1.

There are only two poles because, since we can only specify the initial conditions on at most two capacitors without having specified all capacitor initial conditions, there are only two independent energy storage elements.

We assume $C_{gd}$ is large, so we can apply Miller approximation here:

$$P_1 \approx -\frac{1}{R_s \cdot (C_{gs} + (1+g_{m}R_o)C_{gd})}$$

$$P_2 \approx -\frac{1}{R_o \cdot (C_{gd} + C_{ub})}$$

Adding a resistor, $R_{gd}$, adds another degree of freedom since we can now specify the initial conditions on all three capacitors independently. So, there are now three poles.
The equivalent small signal circuit:

\[ \begin{align*}
V_{in} & \quad R_gd \quad C \\
\quad & \quad R_s \quad C_1 \quad V_{gs} \\
\quad & \quad V_g \cdot V_{gs} \quad r_0 \quad C_2 \\
\quad & \quad V_0
\end{align*} \]

\[ C_1 = C_{gs} \quad C = C_{gd} \quad C_2 = C_{eb} + C_L \]

(include load capacitance)

The transfer function can be found:

\[ \frac{V_o}{v_{in}} = \frac{Gm R_s r_0 \left[ 1 - SC \left( \frac{1}{Gm} - R_{gd} \right) \right]}{1 + bs + fs^2 + ds^3} \]

\[ b = r_0 (C_e + C) + R_s (C_1 + C) + R_{gd} C + Gm R_s r_0 C \]

\[ f = R_s r_0 (C_1 + C_2 + C_{C1} + C_{C2}) + R_{gd} C (R_{C1} + r_0 C_2) \]

\[ d = R_s r_0 R_{gd} C_1 C_2 C \]

Assume \( Gm R_s \), \( Gm r_0 \gg 1 \) and \( C_{gd} \) is large:

\[ \begin{align*}
P_1 & \approx -\frac{1}{Gm R_s r_0 C} \\
P_2 & \approx -\frac{Gm C}{C_1 C_2 + C(C_1 + C_2)} \approx -\frac{G_m}{C_1 C} \\
P_3 & \approx -\frac{1}{R_{gd} C_1}
\end{align*} \]
2.

a) The equivalent small signal circuit shows below:

\[ V_{gs} \cdot S C_{gs} + G_m V_{gs} = -I_T \]
\[ V_{gs} \cdot S R_s C_{gs} + V_{gs} = -V_T \]

\[ Z_{out} = \frac{V_T}{I_T} = \frac{1 + S R_s C_{gs}}{G_m + S C_{gs}} \]

b) When \( S \to 0 \), \( Z_{out} = Z_{dc} = \frac{1}{G_m} \)

\[ S \to \infty, Z_{out} = R_s \]

Since \( \frac{1}{G_m} < R_s \), \( Z_{out} \) shows inductive behavior compared with the circuit.
we have:

\[ R_1 = R_s - \frac{1}{g_m} \]

\[ R_2 = \frac{1}{g_m} \]

\[ L = \frac{C_{gs}}{g_m} \left( R_s - \frac{1}{g_m} \right) \]