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ESE 2023 : 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

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

1. (b)

2. (a)

$$\text{Angle of elevation of beam, } \beta = \tan^{-1}\left[\frac{2h}{D}\right] = \tan^{-1}\left[\frac{2\times 173}{200}\right]$$

$$= \tan^{-1}[1.73]$$

$$\beta = 60°$$

3. (a)

In single mode step indexed fiber, a light ray can travel on only one path so minimum refraction takes places hence, no pulse spreading permits high pulse repetition rates. Single mode fibers doesn't have modal dispersion since there is only one mode propagating in the fiber.

4. (b)

The maximum incidence angle or acceptance angle (θ_0) for a step index fiber is,

$$\theta_0 = \sin^{-1}\left[\sqrt{n_1^2 - n_2^2}\right] = \sin^{-1}\left[\sqrt{(1.52)^2 - (1.41)^2}\right]$$

$$\theta_0 = 34.6°$$

5. (d)

Compared to single-mode fibers, the multi-mode fiber bandwidth–distance product limit is lower. Because multi-mode fiber has a larger core-size and numerical aperture than single-mode fiber, it supports more than one propagation mode; hence it is limited by modal dispersion, while single mode is not.

6. (a)

Given, n_1 = 1.46, Δ = 0.25%, a = 4.5 μm

$$\lambda_c = \frac{2\pi a \cdot n_1 [2\Delta]^{1/2}}{2.405} = \frac{2\pi \times 4.5 \times 10^{-6} \times 1.46[2\times 0.0025]^{\frac{1}{2}}}{2.405}$$

$$\lambda_c = 1.214 \text{ μm}$$

7. (c)

$$\left[\frac{C}{N_0}\right] = \left[\frac{E_b}{N_0}\right] + 10\log_{10}(R_b)$$

$$= 8 + 10\log_{10}[6 \times 10^7]$$

$$= 8 + 10[\log_{10} 6 + 7]$$

$$= 8 + 10(0.77) + 70$$

$$= 85.7 \text{ dB-Hz}$$

8. (c)

For curved earth,

$$f_{\text{MUF}} = f_c\sqrt{1+\frac{(D^2/4)}{\left[h+\left(\frac{D^2}{8R}\right)\right]^2}}$$

$D \rightarrow$ Distance between transmitter and receiver
$h \rightarrow$ height of ionosphere (Virtual height)
$R \rightarrow$ Radius of Earth (6400 km)

9. (c)

Linear velocity of satellite in circular orbit is v.

$$v = \sqrt{\frac{4\times10^{11}}{r(\text{km})}}\text{ m/sec} \qquad \text{and } r = h + R$$

$$r = 29600 + 6400 = 36000 \text{ km}$$

$$v = \sqrt{\frac{4\times10^{11}}{36000}} = \frac{1}{3}\times10^4\text{ m/sec}$$

$$v = 3.33 \text{ km/sec}$$

10. (a)

$$q = \left[i_0\left(\frac{C}{I}\right)\right]^{1/n},$$

where i_0 is the number of co-channel interfering cells and n is the path loss exponent.

$$6 = \left[6\left(\frac{C}{I}\right)\right]^{1/4}$$

$$6\times6\times6\times6 = 6\left(\frac{C}{I}\right)$$

$$\frac{C}{I} = 216$$

$$\left[\frac{C}{I}\right]_{dB} = 10\log_{10}216$$

$$= 10\log_{10}6^3 = 30\log_{10}6$$

$$= 30\times0.77$$

$$\left[\frac{C}{I}\right]_{dB} = 23.1\text{ dB}$$

11. (b)

$$i = 2, j = 2$$

$$N = i^2 + ij + j^2 = 2^2 + 2\times2 + 2^2$$

$$N = 12$$

Distance between two co-channel cells

$$D = R\sqrt{3N} = 5\sqrt{3\times 12}$$
$$D = 5 \times 6 = 30 \text{ km}$$

12. (c)

Connection less packet-switching network:

- No knowledge of the connection.
- Per packet routing is done.
- Route packet based on destination address.

13. (b)

In digital signature to provide confidentiality, the message and the signature must be encrypted using either a secret-key or public-key cryptosystem.

14. (c)

Physical layer does not add header and trailer bits because it deals primarily with networking hardware and signalling.

15. (d)

Connection-oriented:

- byte oriented
- Not suitable for multicasting

Connectionless

- bit oriented
- Suitable for multicasting

16. (c)

SNMP is based on UDP protocol.

17. (c)

- UDP is an unreliable, connection-less protocol.
- It doesn't include handshaking dialogues to provide reliability, ordering or data integrity.
- In UDP, packets may arrive out of order or even lost.

18. (c)

Let C be the resonating capacitance and C_d be the distributed capacitance of the coil.

We know that,

$$Q_1 = \frac{1}{\omega RC} = 255 \text{ (True value)}$$

$$Q_2 = \frac{1}{\omega R(C_d + C)} = 254.5 \text{ (Measured value)}$$

$$\frac{Q_1}{Q_2} = \frac{255}{254.5} = \left(\frac{C + C_d}{C}\right) = 1 + \frac{C_d}{C}$$

$$1.00196 = 1 + \frac{C_d}{C} \Rightarrow \frac{C_d}{C} = 1.96 \times 10^{-3}$$

19. (a)

Bellows are not suitable for dynamic pressure measurements.

22. (b)

SYNC control locks the sweep frequency such that a locked, steady waveform is displayed on a CRO

23. (d)

Given, voltmeter range, 0 to 300 V

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

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

24. (d)

Given,

Ammeter current, $I_{MFSD} = 10$ mA

Ammeter resistance, $R_m = 100\ \Omega$

Voltage, $V_{FSD} = 10$ V

Now, $V_{MFSD} = I_{MFSD} \times R_m = 10 \times 10^{-3} \times 100 = 1$ V

The required series resistance for extension of voltmeter is,

$$R_s = R_m(m - 1)$$

where, $m = \dfrac{V_{FSD}}{V_{MFSD}} = 10$

$$\therefore \quad R_s = 100(10 - 1) = 900\ \Omega$$

25. (b)

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

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

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

$$= 0.01 \text{ mV}$$

26. (a)

Given,

Distance between centre of the screen and deflecting plates $L = 0.2$ m

Length of the deflection plates $l_d = 0.04$ m

Distance between deflecting plates $d = 5$ mm $= 5 \times 10^{-3}$ m

Anode voltage, $E_a = 1$ kV $= 1000$ V

$$\therefore \text{ Deflection factor,} \quad G = \frac{2dE_a}{Ll_d} = \frac{2 \times 5 \times 10^{-3} \times 1000}{0.2 \times 0.04} = 1250 \text{ V/m} = 1.25 \text{ V/mm}$$

28. (d)

The balance/null condition for the bridge circuit is $Z_1Z_4 = Z_2Z_3$,which is independent of source and detector.

29. (b)

The strain gauge should have low temperature coefficient of resistance so that the errors due to temperature variations can be minimized.

30. (c)

Given,

$$\text{Limiting error in current} = \pm 2\%$$
$$\text{Limiting error in power} = \pm 4\%$$
$$P = I^2R$$
$$\ln P = 2 \ln I + \ln R$$
$$\ln R = \ln P - 2 \ln I$$

Differentiating both sides, we get

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

$$\frac{\delta I}{I} = \pm 2\% = 0.02$$

$$\frac{\delta P}{P} = \pm 4\% = 0.04$$

Limiting error, $$\frac{\delta R}{R} = \frac{\delta P}{P} \pm \frac{2\delta I}{I}$$

$$= 0.04 \pm 0.04 = 0.08 = 8\%$$

31. (b)

$$T_d = BINA$$

Controlling torque, $T_c = K\theta$

At balance, $T_c = T_d$

$$K\theta = BINA$$

Deflection, $\theta \propto BI$

Given, magnetic flux density is being doubled i.e. 2 B

Current in the coil also becomes twice = $2I$

New deflecting torque, $\theta' \propto (2B)\ (2I)$

$$\theta' \propto 4\ BI$$

New deflection torque is 4 times of initial deflection torque

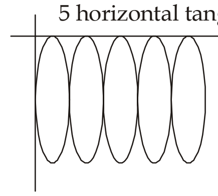
New deflection also becomes 4 times. Hence,

$$\theta' = 4 \times 15° = 60°$$

32. (b)

We know, $$\frac{f_y}{f_x} = \frac{\text{No. of horizontal tangencies}}{\text{No. of vertical tangencies}}$$

$$\frac{3500}{700} = \frac{5}{1}$$



34. (c)

At balance,

$$\left(R_1 + \frac{1}{j\omega C_1}\right)R_2 = (R + j\omega L)\frac{1}{j\omega C_3}$$

By equating real and imaginary parts, we get,

$$R = \frac{R_2 C_3}{C_1} = \frac{10^4 \times 2 \times 10^{-6}}{1 \times 10^{-6}} = 20\ \text{k}\Omega$$

$$L = R_1 R_2 C_3 = 10^4 \times 10^4 \times 2 \times 10^{-6} = 200\ \text{H}$$

35. (c)

In the graded index fiber, the profile of the refractive index is parabolic and due to this refocusing of the signal within the core is increased which eventually increases data rate.

38. (c)

Transducers which require an external power source for their operation is called a passive transducer.

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

39. (b)

We have $y(t) = \sqrt[3]{x^2(-t)} = x^{2/3}(-t)$. The above relation do NOT follow superposition principle and hence, it is Non-linear system.

At, $$t = -1$$

$$y(-1) = x^{2/3}(1)$$

Since, present output depends on future value of input, hence it is Non-causal.

40. (c)

Energy of signal is not affected with time shifting and reversing of signal.

Hence, energy of $x(t)$ = Energy of $x(1 - t)$

Now,

$$\text{Energy of } x(t) = \int_{-\infty}^{\infty} |x(t)|^2 \cdot dt = \int_{-1}^{3} |x(t)|^2 \cdot dt$$

$$= \int_{-1}^{0} (t+1)^2 \cdot dt + \int_{0}^{1} 1 \cdot dt + \int_{1}^{2} 4 \cdot dt + \int_{2}^{3} (-3+t)^2 \cdot dt$$

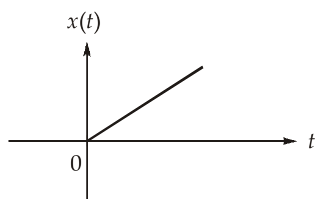
$$= \left[\frac{(t+1)^3}{3}\right]_{-1}^{0} + 1 + 4 + \left[\frac{(t-3)^3}{3}\right]_{2}^{3}$$

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

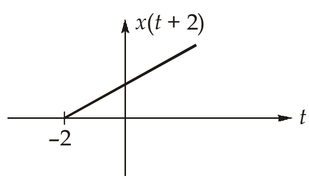
$$= \frac{17}{3} = 5.67 \text{ J}$$

41. (d)

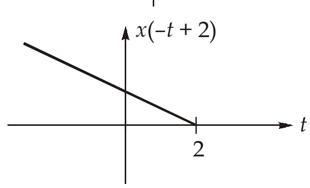
We know



$x(t) = r(t) = t.\, u(t)$



$x(t+2) = r(t+2) = (t+2)u(t+2)$



$x(-t+2) = r(-t+2) = (-t+2)u(-t+2)$

Here, $u(t)$ is unit step signal.
$r(t)$ is unit ramp signal.

42. (c)

We have,

$$I = 2\int_{-4}^{2} (9t+7)\delta(-t-3) \cdot dt$$

We know,

$$\delta(at - b) = \frac{1}{|a|}\delta\left(t - \frac{b}{a}\right)$$

$\therefore$

$$\delta(-t-3) = \delta(-(t+3)) = \delta(t+3)$$

Now,

$$I = 2\int_{-4}^{2} (9t+7)\delta(t+3) \cdot dt$$

$\because \qquad \int_{-\infty}^{\infty} f(t)\cdot\delta(t-t_0)\cdot dt = f(t - t_0)$

$\therefore \qquad I = 2 \times [9(-3) + 7]$

$= -40$

43. (c)

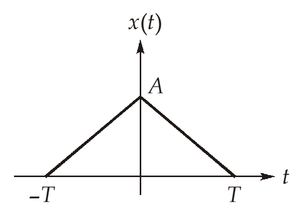
System is Non-invertible:

- If more than 1 inputs generates the same response.
- If a non-zero input generates a zero response.
- If multiple non-zero inputs produces same response.

44. (b)

Signal should have finite number of maxima and minima within any finite interval of T.
Signal should have finite length of discontinuities in any finite interval 'T'.

45. (c)



$\xleftrightarrow{FT} AT\,\text{sinc}^2(fT)$

When; $\quad x(t) = A\,\text{tri}\left(\dfrac{t}{T}\right)$

$X(f) = AT\,\text{sinc}^2(fT)$

$\because \quad X(f) = 2\,\text{sinc}^2(f)$

$\therefore \quad A = 2,\ T = 1$

hence, $\quad x(t) = 2\,\text{tri}(t)$

46. (b)

Signal	Range
$x(t)$	t_1 to t_2
$h(t)$	t_3 to t_4
$y(t)$	(t_1+t_3) to (t_2+t_4)
$x(2t-3)$	$\left(\dfrac{t_1+3}{2}\right)$ to $\left(\dfrac{t_2+3}{2}\right)$
$h(2t+4)$	$\left(\dfrac{t_3-4}{2}\right)$ to $\left(\dfrac{t_4-4}{2}\right)$
$x(2t-3)*h(2t+4)$	$\left(\dfrac{t_1+t_3}{2}\right)-\dfrac{1}{2}$ to $\left(\dfrac{t_2+t_4}{2}\right)-\dfrac{1}{2}$

} assume ($x(t)$, $h(t)$)

$\Rightarrow$ 3 to 7 ($y(t)$)

$$t_1 + t_3 = 3 \quad \Rightarrow \frac{t_1 + t_3}{2} - \frac{1}{2} = 1$$

$$t_2 + t_4 = 7 \quad \Rightarrow \frac{t_2 + t_4}{2} - \frac{1}{2} = 3$$

47. (b)

$$\text{Torque developed, } T = \frac{9.55 E_b I_a}{N} \qquad \ldots(1)$$

$$E_b = \frac{\phi ZNP}{60A}$$

Given wave winding,

$\therefore$ $A = 2$

$\therefore$ $$E_b = \frac{10 \times 10^{-3} \times 600 \times N \times 4}{60 \times 2} = 0.2\text{ N}$$

From equation (1) $$T = \frac{9.55 \times 0.2N \times 50}{N} = 95.50\text{ N-m}$$

48. (a)

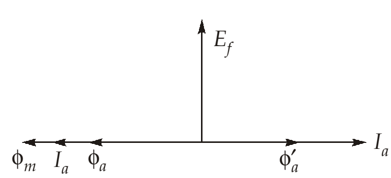
Synchronous speed of motor = synchronous speed of alternator

$$\frac{120 \times f_m}{P_m} = \frac{120 \times f_a}{P_a}$$

$$\frac{120 \times 60}{P_m} = \frac{120 \times 25}{20}$$

$$P_m = 48$$

49. (a)



ϕ_m (Main field flux) and ϕ_a (Armature flux) are in the same direction. Hence, pure magnetization effect.

50. (d)

$$P = \frac{WQH\eta}{75} \times 735.5 \text{ Watts}$$

Given, $W = 1000$ kg/m^3, $Q = 30$ m^3/sec, $\eta = 0.8$, $H = 150$ m

$$P = \frac{1000 \times 30 \times 0.8 \times 150}{75} \times 735.5$$

$$P = 35.3\text{ MW}$$

51. (a)

Commutation can be improved by increasing the brush contact resistance. This cause more voltage drop at the brush bar contacts as compared with the reactance voltage and commutation is improved.

52. (c)

- The curve obtained by plotting power factor versus field current are called as inverted V-curves.
- If the field current is made less than the normal excitation, the synchronous motor is underexcited.

53. (a)

$$\eta = 80\%$$

$$\text{Power output at full load} = 28.8 \text{ kW}$$

$$\text{input power} = \frac{28.8}{0.8} = 36 \text{ kW}$$

$$\therefore \quad \text{Input power} = \sqrt{3} V_L I_L \cos\phi = 36 \text{ kW}$$

$$\text{PF} = \cos\phi = \frac{36 \times 10^3}{\sqrt{3} \times 400 \times 50\sqrt{3}} = 0.6$$

54. (b)

Given, $N = 200$, $A = 10 \text{ cm}^2$, $l = 20$ cm, $\phi = 0.8\,\pi$ mWb, $I = 5$ A

$$H = \frac{NI}{l}$$

$$B = \mu_0 \mu_r H = \frac{\phi}{A}$$

$$\mu_r = \frac{\phi}{\mu_0 H\, A} = \frac{\phi \times l}{\mu_0 NIA}$$

$$= \frac{0.8\pi \times 10^{-3} \times 20 \times 10^{-2}}{4\pi \times 10^{-7} \times 200 \times 5 \times 10 \times 10^{-4}}$$

$$\mu_r = 400$$

55. (d)

Given wave wound, hence $A = 2$

$$\text{Induced Emf} = \frac{\phi ZNP}{60A}$$

$$357 = \frac{\phi \times 18 \times 50 \times 9000 \times 4}{60 \times 2}$$

$$\phi = 1.32 \text{ mWb}$$

56. (b)

Economizer is also known as a feedwater heater. It is a device in which the waste heat of the flue gases is utilized for heating the feed water. The functions economizer:

1. Reduce fuel consumption
2. Preheating a fluid (feed water)
3. Increase the efficiency of the power plant.

57. (d)

If a lead-acid cell is discharged below 1.8 V, then it will slowly corrode/sulfate in the discharged state and lose the ability to be recharged.

58. (c)

Fourier transform is special case of Laplace transform i.e., Laplace on imaginary axis [$s = j\omega$] is a Fourier transform of absolutely integrable signal.

59. (a)

On sudden change in a load, the rotor searches for its new position and starts oscillating. This phenomenon of oscillation of the rotor about its final equilibrium position is called Hunting. Due to shunting, large mechanical stresses and fatigue may develop in the rotor shaft.

Section C : Analog & Digital Communication Systems-2

60. (c)

In QAM, digital information is contained in both amplitude and phase of the signal.

61. (b)

We know, for PCM:

$$\text{SNR} \cong 6n$$

If the number of bits is decreased by 2, then signal to quantization noise ratio decreases by 6 × 2 = 12 dB

$$\therefore \quad (\text{SNR})_{\text{New}} = (\text{SNR})_{\text{Old}} - 12 = 50 - 12 = 38 \text{ dB}$$

62. (d)

We have,

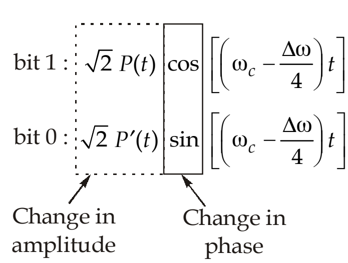
$$N = 10$$
$$f_s = 5 \text{ kHz}$$
$$\text{bit rate: } R_b = (n \times f_s) \times N, \quad \text{where, } n = \log_2 L = \log_2 128 = 7$$
$$= 7 \times 5 \times 10$$
$$= 350 \text{ kbps}$$

$$\therefore \quad \text{Minimum bandwidth} = (\text{B.W})_{\min} = \frac{R_b}{2} = 175 \text{ kHz}$$

63. (c)

If information is contained in Amplitude and phase, then it is QAM.

We have;



64. (b)

Sampling rate for bandpass sampling is given as:

$$f_s \geq \frac{2f_H}{K}; \text{ when } K = \left\lfloor \frac{f_H}{f_H - f_L} \right\rfloor$$

Here, $f_H = 40$ kHz, $f_L = 30$ kHz

∴ $$K = \left\lfloor \frac{40}{40-30} \right\rfloor = 4$$

Now; $$f_s \geq \frac{2 \times 40}{4}$$

$$f_s \geq 20 \text{ kHz}$$

65. (c)

We have, $f_m = 4$ kHz

The sampling frequency $(f_s) = 2f_m$ + Guard band

$= 2 \times 4 + 1$

$= 9$ kHz

Now, bit rate $(R_b) = n.f_s$ $\quad [\, n = \log_2 8 = 3\,]$

$= 3 \times 9$

$= 27$ kbps

66. (a)

We have, $$P(X_1) = \frac{1}{2}$$

$$P(X_2) = \frac{1}{4}$$

$$P(X_3) = \frac{1}{8}$$

$$P(X_4) = \frac{1}{2\alpha} = \frac{1}{8} \quad \because \sum_{i=1}^{N} P(X_i) = 1$$

Now, $$\text{Entropy } H(X) = \sum_{i=1}^{4} P(X_i) \cdot \log_2 \cdot \frac{1}{P(X_i)}$$

$$= \frac{1}{2}\log_2 2 + \frac{1}{4}\log_2 4 + 2 \times \frac{1}{8}\log_2 8$$

$$= \frac{7}{4} \text{bits/symbol}$$

Now, $$\text{code efficiency } (\eta) = \frac{H}{L} \times 100 = \frac{7/4}{2} \times 100$$

$$\%\eta = 87.5\%$$

67. (b)

In BFSK:

$$\text{Bandwidth} = R_b + (f_H - f_L)$$

$\because$ $$\text{Full duplex B.W} = 20 \text{ kHz}$$

$$f_H - f_L = 2 \text{ kHz}$$

$$R_b = (\text{Bandwidth}) - (f_H - f_L)$$

$$= 10 - 2 = 8 \text{ kHz}$$

$$\text{Baud rate} = \frac{R_b}{\log_2 M}$$

$\because$ $M = 2$, $$\text{Baud rate} = \frac{R_b}{\log_2 2} = R_b = 8 \text{ kHz}$$

Note: Since the transmission is full dulpex, hence only 10 kHz will be allocated for each direction.

68. (b)

Pulse Position Modulation (PPM) is an analog modulating scheme in which the amplitude and width of the pulses are kept constant, while the position of each pulse, with reference to the position of a reference pulse varies according to the instantaneous sampled value of the message signal.

Digital modulation scheme:

Pulse code modulation

Delta modulation

Adaptive Delta modulation

69. (b)

For DM: $$\left(\frac{S}{N}\right)_0 = \frac{3 f_s^3}{8\pi^2 f_m^2 \cdot f_x}$$

70. (c)

For BPSK:

$$d_{\min} = 2\sqrt{E_b}$$

Probability of error in coherent BPSK with phase error of 'θ' is

$$P_e = Q\left[\sqrt{\frac{d_{\min}^2 \cos^2\theta}{2N_0}}\right] = Q\left[\sqrt{\frac{2E_b \cos^2\theta}{N_0}}\right]$$

but, $$Q(x) = \frac{1}{2} erfc\left[\frac{x}{\sqrt{2}}\right]$$

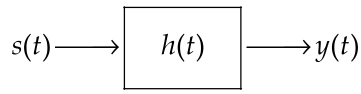
$\therefore$ $$P_e = \frac{1}{2} erfc\left[\sqrt{\frac{E_b \cos^2\theta}{N_0}}\right]$$

71. (c)

In QAM, information is coded in amplitude as well as in phase.

72. (b)

Matched filter:



$$h(t) = s(T - t)$$

73. (c)

We know,

$$\text{channel capacity 'C'} = B\log_2\left(1+\frac{S}{N}\right)$$

$\because$ $C \geq R_b$ where, $R_b \rightarrow$ bit rate

$\therefore$ $R_b \leq B\log_2\left(1+\frac{S}{N}\right)$

$$\frac{S}{N} \geq 2^{\frac{R_b}{B}} - 1$$

$$\geq 2^5 - 1 \qquad \ldots\left[\because \frac{B}{R_b} = 0.2\right]$$

$$\frac{S}{N} \geq 31$$

$$\left(\frac{S}{N}\right)_{dB} \geq 10\log_{10}31 \cong 15 \text{ dB}$$

Remember: $\log_{10}2 = 0.3$
$\log_{10}3 = 0.5$
$\log_{10}5 = 0.7$
$\log_{10}7 = 0.9$

74. (d)

Capacity in CDMA is soft, CDMA has all users on each frequency and users are separated by code.

75. (d)

With Nyquist pulse shaping of baseband binary data,
Minimum channel BW required for baseband transmission is,

$$(\text{BW})_{\text{baseband}} = \frac{R_b}{2}$$

Minimum channel BW required for BPSK modulated signal is,

$$(\text{BW})_{\text{BPSK}} = 2(\text{BW})_{\text{baseband}} = R_b$$