1. **SS 8.73.** An amplifier has a dc gain of $10^5$ and poles at $10^5$ Hz, $3.16 \times 10^5$ Hz, and $10^6$ Hz. Find the value of $\beta$ and the corresponding closed-loop gain, for which a phase margin of $45^\circ$ is obtained.

A phase margin of $45^\circ$ corresponds to a amplifier phase of $-135^\circ$. Assuming that the poles are widely spaced, that phase occurs exactly at the second pole. At the second pole the gain of the amplifier is down by a factor of $1/\sqrt{2}$ relative to what it would be from the first pole. From the first pole it will be down by a factor of $1/3.16$. Total amount down is thus a factor of $0.226$, and the amplifier gain at that point is

$$A(\phi = -135^\circ) = 0.226 \times 10^5 = 2.26 \times 10^4$$

At that point, the value of $\beta$ is

$$\beta = \frac{1}{\alpha} = 3.91 \times 10^{-5}$$

The corresponding closed-loop gain is

$$G_{in} = \frac{A}{1 + A\beta} = \frac{2.26 \times 10^4 e^{-j135^\circ}}{1 + e^{-j135^\circ}} = \frac{2.26 \times 10^4 \times e^{-j135^\circ}}{1 - \frac{1}{\sqrt{2}} - j\frac{1}{\sqrt{2}}} = \frac{2.26 \times 10^4 \times e^{-j135^\circ}}{0.293 - j0.707}$$

The amplitude is

$$|G_{in}| = \frac{2.26 \times 10^4}{\sqrt{0.293^2 + 0.707^2}} = 2.95 \times 10^4$$

(Larger than the open-loop gain at that frequency).

2. **SS 8.75.** For the amplifier described by Fig. 8.37 and with frequency-independent feedback, what is the minimum closed-loop voltage gain that can be obtained for phase margins of $90^\circ$ and $45^\circ$?

Here is the figure with the readings labeled by the two sets of wide dotted lines.
For a 90° phase margin the phase of $A$ should be 90°. That corresponds to $|A| = 90$ dB, and thus a minimum value of $1/\beta = 90$ dB = 31622.8. The corresponding minimum closed loop gain is

$$G_{\text{min}} = \frac{Ae^{-j90^\circ}}{1 + A\beta} = \frac{31622.8e^{-90^\circ}}{1 + e^{-j90^\circ}}$$

which has amplitude

$$|G_{\text{min}}| = \frac{31622.8}{\sqrt{2}} = 2.2 \times 10^4$$

For a 45° phase margin the amplifier open-loop gain is $|A| = 80$ dB = $10^4$. That is also the value of the minimum value of $1/\beta$. The phase of the loop gain is now $-135^\circ$. And the closed-loop gain is

$$G_{\text{min}} = \frac{A}{1 + A\beta} = \frac{10^4e^{-j135^\circ}}{1 + e^{-j135^\circ}} = \frac{10^4e^{-j135^\circ}}{1 - \frac{1}{\sqrt{2}} - j\frac{1}{\sqrt{2}}} = \frac{10^4e^{-j135^\circ}}{0.293 + j\frac{1}{\sqrt{2}}}$$
The minimum amplitude of the gain is then

$$|G_{\text{min}}| = \frac{10^4}{\sqrt{0.293^2 + \frac{1}{2}}} = 1.3 \times 10^4$$

3. SS 8.76. A multipole amplifier having a first pole at 2 MHz and a dc open-loop gain of 80 dB is to be compensated for closed-loop gains as low as unity by the introduction of a new dominant pole. At what frequency must the new pole be placed?

We want to move the second pole to unity open-loop gain, from a open-loop gain of $10^4$ where it is now. To achieve this we need to insert a pole whose frequency is $10^4$ times smaller than the existing pole. Its frequency should thus be

$$f_{\text{new}} = \frac{f_{\text{existing}}}{10^4} = \frac{2 \times 10^6}{10^4} = 200 \text{ Hz}$$