EE 365 Assignment # 3(Solution) [CLO 2]

Print out this cover page and attach above your hand-written, legible submission.

Name:

Reg #:

Total Points	P1 (10)	P2 (10)	P3 (10)	P4 (10)	P5 (10)	P6 (10)	P7 (10)	P8 (10)	P9 (10)	P10 (10)	Grand Total (100)
Obtained Points											

- You may consult TA during his office hours for any queries.
- Late Submission Policy advertised with Assignment 1 (uploaded on Piazza) applies.
- Please work out these ten (10) problems stated below
- **"Agbo & Sadiku"** refers to the text: Principles of Modern Communication Systems by **Agbo** and **Sadiku**, Cambridge University Press, 2019. E.g., Problem 2.32 (Agbo & Sadiku) refers to Exercise 32 of Chapter 2 in this book.
- Show your work and explain reasoning. Solve the problems in the order they are given below.

Problems:

1. Problem 3.1 (Agbo & Sadiku)
2. Problem 3.3 (Agbo & Sadiku)
3. Problem 3.5 (Agbo & Sadiku)
4. Problem 3.11 (Agbo & Sadiku)
5. Problem 3.13 (Agbo & Sadiku)
6. Problem 3.24 (Agbo & Sadiku)
7. Problem 3.31 (Agbo & Sadiku)
8. Problem 3.33 (Agbo & Sadiku)
9. Problem 3.37 (Agbo & Sadiku)
10. Problem 3.45 (Agbo & Sadiku)

3.1

Q no 1:-

Bandwidth = 30KHz

$V = f\lambda$

(a) Without Modulation:-

$$\lambda = \frac{3\times10^8}{30\times10^3}$$

$$\lambda = 10Km$$

length of antenna $L = \frac{\lambda}{10}$

$$\boxed{L = 1Km}$$ Ans

(b) With Modulation:-

$$BW = 30K\overset{Hz}{\times} 100 = 3\times10^6\ Hz$$

$$\lambda = \frac{3\times10^8}{3\times10^6}$$

$$\lambda = 100\ m$$

Length of antenna $L = \lambda/10$

$$\boxed{L = 10m}$$ Ans

3.3

Qno2:-

message signal.

↓

$A_m(t) \cos \omega_c t$

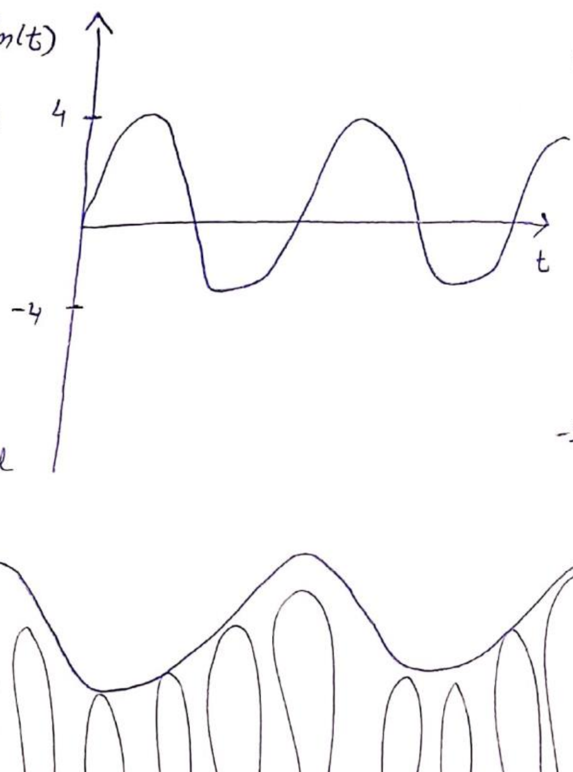
$A_c(t) = 10 \cos \omega_c t$

a) $A_m = 4$

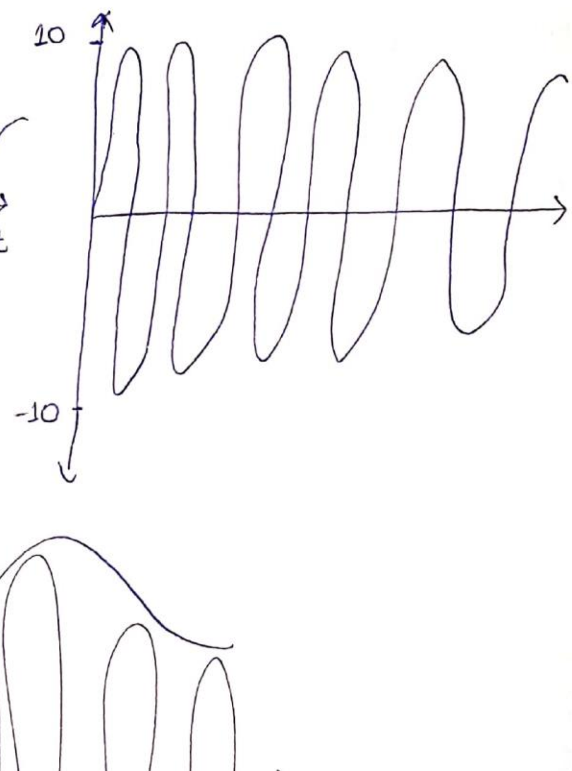
$\mu = \dfrac{A_m}{A_c} = \dfrac{4}{10}$

$\boxed{\mu = 0.4}$ modulation index.

Message signal



Carrier signal.

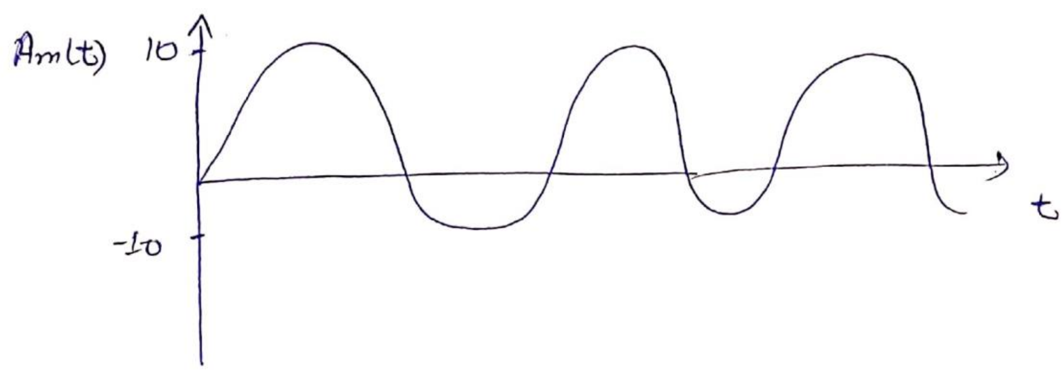


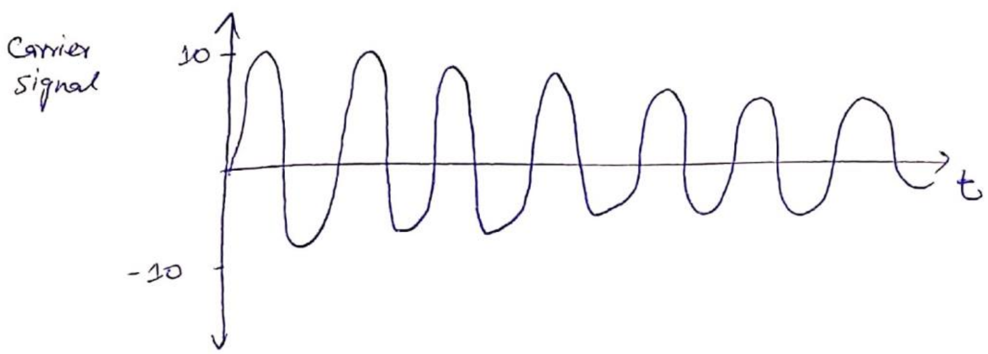
Modulated signal

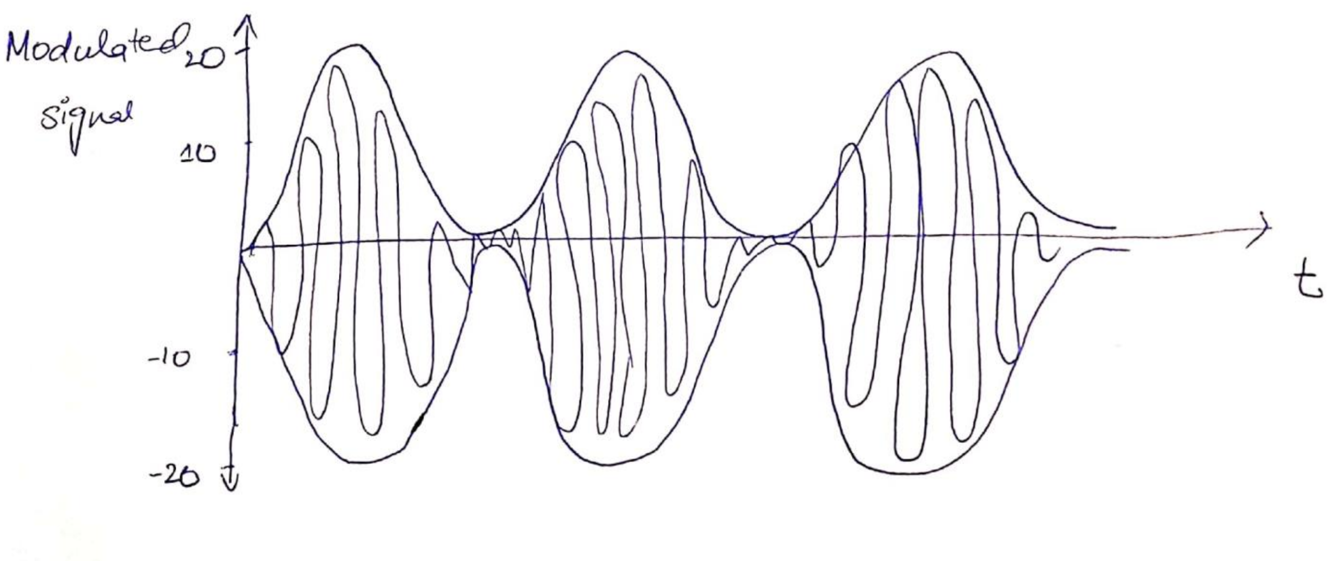
(b) $A_m = 10$

Modulation Index ⇒ $\mu = \frac{A_m}{A_c} = \frac{10}{10}$

$\boxed{\mu = 1}$



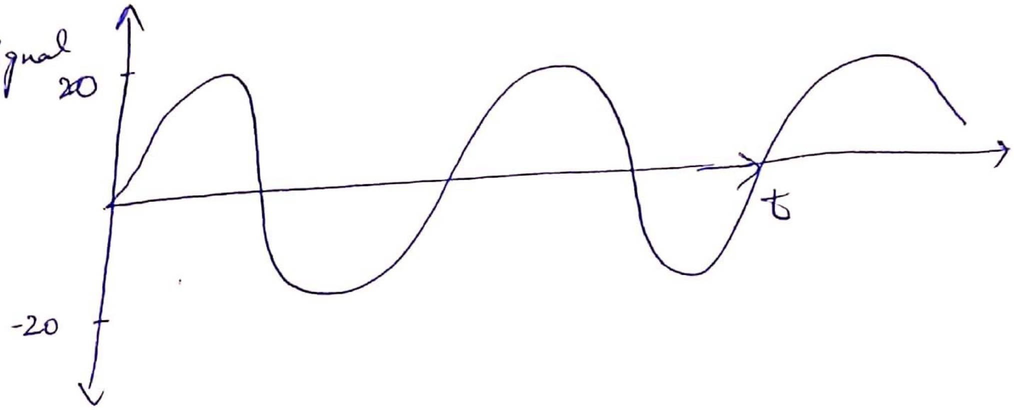




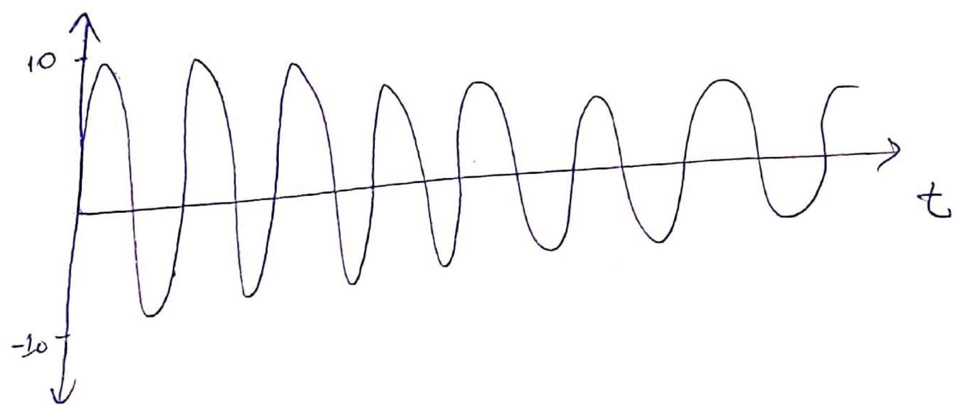
(e) $A_m = 20$

Modulation Index $\Rightarrow$ $\boxed{\mu = \frac{20}{10} = 2}$

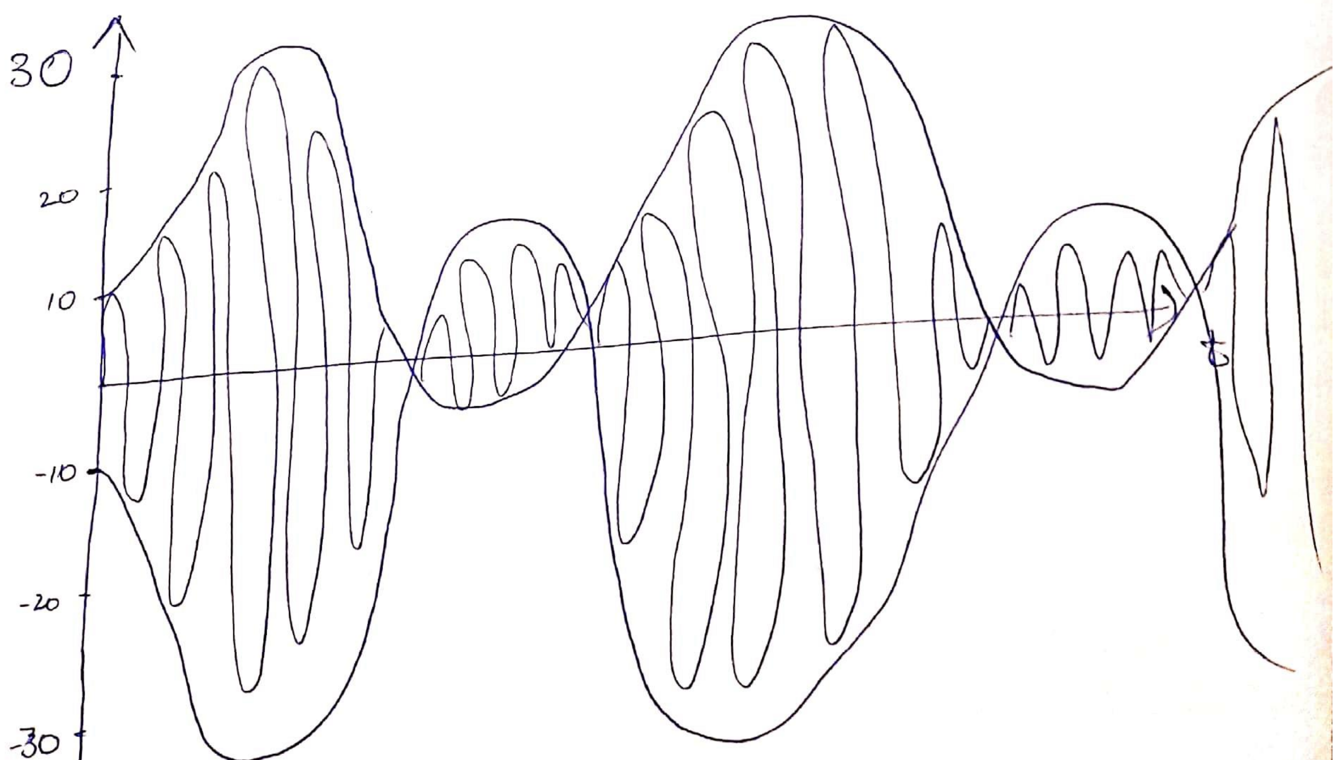
message signal



Carrier signal.



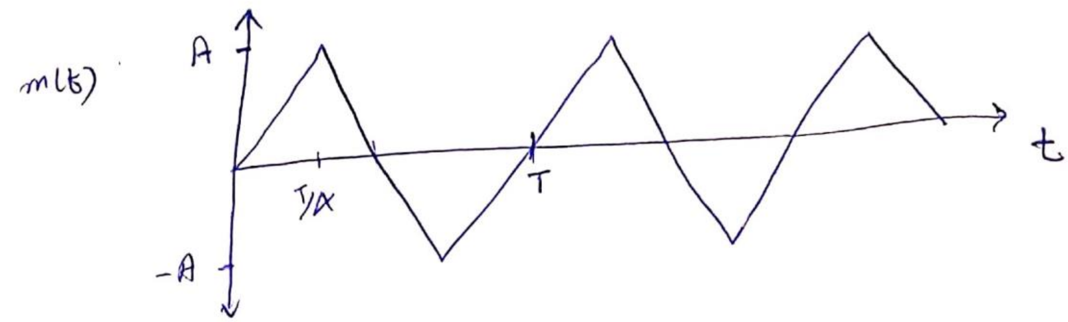
Modulated signal.



3.5

Q no 3:- Carrier signal $= 4 \sin \omega_c t$

Message signal $\Rightarrow$ Triangular waveform



(refered to example 3.3)

$$m(t) = \frac{4A}{T} t \quad , \quad 0 \le t \le \frac{T}{4}$$

$$P_m = \frac{4}{T} \int_0^{T/4} m^2(t)\,dt \Rightarrow \frac{4}{T} \int_0^{T/4} \frac{16A^2}{T^2} t^2\,dt$$

$$P_m = \frac{4}{T} \times \frac{16A^2}{T^2} \left[\int_0^{T/4} t^2\,dt \right]$$

$$P_m = \frac{64A^2}{T^3} \left. \frac{t^3}{3} \right|_0^{T/4}$$

$$P_m = \frac{64A^2}{T^3} \frac{T^3}{64(3)}$$

$$\boxed{P_m = \frac{A^2}{3}}$$

$$\boxed{P_c = \frac{A_c^2}{9}}$$

a) $m_p = 2$

$$\mu = \frac{2}{4}$$

Modulation Index.

$$\boxed{\mu = 0.5}$$

$$\eta = \frac{P_m}{A_c^2 + P_m} \times 100$$

$$\eta = \frac{m_p^2/3}{A_c^2 + m_p^2/3} \times 100$$

$$\eta = \frac{1.33}{16 + 1.33} \times 100$$

$$\boxed{\eta = 7.67\ \%}$$

$$\eta = \frac{\text{output power}}{\text{input power}}$$

$$= \frac{P_m}{P_c + P_m} \times 100$$

$$= \frac{m_p^2/3}{\frac{A_c^2}{2} + \frac{m_p^2}{3}} \times 100 = \frac{1.33}{8 + 1.33} \times 100$$

$$\eta =$$

(b) $m_p = 4$

$$\mu = \frac{4}{4}$$

Modulation Index.

$$\boxed{\mu = 1}$$

$$\eta = \frac{P_m}{A_c^2 + P_m} \times 100$$

$$\eta = \frac{4^2/3}{4^2 + 4^2/3} \times 100$$

$$\boxed{\eta = 25\ \%}$$

3.11

(4)

Qno4:- $i_D = \beta(4V_D + V_D^2)$

$x(t) = R\, i_D \qquad \therefore R = 1$

$$\boxed{x(t) = i_D}$$

$V_D = (A_c \cos w_c t + (\alpha + m(t)))$

$x(t) = \beta\left(4(A_c \cos w_c t + (\alpha + m(t)) + (A_c \cos w_c t + (\alpha + m(t)))^2\right)$

$x(t) = \beta\left(4(A_c \cos w_c t + (\alpha + m(t))) + A_c^2 \cos^2 w_c t + (\alpha + m(t))^2 + 2A_c \cos w_c t\,(\alpha + m(t))\right)$

$$\boxed{x(t) = \beta\left(4(A_c \cos w_c t + (\alpha + m(t))) + \frac{A_c^2}{2}(\cos 2w_c t + 1) + (\alpha + m(t))^2 + 2A_c \cos w_c t\,(\alpha + m(t))\right)}$$

Bandpassfilter of w_c cutt of frequency.

$y(t) = \beta 4 A_c \cos w_c t + 2\beta A_c \cos(w_c t)\,(\alpha + m(t))$

$$\boxed{y(t) = 2\beta A_c \cos(w_c t)\,(2 + (\alpha + m(t)))}$$ Ans

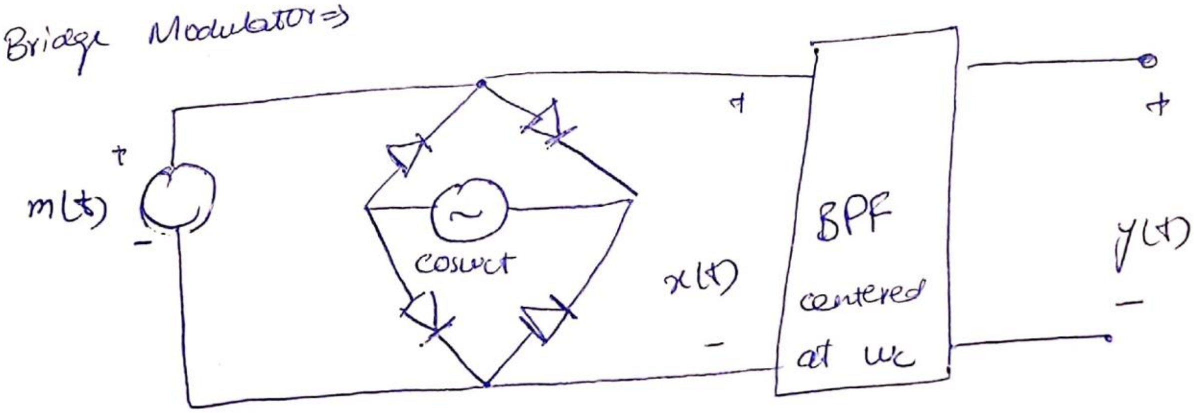
3.24

Qno6:-

Circuit Diagram :-

Band pass filter

Shunt Bridge Modulator =>



Refered to 3.35 :-

$$x(t) = \frac{1}{2} m(t) + \frac{2}{\pi} \left[m(t) \cos w_c t - \frac{1}{3} m(t) \cos 3w_c t + \frac{1}{5} m(t) \cos 5w_c t + \cdots \right]$$

$$\boxed{y(t) = \phi_{DSB\text{-}SC} = \frac{2}{\pi} m(t) \cos(w_c t)}$$ Ans

3.31

Qno7:- $BW = 10\,KHz$

(a) $\phi(t) = m(t)\cos(2\pi \times 10^5 t)$

Local oscillator $\Rightarrow$ $2\cos(1.2\pi \times 10^5 t) + 4\cos(2.8\pi \times 10^5 t)$

$$x(t) = m(t)\cos(2\pi \times 10^5 t)\left[2\cos(1.2\pi \times 10^5 t) + 4\cos(2.8\pi \times 10^5 t)\right]$$

$$x(t) = m(t)\left[2\cos(2\pi \times 10^5 t)\cos(1.2\pi \times 10^5 t) + 4\cos(2\pi \times 10^5 t)\cos(2.8\pi \times 10^5 t)\right]$$

$$x(t) = m(t)\left[\cos(3.2\pi \times 10^5 t) + \cos(0.8\pi \times 10^5 t) + 2\cos(4.8\pi \times 10^5 t) + 2\cos(0.8\pi \times 10^5 t)\right]$$

$$\boxed{x(t) = m(t)\left[3\cos(0.8\pi \times 10^5 t) + 2\cos(4.8\pi \times 10^5 t) + \cos(3.2\pi \times 10^5 t)\right]}$$ Ans

(b) Largest amplitude Term $\Rightarrow$ $3m(t)\cos(0.8\pi \times 10^5 t)$

$$\omega_c = 0.8\pi \times 10^5$$

F_high=(0.8*pi*10^5)/2*pi + 10 kHz= 50 kHz

F_low = (0.8*pi*10^5)/2*pi - 10 kHz= 30 kHz

3.33

Qno8:-

$$m_1(t) = A_1 \cos(8\pi \times 10^3 t)$$

$$m_2(t) = A_2 \cos(12\pi \times 10^3 t)$$

carrier $\rightarrow$ $2\sin(2\pi \times 10^5 t)$

a) $\phi_{QAM}(t) = ?$

$$\phi_{QAM}(t) = A_1 \cos(8\pi \times 10^3 t)\, 2\sin(2\pi \times 10^5 t) - A_2 \cos(12\pi \times 10^3 t)\, 2\cos(2\pi \times 10^5 t)$$

$$\quad'' = A_1\left[\sin(2.08\pi \times 10^5 t) - \sin(-1.92\pi \times 10^5 t)\right] - A_2\left[\cos(2.12\pi \times 10^5 t) + \cos(1.88\pi \times 10^5 t)\right]$$

$$\boxed{\phi_{QAM}(t) = A_1\left[\sin(2.08\pi \times 10^5 t) + \sin(1.92\pi \times 10^5 t)\right] - A_2\left[\cos(2.12\pi \times 10^5 t) + \cos(1.88\pi \times 10^5 t)\right]}$$ Ans

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(b) $z_1(t) = \phi_{QAM}(t) \times 2\sin((2\pi \times 10^5 t) + \alpha)$

$$z_1(t) = A_1\left(\cos(-8\pi \times 10^3 t + \alpha) - \cos(4.08\pi \times 10^5 t + \alpha) + \cos(8\pi \times 10^3 t + \alpha) - \cos(3.92\pi \times 10^5 t + \alpha)\right)$$
$$- A_2\left(\sin(4.12\pi \times 10^5 t + \alpha) + \sin(-12\pi \times 10^3 t + \alpha) + \sin(3.88\pi \times 10^5 t + \alpha) + \sin(12\pi \times 10^3 t + \alpha)\right]$$

LPF:-

$$y_1(t) = A_1\left[\cos(-8\pi \times 10^3 t + \alpha) + \cos(8\pi \times 10^3 t + \alpha)\right] - A_2\left[\sin(-12\pi \times 10^3 t + \alpha) + \sin(12\pi \times 10^3 t + \alpha)\right]$$

$$\boxed{y_1(t) = 2A_1 (\cos\alpha) \cos(8\pi \times 10^3 t) - 2A_2 (\sin\alpha) \cos(12\pi \times 10^3 t)}$$ Ans

(6)

3.37

Qno9:-

Carrier $\Rightarrow$ $A_c \sin\omega_c t$ $\qquad \therefore \omega_c = 10\omega_m$

$\Rightarrow A_c \sin(10\omega_m t)$

(a) $m(t) = A_m \sin(\omega_m t)$

$m_h(t) = -A_m \cos(\omega_m t)$

$$\Rightarrow \phi_{USB}(t) = m(t)\ A_c \sin(10\omega_m t) + A_c \cos(10\omega_m t)\ m_h t$$

$$\phi_{USB}(t) = A_m A_c \sin(10\omega_m t)\sin(\omega_m t) - A_c A_m \cos(10\omega_m t)\cos(\omega_m t)$$

$$\phi_{USB}(t) = \frac{A_c A_m}{2}\left[\cos(9\omega_m t) - \cos(11\omega_m t)\right] - \frac{A_c A_m}{2}\left(\cos(11\omega_m t) + \cos(9\omega_m t)\right)$$

$$\boxed{\phi_{USB}(t) = -A_c A_m \cos(11\omega_m t)}$$

(b) $m(t) = A_1 \sin(\omega_m t) + A_2 \cos(3\omega_m t)$

$m_h(t) = -A_1 \cos(\omega_m t) + A_2 \sin(3\omega_m t)$

$$\boxed{\phi_{USB}(t) = m(t)\ A_c \sin(10\omega_m t) + A_c \cos(10\omega_m t)\ m_h(t)}$$

$$\phi_{USB}(t) = A_c \sin(10\omega_m t)\left[A_1 \sin(\omega_m t) + A_2\cos(3\omega_m t)\right] + A_c \cos(10\omega_m t)\left(-A_1 \cos(\omega_m t) + A_2 \sin(3\omega_m t)\right)$$

$$= A_c\left[\frac{A_1}{2}\left(\cos(9\omega_m t) - \cos(11\omega_m t)\right] + \frac{A_2}{2}\left(\sin(13\omega_m t) + \sin(7\omega_m t)\right)\right] + A_c\left[-\frac{A_1}{2}\left(\cos(11\omega_m t) + \cos(9\omega_m t)\right] + \frac{A_2}{2}\left(\sin(13\omega_m t) - \sin(7\omega_m t)\right)\right]$$

$$\boxed{\phi_{USB}(t) = -A_1 A_c \cos(11\omega_m t) + A_2 A_c \sin(13\omega_m t)}$$

3.45

Qno10:- $\omega_c = 10^6$ rad/s

$\omega_m = 0.4 \times 10^5$ rad/s

$m(t) = 4\cos \omega_m(t)$

carrier $= \cos \omega_c(t)$

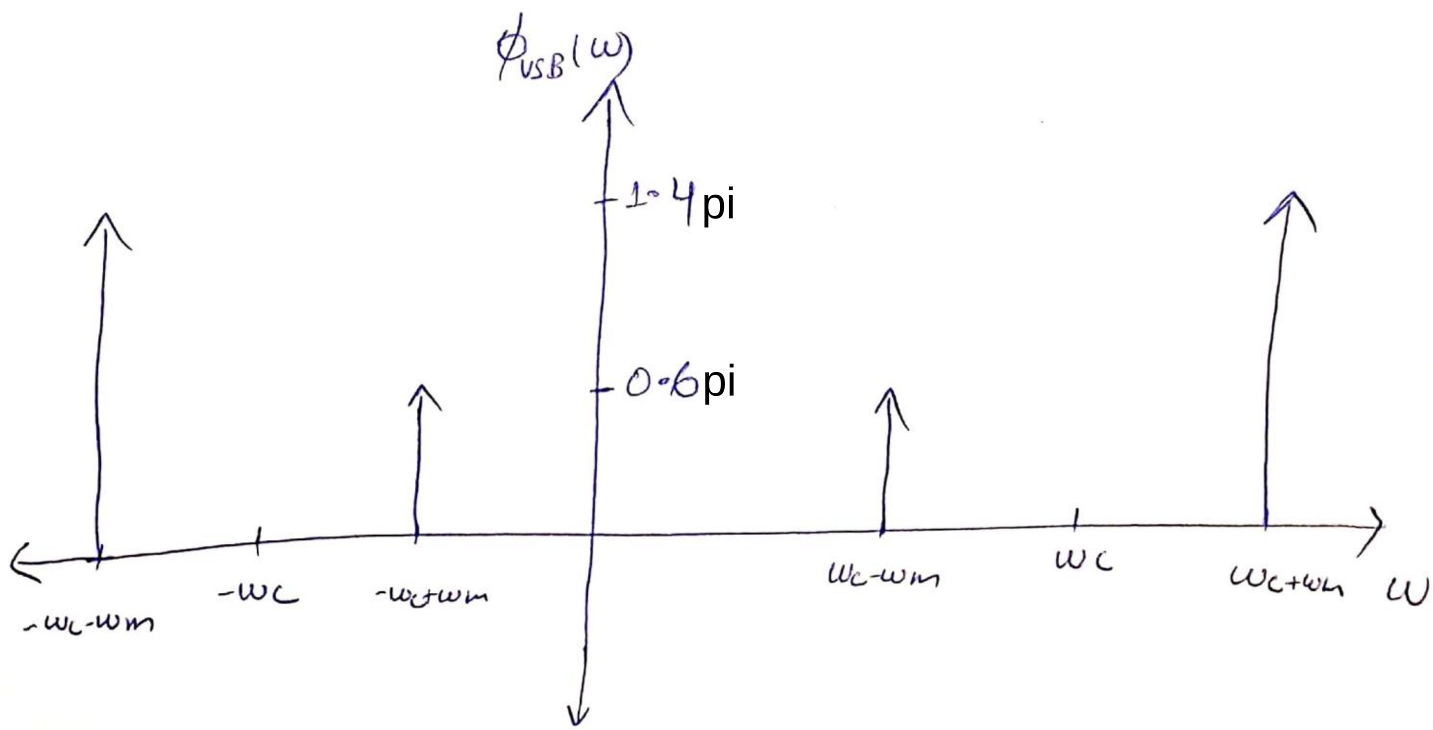
$\phi_{DSB}(t) = 4\cos(\omega_c t)\cos(\omega_m t)$

$$\boxed{\phi_{DSB}(t) = 2\left(\cos((\omega_c+\omega_m)t) + \cos((\omega_c-\omega_m)t)\right)}$$

$\omega_c+\omega_m = 10.4\times10^6$ rad/s | $\omega_c-\omega_m = 9.6\times10^6$ rad/s

$\boxed{H_u(\omega_c+\omega_m) = 0.7}$ | $\boxed{H_u(\omega_c-\omega_m) = 0.3}$

$$\boxed{\phi_{VSB}(t) = 1.4\cos((\omega_c+\omega_m)t) + 0.6\cos((\omega_c-\omega_m)t)}$$



Qno5:

7

Problem 3.13

a)

$B = 5kHz \quad f_c = 500kHz$

$C = 20nF$

as we know

$$RC = \sqrt{\frac{1}{Bf_c}}$$

$$R = \frac{1}{C}\sqrt{\frac{1}{Bf_c}} = \frac{1}{20\times10^{-9}}\sqrt{\frac{1}{5\times10^{3}\times500\times10^{3}}}$$

$$= 1K\Omega$$

b)

$$\phi_{AM}(t) = \left[A_c + A_m\cos\omega_m t\right]\cos\omega_c t = A_c\left[1 + \frac{A_m}{A_c}\cos\omega_m t\right]\cos\omega_c t$$

$$= A_c\left[1 + \mu\cos\omega_m t\right]\cos\omega_c t$$

The AM envelope is $E(t) = A_c[1+\mu\cos\omega_m t]$

the capacitor voltage is $V_c(t) = E(t)$

Ensuring that $V_c(t)$ never lies above

$E(t)$ requires that $\left|\frac{dv_c(t)}{dt}\right| \geq \left|\frac{dE(t)}{dt}\right|$

$E(t)$ & $v_c(t)$ have same peak value

$E \Rightarrow v_c(t) = Ee^{-t/RC} \approx E\left(1-\frac{t}{RC}\right)$

$V_c(t) = Ee^{-t/RC} \approx E\left(1-\frac{t}{RC}\right)$ (Taylor series approximation of e^{-x})

$$\left|\frac{dv_c(t)}{dt}\right| = \frac{E}{RC} = \frac{A_c(1+\mu\cos\omega_m t)}{RC} \geq \left|\frac{dE(t)}{dt}\right|$$

$$= \left|-\mu\omega_m A_c \sin\omega_m t\right|$$

$$\therefore \frac{1}{RC} \geq \frac{\mu\omega_m A_c \sin\omega_m t}{A_c[1+\mu\cos\omega_m t]}$$

Differentiating the first derivative to zero, its maximum occurs @

$\mu = -\cos \omega_m t$.

Thus $\frac{1}{RC} \geq \frac{\mu \omega_m}{\sqrt{1-\mu^2}}$

or

$R \leq \frac{\sqrt{1-\mu^2}}{\mu \omega_m C}$

i) for $\mu = 0.5$ $C = 20nF$

$R_{max} = \frac{\sqrt{1-0.5^2}}{0.5(2\pi \times 5\times10^3)(20\times10^{-9})} = $ 2.76 k Ohm

ii) $\mu = 0.95$ $C = 20nF$

$R_{max} = \frac{\sqrt{1-0.95^2}}{0.95(2\pi \times 5\times10^3)(20\times10^{-9})} = 523.\,\Omega$