1. The s-parameter block given in the problem has data from 1GHz to 300 GHz. The setup is shown below:

The maximum available gain is plotted directly from ADS simulation setup, while the maximum stable gain (MSG) and Mason’s Unilateral Gain (U) are plotted using equations derived in class. The plots of Maximum available gain is shown below. We see that there is a kink in the graph, as expected, because the device goes from conditionally stable region to unconditionally stable region.
We see that below 11 GHz, MSG and Maximum Available Gain curves overlap, meaning that the device is not unconditionally stable below 11 GHz. After 11 GHz, k-factor is greater than 1 and hence the MSG is greater than the maximum available gain of the circuit. This is verified by plotting the stability factor (k). Consistent with our understanding, both MAG and U cross the 0 dB point at the same frequency.
1. The load stability circle and power gain circles are plotted (from 1GHz to 11 GHz)

We see that the load stability circles become smaller and smaller as we go up in frequency. However, the power gain circles always intersect the load stability circle and hence the device is not unconditionally stable.

To get a better feel, let's plot the load stability circle and 12 dB power gain circle at our desired frequency of 5 GHz.
From this plot, we can say that any point on the power gain circle which is not inside the blue circle (load stability circle) is a potential load. Since $|S_{11}| < 1$ and $|S_{22}| < 1$, the centre is stable. For example, m1 (shown above) is a potential load. The farther the load point away from the instability region, better is the design. So m1 might be a good starting point.

2. The source stability and available gain plots are shown for 5 GHz.

We see that the source instability region crosses only a small portion of the unity Smith Chart. So we may begin our design by choosing the load first and conjugate match the source and re-check for stability.
3. Let's now begin designing the amplifier by choosing point m1 (in Gp circle), a load far away from the instability region, and designing the matching network. For this, we use the Smith tool in ADS.
After having designed the load matching network, we again check for source stability as shown below.

\[
\begin{align*}
\text{m1} & \\
\text{indep(m1)=11} & \\
\text{GpCircle1}=0.015 / 0.613 & \\
\text{gain}=12.000000, \text{freq}=5.000000\text{GHz} & \\
\text{impedance} = Z_0 * (1.030 + j2.758E-4) & \\
\end{align*}
\]

Now, since \(|S11| < 1\), we can design conjugate match at the source for impedance matching. Once again, we use the Smith tool in ADS.

The matching network is a simple L match. The component values are shown in the figure below.
The final results are shown below.

After the final design, $|S_{22}|$ is very close to 1. So not only are we very highly mismatched at the load, but we are also close to instability and process variation might push us into the unstable region.

5. In the design of a 2-stage amplifier, first we cascade 2 stages simply without any matching network and observe the stability factor of the amplifier. We see that the stability factor of the amplifier is much greater than 1 over all frequencies. So it is unconditionally stable and we can design for bi-conjugate match to get input and output match.
Let us now plot the MAG of the cascaded amplifier. From the plot below, we see that bi-conjugate match can give about 44.5 dB of stable gain. But we need only 12 dB. Since there is no noise consideration in this problem, we can place a resistor at the input or in between the two stages and reduce the amplifier gain, and readjust the matching network to obtain input and output match.

\[
\text{Eqn} \quad \text{msg} = 10 \log \left( \frac{\text{mag}(S(2,1))}{\text{mag}(S(1,2))} \right)
\]

Following this strategy, the 2 stage amplifier is designed as shown below.
An alternative design is to insert a tank between the two stages and tune it to higher than 5 GHz, so that some of the current produced by the first stage is shunted out at 5 GHz and we get less gain than MAG.