Problem 1 [40 pts] Assume that an uncompensated operational amplifier (Op-Amp) has the following transfer function from the differential voltage $V_p - V_n$ to the output voltage V_o.

$$a(s) = \frac{10^5}{(1 + 10^{-4}s)(1 + 10^{-6}s)}$$

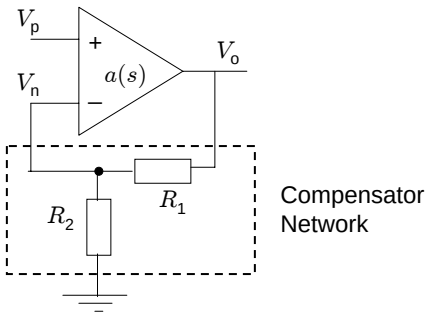

Figure 1: The Op-Amp with the static compensator

1. (5pts) Carefully sketch the bode plot corresponding to $a(s)$. Make sure that your axis are correctly labeled and the asymptotes are evident.

2. (10pts) If the Op-Amp is compensated by the resistive network shown in Figure 1, Provide values for the two compensator resistors so that the closed loop transfer function from V_p to V_o has a DC gain equal to 10.

   To answer this question, assume that V_o is not affected by the load provided by the compensator network, and that the current flowing into the (-) terminal is zero, thus that V_n is determined by the compensator transfer function. *The resistive network realizes a proportional controller; assume this gain to be K.*

3. (10 pts) Describe what is the unit step response you expect from the compensated amplifier, and why. *Hint: Find the gain cross-over frequency and phase margin.*

4. (5pts) Provide the relationship between the pole and zero of a first order lead compensator. To improve the response, the control engineers decide to use a lead compensator. Such a compensator can be built by putting a capacitor in parallel to one of the resistors. Modify the compensator circuit using a capacitor that can realize a lead compensator behavior.

5. (10 pts) Keeping the values of the resistors you have found in Part 2, find a value of the capacitor, for the lead compensator in Part 4, that improves the closed loop step response without reducing the closed loop bandwidth. Explain. *Hint: Increase the phase margin.*