Problem 1 (35 points)

Objective: Determine the DC and AC characteristics of a three-stage CMOS op-amp.

Consider the three-stage CMOS op-amp as shown below. The nMOS transistor parameters are $V_{TN} = 0.7 \, \text{V}$, $k'_n = 80 \, \mu\text{A/V}^2$, $\lambda_n = 0.01 \, \text{V}^{-1}$. The pMOS transistor parameters are $V_{TP} = -0.7 \, \text{V}$, $k'_p = 40 \, \mu\text{A/V}^2$, $\lambda_p = 0.015 \, \text{V}^{-1}$. Assume the reference current is $I_{REF} = 160 \, \mu\text{A}$. 
Problem 2 (25 points, Optional Extra Credit)

Objective: Design a two-pole low-pass Butterworth filter for an audio amplifier application.

Specifications: The circuit with the configuration shown below in (a) is to be designed such that the bandwidth is 20 KHz. Part (b) shows the Bode plot and transfer function magnitude.

Assume an ideal op-amp is available. Also, standard-valued resistors and capacitors must be used.
Problem 3 (25 points)

Objective: Understanding the basic properties of the Schmitt trigger.

What is a non-zero-level Schmitt trigger capable of? Draw such a Schmitt trigger in the non-inverting configuration and derived its hysteresis voltage $V_H$ and mid-point voltage $V_M$. Comment on how this trigger differs from the zero-level Schmitt trigger.
Problem 4 (40 points)

Objective: Comprehensive design problem for a real-world application using analog circuits.

For this Problem, consider the design of an “automatic street lamp”. The lamp lights up automatically at sunset, and turns itself off at sunrise. This is based on the brightness of the outdoor environment using photo detectors, op-amp comparators, diodes, and resistors. Design a circuit to implement this system. Draw a circuit diagram and provide sufficient circuit analysis details to validate your design.