Example 6.2  Calculate the threshold voltage of a silicon nMOS capacitor with a substrate doping \( N_d = 10^{17} \text{ cm}^{-3} \), a 20 nm thick oxide (\( \varepsilon_{ox} = 3.9 \varepsilon_0 \)) and an aluminum gate (\( \Phi_M = 4.1 \text{ V} \)), a \( p^+ \) polysilicon gate and an \( n^+ \) polysilicon gate. Use the polysilicon gate parameters listed in Example 6.1. Repeat for a pMOS capacitor with the same doping and oxide thickness. Assume there is no fixed charge in the oxide or at the oxide-silicon interface.

Solution  The threshold voltage equals:

\[
V_T = V_{FB} + 2\phi_F + \frac{\sqrt{4\varepsilon, qN_d\phi_F}}{C_{ox}}
\]

\[
= -0.93 + 2 \times 0.42 + \frac{\sqrt{4 \times 11.9 \times 8.85 \times 10^{-14} \times 1.6 \times 10^{-19} \times 10^{17} \times 0.42}}{3.9 \times 8.85 \times 10^{-14} / 20 \times 10^{-7}}
\]

\[
= 0.88 \text{ V}
\]

Where the flatband voltage was already calculated in example 6.1. The threshold voltage voltages for nMOS and pMOS capacitors with an aluminum or a poly-silicon gate are listed in the table below.

<table>
<thead>
<tr>
<th></th>
<th>Aluminum</th>
<th>( p^+ ) poly</th>
<th>( n^+ ) poly</th>
</tr>
</thead>
<tbody>
<tr>
<td>nMOS</td>
<td>0.88 V</td>
<td>1.95 V</td>
<td>0.83 V</td>
</tr>
<tr>
<td>pMOS</td>
<td>-1.90 V</td>
<td>-0.83 V</td>
<td>-1.95 V</td>
</tr>
</tbody>
</table>