An MOS capacitor is made on an n-type Si-wafer with a doping concentration of $10^{15}$ cm$^{-3}$. The oxide thickness is 10 nm. The capacitor is formed by depositing a metal through a shadow mask with a diameter of 0.5 mm. Calculate the following assuming the MOS capacitor to be ideal.

1. Oxide capacitance
2. Using the following expression for Debye length calculate the flat-band capacitance.

$$L_D = \sqrt{\frac{2K_s \varepsilon_0 \frac{kT}{q}}{qN_D}}$$

3. Calculate the maximum depletion width using the following expression:

$$W_{d,max} = \sqrt{\frac{2K_s \varepsilon_0 (2\varphi_F)}{qN_D}}$$

where \( \varphi_F = \frac{kT}{q} \ln \frac{N_D}{n_i} \) (\( n_i = 10^{10} \) cm$^{-3}$ is the intrinsic carrier concentration in Si at 300 K).

4. Calculate the minimum capacitance ($C_{min}$).

The dielectric constant $K_s$ of Si is 11.7 and of the oxide $K_{ox}$ is 3.9

Boltzmann constant $k = 8.617 \times 10^{-5}$ eV/K