Problem 4.13

(a) The frequency deviation is

$$\Delta f = k_f A_m = 25 \times 10^3 \times 20 = 5 \times 10^5 \text{Hz}$$

The corresponding value of the modulation index is

$$\beta = \frac{\Delta f}{f_m} = \frac{5 \times 10^5}{10^5} = 5$$

Using Carson's rule, the transmission bandwidth of the FM wave is therefore

$$B_T = 2 f_m(1 + \beta) = 2 \times 100(1 + 5) = 1200\text{kHz} = 1.2\text{MHz}$$

(b) Using the universal curve of Fig. 4.9, we find that for $\beta = 5$:

$$\frac{B_T}{\Delta f} = 3$$

Therefore, the transmission bandwidth is

$$B_T = 3 \times 500 = 1500\text{kHz} = 1.5\text{MHz}$$

which is greater than the value calculated by Carson's rule.

(c) If the amplitude of the modulating wave is doubled, we find that

$$\Delta f = 1\text{MHz} \quad \text{and} \quad \beta = 10$$

Thus, using Carson's rule we now obtain the transmission bandwidth

$$B_T = 2 \times 100(1 + 10) = 2200\text{kHz} = 2.2\text{MHz}$$

On the other hand, using the universal curve of Fig. 4.9, we get

$$\frac{B_T}{\Delta f} = 2.75$$

and $B_T = 2.75$ MHz.

(d) If f_m is doubled, $\beta = 2.5$. Then, using Carson's rule, $B_T = 1.4$ MHz. Using the universal curve, $(B_T/\Delta f) = 4$, and

$$B_T = 4\Delta f = 2\text{MHz}$$