An MOS capacitor on a 14 mil wafer with a sheet resistance of 90 \( \Omega/sq \) (as measured with the M-gage), a 74.1 nm thick oxide (as measured with the ellipsometer) and 0.0704 cm\(^2\) gate contact area yielded the following experimental values for the high-frequency capacitance:

<table>
<thead>
<tr>
<th>( V_G )</th>
<th>( C )</th>
<th>( V_G )</th>
<th>( C )</th>
<th>( V_G )</th>
<th>( C )</th>
</tr>
</thead>
<tbody>
<tr>
<td>-10 V</td>
<td>0.77 nF</td>
<td>-5 V</td>
<td>1.27 nF</td>
<td>0 V</td>
<td>3.03 nF</td>
</tr>
<tr>
<td>-9 V</td>
<td>0.77 nF</td>
<td>-4 V</td>
<td>1.79 nF</td>
<td>-15 V</td>
<td>0.77 nF</td>
</tr>
<tr>
<td>-8 V</td>
<td>0.78 nF</td>
<td>-3 V</td>
<td>2.48 nF</td>
<td>15 V</td>
<td>3.03 nF</td>
</tr>
<tr>
<td>-7 V</td>
<td>0.83 nF</td>
<td>-2 V</td>
<td>2.82 nF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-6 V</td>
<td>0.93 nF</td>
<td>-1 V</td>
<td>2.97 nF</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a) Plot the capacitance versus voltage as obtained from the experiment.

b) Extract from the experimental data the gate oxide capacitance, the oxide thickness, the doping concentration of the substrate and the maximum depletion layer width under thermal equilibrium. How do the oxide thickness and doping concentration compare with those obtained from the ellipsometer and M-gage measurement? Calculate the relative difference for each parameter.

c) Calculate the value of the flatband capacitance using equation [A.6.12] in the handout on the MOS capacitor. Using the experimental C-V curve, determine the flatband voltage. Assuming that the shift in flatband voltage is caused by a surface charge density \( Q_{tot} = qN_{SS} \), located at the oxide-silicon interface, find the surface state density \( N_{SS} \).

d) Calculate the capacitance versus voltage based on the doping concentration and gate oxide capacitance obtained in part b), using the analytical model which is described in the handout. Plot your calculated curve together with the experimental values.

e) Calculate the capacitance at the threshold voltage and plot it together with the flatband capacitance on the plot obtained in part d). Provide the numeric result in addition to the corresponding points on the graph.