Solution to Question #1:

i) The transfer functions are:

$$T_A(s) = \frac{20}{(s+1)(s-10)}, \text{ and } T_B(s) = \frac{50(s-1)}{(s-10)^2}.$$

The precise values are not important. What is important is that: system A has a DC gain of about -2, whereas system B has a DC gain of about $-1/2$, then also, the approximate location and nature of poles/zeros.

ii) Nyquist drawn in Figures 3, 4.

iii) Negative unity-gain feedback stabilizes the second but not the first. The reason being that the Nyquist-diagram of the first has an encirclement count of $N = 1$ whereas for the second, $N = -2$. Clearly, the second system must have two unstable open-loop poles and the closed-loop system with system B in the forward path is stable.

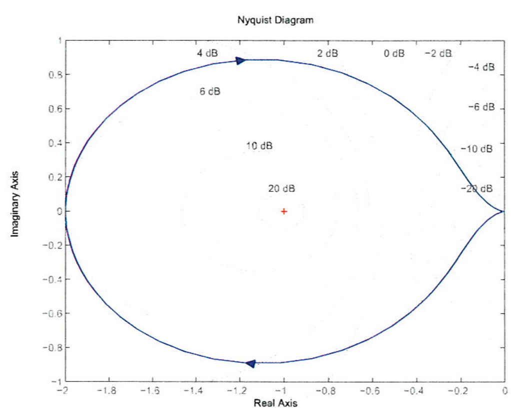

Fig. 3. Nyquist plot for `system 1`.

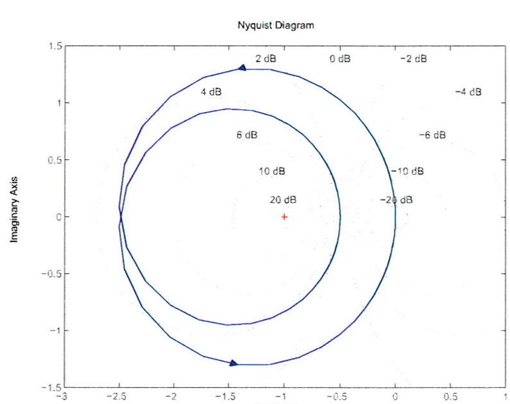

Fig. 4. Nyquist plot for `system 2`.

Solution to Question #2:

i) Using the final-value theorem, the steady-state value of the output is

$$\lim_{t\to\infty} y(t) = \lim_{s\to 0} s\frac{1}{s}\frac{k/(s+1)}{1+k/(s+1)} = \frac{k}{k+1}.$$

Since

$$\begin{aligned}\frac{k}{k+1} &= 2-\sqrt{2}\\ &= \sqrt{2}(\sqrt{2}-1)\\ &= \frac{\sqrt{2}}{\sqrt{2}+1}\end{aligned}$$

it is clear that $k = \sqrt{2}$.

ii) Consider the Nyquist plot for $\sqrt{2}/(s+1)$. This is a circle with center at $s = \sqrt{2}/2$ and diameter $\sqrt{2}$. Thus, the point on the Nyquist diagram which is at a distance 1 from the origin is the point with coordinates $(\frac{\sqrt{2}}{2}, -\frac{\sqrt{2}}{2})$, whose angular distance from $(-1, 0)$ is 135 degrees, and therefore the phase margin is 135^o.

Solution to Question #3:

Simply choose a state-feedback gain $K = [0. \ -1]$ so that $A - BK = \begin{bmatrix} 0 & 1 \\ -1 & -2 \end{bmatrix}$.