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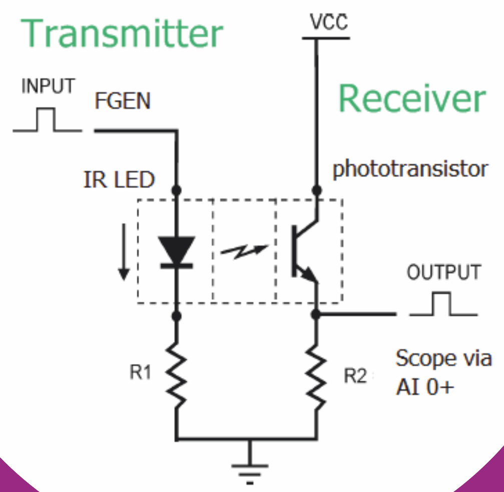
INSTRUMENTATION ENGINEERING

Communication & Optical Instrumentation

(Text Book: **Theory with worked out Examples and Practice Questions**)



Chapter 1 Introduction

(Solutions for Text Book Practice Questions)

01. Ans: (b)

Sol: We know that

$$e^{-at}u(t) \overset{F.T}{\leftrightarrow} \frac{1}{a+j\omega}$$

$$e^{at}u(-t) \overset{F.T}{\leftrightarrow} \frac{1}{a-j\omega}$$

$$e^{-at}u(t) - e^{at}u(-t) \overset{F.T}{\leftrightarrow} \frac{1}{a+j\omega} - \frac{1}{a-j\omega}$$

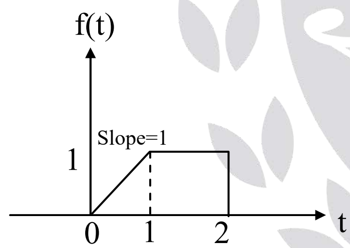
Put a = 0

$$u(t) - u(-t) \overset{F.T}{\leftrightarrow} \frac{1}{j\omega} - \frac{1}{-j\omega}$$

$$\text{sgn}(t) \overset{F.T}{\leftrightarrow} \frac{2}{j\omega}$$

02. Ans: (a)

Sol:



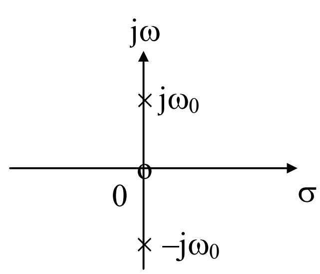
$f(t) = r(t) - r(t-1) - u(t-2)$

03. Ans: (a)

Sol: The convergence of Fourier transform is along the $j\omega$-axis in s-plane.

04. Ans: (a)

Sol:

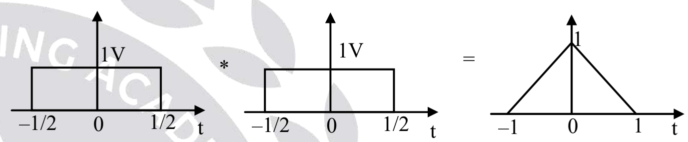


$$F(s) = \frac{s}{s^2+\omega_0^2} \overset{I.L.T}{\leftrightarrow} f(t) = \cos\omega_0 t$$

$$f(t) = \cos\omega_0 t \overset{I.L.T}{\leftrightarrow} F(\omega) = \pi[\delta(\omega-\omega_0) + \delta(\omega+\omega_0)]$$

05. Ans: (d)

Sol:



06. Ans: (c)

Sol: Given $x(t) = e^{-at^2}$

Fourier transform of x(t) is

$$X(\omega) = \int_{-\infty}^{\infty} x(t)e^{-j\omega t}dt$$

$$= \int_{-\infty}^{\infty} e^{-at^2}e^{-j\omega t}dt$$

$$= \int_{-\infty}^{\infty} e^{-\left(at^2+j\omega t\right)}dt$$

$$= e^{-\frac{\omega^2}{4a}} \int_{-\infty}^{\infty} e^{-\left[\sqrt{a}t+\frac{j\omega}{2\sqrt{a}}\right]^2} dt$$

Let $p = \sqrt{a}t + \frac{j\omega}{2\sqrt{a}}$

$dp = \sqrt{a}dt$

$$X(\omega) = \frac{e^{-\frac{\omega^2}{4a}}}{\sqrt{a}} \int_{-\infty}^{\infty} e^{-p^2}dp$$

$$\int_{-\infty}^{\infty} e^{-p^2}dp = \sqrt{\pi}$$

$$X(\omega)=\frac{e^{-\frac{\omega^2}{4a}}}{\sqrt{a}}\sqrt{\pi}$$

$$X(\omega)=\sqrt{\frac{\pi}{a}}e^{-\frac{\omega^2}{4a}}$$

07. Ans: (d)

Sol: The EFS expression of a periodic signal x(t) is $x(t) = \sum_{n=-\infty}^{\infty} c_n e^{jn\omega_0 t}$

where, 'c_n' is EFS coefficient.

Apply F.T on both sides

$$X(\omega) = \sum_{n=-\infty}^{\infty} c_n \, FT\left[e^{jn\omega_0 t}\right]$$

$$1 \leftrightarrow 2\pi\delta(\omega)$$

$$e^{jn\omega_0 t} \leftrightarrow 2\pi\delta(\omega - n\omega_0)$$

$$X(\omega) = 2\pi \sum_{n=-\infty}^{\infty} c_n \delta(\omega - n\omega_0)$$

So, it is a train of impulse.

08. Ans: (a)

Sol: $V(j\omega) = e^{-j2\omega}; \ |\omega| \le 1$

$$\text{Energy} = \frac{1}{2\pi}\int_{-\infty}^{\infty}|V(j\omega)|^2.d\omega$$

$$= \frac{1}{2\pi}\int_{-1}^{1}\left|e^{-j2\omega}\right|^2.d\omega$$

$$= \frac{1}{2\pi}\int_{-1}^{1}1d\omega$$

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

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

09. Ans: (b)

Sol: Parseval's theorem is used to find the energy of the signal in frequency domain.

$$\therefore \int_{-\infty}^{\infty}|f(t)|^2 dt = \frac{1}{2\pi}\int_{-\infty}^{\infty}|F(j\omega)|^2 d\omega$$

10. Ans: (a)

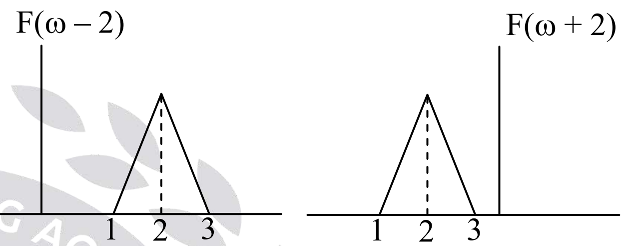
Sol: $f(t) = A.e^{-a|t|} \overset{F.T}{\leftrightarrow} F(j\omega) = \dfrac{2Aa}{a^2+\omega^2}$

11. Ans: (d)

Sol: m(t) = f(t) cos2t

Apply Fourier transform

$$M(f) = \frac{1}{2}[F(\omega-2)+F(\omega+2)]$$



12. Ans: (b)

Sol: For band limited signals,

$S(f) \neq 0; \ |f| < W$

$S(f) = 0; \ |f| > W$

13. Ans: (a)

Sol: In a communication system, antenna is used to convert voltage variations to field variation and vice-versa.

14. Ans: (d)

Sol: Hilbert transform of f(t) is

$$H.T\{f(t)\} = f(t) * \frac{1}{\pi t}$$

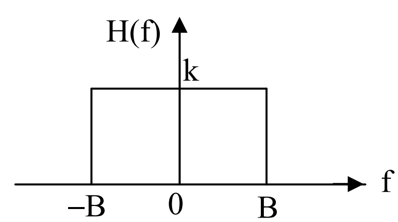
It is in the terms of 't'.

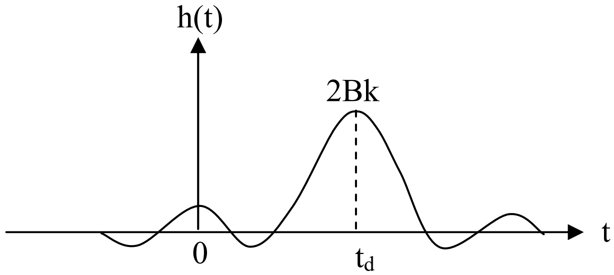
15. Ans: (a)

Sol: For an ideal LPF

$$H(f) = k\ e^{-j\omega t_0} \quad \text{for } -B < f < B$$

$$h(t) = F^{-1}[H(f)] = 2Bk \text{ sinc } 2B\,(t - t_d)$$





$h(t) \neq 0$ for $t < 0$

Output exists before input is applied i.e. non-causal, which is physically impossible.

16. Ans: (b)

Sol: $\delta(at) = \frac{1}{|a|}\delta(t)$

$\delta(2t) = \frac{1}{2}\delta(t)$

17. Ans: (a)

Sol: By modulation we are translating the low frequency spectrum into high frequency spectrum.

18. Ans: (a)

Sol: We know that

$P(dBm) = 10\log(P\times10^3)$

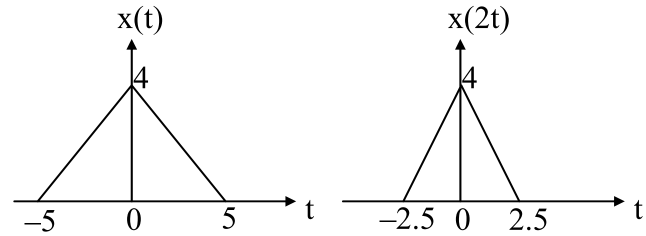
$-10 = 10\log(P\times10^3)$

$P\times10^3 = 10^{-1}$

$P = 10^{-4} = 100\ \mu W$

19. Ans: (a)

Sol: $x(2t)$ means signal time axis is compressed by 2



20. Ans: (b)

Sol: Audio frequency is between 20Hz to 20kHz

21. Ans: (d)

Sol: Telephone channel carries voice. Voice frequency is between 300 Hz to 3500 Hz. So bandwidth is 3200Hz. So we approximately consider 4kHz is the bandwidth requirement of a telephone channel.

22. Ans: (c)

Sol: From the signal spectrum f_H = 530 kHz, f_L = 50 kHz

Bandwidth = $f_H - f_L$ = 530 kHz – 50 kHz = 480 kHz

Chapter 2 Amplitude Modulation

01. Ans: (a)

Sol: $V(t) = A_c.\cos\omega_c t + 2\cos\omega_m t \,.\, \cos\omega_c t.$

Comparing this with the AM-DSB-SC signal

$A\cos\omega_c t + m(t).\cos\omega_c t$, it implies that

$m(t) = 2\cos\omega_m t \Rightarrow E_m = 2$

To implement Envelope detection,

$A_c \geq E_m$

$\therefore (A_c)_{min} = 2$

02. Ans: (d)

Sol: $m(t) = (A_c + A_m\cos\omega_m t)\cos\omega_c t.$

$$= A_c\left(1 + \frac{A_m}{A_c}\cos\omega_m t\right)\cos\omega_c t.$$

Given

$A_c = 2A_m$

$$= A_c\left(1 + \frac{1}{2}\cos\omega_m t\right)\cos\omega_c t.$$

$$P_T = \frac{A_c^2}{2}\left[1 + \frac{\mu^2}{2}\right],\; P_s = \frac{A_c^2}{2}\left[\frac{\mu^2}{4}\right]$$

$$\frac{P_T}{P_S} = \frac{1 + \frac{\mu^2}{2}}{\frac{\mu^2}{4}} = \frac{1 + \frac{1}{8}}{\frac{1}{16}} = \frac{9}{8} \times 16$$

$P_T = 18\, P_s$

03. Ans: (a)

Sol: $m(t) = 2\cos 2\pi f_1 t + \cos 2\pi f_2 t$

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

$S(t) = [A_c + m(t)]\cos 2\pi f_c t$

$$S(t) = A_c\left[1 + \frac{1}{A_C}m(t)\right]\cos 2\pi f_c t$$

$$K_a = \frac{1}{A_c}$$

$A_{m1} = 2,\; A_{m2} = 1$

$$\mu_1 = K_a A_{m1} = \frac{2}{A_C},\; \mu_2 = K_a A_{m2} = \frac{1}{A_C}$$

$$\mu = \sqrt{\mu_1^2 + \mu_2^2}$$

$$\Rightarrow 0.5 = \sqrt{\frac{4}{A_c^2} + \frac{1}{A_c^2}}$$

$$\Rightarrow A_C = \sqrt{20}$$

04. Ans: (c)

Sol: $m(t) = -0.2 + 0.6\sin\omega_1 t,\; k_a = 1,\; A_c = 100$

$S(t) = A_c[1 - 0.2 + 0.6\sin\omega_1 t]\cos\omega_c t$

$= 100[0.8 + 0.6\sin\omega_1 t]\cos\omega_c t$

$V_{max} = A_c[1 + \mu] = 100[0.8 + 0.6] = 140\text{ V}$

$V_{min} = A_c[1 - \mu] = 100[0.8 - 0.6] = 20\text{ V}$

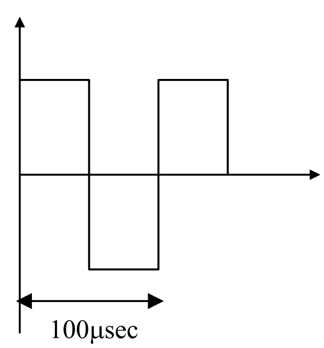
$= 20\text{V to } 140\text{ V}$

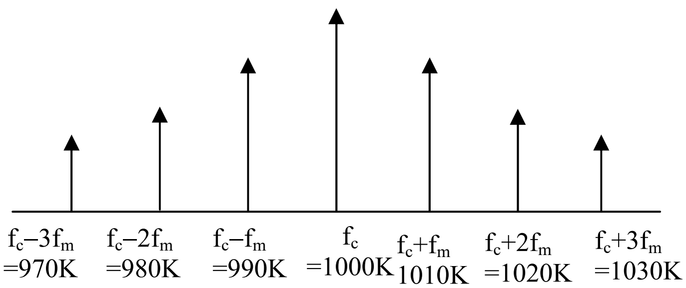
05. Ans: (c)

Sol: $f_C = 1\text{ MHz} = 1000\text{ kHz}$

The given m(t) is symmetrical square wave of period T = 100 μsec

$$f_m = \frac{1}{T_0} = 10\text{ kHz}$$



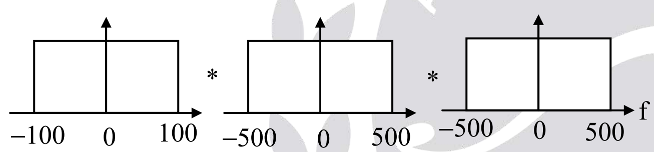


These frequencies 980k, 1020k are not present because the symmetrical square wave it consists of half wave symmetries only odd harmonics are present, even harmonics are dismissed.

06. Ans: (d)

Sol: $m(t) = \text{sinc}(200t)\text{sinc}^2(1000t)$

$= \text{sinc}(200t)\text{sinc}(1000t)\text{sinc}(1000t)$

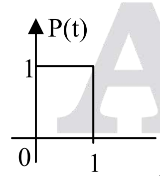


So, highest frequency component in the signal m(t) is 100 + 500 + 500 = 1100

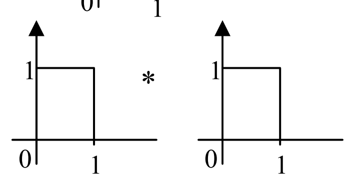
BW = 2 × 1100
BW = 2200 Hz

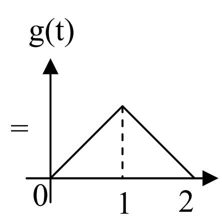
07. Ans: (a)

Sol: $P(t) = u(t) - u(t-1) \Rightarrow$



$g(t) = P(t) * P(t) =$





$x(t) = 100(P(t) + 0.5g(t))\cos\omega_c t$

$= 100(1 + 0.5t)\cos\omega_c t$

$= A_c(1 + K_a m(t))\cos\omega_c t$

$k_a = 0.5,\ m(t) = t$

$\mu = k_a[m(t)]_{max}$

$\mu = 0.5 \times 1 = 0.5$

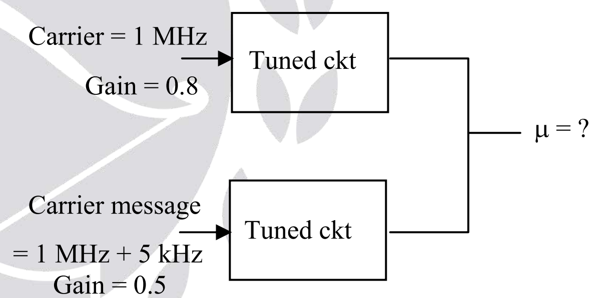
08. Ans: (d)

Sol: $R_L C \le \dfrac{\sqrt{1-\mu^2}}{2\pi f_m \mu}$

So it depends on depth of modulation and the highest modulation frequency.

09. Ans: (b)

Sol: $S(t) = 10\cos 2\pi 10^6 t + 8\cos 2\pi 5\times 10^3 t\cos 2\pi 10^6 t$

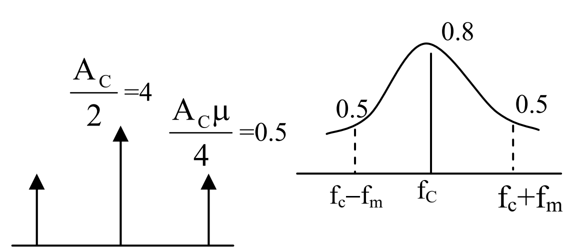


$S(t) = 0.8 \times 10\cos 2\pi 10^6 t$

$\quad + 0.5\times 8\cos 2\pi 5000t\cos 2\pi 10^6 t$

$= 8\left(1+\dfrac{4}{8}\cos 2\pi 5000t\right)\cos 2\pi 10^6 t$

$\mu = \dfrac{4}{8} = \dfrac{1}{2} = 0.5$



10. Ans: (d)

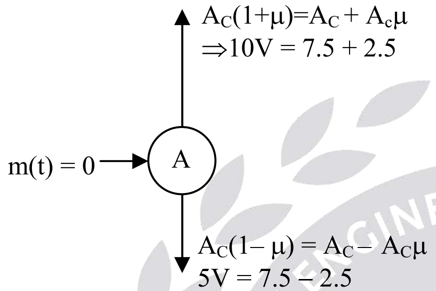
Sol: $A_{max} = 10V$

$A_{min} = 5V$

$\mu = 0.1$

$$\mu = \frac{A_{max} - A_{min}}{A_{max} + A_{min}} = \frac{1}{3} = 0.33$$

$$A_C = \frac{A_{max} + A_{min}}{2} = \frac{10+5}{2} = 7.5 \text{ V}$$



Amplitude deviation $A_C\mu = 7.5\times\frac{1}{3} = 2.5$ V

$\mu_2 = 0.1 \Rightarrow A_{c2}\mu_2 = 2.5$

$A_{c2} = 25$ V

Which must be added to attain = 17.5

11. Ans: (d)

Sol: Modulation index

$\mu = k_a\,|m(t)|_{max}$

$$k_a = \frac{2b}{a} = \frac{2(\text{square term coefficient})}{\text{linear term coefficient}}$$

$|m(t)|_{max} = 1$

$$\mu = 2\left(\frac{b}{a}\right)$$

$$P_{SB} = \frac{1}{2}P_C \Rightarrow P_C\frac{\mu^2}{2} = \frac{1}{2}P_C$$

$$\mu^2 = 1 \Rightarrow \left(2\frac{b}{a}\right)^2 = 1$$

$$\Rightarrow 2\frac{b}{a} = 1 \Rightarrow \frac{a}{b} = 2$$

12. Ans: 0.125

Sol: $s(t) = \cos(2000\pi t) + 4\cos(2400\pi t) + \cos(2000\pi t)$

Here $4\cos(2400\pi t)$ is the carrier signal.

$\cos(2000\pi t)$ and $\cos(2000\pi t)$ are the sideband message signals.

$$P_c = \frac{4^2}{2} = 8 \text{ W}$$

$$P_m = \frac{1}{2} + \frac{1}{2} = 1 \text{ W}$$

$$\frac{P_m}{P_c} = \frac{1}{8} = 0.125$$

13. Ans: (a, c & d)

Sol: $S_{AM}(t) = 10\cos(2\pi\times5000t) + 25\cos(2\pi\times5200t) + 25\cos(2\pi\times4800t)$

$\therefore$ USB Frequency = 5200 Hz

LSB Frequency = 4800 Hz

$$\frac{A_c\mu}{2} = 25$$

$$\frac{10\times\mu}{2} = 25$$

$\therefore\ \mu = 5$

a, c & d are correct.

NOTE: options are changed for

(a) $\mu = 5$ (b) $\mu = 2.5$

14. Ans: (a & c)

Sol: $S_{AM}(t) = K_1\cos(2\pi\times5000t) + K_2\cos(2\pi\times5200t) + K_3\cos(2\pi\times4800t)$

$c(t) = 10\cos(2\pi\times5000t)$

$K_1 = 10 = A_C$ $\qquad f_c + f_m = 5200$ Hz

$\mu = 0.5$ $\qquad f_c - f_m = 4800$ Hz

$\therefore\ \frac{A_c\mu}{2} = K_2 = K_3$ $\qquad \therefore\ 2f_m = 400$ Hz

$\frac{10\times0.5}{2} = K_2 = K_3$ $\qquad f_m = 200$ Hz

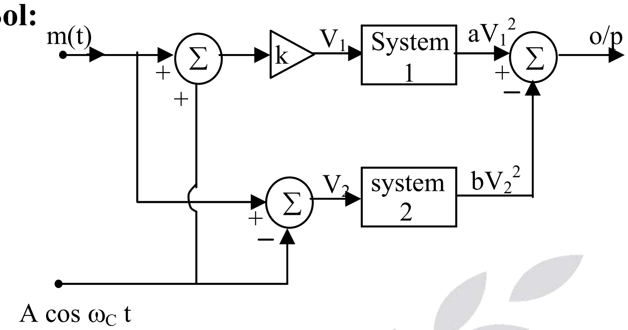
$\therefore\ K_2 = K_3 = 2.5$

a & c are correct.

Chapter 3 Sideband Modulation Techniques

01. Ans: (c)

Sol:



$V_1 = k\,[m(t) + c(t)]$

$V_2 = [m(t) - c(t)]$

$V_0 = aV_1^2 - b\,V_2^2$

$= ak^2[m(t) + c(t)]^2 - b[m(t) - c(t)]^2$

$= ak^2\,[m^2(t) + c^2(t) + 2m(t)c(t)]$

$\quad - b[m^2(t) + c^2(t) - 2m(t)c(t)]$

$= [ak^2 - b]m^2(t) + [ak^2 - b]c^2(t)$

$\quad + 2[ak^2+b][m(t)c(t)]$

on verification if $k = \sqrt{\dfrac{b}{a}}$

$S(t) = 4bm(t)c(t) \rightarrow$ DSBSC Signal

02. Ans: (d)

Sol: Given A = 10

$m(t) = \cos 1000\pi t$

$b = 1$

B.W = ? and power = ?

$s(t) = 4b.A\cos 2\pi f_c t.\cos 2\pi\,(500)t$

$= 40.\cos 2\pi f_c t.\cos 2\pi\,(500)t$

$B.W = 2\,f_m$

$= 2\,(500)$

$= 1$ kHz

$$\text{Power} = \frac{A_c^2 A_m^2}{4} = \frac{1600\times 1}{4} = 400\,\text{W}$$

03. Ans: (c)

Sol: Carrier $= \cos 2\pi\,(100 \times 10^6)t$

Modulating signal $= \cos(2\pi \times 10^6)t$

Output of Balanced modulator

$= 0.5[\cos 2\pi\,(101 \times 10^6)t + \cos 2\pi(99\times10^6)t]$

The Output of HPF is $0.5\cos 2\pi(101 \times 10^6)t$

Output of the adder is

$= 0.5\cos 2\pi\,(101\times10^6)\,t + \sin 2\pi\,(100\times10^6)t$

$= 0.5\cos 2\pi[(100+1)10^6 t] + \sin 2\pi(100\times10^6)t$

$= 0.5[\cos 2\pi\,(100 \times10^6)t.\cos 2\pi\,(10^6)t$

$\quad - \sin 2\pi(100 \times 10^6)t.\sin 2\pi\,(10^6)t]$

$\quad + \sin 2\pi(100 \times10^6)t]$

$= 0.5\cos 2\pi\,(100 \times10^6)t.\cos 2\pi\,(10^6)t$

$\quad + \sin 2\pi(100\times10^6)t\,[1-0.5\sin 2\pi\,(10^6)t]$

Let $0.5\cos 2\pi\,(10^6)t = r(t)\cos\theta(t)$

$1 - 0.5\sin 2\pi\,(10^6)t = r(t).\sin\theta(t)$

The envelope is

$r(t) = [\,0.25\cos^2 2\pi\,(10^6)t$

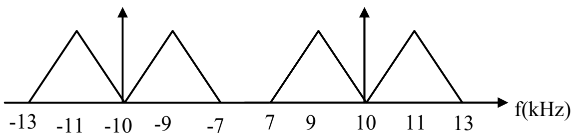
$\quad + \{1- 0.5\sin 2\pi\,(10^6)t\}^2]^{1/2}$

$= [1.25 - \sin 2\pi(10^6)t]^{1/2}$

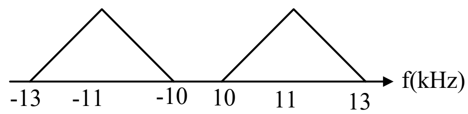
$= [\dfrac{5}{4} - \sin 2\pi\,(10^6)t]^{1/2}$

04. Ans: (b)

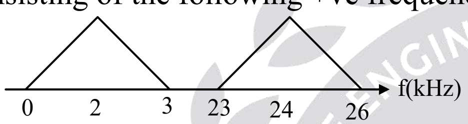
Sol: Output of 1st balanced modulator is



Output of HPF is



The Output of 2nd balanced modulator is consisting of the following +ve frequencies.



Thus, the spectral peaks occur at 2 kHz and 24 kHz.

05. Ans: (c)

Sol: Given

$$f_{m_1} = 100\text{Hz},\ f_{m_2} = 200\text{Hz},\ f_{m_3} = 400\text{Hz},$$

$$f_c = 100\text{KHz},\ f_{c_{L0}} = 100.02\text{KHz}$$

$$S(t)/_{T_X} = \frac{A_c A_m}{2}[\cos(f_c + f_{m_1})t + \cos(f_c + f_{m_2})t + \cos(f_c + f_{m_3})t]$$

$$S(t)/R_x = [S(t)/T_x]A_c \cos 2\pi f_{c_{L0}} t$$

$$\Rightarrow \frac{A_c^2 A_m}{4}[\cos(f_c + f_{c_{Lo}} + f_{m_1}) + \cos(f_{m_1} - 20) + \cos(f_c + f_{c_{Lo}} + f_{m_2}) + \cos(f_{m_2} - 20) + \cos(f_c + f_{c_{Lo}} + f_{m_3}) + \cos(f_{m_3} - 20)]$$

Detector output frequencies:

80Hz, 180Hz, 380Hz

06. Ans: (b)

Sol: Given

SSB AM is used, LSB is transmitted

$$f_{LO} = (f_c + 10)$$

$$S(t)/T_X = \frac{A_c A_m}{2}\cos 2\pi[f_c - f_m]t$$

$$S(t)/R_X = \left[\frac{A_c A_m}{2}\cos 2\pi(f_c - f_m)t\right]\cos 2\pi(f_c + 10)t$$

$$\Rightarrow \frac{A_c A_m}{4}[\cos 2\pi(2f_c + 10 - f_m)t + \cos 2\pi(10 + f_m)t]$$

i.e., from 310 Hz to 1010 Hz

07. Ans: (b)

Sol: BW of Basic group = 12×4 = 48 kHz

BW of super group = 5×48 = 240 kHz

08. Ans: (d)

Sol: Given 11 voice signals

B.W. of each signals = 3 kHz

Guard Band Width = 1 kHz

Lowest f_c = 300 kHz

Highest f_c =

$$\Rightarrow f_{c_H} + f_{m_{lost}} = 300\text{kHz} + 11(3\text{kHz}) + 10(1\text{kHz})$$

$$= 343 \text{ kHz}$$

$$f_{c_H} = 343\,\text{kHz} - 3\,\text{kHz}$$

$$= 340\,\text{kHz}$$

09. Ans: (b)

Sol: f_{m1} = 5 kHz → AM

f_{m2} = 10 kHz → DSB

f_{m3} = 10kHz → SSB

f_{m4} = 2kHz → SSB

f_{m5} = 5kHz → AM

f_g = 1kHz

$$BW = (2f_{m1} + 2f_{m2} + f_{m3} + f_{m4} + 2f_{m5} + 4f_g)$$

$$= 2\times 5 + 2\times 10 + 10 + 2 + 2\times 5 + 4\times 1$$

$$= 10 + 20 + 10 + 10 + 6$$

$$= 56 \text{ kHz}$$

$\therefore$ BW = 56 kHz

10. Ans: (b & c)

Sol: Power in AM = $P_C + P_{USB} + P_{LSB}$

Power in DSB-SC = $P_{USB} + P_{LSB}$, power in SSB-SC = P_{USB} (or) P_{LSB}

$\therefore$ Power in AM > DSB-SC > VSB = SSB

Option (b) is correct

BW in AM = $2f_{max}$

BW in DSB-SC = $2f_{max}$

BW in SSB-SC = f_{max}

BW in VSB-SC = $f_{max} + \Delta f$

$\therefore$ BW in AM = BW in DSB-SC
> BW of VSB
> BW of SSB

Option (c) is correct

11. Ans: (a, c & d)

Sol: For DSB-SC $\eta = 100\%$

BW = $2f_{max} = 2 \times 3 \times 10^4 = 60$(kHz)

$S(t) = m(t)\, c(t)$

$= 50\cos(2\pi \times 10^7 t)\cos(2\pi \times 10^4 t)$
$+ 50\cos(2\pi \times 10^7 t)\, 5\cos(5\pi \times 10^4 t)$
$+ 50\cos(2\pi \times 10^7 t)\, 4\cos(6\pi \times 10^4 t)$

$P_t = 26.25$(kW)

(a, c & d are correct)

Chapter 4 Angle Modulation

01. Ans: (a)

Sol: $s(t) = 10\cos(20\pi t + \pi t^2)$

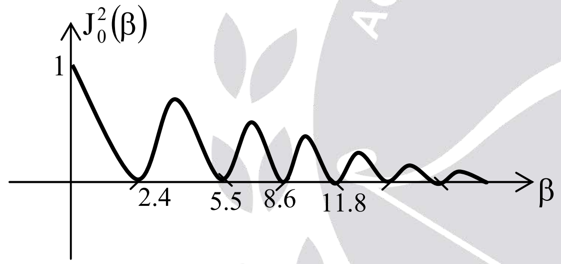
$$f_i = \frac{1}{2\pi}\frac{d\theta_i(t)}{dt}$$

$$f_i = \frac{1}{2\pi}\left[20\pi + 2\pi t\right]$$

$$\frac{df_i}{dt} = \frac{1}{2\pi}\times 2\pi \times 1 = 1\,\text{Hz/sec}$$

02. Ans: (d)

Sol: $P_{fc} = \dfrac{A_c^{\,2} J_0^{\,2}(\beta)}{2}$



So, $J_0^{\,2}(\beta)$ is decreasing first, becoming zero and then increasing so power is also behave like $J_0^{\,2}(\beta)$.

03. Ans: (a)

Sol: In an FM signal, adjacent spectral components will get separated by

$f_m = 5$ kHz

Since $BW = 2(\Delta f + f_m) = 1$MHz

$= 1000 \times 10^3$

$\Delta f + f_m = 500$ kHz

$\Delta f = 495$ kHz

The n^{th} order non-linearity makes the carrier frequency and frequency deviation increased by n-fold, with the base-band signal frequency (f_m) left unchanged since n = 3,

$\therefore (\Delta f)_{New} = 1485$ kHz &

$(f_c)_{New} = 300$ MHz

New BW $= 2(1485 + 5)\times 10^3$

$= 2.98$ MHz

$= 3$ MHz

04. Ans: (d)

Sol: $S(t) = A_c \sum_{n=-\infty}^{\infty} J_n(\beta)\cos 2\pi(f_c + nf_m)t$

$\Delta f = 3(2f_m) = 12$ kHz

$$\beta = \frac{\Delta f}{f_m} = 6$$

$$\therefore S(t) = \sum_{n=-\infty}^{\infty} 5.J_n(6)\cos 2\pi(f_c + nf_m)t$$

$f_c = 1000$kHz, $f_m = 2$ kHz

$= \cos 2\pi(1008 \times 10^3)t$

$= \cos 2\pi(1000 + 4\times 2)\times 10^3 t$

i.e., n = 4

The required coefficient is $5.J_4(6)$

05. Ans: (c)

Sol: $2\pi f_m = 4\pi\, 10^3$

$\Rightarrow f_m = 2k$

$J_0(\beta) = 0$ at $\beta = 2.4$

$$\beta = \frac{k_f\ A_m}{f_m} \Rightarrow 2.4 = \frac{k_f \times 2}{2k}$$

$k_f = 2.4$ KHz /V

at $\beta = 5.5$

$$5.5 = \frac{2.4\,k \times 2}{f_m}$$

$\Rightarrow f_m = 872.72$ Hz

06. Ans: (c)

Sol: $\beta = 6$

$J_0(6) = 0.1506$; $J_3(6) = 0.1148$

$J_1(6) = 0.2767$; $J_4(6) = 0.3576$

$J_2(6) = 0.2429$;

$$\frac{P_{f_c \pm 4f_m}}{P_T} = ? \qquad P_T = \frac{A_c^{\,2}}{2R}$$

$$P_{f_c \pm 4f_m} = \frac{A_C^2}{R}\left[\frac{J_0^2(\beta)}{2} + J_1^2(\beta) + J_2^2(\beta) + J_3^2(\beta) + J_4^2(\beta)\right]$$

$$P_{f_c \pm 4f_m} = \frac{A_C^2}{R}\left[\frac{J_0^2(\beta)}{2} + J_1^2(\beta) + J_2^2(\beta) + J_4^2(\beta)\right]$$

$$\frac{P_{f_c \pm 4f_m}}{P_T} = \frac{0.2879}{1/2} = 0.5759 = 57.6\ \%$$

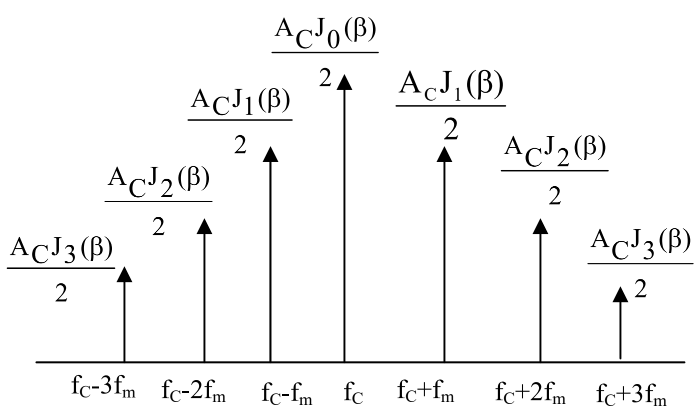
07. Ans: (c)

Sol: $m(t) = 10\cos 20\pi t$

$f_m = 10$ Hz

inserting correct signal and frequency

$$\beta = \frac{k_f\, A_m}{f_m} = \frac{5 \times 10}{10} = 5$$



From f_c to $f_c + 4f_m$ pass through ideal BPF

Powers in these frequency components

$$P = \frac{A_C^2}{2R} J_0^2(\beta) + 2\frac{A_C^2}{2R} J_1^2(\beta) + 2\frac{A_C^2}{2R} J_2^2(\beta)$$

$$+ 2\frac{A_C^2}{2R} J_3^2\beta + 2\frac{A_C^2}{1R} J_4^2(\beta)$$

$$= \frac{A_C^2}{2R}\left[\begin{matrix}(-0.178)^2 + 2(-0.328)^2 + 2(0.049)^2 \\ + 2(0.365)^2 + 2(0.391)^2\end{matrix}\right]$$

$= 41.17$ Watts

08. Ans: (d)

Sol: $P_t = \dfrac{A_C^2}{2R}$ $(R = 1\Omega)$

$$= \frac{100}{2} = 50\ \text{W}$$

$$\%\ \text{Power} = \frac{\text{Power in components}}{\text{total power}} \times 100$$

$$= \frac{41.17}{50} \times 100$$

$= 82.35\%$

09. Ans: (d)

Sol: In frequency modulation the spectrum contains $f_c \pm nf_1 \pm mf_2$, where n & m = 0, 1, 2, 3………

10. Ans: (c)

Sol: Given $f_c = 1$MHz

$f_{max} = f_c + k_f\, A_m$

$k_p = 2\pi\, k_f$

$$k_f = \frac{k_p}{2\pi} = \frac{\pi}{2\pi}$$

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

$$= \left(10^6 + \frac{1}{2}\times 10^5\right) = \left(10^6 + 0.5\times 10^5\right)$$

$$= \left(10^6 + 5\times 10^4\right)$$

$$= \left(10^3 + 50\right)10^3$$

$$= (10^3 + 50)\text{ k}$$

$$= 1050\text{ kHz.}$$

$$f_{min} = f_c - k_f A_m$$

$$= \left(10^6 - \frac{1}{2}\times 10^5\right)$$

$$= \left(10^6 - 0.5\times 10^5\right)$$

$$= \left(10^6 - 5\times 10^4\right)$$

$$= \left(10^3 - 50\right)10^3$$

$$= (10^3 - 50)\text{ k}$$

$$= 950\text{ kHz}$$

11. Ans: (d)

Sol: $\beta = \dfrac{\Delta f}{f_m}$

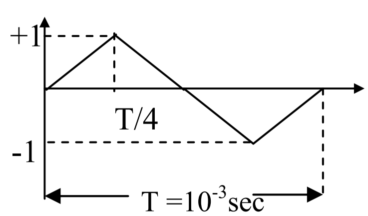
$$\Delta\phi = \frac{\Delta f}{f_m}$$

$$\Delta f = \Delta\phi\, f_m$$

$$= k_p A_m f_m$$

12. Ans: (c)

Sol: Given



$f_c = 100\times 10^3$ Hz

$k_f = 10\times 10^3$Hz

$m(t)|_{max} = +1$, $m(t)|_{min} = -1$

$$f_i = f_c \pm \Delta f$$

$$= f_c \pm k_f A_m$$

$$= 100\times 10^3 \pm 10\times 10^3\,(m(t))$$

$$= 110\text{ kHz \& } 90\text{ kHz}$$

13. Ans: (c)

Sol: $S(t) = A_c\cos\underbrace{(2\pi f_c t + k_p m(t))}_{\theta_i(t)}$

$$f_i = \frac{1}{2\pi}\frac{d}{dt}\theta_i(t)$$

$$= \frac{1}{2\pi}\frac{d}{dt}(2\pi f_c t + k_p m(t))$$

$$= f_c + \frac{1}{2\pi}k_p\frac{d}{dt}m(t)$$

$$f_{max} = f_c + \frac{k_p}{2\pi}\frac{1}{\left(\frac{10^{-3}}{4}\right)} = f_c + \frac{k_p}{2\pi}\times 4\times 10^3$$

$$= 100\text{ kHz} + \frac{\pi}{2\pi}\times 4\times 10^3$$

$$= 102\text{ kHz}$$

$$f_{min} = f_c - k_p\frac{1}{\left(\frac{10^{-3}}{4}\right)}$$

$$= f_c - 2\text{ kHz}$$

$$f_{min} = 98\text{kHz}$$

14. Ans: (c)

Sol: Given,

$$S(t) = A_c\cos(\theta_i(t))$$

$$= A_c\cos(\omega_c t + \phi(t))$$

$$m(t) = \cos(\omega_m t)$$

$$f_i(t) = f_c + 2\pi k(f_m)^2\cos\omega_m t$$

$$f_i = \frac{1}{2\pi}\frac{d\theta_i(t)}{dt}$$

$\theta_i(t) = \int 2\pi f_i(t)dt$

$$\theta_i(t) = \int 2\pi[f_c + 2\pi k(f_m)^2 \cos\omega_m t]dt$$

$$\theta_i(t) = 2\pi f_c t + (2\pi f_m)^2 k \frac{\cos\omega_m t}{\omega_m t}$$

$\theta_i(t) = \omega_c t + \omega_m k \sin\omega_m t$

15. Ans: (b)

Sol: $\Delta f_{max} = K_f\,|m(t)|_{max}$

$$= \frac{100}{2\pi}\times[10]$$

$$\Delta f_{max} = \left(\frac{500}{\pi}\right)\text{Hz}$$

16. Ans: (b)

Sol: Given that

$s(t) = \cos[\omega_c t + 2\pi m(t)]$volts

$$f_i = \frac{1}{2\pi}\frac{d}{dt}[\omega_c t + 2\pi m(t)]$$

$$= \frac{1}{2\pi}\frac{d}{dt}[2\pi f_c t + 2\pi m(t)]$$

$$f_i = f_c + \frac{d}{dt}[m(t)]$$

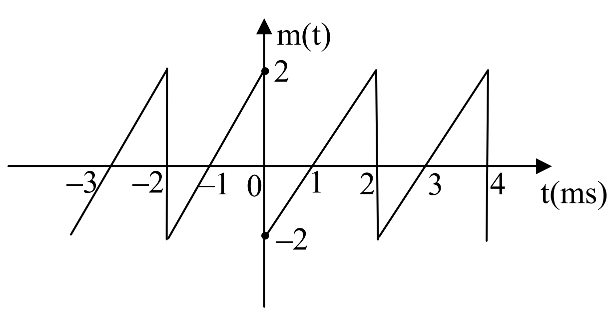
we know that $f_i = f_c + k_f m(t)$

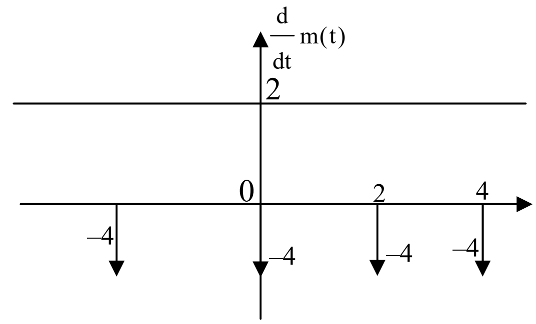
Here $k_f m(t) = \frac{d}{dt}[m(t)]$

$\Delta f = \max\{k_f m(t)\}$

$$\Delta f = \max\left[\frac{d}{dt}m(t)\right]$$

$\Delta f = 2\text{kHz}$





17. Ans: (a)

Sol: $\beta_p = k_p \max[|m(t)|] = 1.5\times 2 = 3$

$$\beta_f = \frac{k_f \max[|m(t)|]}{f_m}$$

$$= \frac{3000\times 2}{1000}$$

$= 6$

18. Ans: (a)

Sol: Using Carson's rule we obtain

$BW_{PM} = 2(\beta_p + 1)f_m = 8\times 1000 = 8000\text{Hz}$

$BW_{FM} = 2(\beta_f + 1)f_m = 14\times 1000 = 14000\text{Hz}$

19. Ans: 70 kHz

Sol: $s(t) = A_c\cos[2\pi f_c t + k_p m(t)]$

$$f_i = f_c + \frac{k_p}{2\pi}\frac{d}{dt}x(t)$$

$$= 20k + \frac{5}{2\pi}\times 5\frac{d}{dt}\left(\sin 4\pi 10^3 t - 10\pi\cos 2\pi 10^3 t\right)$$

$$= 20k + \frac{25}{2\pi}\times\begin{bmatrix}\cos(4\pi 10^3 t - 10\pi\cos 2\pi 10^3 t) \\ (4\pi 10^3 + 10\pi\sin 2\pi 10^3 t\times 2\pi 10^3)\end{bmatrix}$$

$$f_{i(t=0.5ms)} = 20k + \frac{25}{2\pi}\times\cos(4\pi + 10\pi)\times 4\pi\times 10^3$$

$$= 20k + \frac{25}{2\pi}\times 4\pi\times 10^3$$

$= 20k + 50k$

$f_{i(t=0.5ms)} = 70\text{kHz}$

20. Ans: (a, b & c)

Sol: $s(t) = 100\cos[2\pi \times 10^7 t + 10\sin(8\pi \times 10^3 t)]$

$$\Delta f_i(t) = \frac{1}{2\pi}\frac{d}{dt}\left[10\sin\left(8\pi\times10^3 t\right)\right]$$

$\Delta f_i(t) = 40 \times 10^3 \cos[8\pi\times10^3 t]$

$\Delta f_{max} = 40(\text{kHz})$

$$\beta = \frac{\Delta f_{max}}{f_{max}} = \frac{40\times10^3}{4\times10^3} = 10$$

$BW = 2[\beta+1]\, f_{max} = 2\,[10 + 1]\, 4\times10^3$

$= 88(\text{kHz})$

$$P_T = P_C = \left[\frac{100}{\sqrt{2}}\right]^2 = 5(\text{kW})$$

$\therefore$ a, b & c are correct

21. Ans: (a, c & d)

Chapter 5 Radio Receivers

01. Ans: (d)

Sol: The image channel selectivity of super heterodyne receiver depends upon Pre selector and RF amplifier only.

02. Ans: (b)

Sol: The image (second) channel selectivity of a super heterodyne communication receiver is determined by the pre selector and RF amplifier.

03. Ans: (d)

Sol: Given $f_s = 4$ to 10 MHz

$IF = 1.8$ MHz

$f_{si} = ?$

$f_{si} = f_s + 2\times IF$

$= 7.6$ MHz to 13.6 MHz

04. Ans: (a)

Sol: Image frequency $f_{si} = f_s + 2\times IF$

$= 700\times10^3 + 2(450\times10^3)$

$= 1600$ kHz

Local oscillator frequency, $f_l = f_s + IF$

$(f_l)_{max} = (f_s)_{max} + IF = 1650 + 450$

$= 2100$ kHz

$(f_l)_{min} = (f_s)_{min} + IF = 550 + 450$

$= 1000$ kHz

$$R = \frac{C_{max}}{C_{min}} = \left(\frac{f_{l\,max}}{f_{l\,min}}\right)^2 = \left(\frac{2100}{1000}\right)^2 = 4.41$$

05. Ans: (a)

Sol: f_s(range) = 88 - 108MHz

Given condition $f_{IF} < f_{LO}$, f_{si}>108 MHz

$f_{si} = f_s + 2\times IF$

$f_{si} > 108$ MHz

$f_s + 2IF > 108$ MHz

88MHz + 2×IF > 108 MHz

IF > 10MHz

Among the given options IF = 10.7 MHz

06. Ans: (a)

Sol: Range of variation in local oscillator frequency is

$f_{Lmin} = f_{smin} + IF$

$= 88 + 10.7$

$f_{Lmin} = 98.7$ MHz

$f_{Lmax} = f_{smax} + IF$

$= 108 + 10.7$

$f_{Lmax} = 118.7$ MHz

07. Ans: 5

Sol: $f_s = 58$ MHz – 68 MHz

When $f_s = 58$ MHz

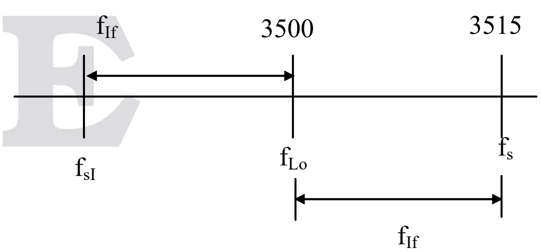
$f_{si} = f_s + 2IF > 68$ MHz

$2IF > 10$ MHz

$IF \geq 5$ MHz

08. Ans: 3485 MHz

Sol:



$f_{If} = 15$ MHz

$f_{Lo} = 3500$ MHz

$f_s - f_{Lo} = f_{IF}$

$f_s = f_{Lo} + f_{IF} = 3515$ MHz

f_{si} = image frequency $= f_s - 2\,f_{IF}$

$= 3515 - 2\times15$

$= 3485$ MHz

09. Ans: (a, b & c)

Sol: $\rightarrow f_{IM} = f_S + 2f_{IF} = 555\times10^3 + 2(455\times10^3)$

$= 1465$ kHz

$\rightarrow f_{IF} = f_{lo} - f_S = 1010\times10^3 - 555\times10^3$

$= 455\times10^3$ Hz

$\rightarrow \text{IRR} = \sqrt{1+Q^2\rho^2} = 113$

$Q = 50$

$$\rho = \frac{f_{IM}}{f_S} - \frac{f_S}{f_{IM}} = \frac{1465}{555} - \frac{555}{1465}$$

$\therefore$ a, b & c are correct.

10. Ans: (b & c)

Sol: $\rightarrow f_{lo} - f_s = f_{IF}$

$f_{lo} = f_{IF} + f_s$

$= 555\times10^3 + 1500\times10^3$

$= 2055$ kHz

$\rightarrow f_{IM} = f_s + 2f_{IF}$

$= 1500\times10^3 + 2(555\times10^3)$

$= 2610$ kHz

$\therefore$ b & c are correct.

Chapter 6 Baseband Data Transmission

01. Ans: (d)

Sol: $\Delta = \dfrac{V_{max} - V_{min}}{2^n}$

$\Delta \,\alpha\, \dfrac{1}{2^n}$; $\dfrac{\Delta_1}{\Delta_2} = \dfrac{2^{n_2}}{2^{n_1}}$

$\dfrac{0.1}{\Delta_2} = \dfrac{2^{n+3}}{2^n}$

$\Delta_2 = 0.1 \times \dfrac{1}{8}$

$= 0.0125$

02. Ans: (3)

Sol: $(BW)_{PCM} = \dfrac{n f_s}{2}$

Where 'n' is the number of bits to encode the signal and L = 2^n, where 'L' is the number of quantization levels.

$L_1 = 4 \Rightarrow n_1 = 2$

$L_2 = 64 \Rightarrow n_2 = 6$

$\dfrac{(BW)_2}{(BW)_1} = \dfrac{n_2}{n_1} = \dfrac{6}{2} = 3$

$(BW)_2 = 3\ (BW)_1$

03. Ans: (c)

Sol: Given,

Two signals are sampled with f_s = 44100s/sec and each sample contains '16' bits

Due to additional bits there is a 100% overhead.

Out put bit rate =?

$R_b = n^{|} f_s^{|}$

$f_s^{|} = 2f_{s|} = 2\ [44100]$

($\because$ two signals sampled simultaneously)

$n^{|} = 2n$

($\because$ due to overhead by additional bits)

$R_b = 4\ (nf_s) = 2.822$Mbps

04. Ans: (c)

Sol: Number of bits recorded over an hour

$= R_b \times 3600 = 10.16$ G.bits

05. Ans: (c)

Sol: $p(t) = \dfrac{\sin(4\pi W t)}{4\pi W t\ (1-16W^2 t^2)}$

At $t = \dfrac{1}{4W}$; $P\left(\dfrac{1}{4W}\right) = \dfrac{0}{0}$

Use L-Hospital Rule

$$\underset{t\to\frac{1}{4W}}{Lt}\ p(t) = \underset{t\to\frac{1}{4W}}{Lt} \frac{4\pi W\ \cos(4\pi W t)}{4\pi W - 64\pi W^3 (3t^2)}$$

$$= \frac{4\pi W(-1)}{4\pi W - 64\pi W^3\, 3\left(\frac{1}{16W^2}\right)}$$

$$= \frac{-4\pi W}{-8\pi W} = 0.5$$

06. Ans: 35

Sol: Given bit rate R_b = 56 kbps, Roll of factor $\alpha = 0.25$

BW required for base band binary PAM system

$BW = \dfrac{R_b}{2}[1+\alpha] = \dfrac{56}{2}[1+0.25]\text{kHz} = 35\text{kHz}$

07. Ans: 16

Sol: $R_b = nf_s$ = 8bit/sample × 8kHz = 64 kbps

$(B_T)_{min} = \dfrac{R_b}{2\log_2 M}$

$= \dfrac{R_b}{2\log_2 4} = \dfrac{R_b}{2\times 2}$

$= \dfrac{R_b}{4} = \dfrac{64}{4}$

$= 16$kHz

08. Ans: (b)

Sol: Given $f_s = 1/T_s = 2k$ symbols/sec

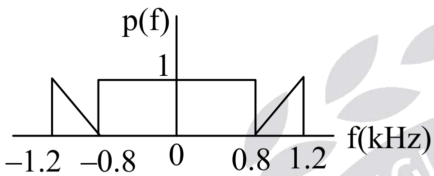
If $P(f) \overset{F.T}{\leftrightarrow} p(t)$,

Condition for zero ISI is given by

$$\frac{1}{T_s}\sum_{n=-\infty}^{\infty} P(f - n/T_s) = p(0)$$

$$\Rightarrow \sum_{n=-\infty}^{\infty} P(f - n/T_s) = p(0)T_s$$

p(0) = area under P(f)

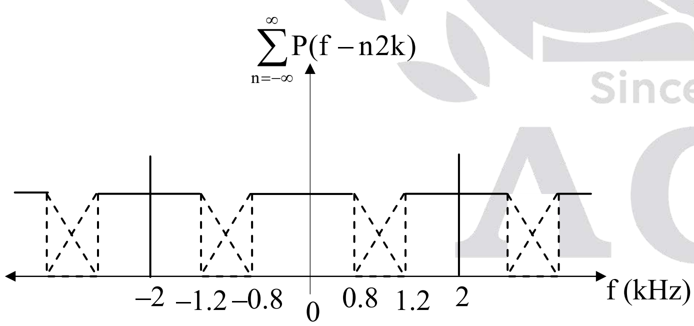


$$\text{Area} = 2\times\frac{1}{2}(1)(0.4)k + 2\times 0.8k = 2k$$

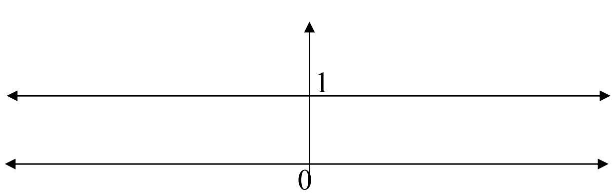
$$p(0)\,T_s = 2k \times \frac{1}{2k} = 1$$

$$\Rightarrow \sum_{n=-\infty}^{\infty} P(f - n/T_s) = 1$$

The above condition is satisfied by only option (b)



$\Downarrow$



$$\therefore \sum_{n=-\infty}^{\infty} P(f - n2k) = 1$$

Option (a) is correct if pulse duration is from –1 to + 1

Option (c) is correct if the transition is from 0.8 to 1.2, –0.8 to –1.2

Option (d) is correct if the triangular duration is from –2 to +2

09. Ans: 200

Sol: m(t) = sin 100πt + cos 100πt

$= \sqrt{2}\cos[100\pi t + \phi]$

$$\Delta = 0.75 = \frac{V_{max} - V_{min}}{L} = \frac{\sqrt{2} - (-\sqrt{2})}{L} = \frac{2\sqrt{2}}{L}$$

$$L = \frac{2\sqrt{2}}{0.75} \approx 4 = 2^n$$

So n = 2

f = 50 Hz so Nyquist rate = 100

So, the bit rate = 100 × 2 = 200 bps

10. Ans: (b)

Sol: Given

$f_{m_1} = 3.6\text{kHz} \Rightarrow f_{s_1} = 7.2\text{kHz}$

$f_{m_2} = f_{m_3} = 1.2\text{kHz} \Rightarrow f_{s_2} = f_{s_3} = 2.4\text{kHz}$

$f_s = f_{s_1} + f_{s_2} + f_3$

$= 12\text{kHz}$

No. of Levels used = 1024

$\Rightarrow$ n = 10bits

$\therefore$ Bit rate = nf_s

$= 10 \times 12$ kHz

$= 120$ kbps

11. Ans: (a)

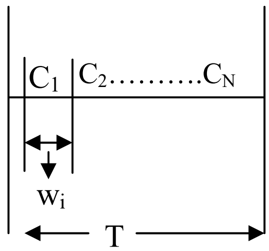
Sol: $(f_s)_{min} = (f_{s_1})_{min} + (f_{s_2})_{min} + (f_{s_3})_{min} + (f_{s_4})_{min}$

$= 200 + 200 + 400 + 800$

$= 1600$ Hz

12. Ans: (c)

Sol:



Minimum B.W of TDM is $\sum_{i=1}^{N} w_i$

13. Ans: (b)

Sol: Number of patients = 10

ECG signal B.W = 100Hz

$(Q_e)_{max} \le (0.25)\ \%V_{max}$

$\frac{2V_{max}}{2\times 2^n} \le \frac{0.25}{100} V_{max}$

$2^n \ge 400$

$n \ge 8.64$

$n = 9$

Bit rate of transmitted data = 10×9×200

= 18kbps

14. Ans: (a)

Sol: Peak amplitude → A_m

Peak to peak amplitude A_m

$\frac{-\Delta}{2} \le Q_e \le \frac{\Delta}{2}$

PCM maximum tolerable $\frac{\Delta}{2} = 0.2\%\ A_m$

$\Delta = \frac{\text{Peak to peak}}{L} \Rightarrow \frac{2A/m}{2L} = \frac{0.2}{100} A_m$

$(\because \Delta = \frac{2A_m}{L})$

$\Rightarrow L = 500$

$2^n = 500$

$n = 9$

$R_b = n(f_S)_{TDM} + 9$

$f_S = R_N + 20\%R_N = R_N + 0.2R_N$

$f_S = 1.2R_N = 1.2 \times 2\times\omega$

$f_S = 2.4$ K samples/sec

$(f_S)_{TDM} = 5(f_S)$

$= 5 \times 2.4$ K

$= 12$ K sample/sec

$R_b = (nf_S) + 0.5\%(nf_S)$

$= (9 \times 12k) + \frac{0.5}{100}(9\times 12k)$

$= 108540$ bps

15. Ans: (b)

Sol: To avoid slope over loading, rate of rise of the o/p of the Integrator and rate of rise of the Base band signal should be the same.

$\therefore \Delta f_s$ = slope of base band signal

$\Delta \times 32 \times 10^3 = 125$

$\Delta = 2^{-8}$ Volts.

16. Ans: (b)

Sol: $x(t) = E_m \sin 2\pi f_m(t)$

$\frac{\Delta}{T_S} < \left|\frac{dm(t)}{dt}\right|$ → slope overload distortion takes place

$\Delta f_S < E_m 2\pi f_m$

$\Rightarrow \frac{\Delta f_S}{2\pi} < E_m f_m \qquad (\because \Delta = 0.628)$

$\Rightarrow \frac{0.628 \times 40K}{2\pi} < E_m f_m$

$f_S = 40$ kHz $\Rightarrow 4$ kHz $< E_m f_m$

Check for options

(a) $E_m \times f_m = 0.3 \times 8\text{ K} = 2.4\text{ kHz}$
$(4K \nless 2.4\text{ K})$

(b) $E_m \times f_m = 1.5 \times 4K = 6\text{ kHz}$
$(4K < 6\text{ K})$ correct

(c) $E_m \times f_m = 1.5 \times 2\text{ K} = 3\text{ kHz}$
$(4K \nless 3K)$

(d) $E_m \times f_m = 30 \times 1\text{ K} = 3\text{ kHz}$
$(4K \nless 3K)$

17. Ans: (a)

Sol: Given

$m(t) = 6\sin(2\pi\times10^3 t) + 4\sin(4\pi\times10^3 t)$

$\Delta = 0.314$ V

Maximum slope of $m(t) = \frac{d}{dt}(m(t))/t = \frac{\pi}{2}$

$= 2\pi\times10^3(6) + 4\pi\times10^3[4] = 28\pi\times10^3$

18. Ans: (c)

Sol: Pulse rate which avoid distortion

$$\Delta f_s = \frac{d}{dt}m(t)$$

$$f_s = \frac{28\pi\times10^5}{0.314}$$

$f_s = 280\times10^3$ pulses/sec

19. Ans: (a, b & c)

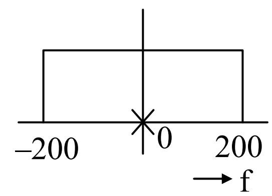
Sol: a. $r_b = (Nn + EB)f_s$
$r_b = (80 + 5)\ 5000 = 425(\text{kbps})$
b. $r_b = Nnf_s$
$r_b = 10(8+1)\ 5000 = 450(\text{kbps})$
c. $r_b = (Nn + EB)f_s$
$r_b = (80 + 10)\ 5000 = 450(\text{kbps})$
d. $r_b = Nnf_s$
$r_b = 10(8+0.8)\ 5000 = 440(\text{kbps})$
$\therefore$ a, b & c are correct

20. The message signal
$m(t) = \text{Sinc}(400t) \times \text{Sinc}(600t)$
is sampled then which of the following option is/are correct.
NOTE: options are changed
(a) Nyquist rate = 2 kHz
(b) Nyquist rate = 1 kHz
(c) Nyquist interval = 0.5 ms
(d) Nyquist interval = 1 ms

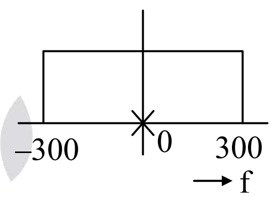
20. Ans: (b & d)

Sol:

Sinc(400t) $\xrightarrow{\text{CTFT}}$



Sinc(600t) $\xrightarrow{\text{CTFT}}$



M(f) frequency will range from –500 to 500 Hz

$\therefore\ f_q = 2f_{max} = 1$ kHz

$$T_{S_{MAX}} = \frac{1}{f_q} = 1\text{ms}$$

b & d are correct

Chapter 7 Bandpass Data Transmission

01. Ans: (c)

Sol: $(BW)_{BPSK} = 2f_b = 20$ kHz

$(BW)_{QPSK} = f_b = 10$ kHz

02. Ans: (b)

Sol: $f_H = 25$ kHz ; $f_L = 10$ kHz

$\therefore$ Center frequency

$= \left(\frac{25+10}{2}\right)$ kHz

$= 17.5$ kHz

$\therefore$ Frequency offset,

$\Omega = 2\pi\,(25 - 17.5) \times 10^3$

$= 2\pi\,(7.5) \times 10^3$

$= 15 \times 10^3\pi$ rad/sec.

The two possible FSK signals are orthogonal, if $2\Omega T = n\pi$

$\Rightarrow 2(15\pi) \times 10^3 \times T = n\pi$

$\Rightarrow 30 \times 10^3 \times T = n$ (integer)

This is satisfied for, $T = 200\mu$sec.

03. Ans: (a)

Sol: $r_b = 8$ kbps

Coherent detection

$\Delta f = \frac{nr_b}{2}$

Best possible n = 1

$\Delta f = \frac{8K}{2} = 4K$

To verify the options $\Delta f = 4k$

i.e. $f_{C2} - f_{C1} = 4K$

(a) 20 K – 16 K = 4 K

(b) 32 K – 20 K = 12 K

(c) 40 K – 20 K = 20 K

(d) 40 K – 32 K = 8 K

04. Ans: (a)

Sol: Non coherent detection of PSK is not possible. So to overcome that, DPSK is implemented. A coherent carrier is not required to be generated at the receiver.

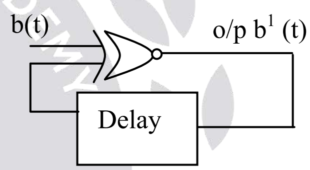
05. Ans: (c)

Sol: In QPSK baud rate $= \frac{\text{bit rate}}{2} = \frac{34}{2}$

$= 17$ Mbps

06. Ans: (d)

Sol:



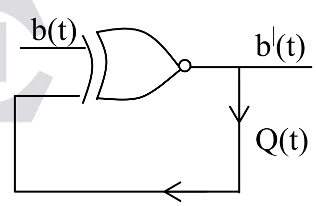
b(t)	0	1	0	0	1
$b^1(t)_{(\text{Ref.bit})}$	0	0	1	0	0
Phase	π	π	0	π	π

07. Ans: (b)

Sol: Given

Bit stream 110 111001

Reference bit = 1



$b^{|}(t) = b(t) \odot Q(t)$

1 1 0 1 1 1 0 0 1

1

1 1 0 0 0 0 1 0 0

0 0 π π π π 0 π π

08. Ans: (d)

Sol: $r_b = 1.544 \times 10^6$

$\alpha = 0.2$

$$BW = \frac{r_b}{\log_2^M}(1+\alpha)$$

$$= \frac{1.544\times10^6}{2}(1+0.2) \quad (\because M = 4)$$

$BW = 926.4 \times 10^3$ Hz

09. Ans: 0.25

Sol: BW = 1500 Hz

BW required for M-ary PSK is

$$\frac{R_b[1+\alpha]}{\log_2 16} = 1500\text{Hz}$$

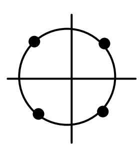
$\Rightarrow R_b\,[1 + \alpha] = 1500 \times 4 = 6000$

$$\Rightarrow (1+\alpha) = \frac{6000}{4800}$$

Roll off factor $\Rightarrow \ \alpha = \dfrac{6000}{4800} - 1 = 0.25$

10. Ans: (b)

Sol:



Here only phase is changing.

From options (b) is the optimum answer.

11. Ans: (b)

Sol: Here 16-points are available in constellation which are varying in both amplitude and phase. So, it 16QAM.

12. Ans: (d)

Sol: $$BW = \frac{r_b}{\log_2 M}(1+\alpha)$$

$$36\times10^6 = \frac{r_b}{2}(1+0.2)(\because M = 4, \text{QPSK})$$

$r_b = 60\times10^6$ bps

NOTE: new question 13th is added in text book

13. Which among the following modulation, schemes consume less bandwidth

(a) B-PSK (b) Q-PSK

(c) 64-PSK (d) 64-QAM

13. Ans: (c & d)

Sol: Bandwidth of 64-PSK $= \dfrac{2r_b}{6} = \dfrac{r_b}{3}$

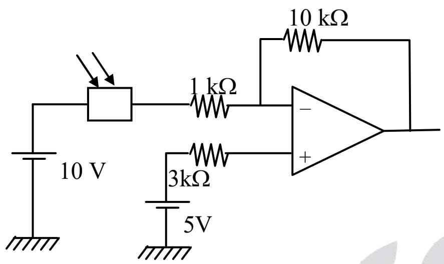
Bandwidth 64-QAM = Bandwidth of 64-PSK

14. Ans: (a, b & d)

Sol: M-ary ASK constellation plot will always come on a single line (either x-axis or y-axis).

Chapter 9 Optical Sources & Detectors

01.
Sol:



1st case:

$R_p \rightarrow 1$ kΩ, no 10 V source

2nd case:

$R_p \rightarrow 5$ kΩ →10 V source is present

So, $V = V_{01(\text{Only}10\text{V})} + V_{02(\text{Only}5\text{V})}$

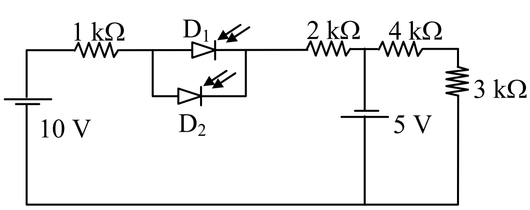
$$V = \frac{-10\,k\Omega}{1k\,\Omega + R_p}$$

$$= \left(\frac{-10k\Omega}{1k\Omega + 5k\Omega}\right)\times 10 + \left(1 + \frac{10k\,\Omega}{1k\Omega + 1k\Omega}\right)\times 5$$

$$V = \left(\frac{-10k\Omega}{6k\Omega}\times 10\right) + \left(1 + \frac{10k\Omega}{2k\Omega}\right)\times 5$$

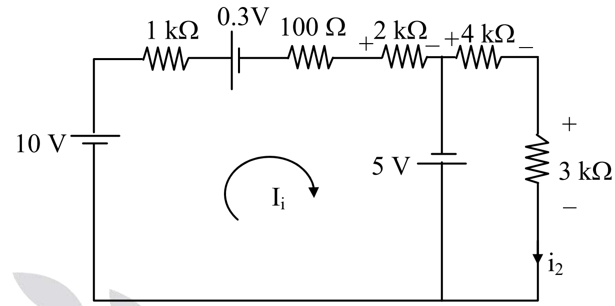
V = 13.33 V

02.
Sol:



D_1,D_2 are in forward bias

D_2–ON, D_1 –OFF



$V_{2k} = ?$

$V_{3k\,\Omega} = ?$

$$i_2 = \frac{-5V}{4k\Omega + 3k\Omega} = \frac{-5V}{7k\Omega} = -0.714 \text{ mA}$$

$V_{3k\,\Omega} = i_2 \times 3$ kΩ

$= (-0.714) \times 3 \times 10^3$

$= -2.14$ V

From circuit

$I_i = 1.41$ mA

So

$V_{2k} = 1.41$ mA $\times 2$ kΩ = 2.8 V

03. Ans: (c)

Sol: Given data.

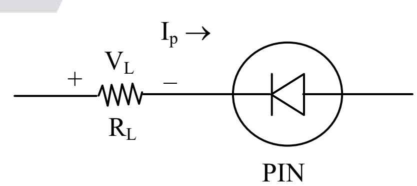
$C_j = 6$ pF

$A = 10$ mm^2

$R = 0.5$ A/W

$I = 1$mW/cm^2

$R_L = 100$ kΩ



$V_L = ?$

We know

$V_L = I_P \times R_L$

$$R = \frac{I_p}{P_0}$$

$P_0 = A \times I$

$$I_p = \frac{0.5A}{W} \times A \times I$$

$$I_p = \frac{0.5A}{W} \times 10mm^2 \times \frac{1mW}{10mm^2}$$

$$I_p = \left(0.5 \times \frac{10}{100} \times 1m\right) Amp$$

$I_p = 5\times10^{-5}$ amp

$V_L = I_p \times R_L = 5\times10^{-5}\times100\ k\Omega$

$\therefore\ V_L = 5$ volts

04. Ans: (c)

Sol: Given:

$\eta = 0.65$

$\lambda = 900$ nm

$P_0 = 0.5\ \mu w$

$I_m = 10\ \mu A$

M = ?

$$M = \frac{I_m}{I_p} = \frac{10\mu A}{I_p}$$

We know

$$\eta = \frac{EI_p}{P_0 q}$$

$$0.65 = \frac{hcI_p}{\lambda P_0 q}$$

$$\Rightarrow 0.65 = \left(\frac{6.6\times10^{-34}\times3\times10^8}{900n\times0.5\times10^{-6}\times1.6\times10^{-19}}\right)\times I_p$$

$\Rightarrow\quad I_p = 2.36\times10^{-7}$

$$M = \frac{10\mu A}{2.36\times10^{-7}A}$$

$= 42.4 \approx 43$

05. Ans: –1V

Sol: Output is independent V_r

06. Ans: 2

Sol: Given

Area = 10 mm^2

Sensitivity = 0.5 A/W

Intensity = 4 W/m^2

Photodiode current

I_p = Area × sensitivity × Intensity

$I_P = 10\ mm^2 \times 0.5\ A/W \times 4W/m^2$

$I_p = 20\ \mu A$

I to V converter sensitivity is 100 mV/μA

$$\text{So, } V_o = \frac{100mV}{\mu A}\times 20\mu A$$

= 2 Volt

07. Ans: 75.18

Sol: $$\frac{I}{P} = \frac{\eta e\lambda}{hc}$$

$$I = \frac{\eta e\lambda}{hc}\times P$$

$$= \frac{0.75\times1.6\times10^{-19}\times830\times10^{-9}\times100\times10^{-6}}{6.624\times10^{-34}\times2\times10^8}$$

$I = 75.18\mu A$

08. Ans: (a, b & d)

Sol: The sensitivity of photovoltaic cell is almost constant when it is short circuited & is almost negligible when the load resistance is about 10 kΩ. The sensitivity of a photovoltaic cell decreases with increase of load resistance.

09. Ans: (a & b)

Sol: The photodiode is used in the detection of both visible & invisible light.

Chapter 10 LED's & LASERs

01. Ans: (b)

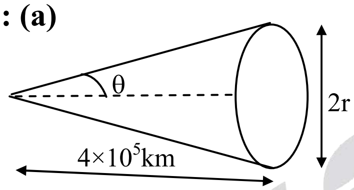
Sol: $2i = 115^0.34' = 115.566^0$,

$i = 57.783^0$, $\quad u = \tan i = \tan 57.783^0$

$= 1.587$

02. Ans: (a)

Sol:



$\theta = 1$ m rad

$$\tan\theta = \frac{r}{4\times10^5\times1000} = 1 \text{ mrad}$$

$(\tan\theta \approx \theta)$

$r = 4\times10^5$ meters

$= 400$ km

Diameter $= 2\times r$

$= 2\times400$ km

$= 800$ km

03. Ans: (b)

Sol: Given:

$L = 500$ mm

Bandwidth $= 1500$ MHz

$\Delta f = ?$

Number of longitudinal oscillating modes

$$= \frac{BW}{\Delta f}$$

We know

$$\Delta f = \frac{C}{2L}$$

Number of longitudinal oscillating modes

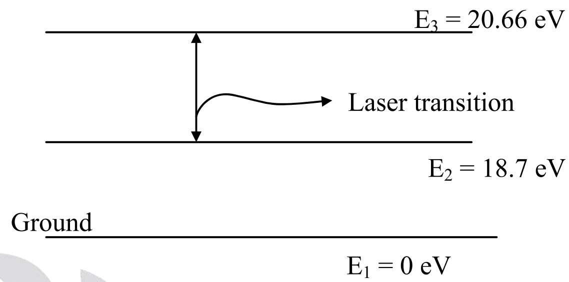
$$= \frac{1500\,\text{MHz}}{\left(\dfrac{3\times10^8}{2\times500\times10^{-3}}\right)}$$

$$= \frac{1500\times10^6}{3\times10^8}\times1000\times10^{-3}$$

$= 5$

04. Ans: (c)

Sol:



05. Ans: (c)

Sol: $E_3 - E_2 = \dfrac{hc}{\lambda}$

$$\lambda = \frac{hc}{E_3 - E_2} = \frac{6.625\times10^{-34}\times3\times10^8}{(20.66-18.7)\times1.6\times10^{-19}\,\text{J}}$$

$= 633.8$ nm

06. Ans: (d)

Sol: Given

$\lambda = 6328\ \overset{0}{A}$

Bandwidth $= 1$ MHz

$C_l = ?$

We know

$$C = \frac{C_\ell}{C_t}$$

$$C_l = 3\times10^8\times\frac{1}{1\text{MHz}} \quad \left(\because C_t = \frac{1}{f}\right)$$

$C_l = 300$ m

07. Ans: 40

Sol: Area for photodiode D_1

$A_1 = 10\text{mm}\times(5\text{mm} + 0.1\text{mm})$

$= 51\times10^{-6}\ \text{m}^2$

Area for photodiode D_2

$A_2 = 10\text{mm}\times(5\text{mm} - 0.1\text{mm})$

$= 49\times10^{-6}\ \text{m}^2$

$$P_1 = 50\left(\frac{W}{m^2}\right)\times51\times10^{-6}(m^2)$$

$P_1 = 50 \times 51 \times 10^{-6} (W)$

$P_2 = 50\left(\frac{W}{m^2}\right) \times 49 \times 10^{-6} (m^2)$

$P_2 = 50 \times 49 \times 10^{-6} (W)$

Difference between photo currents

$\Delta I = I_{D1} - I_{D2}$

$= \text{Photodiode sensitivity} \times \Delta P$

$= 0.4\left(\frac{A}{W}\right) \times (P_1 - P_2)$

$= 0.4 \times 50(51 - 49) \times 10^{-6}$

$= 0.4 \times 50 \times 2 \times 10^{-6}$

$= 40\ (\mu A)$

08. Ans: 2

Sol: $E_g = \frac{hC}{\lambda}$

$E_g = \frac{4.13567 \times 10^{-15} \times 3 \times 10^{8}}{620 \times 10^{-9}}$

$= 2eV$

09. Ans: (a, b, c & d)

Sol: The laser light exhibits some peculiar properties compared with the conventional light which make it unique, these are

(i) Monochromatic

(ii) Coherence

(iii) Directionality

(iv) Highly intense brightness

(v) High radiant energy

(vi) Polarized

Chapter 11 Interferometers

01.

Sol: Given data:

$t = 5\ \mu m$

$n = 5$

$\lambda = 589$ nm

$\mu_g = ?$

We know

$t(\mu_g - 1) = n\lambda$

$\Rightarrow 5\times10^{-6}(\mu_g - 1) = 5\times589\times10^{-9}$

$$\Rightarrow (\mu_g - 1) = \frac{5\times589\times10^{-9}}{5\times10^{-6}}$$

$\Rightarrow (\mu_g - 1) = 0.589$

$\Rightarrow \mu_g = 1.589$

02.

Sol: Given data:

$\lambda = 515$ nm

Refractive index $(\mu) = 1.6$

$\theta_R = 45^o$

$t = ?$

we know

$t(\mu - 1) = n\lambda$

$$t = \frac{n\lambda}{(\mu-1)}$$

$$\Rightarrow \quad t = \frac{515\times10^{-9}}{1.6-1} = 8.58\times10^{-7}$$

$\Rightarrow \quad t = 0.85\ \mu m$

03.

Sol: Given data

$t = 1.5\ \mu m$

$\lambda = 0.5\ \mu m$

$n = ?$

We know

$$t = \frac{n\lambda}{2}$$

$$\Rightarrow 1.5\times10^{-6} = \frac{n\times0.5\times10^{-6}}{2}$$

$$\Rightarrow \frac{1.5\times10^{-6}\times2}{0.5\times10^{-6}} = n$$

$\Rightarrow n = 6$

04.

Sol: Given data:

$n = 100$

$\lambda = 6328 A^o$

$t = 20$ cm

$\mu = ?$

We know

$$2t(\mu - 1) = n\lambda$$

$\Rightarrow 2\times20\times10^{-2}(\mu - 1) = 100\times6328\times10^{-10}$

$\mu = 1.0001582 \approx 1$

05.

Sol: Given data

R.I = μ_g = 1.53

μ_{air} = 1.0

$$R = \left(\frac{\mu_g - \mu_{air}}{\mu_g + \mu_{air}}\right)^2$$

R = 0.044

R = 4.4 % of loss

06. Ans: (b & c)

Sol: A Michelson interferometer consists of

(i) Movable mirror

(ii) Fixed mirror

(iii) Source (monochromatic)

(iv) Detector

(v) Half silvered glass plate

07. Ans: (c & d)

Sol: The phenomenon of interference is shown both by longitudinal and by transverse waves.

Chapter 12 Fiber Optics

01. Ans: (d)

Sol: $NA = \sqrt{n_1^2 - n_2^2}$

$$= \sqrt{(1.44)^2 - (1.4)^2}$$

$$= 0.34$$

02. Ans: (c)

Sol: Given data

$\varepsilon_r = 2.5$

$n = ?$

n = refractive index

We know,

$n = \sqrt{\varepsilon_r \mu_r}$

ε_r = relative permittivity

μ_r = relative permeability

$n = \sqrt{2.5}$ $(\because \mu_r = 1)$

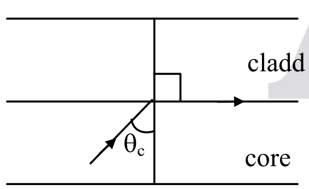
$= 1.58$

03. Ans: (d)

Sol: $n_1 = 1.6$

$n_2 = 1.422$

$\theta_c = ?$



$$\frac{\sin\theta_c}{\sin 90^o} = \frac{n_2}{n_1}$$

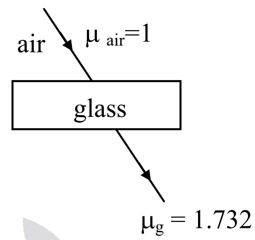
$$\theta_c = \sin^{-1}\left(\frac{1.422}{1.64}\right)$$

$$= 60.12^0$$

$$\simeq 60^0$$

04. Ans: (c)

Sol: $\mu_g = 1.732$



$$\tan\theta_B = \frac{\mu_g}{\mu_{air} = 1}$$

$$\theta_B = \tan^{-1}(1.732)$$

$$\theta_B = 60^o$$

05. Ans: (a)

Sol: Given $\mu_{glass} = 1.720$

$$R = \left(\frac{\mu_{air} - \mu_{glass}}{\mu_{air} + \mu_{glass}}\right)^2 \times 100$$

$$R = \left(\frac{1-1.72}{1+1.72}\right)^2 \times 100$$

$$= 7\ \%$$

06. Ans: (d)

Sol: $\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$

Given

$n_1 = 1.641$

$n_2 = 1.422$

$$\theta_c = \sin^{-1}\left(\frac{1.422}{1.641}\right)$$

$$= 60^o$$

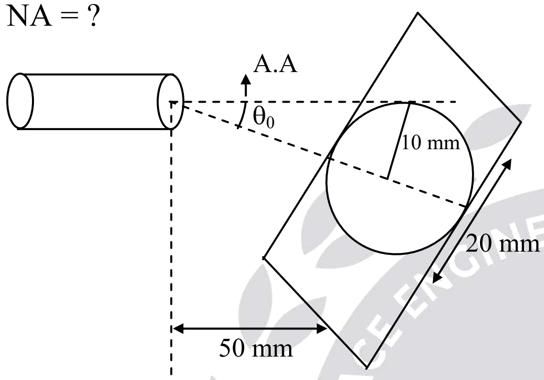
07. Ans: (d)

Sol: $\frac{\mu_t}{\mu_g} = \frac{1.33}{1.5} = \frac{C}{V_t} \times \frac{V_g}{C}$

$\frac{V_t}{V_g} = \frac{1.55}{1.33}$

08. Ans: (b)

Sol: NA = ?



$NA = \sqrt{n_1^2 - n_2^2}$

$NA = \mu_0 \sin\theta_0$

$NA = \sin\theta_0$

$NA = \frac{10}{\sqrt{10^2 + 50^2}}$

$= 0.196$

≈ 0.2

09. Ans: 0.75

Sol: $\frac{n_1}{n_2} = \frac{t_1}{t_2} = 0.75 \quad (n \propto t)$

10. Ans: (a, b, c & d)

Sol: Factors affecting the propagation of light through optical sensors:

(i) The size of fiber

(ii) The amount of light injected into fiber

(iii) The coherence of light source

(iv) The composition of fibers

(v) The N.A of the source & fiber

11. Ans: (a, b, & c)

Sol: In case of optical fiber to get TIR the condition is RI of core $\geq$ RI of cladding.

We know R.I of glass is greater than R.I of plastic so from this information we can say that option (a), (b) & (c) are correct.

Chapter 13 UV VIS Spectrophotometer

01. Ans: 4.35

Sol: In a TOF mass spectrometer

$$t = L\sqrt{\frac{m}{2eV}}$$

L = 85 cm

$m_A = 200 \times 1.66 \times 10^{-27}$

$m_B = 300 \times 1.66 \times 10^{-27}$

$eV = 1.6 \times 10^{-19} \times 2 \times 10^3$

$$t_A = L\sqrt{\frac{m_A}{2eV}}$$

$$= 0.85\sqrt{\frac{200\times1.66\times10^{-27}}{2\times1.6\times10^{-19}\times2\times10^3}} = 19.36\ \mu\text{sec}$$

$$t_B = L\sqrt{\frac{m_B}{2eV}}$$

$$= 0.85\sqrt{\frac{300\times1.66\times10^{-27}}{2\times1.6\times10^{-19}\times2\times10^3}} = 23.71\ \mu\text{sec}$$

$\Delta t = t_B - t_A = 4.35\ \mu$sec

02. Ans: 0.707 m

Sol: In case of mass spectrometer

$$t = L\sqrt{\frac{m}{2eV}}$$

for ion A $\rightarrow t_A = L_A\sqrt{\frac{m_A}{2eV}}$

for ion B $\rightarrow t_B = L_B\sqrt{\frac{m_A}{2eV}}$

$$\frac{t_p}{t_B} = \frac{L_A}{L_B}\sqrt{\frac{m_A}{m_B}}$$

$\frac{m_A}{m_B} = \frac{1}{2}$ (given)

We want to find distance of ion B crossed from starting point when ion A reached at the end of tube i.e. $t_A = t_B$

$$= \frac{1}{L_B}\sqrt{\frac{1}{2}}$$

$$L_B = \frac{1}{\sqrt{2}} = 0.707\text{ m}$$

03. Ans: 524

Sol: Resolving power of mass spectrometer

$$= \frac{\text{mass of sulphur}}{\text{mass of sulphur} - \text{mass of oxygen}}$$

$$= \frac{32.0600}{32.0600 - 31.9988}$$

$= 523.86$

$\cong 524$

04. Ans: (a & b)

Sol: A mass spectrum is a graph obtained by performing mass spectrometry.

It is a relation between the mass to charge ratio of ion signal.

A mass spectrum used for working out the relative atomic mass or relative molecular mass of the substance.

05. Ans: (b, c & d)

Sol: Mass spectroscopy is an analytical technique in which sample is converted into rapidly moving ions which are then separated & characterized. The composition analysis of an alloy, a natural gas, a solid is not done using mass spectrometer.