

- For multimode fiber, critical radius of curvature is given by $R_c = \frac{3n_1^2\lambda}{4\pi\left(n_1^2-n_2^2\right)^{3/2}}$ while for single mode fiber, critical radius of curvature is given by

$$R_c = \frac{20\lambda}{(n_1-n_2)^{3/2}}\left[\frac{2.748\lambda_c-0.996\lambda}{\lambda_c}\right]^{-3}$$

- In graded-index multimode fibers, the effect of modal dispersion is significantly reduced because the speed of light inside the core varies with the refractive index. Therefore, dispersion in multimode graded index fiber is less than that of multimode step index fiber.

Hence, statement 1 and 2 are wrong.

5. (a)

We have,

$$\text{Path difference} = 0.1 \text{ inch}$$

$$= 0.254 \text{ cm} \qquad \because 1 \text{ inch} = 2.54 \text{ cm}$$

$$= \frac{0.254}{100}\text{m}$$

$$\text{Phase difference} = 1.06 \text{ radian}$$

$$\text{Phase difference} = \frac{2\pi}{\lambda}(\text{Path difference})$$

$$1.06 = \frac{2\pi}{\lambda} \times \frac{0.254}{100}$$

$$\lambda = \frac{2\pi \times 0.254}{1.06 \times 100} = 0.015 \text{ m}$$

$$f = \frac{3 \times 10^8}{1.5 \times 10^{-2}} = 20 \text{ GHz}$$

K band is ranging from 18-27 GHz.

Hence, option (a) is correct.

Note:

- To avoid complex calculation, we can proceed with approximation, answer will not be changed.
-

Band	**Frequency range**
L	1-2 GHz
S	2-4 GHz
C	4-8 GHz
X	8-12 GHz
Ku	12-18 GHz
K	18-27 GHz
Ka	27-40 GHz

6. (a)

- At high frequency, skip distance is high and for the frequency less than critical frequency, skip distance is zero.
- Microwave bending correction factor $K = \dfrac{\text{Value of parameter for the optical horizon}}{\text{Value of parameter for the radio horizon}}$

  Hence, $K > 1 \Rightarrow$ Value of the parameter for the radio horizon is smaller than optical horizon.

Hence, statement 3 is incorrect.

7. (a)

$$E = \sqrt{P_d \eta} = \frac{\sqrt{30 P_t G_t}}{d} \text{ volt/meter}$$

$$6 \times d = \sqrt{30 P_t G_t}$$

$$6 \times 10 \times 1000 = \sqrt{30 P_t G_t}$$

$$\sqrt{30 P_t G_t} = 6 \times 10^4$$

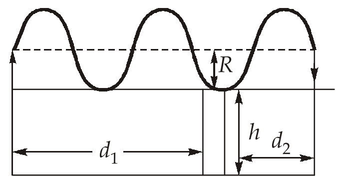
Given: $G_t = 30 \text{ dB} \Rightarrow 1000$

$$\sqrt{30 \times P_t \times 1000} = 6 \times 10^4$$

$$P_t \times 3 \times 10^4 = 36 \times 10^8$$

$$P_t = 120 \text{ kWatt}$$

8. (d)



$$\text{Height of antenna} = 36\text{ m} = h + R$$
$$R = (36 - 1.4)\text{m}$$
$$R = 34.6\text{ m}$$
$$R = \text{radius of first Fresnel's zone}$$
$$R = 17.3\left(\frac{d_1 d_2}{(d_1+d_2)f}\right)^{1/2} \quad \ldots f \text{ in GHz}$$
$$\lambda = 30\text{ cm} = 0.3\text{ m}$$
$$f = \frac{3\times10^8}{0.3} = 1\text{ GHz}$$
$$34.6 = 17.3\left(\frac{d_1 d_2}{(d_1+d_2)1}\right)^{1/2}$$
$$4 = \frac{d_1 d_2}{d_1 + d_2} \quad \ldots\text{(i)}$$

Distance between the antenna is $D = d_1 + d_2$
Accroding to given question we have,

$$d_1 = \frac{2}{3}(d_1 + d_2) \quad \ldots\text{(ii)}$$

from equation (i) and (ii)

$$d_1 = 12\text{ m and } d_2 = 6\text{ m}$$
$$D = d_1 + d_2 = 18\text{ m}$$

Hence, option (d) is correct.

9. (b)

We know that,

$$\text{Time period of satellite } T = \frac{2\pi r}{V} = \frac{2\pi}{\sqrt{GM}} r^{3/2} \text{ seconds}$$

Substituting value of G, M

$$T = 3.14 \times 10^{-7}\, r^{3/2} \text{ seconds}$$

Here, we have $T = 3.14 \times 10^4$ sec

$$3.14 \times 10^4 = 3.14 \times 10^{-7}\, r^{3/2}$$
$$r^{3/2} = 10^{11}\text{ m}$$
$$\text{r} = (10^{11})^{2/3}\text{ m}$$
$$r = 10^6 \times (10)^{4/3}\text{ m}$$
$$r \cong 21544\text{ km}$$

$$r = a + h$$
$$21544 = a + 6400$$
$$a = 15144 \text{ km}$$
$$\text{Length of major axis} = 2a$$
$$= 30288 \text{ km}$$

Hence, option (b) is correct.

10. (d)

All the statements are correct.

11. (a)

We have free space path loss given by

$$P_L = \left(\frac{4\pi d}{\lambda}\right)^2$$
$$10\log_{10} P_{L_1} = 200 \text{ dB}$$
$$P_{L_1} = 10^{20} \text{ W}$$
$$10\log_{10} P_{L_2} = (200 - 60) \text{ dB}$$
$$P_{L_2} = 10^{14} \text{ W}$$
$$\frac{P_{L_1}}{P_{L_2}} = \left(\frac{\lambda_2}{\lambda_1}\right)^2$$
$$10^6 = \left(\frac{\lambda_2}{\lambda_1}\right)^2$$
$$10^3 = \frac{\lambda_2}{\lambda_1}$$
$$10^3\lambda_1 = \lambda_2 \qquad \because \lambda = \frac{c}{f}$$
$$\frac{10^3 \times c}{f_1} = \frac{1 \times c}{f_2}$$
$$10^3 f_2 = f_1$$
$$f_2 = \frac{f_1}{10^3}$$

Hence, option (a) is correct.

12. (b)

From observation, the IP address 84.42.58.11 is a class A address; therefore the address is ANDed with the class default mask to determine the network address.

IP address (decimal) 84 42 58 11

IP address (binary) : 01010100 0010 1010 0011 1010 00001011
Default mask: 11111111 00000000 00000000 00000000
Result of ANDing: 01010100 00000000 00000000 00000000
Network address: 84 . 0 . 0 . 0

13. (c)

The total header length is the sum of the IP and ICMP header:

$$\text{Total header length} = 20 + 8 = 28 \text{ bytes}$$

Thus, the length of the ICMP data field is

$$\text{ICMP data field} = \text{Ethernet frame length} - \text{IP and ICMP header length}$$
$$= 480 - 28$$
$$= 452 \text{ bytes}$$

14. (c)

The transmitter's is window size = N
The receiver's window size = M
In sliding window ARQ scheme , the sending process sends a number of frames without worrying about receiving an ACK packet upto a certain limit called the window size. As the maximum number of unacknowledged packets at sender will be M and at the receiver it will be N, therefore, for the scheme to work properly, we will need a total of $M + N$ distinct sequence numbers.

15. (c)

Dynamic Host Configuration Protocol (DHCP) is a protocol that automatically assign TCP/IP addressing information to workstations over the network. The most common options set by DHCP are the network address, subnet mask, default gateway, and DNS server address.

16. (a)

It is necessary to convert all decibel values to equivalent power ratios. Hence,

$$F_2 = 20 \text{ dB} = 100$$
$$F_1 = 10 \text{ dB} = 10$$
$$G_1 = 30 \text{ dB} = 10^3$$
$$F = F_1 + \frac{F_2 - 1}{G_1}$$
$$F = 10 + \frac{100 - 1}{10^3}$$
$$F = 10.099$$

This is the overall noise factor. The overall noise figure is

$$(F)_{dB} = 10 \log_{10} 10.099$$
$$\cong 10$$

17. (b)

Mean square shot noise current, $I_n^2 = 2I_{dc}\, qB_n$

where, I_{dc} is the direct current in amperes, q is the magnitude of electron charge and B_n is the equivalent noise bandwidth in Hz.

$$I_n^2 = 2 \times 1 \times 10^{-3} \times 1.6 \times 10^{-19} \times 10^6$$

$$I_n^2 = 3.2 \times 10^{-16}\ \text{A}^2$$

$$\therefore \quad I_n = 1.78 \times 10^{-8}$$

$$I_n = 17.8\ \text{nA}$$

18. (c)

Speed of the vehicle = 60 km/hr

Radius of cell (R) = 3 km

Diameter of cell, D = 6 km

Time period between handoff is the time taken by the vehicle to move from one cell to the other.

$$\Rightarrow \quad t = \frac{D}{V} = \frac{6}{60} = \frac{1}{10}\text{hour}$$

$$\frac{1}{10}\text{hr} = 6\ \text{min} = 360\ \text{seconds}$$

Hence, option (c) is correct.

19. (d)

Bourdon gauges are mechanical devices utilising the mechanical deformation of a flattened but bent tube that winds or unwinds depending on the pressure difference between the inside and the outside.

20. (c)

Given, Settling time of DAC,

$$t_s = 130\ \mu\text{sec}$$

We know that, $t_s = 4\tau$; for 2% tolerance

$$\tau = \frac{130 \times 10^{-6}}{4} = 32.5\ \mu\text{sec}$$

$$\therefore \quad \text{maximum frequency, } f_{max} = \frac{1}{\tau} = 30.77\ \text{kHz}$$

21. (d)

Tachometer, is a device used for indicating the angular speed of a rotating shaft. The term is usually restricted to mechanical or electrical instruments that indicate instantaneous values of speed in revolutions per minute, rather than devices that count the number of revolutions in a measured time interval and indicate only average values for the interval.

22. (d)

For a galvanometer, deflection torque,

$$T_d = NBAI \sin\theta$$

$$\text{(or)}\quad T_d = GI \sin\theta$$

where, Galvanometer constant, $G = NBA$

$$G = 100 \times 0.08 \times 30 \times 30 \times 10^{-6}$$

$$\therefore \quad G = 72 \times 10^{-4}\ \text{Wb}$$

23. (a)

To reduce the loading effect, an instrument must possess a high input impedance. This is because a high input impedance instrument draws a very little current from the source minimizing the loading effect. CRO has highest input impedance than PMMC, hot wire, and electrodynamic type instruments. Therefore, the error in the measured parameter due to the loading effect will be less in CRO than that of others.

24. (c)

$$P = I^2R$$

Taking log on both sides

$$\ln P = 2\ln I + \ln R$$

Differentiating both sides, we get

$$\frac{\partial R}{R} = \frac{\partial P}{P} - \frac{2\partial I}{I}$$

So, limitting error for resistance,

$$\frac{\partial R}{R} = \pm\left(\frac{\partial P}{P} + \frac{2\partial I}{I}\right)$$

$$= \pm 0.03 \pm 2 \times (0.02)$$

$$= \pm 0.03 \pm 0.04$$

$$= \pm 0.07 \text{ or } \pm 7\%$$

25. (b)

Rate of change of mutual inductance is

$$\frac{dM}{d\theta} = \frac{K\theta}{I^2} = \frac{0.3 \times 10^{-6} \times 120}{12 \times 12} = 0.25 \times 10^{-6}\ \text{H/rad}$$

$$= \frac{0.25\pi}{180} \times 10^{-6}\ \text{H/degree}$$

$$= \frac{0.25}{57.3} \times 10^{-6}\ \text{H/degree}$$

$$= 0.00436\ \mu\text{H/degree}$$

Final inductance = initial inductance + change in inductance

$$= (2.5 + 0.00436 \times 120) \times 10^{-6}\ \text{H}$$

$$= (2.5 + 0.5232)\ \mu\text{H}$$

$$= 3.0232\ \mu\text{H}$$

$$\cong 3\ \mu\text{H}$$

26. (d)

- Wheatstone Bridge: Used for medium resistance measurement.
- Schering bridge: Used for capacitance measurement.
- Hay's bridge: Used for measuring inductance of high Q-coils
- Wien's bridge: Used for frequency measurement.

27. (b)

Let C_s be the self capacitance and C_d be the distributed capacitance of the coil

Given: $$Q_1 = \frac{1}{wRC_s} = 360 \text{ (True value)}$$

and $$Q_2 = \frac{1}{wR(C_s + C_d)} = 359.8 \text{ (measured value)}$$

$\therefore$ $$\frac{Q_1}{Q_2} = \frac{360}{359.8} = \left(\frac{C_s + C_d}{C_s}\right) \quad \text{or,}$$

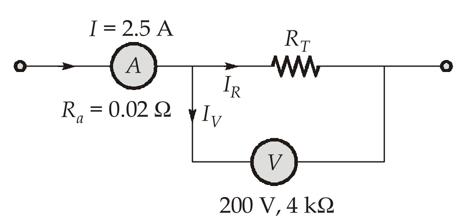
$$\frac{C_d}{C_s} + 1 = 1.00055$$

$$\frac{C_d}{C_s} = 0.000555$$

$$\frac{C_d}{C_s} = 5.55 \times 10^{-4}$$

28. (c)

Given:



$$I_V = \frac{200}{4 \times 10^3} = 5 \times 10^{-2} = 0.05\text{A}$$

$$I_R = 2.5 - 0.05 = 2.45 \text{ A}$$

$$R_T = \frac{V}{I_R} = \frac{200}{2.45} = \frac{20000}{245} = 81.632\ \Omega \text{ = true value of resistance}$$

$$R_m = \frac{V}{I} = \frac{200}{2.5} = 80\ \Omega \text{ = measured value of resistance}$$

$\therefore$ $$\text{Error, } \in_r = \frac{R_m - R_T}{R_T} = \frac{80 - 81.632}{81.632} = \frac{-1.632}{81.632}$$

$$\% \in_r = \frac{-1.632 \times 100}{81.632} = \frac{-163.2}{81.632} \cong -2\%$$

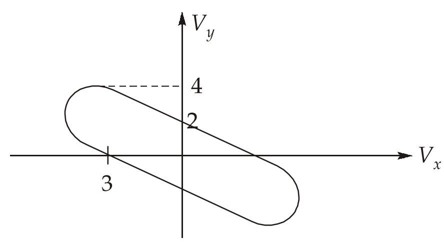
29. (c)

In the null detector, the measured quantity is balanced out. This means the detector has to cover a small range around the balance (null) point and therefore, must highly sensitive to detect small changes.

30. (b)

- PCM modulation techniques is the most efficient for pulse telemetry.
- The digital data acquisition systems are used when the physical quantity being monitored has a narrow bandwidth (i.e., when the quantity varies slowly) and a high accuracy and low per channel cost is required.
- The digital data acquisition systems are in general, more complex than analog systems both in terms of instrumentation involved and the volume and complexity of input data they can handle.

31. (c)



$$\phi = 180° - \sin^{-1}\left(\frac{2}{4}\right)$$

$$\phi = 180° - \sin^{-1}\left(\frac{2}{4}\right)$$

$$\phi = 150°$$

32. (c)

$$V(t) = 5\sin(2\pi \times 100t)$$

∴ $$T = \frac{2\pi}{\omega} = \frac{2\pi}{2\pi \times 100} = \frac{1}{100} = 10\,m\text{sec}$$

Now, each division in x-scale = 5 ms and number of divisions = 12

∴ Total x-scale length = 12 × 5 = 60 msec

∴ No. of cycles of the waveform on the screen

$$= \frac{60}{10} = 6 \text{ cycles}$$

33. (c)

50 Ω will be displayed as: 0 5 0 . 0 Ω. The error = ±(0.5% of reading + 5 counts)

The number of counts from 0 to 1999 are 2000.

∴ $$\text{error} = \pm\left[\left(50 \times \frac{0.5}{100}\right) + 5 \times \frac{200}{2000}\right]\Omega$$

$$= \pm 0.75\ \Omega$$

34. (c)

Sensitivity of the LVDT,

$$S = \frac{E_0}{l} = \frac{5}{25} = \frac{1}{5}\frac{\text{V}}{\text{mm}}$$

For the core at –18.75 mm away from the centre,

$$\text{output voltage } E_{01} = \text{sensitivity} \times (-18.75)$$

$$= \frac{1}{5} \times (-18.75) = -3.75 \text{ volt}$$

35. (c)

We have,

$$\text{Gauge factor, } G_f = \frac{\Delta R / R}{\Delta L / L}$$

$$\frac{\Delta L}{L} = \frac{\Delta R / R}{G_f} = \frac{\frac{0.013}{240}}{2.2} = \frac{0.013}{240 \times 2.2}$$

$$\frac{\Delta L}{L} = 2.46 \times 10^{-5}$$

$$\text{stress} = \text{strain} \times Y$$

$$\text{stress} = 2.46 \times 10^{-5} \times 207 \times 10^9$$

$$= 509.22 \times 10^4$$

$$= 5.092 \times 10^6 \text{ N/m}^2$$

36. (b)

In permanent cell splitting technique, the channel allocation, transmitting power, traffic load considerations have to be done at the first step itself. Hence, there is a chance of unused channel in the cell site during low traffic hour, whereas in dynamic cell splitting technique, the allocation of channel are done in practical field increasing the allocated spectrum efficiency.

37. (b)

The slow but continuous rotation of the energy meter when only pressure coil is excited and no current is flowing through the current coil is called creeping. It is due to the additional torque provided by the friction compensating vane which makes the disc continue to rotate. To prevent creeping, two diametrically opposite holes are drilled on the disc. Due to this hole, the disc will come to rest when the hole comes under the edge of pole shunt magnet.

38. (b)

Flash type ADC is the fastest because the conversion is performed simultaneously through a set of comparators. However, an n-bit flash ADC requires $2^n - 1$ comparators and 2^n resistors, making it very expensive. Because of fast conversion rate, flash type ADCs are employed on very high speed digital acquisition system. Thus, Statement (II) is not the correct explanation of Statement (I).

Section B : Signals and Systems-1 + Basic Electrical Engineering-1

39. (c)

For a continuous time signal, if the signal $f_1(t)$ is periodic with time period T_1 and $f_2(t)$ is periodic with time period T_2, then $f(t) = f_1(t) + f_2(t)$ will be periodic if and only if $\frac{T_1}{T_2}$ is a rational number.

$$x_1(t) = 3\cos\pi t + \sin 6\pi t$$

$$T_1 = \frac{\pi}{2\pi} = \frac{1}{2}$$

$$T_2 = \frac{6\pi}{2\pi} = 3$$

$$\frac{T_1}{T_2} = \frac{1/2}{3} = \frac{1}{6} = \text{rational number}$$

$x_1(t)$ is periodic

$$x_2(t) = \cos 5\pi t + 6\cos(12\pi t)$$

$$T_1 = \frac{5\pi}{2\pi} = \frac{5}{2}$$

$$T_2 = \frac{12\pi}{2\pi} = 6$$

$$\frac{T_1}{T_2} = \frac{5}{2\times 6} = \frac{5}{12} = \text{rational number}$$

$\therefore$ $x_2(t)$ is periodic.

40. (d)

$$y(t) = \frac{d}{dt}\left\{e^{-t}x(t)\right\} = e^{-t}\frac{dx(t)}{dt} - e^{-t}x(t)$$

This is a linear differential equation with variable coefficient, so system is linear but time variant.

We have, $\frac{dx(t)}{dt} = \lim\limits_{\Delta t\to 0}\frac{x(t)-x(t-\Delta t)}{\Delta t}$, hence the system has memory as $y(t)$ depends on $x(t - \Delta t)$.

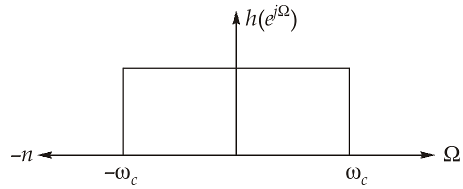
For $0 \le t < \infty$, a bounded input $x(t)$ gives bounded output $y(t)$. However, for $t = -\infty$, the bounded input $x(t)$ gives unbounded output $y(t)$. Hence, the system is unstable.

41. (b)

$$h[n] = \begin{cases} \frac{\omega_c}{\pi} & ;\ n = 0 \\ \frac{\sin\omega_c n}{\pi n} & ;\ n \neq 0 \end{cases}$$

Since $h(n) \neq 0$ for $n < 0$ or negative values of n. So, the system is non causal.

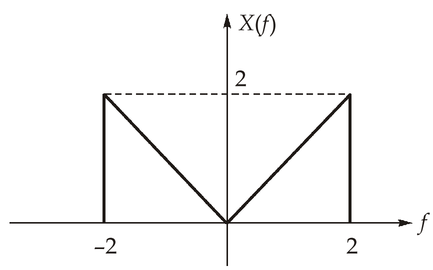
The DTFT of $\frac{\sin\omega_c n}{\pi n}$ represents a rectangular function represented as below:



Hence, it represents the characteristics of ideal low pass filter.

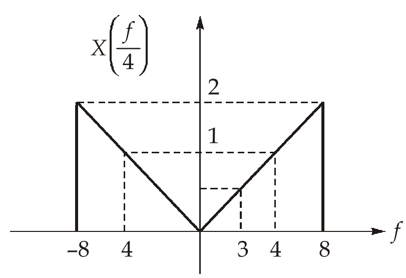
42. (d)

Given signal, $$X(f) = \begin{cases} |f|, & |f| < 2 \\ 0, & |f| \geq 2 \end{cases}$$



$$x(t) \longleftrightarrow X(f)$$

$$x[4(t-2)] \longleftrightarrow \frac{1}{4} e^{-4\pi f} X\left(\frac{f}{4}\right)$$



$$Y(f) \longleftrightarrow \frac{1}{4} e^{-4\pi f} X\left(\frac{f}{4}\right)$$

$$|Y(3)| = \frac{1}{4} X\left(\frac{3}{4}\right) = \frac{1}{4} \times \frac{3}{4} = \frac{3}{16}$$

43. (a)

$$x(t) = e^{-at} u(-t)$$

$$e^{at} u(t) \longleftrightarrow \frac{1}{a - j\omega}$$

$$e^{-at} u(-t) \longleftrightarrow \frac{-1}{a + j\omega}$$

The Fourier Transform exists if the signal is absolutely integrable. Hence, the F.T of $e^{-at}\,u(-t)$ will exist

if $$-a > 0$$
$$a < 0$$

44. (a)

According to Dirichlet conditions for existence of Fourier series,

- $x(t)$ must be absolutely integrable over a period.
- $x(t)$ must have a finite number of maxima and minima in the interval
- $x(t)$ must have a finite number of discontinuities in the interval.

45. (b)

Since, Trigonometric Fourier series has no cosine terms and has only sine terms, therefore, it will be an odd signal i.e., it will satisfy.

$$x(t) = -x(-t)$$

or we can write $$x(t - T) = -x(-t + T)$$

But signal is periodic with period T.

Therefore, $$x(t - T) = x(t)$$
$$x(t) = x(T - t) \quad \text{...(i)}$$

The trigonometric fourier series contains only odd harmonics i.e., no terms of frequency,

$$\omega = \frac{2\pi\times 2K}{T},\; K = 1, 2, 3, 4, \ldots$$

i.e., no even harmonics

This means signals contains half wave symmetry which implies that

$$x(t) = -x\left(t-\frac{T}{2}\right) \quad \text{...(ii)}$$

From equation (i) and (ii), we get

$$x(t) = x(T-t) = -x\left(t-\frac{T}{2}\right)$$

46. (c)

Differentiation will destroy the DC component of the original spectrum, therefore there is no one to one relation between $x(t)$ and $\frac{dx(t)}{dt}$.

47. (c)

By modulation property,

$$f(t)\cos\omega_0 t \xleftrightarrow{FT} \frac{1}{2}\left[F(\omega-\omega_0)+F(\omega+\omega_0)\right]$$

$$\cos t\, u(t) \xleftrightarrow{FT} \frac{1}{2}\left[u(\omega-1)+u(\omega+1)\right]$$

$$2\cos t\, u(t) \xleftrightarrow{FT} \left[u(\omega-1)+u(\omega+1)\right]$$

48. (a)

The generated emf is given by

$$E_{ph} \propto N_{ph}\, LD(f_{Bm} = \text{constant})$$

We have, $N'_{ph} = \frac{1}{3} N_{ph}, L' = 3L, D' = 3D$

Hence,
$$E'_{ph} = \left(\frac{1}{3} \times 3 \times 3\right) N_{ph} LD$$
$$E'_{ph} = 3\, E_{ph}$$

49. (a)

Z = Total number of conductors per phase.

N = Total number of turns per phase

Generated voltage per phase $E_p = 4.44\, K_c K_d f \phi N$

or
$$E_p = 2.22\, K_c K_d f \phi Z$$
$$K_w = \text{Winding factor} \Rightarrow K_c K_d = 0.9$$
$$Z = \frac{\text{Conductors per slot} \times \text{number of slots}}{\text{Number of phase}}$$
$$Z = \frac{120 \times 8}{3}$$
$$Z = 320 \text{ conductors per phase}$$
$$E_p = 2.22 \times 0.9 \times 50 \times 0.05 \times 320$$
$$E_p \cong 1598 \text{ Volt}$$

50. (d)

Zero cracking power is used for battery ratings.

The indications of the fully charged cell are

- Voltage
- Specific gravity of the electrolyte
- Gassing
- Colour of plates

51. (a)

- Low head plants require larger volume of water than high and medium head plants to produce same amount of power. Hence, the reservoir capacity should be large.
- When sudden pressure variations occur due to rapid valve closure or opening, water hammer effects can damage pipes, valves, or even machinery. Surge tanks absorb excess pressure, allowing for a more controlled and gradual change, thereby reducing the risk of system failure.
- Water turbines converts the kinetic energy of water into mechanical energy.

Hence, statement 3 is incorrect.

52. (a)

$$\text{Pole pitch} = \text{distance between two adjacent poles}$$

$$= \frac{\text{periphery of the armature}}{\text{number of poles of the generator}} = \frac{\pi D}{P} = 0.28 \text{ m}$$

$$\text{Pole arc} = 0.7 \times \text{pole pitch} = 0.7 \times 0.28 \approx 0.196 \text{ m}$$

$$\text{Pole arc} = 0.2 \text{ m}$$

$$\text{Area of pole face} = \text{pole arc} \times \text{axial length}$$

$$= 0.2 \times 0.2$$

$$= 0.04 \text{ m}^2$$

$$E = \frac{NP\phi Z}{60A} \qquad \text{For lap-winding, } A = P = 4$$

$$E = \frac{500 \times 4 \times \phi \times 1200}{60 \times 4} \qquad \because \; E = 250 \text{ V}$$

$$\therefore \quad \frac{250 \times 60 \times 4}{500 \times 4 \times 1200} = \phi$$

$$\phi = \frac{1}{40} \text{Wb}$$

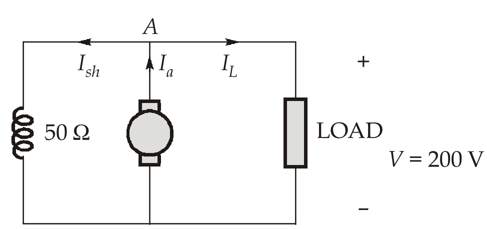
Average flux density in the air gap,

$$B = \frac{\text{flux per pole}}{\text{area of pole face}}$$

$$B = \frac{1}{40 \times 0.04}$$

$$B = 0.63T$$

53. (c)



$$I_{sh} = \frac{V}{R_{sh}} = \frac{200}{50} = 4\text{A}$$

$$I_L = \frac{30 \times 10^3}{200} = 150 \text{ A}$$

KCL at node A gives $I_a = 154$ A

$$\text{Copper losses} = I_a^2 R_a + I_{sh}^2 R_{sh}$$

$$= (154)^2 \left(\frac{1}{4}\right) + (4)^2 50$$

$$= \frac{154 \times 154}{4} + 800$$

$$= 6729 \text{ Watt}$$

$$\eta = \frac{\text{Output}}{\text{Output + Copper loss + Iron loss + Friction loss}}$$

$$\eta = \frac{30 \times 10^3}{(30 \times 10^3) + 6729 + 1000}$$

$$\eta = \frac{30000}{37729} \times 100$$

$$\eta = 79.51$$

$$\eta \approx 80\%$$

54. (c)

- For a given number of poles and armature conductors, wave winding gives more emf than that of lap winding. Hence, wave winding is preferred for high voltage and low current application.
- In wave winding, number of parallel paths is 2 and it is independent of number of poles. Whereas, in a lap winding, the number of parallel paths is always equal to the number of poles.

Hence statement 2 and 3 are incorrect.

55. (b)

For a series motor, $\phi \propto I_a$

$$\tau \text{ (torque)} \propto \phi I_a$$

$$\tau \propto I_a^2$$

$$\tau = KI_a^2$$

$$\frac{\tau_2}{\tau_1} = \frac{KI_{a_2}^2}{KI_{a_1}^2}$$

$$\frac{0.5\tau_1}{\tau_1} = \frac{I_{a_2}^2}{(100)^2}$$

$$I_{a_2}^2 = 5000 \text{ A}$$

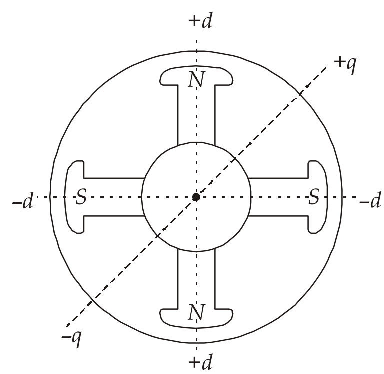
$$I_{a_2} = \sqrt{5000} = 70.71 \text{ A}$$

56. (c)

Statement (I) is correct and statement (II) is wrong.

Explanation:

- Magnetic axis of the rotor



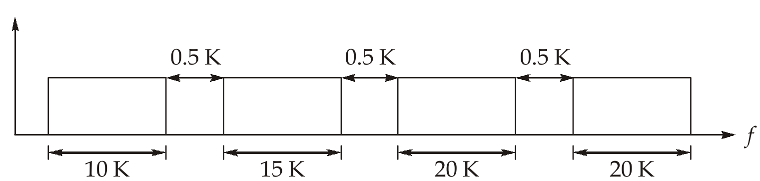
- The axis of symmetry of the north magnetic poles of the rotor is called the direct axis or d-axis.
- The axis of symmetry of the south magnetic poles is called the negative d-axis.
- The axis of symmetry half way between adjacent north and south poles is called the quadrature axis or q-axis.
- The quadrature axis is so named because it is 90° electric degree away from the direct axis.

Section C : Analog & Digital Communication Systems-2

57. (c)

In FDM, if guard band is provided, then transmission bandwidth for SSB-SC is

$$BW = f_{m1} + f_{m2} + f_{m3} + ...+ f_{mn} + (n - 1)f_g$$
$$BW = 10 + 15 + 20 + 20 + (3) \times 0.5$$
$$BW = 66.5 \text{ kHz}$$



58. (d)

Information in each element = $\log_2 10$ bits

Information in each picture is $3 \times 10^5 \log_2 10$ bits

The transmitted information rate is $30 \times 3 \times 10^5 \log_2 10$ bits/sec

From channel capacity theorem,

$$C = B \log_2(1 + \text{SNR})$$
$$90 \times 10^5 \log_2 10 = B \log_2(64)$$
$$\frac{90 \times 10^5 \log_2 10}{6} = B$$
$$B = 49.82 \times 10^5$$
$$B \cong 5 \text{ MHz}$$

59. (c)

For the given problem

$$m(t) = 2\cos(400t) + 4\sin\left(500t + \frac{\pi}{3}\right)$$

Amplitude of carrier signal, $A_c = 10$

$$\text{Power of message signal, } P_m = \frac{(2)^2}{2} + \frac{(4)^2}{2} = \frac{4}{2} + \frac{16}{2} = 10\text{ W}$$

Power in the DSB-SC modulated signal,

$$P_t = \frac{A_c^2}{2} \times P_m = \frac{100}{2} \times 10 = 500\text{ W}$$

60. (d)

- AM is more susceptible to noise because noise affects amplitude, which is where information is stored in an AM signal. FM is less susceptible to noise because information in an FM signal is transmitted through varying the frequency, and not the amplitude.
- FM requires more complex and expensive transmitters and receivers, as they need to generate and detect frequency variations accurately and precisely.

61. (b)

The FM signal can be expressed as

$$S(t) = A_c \sum_{n=-\infty}^{\infty} J_n(\beta)\cos\left[2\pi(f_c + nf_m)t\right]$$

- The FM signal consists of infinite sidebands, whose amplitude varies as $A_c J_n(\beta)$. Hence, the amplitude of any sideband depends on the modulation index, β.
- The amplitude of carrier frequency, f_c is obtained by substituting $n = 0$ as $A_c J_0(\beta)$. Hence, the carrier frequency disappear when $J_0(\beta) = 0$.

62. (b)

The rectangular pulse $c(t)$ samples the signal $x(t)$ with sampling period

$$T_s = 10^{-3}\text{ sec}$$

Hence, $$\text{sampling rate, } f_s = \frac{1}{T_s} = \frac{1}{10^{-3}} = 1000\text{ Hz}$$

As per the sampling theorem, $x(t)$ can be recovered from the sampled signal using an ideal LPF only if

$$f_s \geq 2f_m$$

where, f_m is the maximum frequency component in the signal $x(t)$.

$\Rightarrow$ $$1000 \geq 2f_m$$

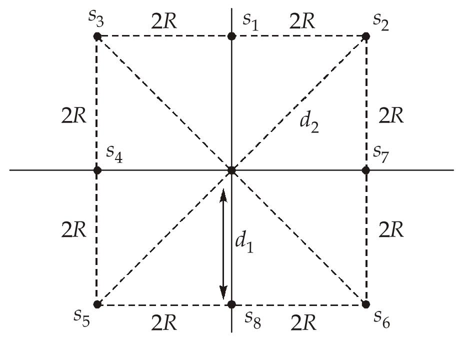
$$f_m \leq 500\text{ Hz}$$

$$\frac{\omega_m}{2\pi} \leq 500\text{ Hz}$$

$$\omega_m \leq 1000\pi\text{ rad/sec}$$

Hence, $X(j\omega) = 0$ for $\omega > 1000\pi$ rad/sec.

63. (a)



The point S_1, S_4, S_7, S_8 are equidistant from origin with d_1 = 2R.
The constellation points S_3, S_2, S_5 and S_6 are equidistant from the origin with distance

$$d_2 = \sqrt{(2R)^2 + (2R)^2} = 2\sqrt{2}R$$

Since, the square of the distance of the signalling point from origin gives the energy of the transmitted state.
For equally probable signals, the average energy transmitted for given constellation is

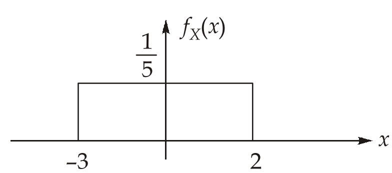
$$E_{avg} = \frac{4\times(2R)^2 + 4\times(2\sqrt{2}R)^2}{8}$$

$$E_{avg} = \frac{4\times4R^2 + 4\times8R^2}{8}$$

$$= \frac{48R^2}{8} = 6R^2$$

64. (c)

The message signal $X(t)$ is uniformly distributed in the range [–3, 2].



$$\text{Signal power, } S = \int_{-\infty}^{\infty} x^2 f_x(x)dx$$

$$S = \int_{-3}^{2} x^2 \frac{1}{5}dx = \frac{7}{3}\text{W}$$

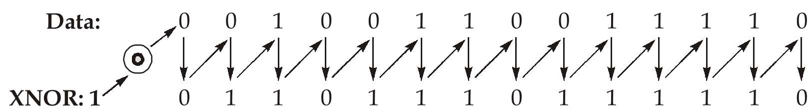
$$\text{Noise power, } N_Q = \frac{\Delta^2}{12} = \frac{1}{12}\text{W}$$

$$\because \quad \Delta = \frac{4-(-4)}{8} = 1$$

$$\text{SQNR} = \frac{\frac{7}{3}}{\frac{1}{12}} = \frac{7}{3} \times 12 = 28$$

65. (c)

DPSK bit stream is obtained by XNORing current bit to previous bit. Assume bit '1' as initial reference bit.



So, DPSK bit stream is 01101110111110.

66. (c)

BW for NRZ rectangular pulse

$$\text{BW} = R_b$$

BW for an 8-ary multi amplitude signalling is

$$\text{BW} = \frac{R_b}{\log_2 8}$$

$$\text{BW} = \frac{R_b}{3}$$

Hence, BW requirement is reduced by a factor of 3.

67. (d)

$$\text{SNR} = \frac{3}{8\pi^2} \frac{f_s^3}{f_m^2 \cdot f_c}$$

$$\text{SNR} = \frac{3}{8\pi^2} \times \frac{(40 \times 10^3)^3}{(10 \times 10^3)^2 \times (10 \times 10^3)}$$

$$\text{SNR} = \frac{3}{8\pi^2} \times \frac{(40)^3}{10^3}$$

$$\text{SNR} = 2.43$$

68. (d)

As compared to PCM system, in Delta Modulation, each sample is sent using only one bit. Hence, DM is very easy to implement and requires less bandwidth. Because of only two levels in DM, quantization noise is high compared to PCM.

69. (b)

$$x(t) = \cos(2\pi f_c t + \phi(t))$$

The pre-envelope of the signal is

$$x_+(t) = x(t) + j\hat{x}(t)$$

$$x_+(t) = \cos(2\pi f_c t + \phi(t)) + j \sin(2\pi f_c t + \phi(t))$$

$$x_+(t) = e^{j(2\pi f_c t + \phi(t))}$$

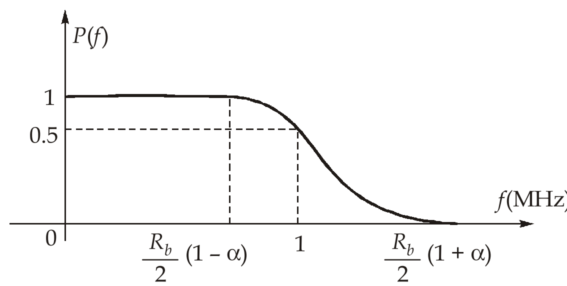
The complex envelope is given by

$$x_c(t) = x_+(t)e^{-j(2\pi f_c t)}$$

$$x_c(t) = e^{j(2\pi f_c t + \phi(t))} \cdot e^{-j2\pi f_c t}$$

$$x_c(t) = e^{j\phi(t)}$$

70. (a)



$$f_1 = \frac{R_b}{2}(1-\alpha) \quad \text{and} \quad f_2 = \frac{R_b}{2}(1+\alpha)$$

$$\frac{R_b}{2}(1-\alpha) = 0.9 \text{ MHz} \quad \text{...(1)}$$

$$\frac{R_b}{2}(1+\alpha) = 1.1 \text{ MHz} \quad \text{...(2)}$$

from (1) and (2), we get

$$\frac{1-\alpha}{1+\alpha} = \frac{0.9}{1.1}$$

$$11 - 11\alpha = 9 + 9\alpha$$

$$2 = 20\alpha$$

$$\frac{2}{20} = \alpha$$

$$\alpha = 0.1$$

71. (c)

The entropy of source is given as

$$H(s) = \sum_{i=1}^{4} P(s_i)\log_2 \frac{1}{P(s_i)}$$

$$H(s) = \frac{1}{8}\times 3 + \frac{1}{8}\times 3 + \frac{1}{4}\times 2 + \frac{1}{2}\times 1$$

$$H(s) = \frac{3}{8} + \frac{3}{8} + 1 = \frac{7}{4} \text{ bits/symbol}$$

$\therefore$ $$H(s^2) = 2H(s)$$

$$H(s^2) = 2\times\frac{7}{4} = \frac{7}{2} = 3.5 \text{ bits/symbol}$$

{In general, $H(s^n) = nH(s)$}

72. (b)

The sampling rate is equal to the Nyquist rate. Hence,

$$f_s = 2\text{ B samples/sec}$$

The samples are quantized and encoded. The average information in a sample is

$$H = \sum_{i=4}^{P} P(Q_i)\log_2 \frac{1}{P(Q_i)}$$

$$H = \frac{1}{8}\times 3+\frac{3}{8}+\frac{1}{2}+\frac{1}{2}$$

$$H = \frac{6}{8}+1=\frac{7}{4}\frac{\text{bits}}{\text{sample}}$$

Information Rate, $R = f_s \cdot H$

$$R = 2B\times\frac{7}{4}=3.5B\frac{\text{bits}}{\text{sec}}$$

73. (d)

For FDM, communication channel must have large bandwidth as it is based on sharing the available bandwidth of a communication channel among the signals.

74. (b)

Double spotting means the same stations gets picked up at two different nearby points on the receiver dial. It is due to poor front end selectivity of RF amplifier i.e., inadequate image frequency rejection.

75. (a)

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