Solution 1: (7.7-2)

Baseband bandwidth: $BW_{BB} = (1+\alpha)\frac{R_S}{2} = (1+\alpha)\frac{R_b}{2\log_2 M}$

Passband bandwidth: $BW_{PB} = 2BW_{BB}$

Part a)

$\alpha = 0 \Rightarrow \quad BW_{BB} = (1+0)\frac{12000}{2\log_2 16} = \frac{12000}{8} = 1500Hz \qquad BW_{PB} = 2*1500 = 3000Hz$

Part b)

$\alpha = 0.2 \Rightarrow \quad BW_{BB} = (1+0.2)\frac{12000}{2\log_2 16} = 1.2\times\frac{12000}{8} = 1800Hz \qquad BW_{PB} = 2*1800 = 3600Hz$

Solution 2: (7.7-3)

Part a)

Quantization error: $\Delta v = \frac{2m_p}{L}$

$\frac{\Delta v}{2} \le 0.005m_p \Rightarrow \frac{2m_p}{2L} \le 0.005m_p \Rightarrow L \ge 200 \Rightarrow L = 2^n = 2^8 = 256 \Rightarrow n = 8$

Therefore, each sample requires $n = 8$ bits.

Since each 4-ary pulse represents 2 bits, each sample will require four 4-ary pulses.

Part b)

Nyquist rate is $3.2\times 2 = 6.4kHz$.

The sampling rate is 25% above Nyquist rate which $f_s = 6.4\times 1.25 = 8kHz$

Each sample requires four 4-ary pulses and therefore the pulse rate will be

$$R_S = 4f_s = 4\times 8000 = 32000 \text{ pulses/sec}$$

Minimum Bandwidth: $BW_{BB} = \frac{R_S}{2} = \frac{32000}{2} = 16000Hz$,

$BW_{PB} = 2BW_{BB} = 2\times 16000 = 32000Hz$

Part c)

$BW_{BB} = (1+\alpha)\frac{R_S}{2} = (1+0.25)\frac{32000}{2} = 20000Hz, \quad BW_{PB} = 2BW_{BB} = 2\times 20000 = 40000Hz$

Solution 3: (7.7-4)

In this question we use polar full-width rectangular pulses.

Part a)

For binary signaling: $BW_{BB} = \dfrac{R_b}{2}$

For 16-ary signaling: $BW_{BB} = \dfrac{R_s}{2} = \dfrac{R_b}{2\log_2 16} = \dfrac{R_b}{8}$

Reduction in bandwidth: $\dfrac{R_b}{2} \div \dfrac{R_b}{8} = 4$

Part b)

For binary case, we use $\pm A/2$ and the energy of signal would be

$$E_b = \int_0^{T_b} \left(\frac{A}{2}\right)^2 dt = \frac{A^2}{4} T_b \Rightarrow \quad P_b = \frac{E_b}{T_b} = \frac{A^2}{4}$$

For 16-PAM, we use:

$$\pm A/2, \ \pm 3A/2, \ \pm 5A/2, \ \pm 7A/2, \ \pm 9A/2, \ \pm 11A/2, \ \pm 13A/2, \ \pm 15A/2$$

$$E_{16PAM} = \frac{2}{16}\left[\frac{A^2}{4} + \frac{9A^2}{4} + \frac{25A^2}{4} + \frac{49A^2}{4} + \frac{81A^2}{4} + \frac{121A^2}{4} + \frac{169A^2}{4} + \frac{225A^2}{4}\right] T_S$$

$$E_{16PAM} = 85\frac{A^2}{4} T_S \Rightarrow \quad P_{16PAM} = \frac{E_{16PAM}}{T_S} = 85P_b$$

Solution 4: (7.7-5)

Part a)

$$BW_{BB} = \frac{R_b}{2} \Rightarrow \quad BW_{PB} = R_b$$

For binary case, we use $\pm A/2$ and the energy of signal would be

$$E_b = \int_0^{T_b/2} \left(\frac{A}{2}\right)^2 dt = \frac{A^2}{4} \times \frac{T_b}{2} = \frac{A^2 T_b}{8} \Rightarrow \quad P_b = \frac{E_b}{T_b} = \frac{A^2}{8}$$

Part b)

$$BW_{BB} = \frac{R_S}{2} = \frac{R_b}{2\log_2 M} \Rightarrow \quad BW_{PB} = \frac{R_b}{\log_2 M}$$

$$E_{MPAM} = \frac{2}{M}\left[\frac{A^2}{8} + \frac{(3A)^2}{8} + \frac{(5A)^2}{8} + \ldots + \frac{(M-1)^2 A^2}{8}\right]T_S = \frac{2}{M}\left[1 + 3^2 + 5^2 + \ldots + (M-1)^2\right]\frac{A^2}{8}T_S$$

$$E_{MPAM} = \frac{2}{M}\left[\frac{M^3 - M}{6}\right]\frac{A^2}{8}T_S = \frac{M^2 - 1}{3}\frac{A^2 T_S}{8}$$

$$P_{MPAM} = \frac{E_{MPAM}}{T_S} = \frac{(M^2 - 1)A^2}{24}$$

Proof of $\left[1 + 3^2 + 5^2 + 7^2 \ldots + (M-1)^2\right] = \frac{M^3 - M}{6}$

$$\left[1 + 3^2 + 5^2 + 7^2 \ldots + (M-1)^2\right] = \sum_{k=0}^{m=(M-2)/2} (2k+1)^2 = 4\sum_{k=0}^{m=(M-2)/2} k^2 + 4\sum_{k=0}^{m=(M-2)/2} k + \frac{M}{2}$$

$$= 4 \times \frac{m(m+1)(2m+1)}{6} + 4 \times \frac{m(m+1)}{2} + \frac{M}{2} = \frac{2m(m+1)(2m+1) + 6m(m+1)}{3} + \frac{M}{2}$$

$$= \frac{4m^3 + 6m^2 + 2m + 6m^2 + 6m}{3} + \frac{M}{2} = \frac{4m^3 + 12m^2 + 8m}{3} + \frac{M}{2}$$

$$= \frac{4\left(\frac{M-2}{2}\right)^3 + 12\left(\frac{M-2}{2}\right)^2 + 8\left(\frac{M-2}{2}\right)}{3} + \frac{M}{2} = \frac{4\left(\frac{M-2}{2}\right)^3 + 12\left(\frac{M-2}{2}\right)^2 + 8\left(\frac{M-2}{2}\right)}{3} + \frac{M}{2}$$

$$= \frac{(M-2)^3}{6} + (M-2)^2 + \frac{4(M-2)}{3} + \frac{M}{2} = \frac{M^3 - M}{6}$$

Solution 5: (7.7-6)

$256 = 2^n \Rightarrow \quad n =$ Number of bits per sample $= 8$

$$R_b = n \times f_S = 8 \times 44.1 = 352.8 \quad kbits/\sec$$

$$BW_{BB} = (1+\alpha)\frac{R_S}{2} = (1+\alpha)\frac{R_b}{2\log_2 M} = (1+0.25)\frac{352{,}8}{2\log_2 M} = \frac{441}{2\log_2 M} \le 30 \Rightarrow$$

$$\log_2 M \ge \frac{441}{60} \Rightarrow \quad M \ge 2^{\left(\frac{441}{60}\right)} \Rightarrow \quad M \ge 2^{7.35} \quad M = 2^8$$

Note that we have taken smallest possible M satisfying the bandwidth requirement to achieve the best possible performance.

Solution 6: (7.8-1)

Part a)

$$BW_{PB} = R_b = 10^6\, Hz = 1 \quad MHz$$

Part b)

$$\Delta f = \frac{f_{C1} - f_{C2}}{2} = \frac{100}{2} = 50 \quad kHz$$

$$B = \frac{R_b}{2} = \frac{10^6}{2} = 500 \quad kHz$$

$$BW_{PB} = 2(\Delta f + B) = 2(50 + 500) = 1100 \quad kHz$$

Solution 7: (7.8-2)

Part a)

$$BW_{PB} = (1+\alpha)R_b = (1+0.2)\times 10^6\, Hz = 1.2 \quad MHz$$

Part b)

$$B = (1+\alpha)\frac{R_b}{2} = (1+0.2)\frac{10^6}{2} = 600 \quad kHz$$

$$BW_{PB} = 2(\Delta f + B) = 2(50 + 600) = 1300 \quad kHz$$

Solution 8:

Part a)

$$P_e = Q\left(\frac{A_P}{\sigma_n}\right) = 10^{-7}$$

From Q-function table: $\dfrac{A_P}{\sigma_n} = 5.20$

$$\sigma_n = 1 \quad mV \Rightarrow \quad A_P = 5.20\times 10^{-3} \quad V$$

Power of the signal for a polar full width pulse is: $P_{received} = A_P^2 = \left(5.20\times 10^{-3}\right)^2 = 27.04\times 10^{-6} \quad Watts$

Part b)

$$40dB = 10\log X \Rightarrow \quad X = 10^4 = 10000$$

Transmitted power $= 10000 P_{received} = 10000\times 27.04\times 10^{-6} = 0.2704 \quad Watts$

Part c)

Average number of errors in one hour $= 3600\times 100000\times 10^{-7} = 36$