5.1-2)

a)  

The FM instantaneous frequency varies between 0.999 MHz and 1.001 MHz as $m(t)$ varies between -1 and +1.

The PM signal has a constant instantaneous frequency of 1.0005 MHz but there is a 180° phase shift at the discontinuities in $m(t)$.

The graphs below show the message, the FM and the PM waveforms respectively from top to bottom. The carrier frequency has been reduced by a factor of 100 and $k_f$ has been increased by a factor of 4 (for the FM waveform) in order to more clearly see the changes in the waveforms.

b)  

The PM waveform is equivalent to a PM rectangular waveform with $k_p = \pi$. Based on just the phase shifts it would be impossible to distinguish this $m(t)$ from one that had a slope 3 times greater or with a negative slope. Keeping the phase deviation less than $\pi$ prevents this problem.

5.1-4)

a)  

$m(t) = 3\pi t$
b) \( m(t) = 3\pi \)

5.2-5)

a) \( P = 12.5 \text{ W} \)

b) \( \Delta f = 20 \text{ kHz} \)

c) \( \Delta \varphi = 26 \text{ rad} \)

d) \( B_{EM} = 42 \text{ kHz} \)

5.2-7)

a) \( B_{FM} = 202 \text{ kHz}, \quad B_{PM} = 22 \text{ kHz} \)

b) \( B_{FM} = 402 \text{ kHz}, \quad B_{PM} = 42 \text{ kHz} \)

c) \( B_{FM} = 204 \text{ kHz}, \quad B_{PM} = 442 \text{ kHz} \)

d) \( B \) of PM is more sensitive to changes in spectrum of \( m(t) \).

5.2-9)

a) \[
\sum_{n=-\infty}^{\infty} J_n^2(\beta) = 1
\]

Hint: Compare the total power of the carrier to the total power determined from the Fourier Series expansion of the tone-modulated carrier.

b) \( J_{-n}(\beta) = (-1)^n J_n(\beta) \)

Hint: Make the variable substitution \( x = \pi - \lambda \) in the defining integral for \( J_n(\beta) \).
Recognize that the integrand is periodic with period 2\( \pi \) and that the same result would be obtained by integrating over any 2\( \pi \) interval.

You can also show (by a similar method) that \( J_n(-\beta) = (-1)^n J_n(\beta) \)

5.3-2)

a) I believe this is the only system that exactly meets the specifications.
At the output of the NBFM generator $f_c = 100$ kHz, $\Delta f = 10$ Hz.

At the output of the first multiplier (x125) $f_c = 12.5$ MHz, $\Delta f = 1250$ Hz.

The mixer produces sum and difference frequencies of $f_c$ equal to 23.365 MHz and 1.635 MHz. The $\Delta f$ is 1250 Hz at both carrier frequencies. Mixing does not change the $\Delta f$ value.

At the output of the BPF $f_c = 1.635$ MHz, $\Delta f = 1250$ Hz. (Assuming $B = 15$ kHz, the required BPF bandwidth is 32.5 kHz.)

As specified, at the output of the second multiplier (x60) $f_c = 98.1$ MHz, $\Delta f = 75$ kHz.

The first multiplier consists of three frequency quintuplers ($x5^3$).

The second multiplier consists of two doublers ($x2^2$), one tripler ($x3$) and one quintupler ($x5$).

b) By varying the local oscillator between 10 MHz and 11 MHz the output carrier frequency varies between 90 MHz and 150 MHz. The center frequency of the BPF would need to vary between 1.5 MHz and 2.5 MHz (or have a fixed center frequency of 2 MHz and a BW of approximately 1 MHz in order to pass the range of difference frequencies while filtering out all of the corresponding sum frequencies).