OFFLINE TEST SERIES

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ESE-2017 : Prelims Exam

UPSC Engineering Services Examination

E & T ENGINEERING

Answer Key & Solutions

Test 9: Part Syllabus Technical

Communication Systems + EMT

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

DETAILED EXPLANATIONS

1. (d)

$$d_{min} = \frac{2D^2}{\lambda}$$

$$= 2\times\frac{0.25}{3\times10^{-2}}$$

$$= \frac{0.5}{3}\times100 = \frac{50}{3}\text{ m}$$

6. (d)

The power dissipated by the FM wave is P

$$\therefore \quad P = \frac{A_c^2}{2R}\text{ W}$$

$$\because \quad A_c = 25\text{ V}$$

$$R = 100\ \Omega$$

$$\therefore \quad P = \frac{25^2}{2\times100} = 3.125\text{ W}$$

7. (b)

Given that $\quad P_t = 1.25\,P_c = P_c\left(1+\frac{\mu^2}{2}\right)$

$$\frac{P_t}{P_c} = 1.25$$

modulation index in AM system is $\quad \mu = \left[2\left(\frac{P_t}{P_c}-1\right)\right]^{1/2}$

$$\mu = \left[2(1.25-1)\right]^{1/2}$$

$$\mu = [2\times0.25]^{1/2} = \frac{1}{\sqrt{2}}$$

$$\mu \approx 0.7$$

10. (d)

Given $\quad IF = 455\text{ kHz}$

Tuned frequency $\quad f_s = 1000\text{ kHz}$

∴ Image frequency $\quad f_{si} = f_s + 2(IF)$

$$= [1000 + 2\times455]\text{ kHz}$$

$$= [1000 + 910]\text{ kHz}$$

$$\therefore \quad f_{si} = 1910\text{ kHz}$$

12. (b)

In case of $20\cos(200\pi t) + 30\,m(t)\cos(200\pi t) = 20\left[1+\frac{3}{2}m(t)\right]\cos 200\pi t$

$\because$ Modulation index $\mu = \frac{3}{2} > 1$. So phase reversal occur. So output will be distorted.

In case of $20\cos(200\pi t) + 16m(t)\cos(200\pi t)$

$\therefore$ Modulation index $\mu = \frac{4}{5} < 1$. So it can be completely obtained by envelope detector.

13. (c)

To describe a double sideband suppressed carrier (DSBSC) modulated wave as a function of time.

$$S(t) = C(t)\,m(t)$$
$$C(t) = A_c\cos(2\pi f_c t)$$

this modulated wave undergoes a phase reversal whenever the message signal $m(t)$ crosses zero.

15. (b)

Given
$$f_H = 410 \text{ kHz}; \quad f_L = 390 \text{ kHz}$$
$$k = \text{integer value of } \left[\frac{f_H}{f_H - f_L}\right]$$
$$= \text{integer value of } \left[\frac{410}{20}\right] = 20$$
$$\text{bandwidth} = \frac{2f_H}{k} = \frac{2\times 410}{20} = 41\,\text{kHz}$$

16. (a)

The channel signal to noise ratio for AM

$$(\text{SNR})_{C,\,\text{AM}} = \frac{A_c^2(1+k^2p)}{2WN_0}$$

where,
A_c = maximum carrier amplitude
k = modulation index
p = average power of the message signal
W = message bandwidth

The output signal to noise ratio of AM receiver using an envelope detector,

$$(\text{SNR})_{O,\,\text{AM}} = \frac{A_c^2k^2p}{2WN_0}$$

Figure of merit of the detector

$$= \frac{(\text{SNR})_{O,\text{AM}}}{(\text{SNR})_{C,\text{AM}}} = \frac{k^2p}{1+k^2p}$$

18. (b)

$$R(\tau) = \text{Auto correlation function}$$

$$= \underset{T\to\infty}{Lt} \frac{1}{T} \int_{-T/2}^{T/2} x(t)x(t-\tau)\,dt$$

$$= \underset{T\to\infty}{\text{Lt}} \frac{1}{T} \int_{T/2}^{T/2} A^2 \cos(\omega_0 t + \phi)\cos(\omega_0 t - \omega_0\tau + \phi)\,dt$$

$$R(\tau) = \frac{A^2}{2}\cos\omega_0\tau$$

20. (d)

The minimum value of random variable is –1 at $s = 0$ and the maximum value is 124 at $s = 5$.

21. (c)

∵ The input is a white process, mean it is uncorrected. Thus $(\text{PCM})_{\text{BW}} = (\text{DPCM})_{\text{BW}}$.

22. (b)

For a signal with uniform distribution

$$(\text{SNR})_Q = (6.02)n$$

$$= 6.02 \times 5 = 30.1 \text{ dB}$$

23. (b)

∵ The SNR at the output = $(\text{SNR}) \cdot \cos^2 \phi_e$

whose ϕ_e is the phase error

∴ $$(\text{SNR})' = (\text{SNR}) \cdot \cos^2 45° = \frac{\text{SNR}}{2}$$

24. (b)

$$\text{minimum B.W} = \frac{R_b}{\log_2 M} \quad \text{for } M\text{-PSK}$$

thus for $M = 4$, we have

$$\text{B.W} = \frac{R_b}{\log_2 4} = \frac{R_b}{2} = 20 \text{ kHz}$$

25. (c)

For an M-PSK signal, bandwidth efficiency

$$\rho = \frac{\text{Bit rate}}{\text{Bandwidth}}$$

now, $$\text{Bit rate} = R_b$$

$$\text{B.W} = \frac{2R_b}{\log_2 M}$$

∴ $$\rho = \frac{\log_2 M}{2}$$

$$= \frac{\log_2 16}{2} = \frac{4}{2} = 2$$

26. (a)

$\therefore$ Bandwidth of sinc$(100t)$ = 50 Hz

Bandwidth of sinc$^3(100t)$ = 150 Hz

thus Nyquist frequency = $2f_{max} = 2 \times 150 = 300$ Hz

28. (b)

$\because$ $(\text{SNR})_Q \propto L^2$

thus $(\text{SNR})_Q = kL^2$

if $L \to 2L$

then
$$(\text{SNR})'_Q = k(2L^2) = 4\,(kL^2) = 4\,(\text{SNR})_Q$$

30. (a)

$$H(x)\big|_{max} = \log_2 K = 3 \text{ bits/symbol.}$$

$$\therefore \quad K = 2^3 = 8 \text{ symbols.}$$

31. (d)

$$H(s) = -\sum_{i=0}^{N} p_i \log_2 p_i$$

$$= \frac{1}{16}\log_2 16 + \frac{1}{16}\log_2 16 + \frac{1}{8}\log_2 8 + \frac{1}{4}\log_2 4 + \frac{1}{2}\log_2 2$$

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

32. (a)

To prevent slope overload

$$\frac{\Delta}{f_s} > \left|\frac{d}{dt}x(t)\right|_{max}$$

$$\Delta \cdot f_s \geq 100$$

$$\Delta \geq 1 \text{ V}$$

33. (b)

$$R_b = rH(s)$$

$$r = 2 \cdot (f_B) = 20 \text{ kHz}$$

Now
$$H(s) = \frac{1}{8}\log_2 8 + \frac{1}{8}\log_2 8 + \frac{1}{4}\log_2 4 + \frac{1}{4}\log_2 2$$

$$= \frac{1}{2} + \frac{1}{2} + \frac{6}{8}$$

$$= 1.75 \text{ bits/sample}$$

$$\therefore \quad R_b = 20 \times 1.75 \text{ kbps} = 35 \text{ kbps}$$

34. (c)

$$H(x) = \log_2 M = \log_2 8 = 3 \text{ bits/symbol}$$

for 60% efficiency

$$\eta = \frac{H(\max)}{L}$$

$$0.60 = \frac{3}{L}$$

or

$$L = 5 \text{ bits/symbol}$$

35. (b)

$$\text{B.W} = nB + (n-1) \text{ Guard band}$$
$$= 5 \times (2 \times 5) + 4 \times 1$$
$$= 54 \text{ kHz}$$

36. (b)

$$E[X] = \int_{-\infty}^{\infty} x \cdot f_X(x)\, dx$$

$$= \int_{-1}^{3} \frac{1}{4} x \cdot dx = 1$$

38. (d)

$$\nabla \cdot \vec{A} = \frac{1}{r^2} \frac{\partial}{\partial r}\left(r^2 \cdot \frac{2}{r^2}\right)$$

$$= \frac{1}{r^2} \frac{\partial}{\partial r}(2) = 0$$

39. (c)

$$\oint_s \vec{E} \cdot \overrightarrow{dS} = \frac{Q}{\epsilon_0}$$

$$= \frac{8 \times 10^{-12}}{\frac{10^{-9}}{36\pi}}$$

$$= 36\pi \times 8 \times 10^{-3}$$

$$= 0.9 \text{ Vm}$$

41. (b)

$$\frac{\sigma}{\omega \epsilon} = \frac{10^6}{2\pi \times 10^9 \times 5 \times 8.854 \times 10^{-12}} >> 1$$

42. (b)

$$\frac{E}{\eta} = H$$

$$\Rightarrow \quad \mu E = \eta B$$

$$\Rightarrow \quad E = \frac{120\pi \times 1.5 \times 10^{-7}}{4\pi \times 10^{-7}} = 45 \text{ V/m}$$

44. (b)

$$v = \frac{c}{\sqrt{\epsilon_r}}$$

$$\Rightarrow \quad 0.5 \times 3 \times 10^8 = \frac{3 \times 10^8}{\sqrt{\epsilon_r}}$$

$$\Rightarrow \quad \epsilon_r = 4$$

45. (c)

$$P_{avg} = \frac{1}{2} H^2 \eta \times \text{area}$$

$$= \frac{1}{2} 20^2 \times 120\,\pi \times 2 \times 10^{-4} \times 10^{-6}$$

$$= 24000\,\pi \times 2 \times 10^{-4} \times 10^{-6} = 4.8\pi\ \mu\text{W}$$

48. (d)

$$E = -\nabla V = -2(2x\,\hat{a}_x + 2y\,\hat{a}_y + 2z\,\hat{a}_z)$$

$$\Rightarrow \quad \nabla \cdot \vec{E} = -4 - 4 - 4 = -12$$

$$\Rightarrow \quad \rho_v = \epsilon_0\,(\nabla \cdot \vec{E}) = -12\,\epsilon_0$$

49. (d)

$$v = \frac{1}{\sqrt{LC}} = \frac{3 \times 10^8}{2} = 1.5 \times 10^8 \text{ m/s}$$

$$Z_0 = \sqrt{\frac{L}{C}}$$

$$\Rightarrow \quad Z_0 \times v = \frac{1}{C}$$

$$\Rightarrow \quad C = \frac{1}{Z_0 \times v}$$

$$\Rightarrow \quad C = \frac{1}{200 \times 1.5 \times 10^8}$$

$$= \frac{10^{-10}}{3} = \frac{100}{3} \text{ pF}$$

50. (a)

$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0} = 1$$

$$\text{SWR} = \frac{1+|\Gamma|}{1-|\Gamma|} = \infty$$

54. (b)

$$s = \frac{Z_L}{Z_0} = 2$$

$$\Rightarrow \quad Z_{in(max)} = sZ_0 = 2 \times 100 = 200\ \Omega$$

55. (b)

$$\text{Loss tangent}(\tan\delta) = \frac{\sigma}{\omega \in} = 1.732$$

Also,

$$\delta = 2\theta_\eta$$

$$\therefore \quad \theta_\eta = 30°$$

58. (b)

$$f > f_c = \gamma_g = j\beta_g$$

59. (b)

$$f_c = \frac{c}{2a\sqrt{\epsilon_r}}$$

$$= \frac{3\times 10^{10}}{2\times 4\times 2} = 1.875\ \text{GHz}$$

60. (a)

$$(A_e)_{max} = \frac{\lambda^2}{4\pi}D = \left(\frac{3\times 10^8}{150\times 10^6}\right)^2 \times \frac{1}{4\pi} \times 100$$

$$= 4\times\frac{100}{4\pi} = \frac{100}{\pi} = 31.8\,\text{m}^2$$

61. (b)

Axial magnetic field $\Rightarrow$ TE mode

$$\eta_{TE} = \frac{120\pi}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}}$$

$$= \frac{120\pi}{\sqrt{1-\frac{1}{2}}} = \sqrt{2}\ 120\pi\ \Omega$$

$$= 170\pi\ \Omega$$

66. (b)

$$D = 4\pi \frac{U_{max}}{P_{rad}}, \qquad U_{max} = 1$$

$$P_{rad} = \int_{\phi=0}^{2\pi} \int_{\theta=0}^{\pi/2} \sin\theta \cdot \sin\theta \, d\theta \, d\phi$$

$$= 2\pi \int_{\theta=0}^{\pi/2} \left(\frac{1-\cos 2\theta}{2}\right) d\theta$$

$$= \frac{\pi^2}{2}$$

$$\Rightarrow \qquad D = \frac{4\pi}{\frac{\pi^2}{2}} = \frac{8}{\pi}$$

68. (d)
Both DSB modulation scheme and SSB modulation scheme has same noise performance.

69. (a)
$(SNR)_{dB} = 6n$
Thus increasing number of bits, the performance will be better.
Number of bits increases results in decrease of step size which results in quantization noise reduction.

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