Midterm Exam (closed book/notes)

Name (Last, First)

SID

EE 20/40 or 16AB

Guidelines: Closed book. You may use a calculator.
Do not unstaple the exam. In order to maximize your score, write clearly and indicate each step of your calculations. We cannot give you partial credit if we do not understand your reasoning. Feel free to use scratch paper but copy the final results to the exam (do not staple any additional sheets).

The resistance of a material is related to the physical dimensions and resistivity by

$$R = \frac{\rho L}{tW} = \frac{\rho}{t}\frac{L}{W} = R_{sq}\frac{L}{W}$$

The capacitance of a parallel plate structre is given by

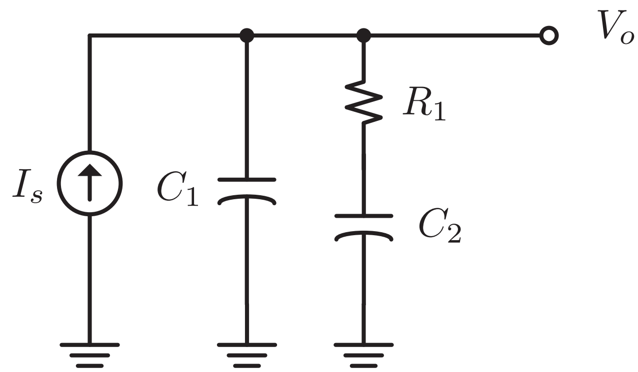
$$C = \frac{\epsilon A}{d}$$

The conductivity of a material depends on charge density (n and p), mobility $\mu_{n,p}$, and charge of carriers q_e:

$$\sigma = q_e(\mu_n n + \mu_p p)$$

where $q_e = 1.60217662 \times 10^{-19}$C for an electron.

1. (25 points) Consider a circuit with input current I_s and output voltage V_o:



(a) Find the transfer function V_o/I_s and put into a standard form.

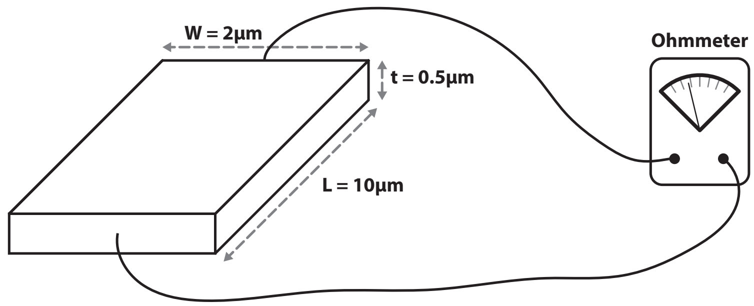
(b) What is the DC gain ?

(c) What are the poles and zeros?

(d) Draw the magnitude Bode plot using the following numerial values: $C_1 = 4\text{nF}$, $C_2 = 6\text{nF}$, $R_1 = 625\Omega$. Clearly label the graph, including the x-axis intercept point and any breakpoints. You may approximate the plot by using strainge lines.

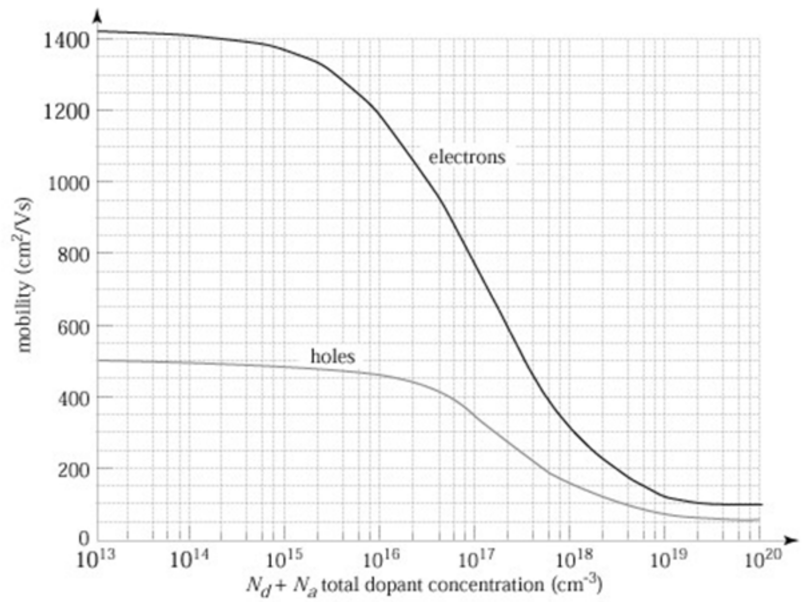
(e) Draw the phase Bode plot using the same numerical values. Clearly label the graph. You may approximate the plot by using strainge lines.

2. (25 points) You are working in a fabrication lab, and you find a slab of silicon, with dimensions as shown below. You know that it has been doped with **n-type** material, but are not sure what concentration. Using an ohmmeter, you measure the resistance to be about $4.5M\Omega$, measuring across the longest dimension of the material as shown.



(a) Based on the dimensions shown, what is the resistivity of the sample? The conductivity?

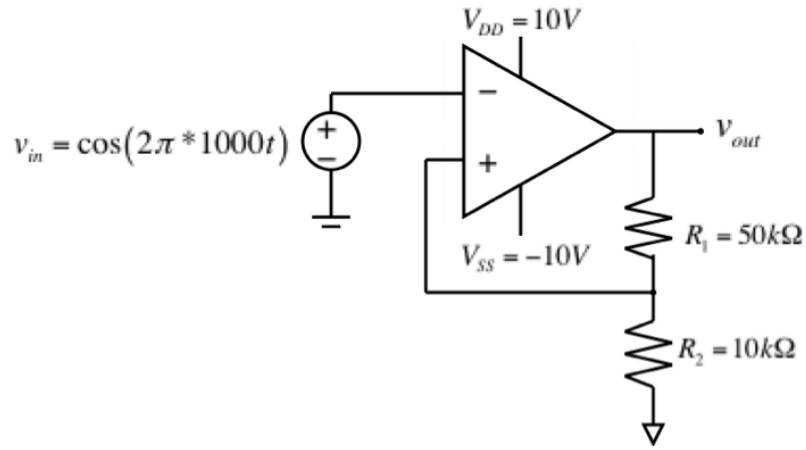
(b) You find out from another student in the lab that the material has only been doped lightly ($N_D < 10^{15}$). Based on this information, and the mobility curves shown below, estimate the doping concentration.



(c) If you increase the doping by a factor of 1000, will the measured resistance also increase by a factor of 1000? Explain.

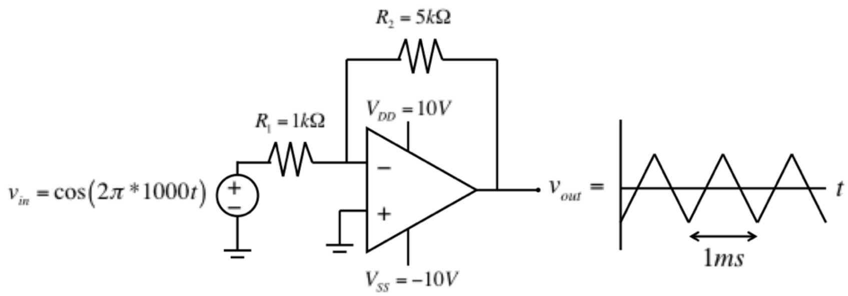
3. (25 points) Anna Log and Digg Ital are back in the EE105 Lab working on Op Amp Circuits. They have tried many configurations and just cant get their circuits to work properly! Since you are an EE105 Lab expert, you decide to join their lab group this week and explain to them how to fix their Op Amp ircuits.

   None of the circuits below is working as expected. For each circuit, (i) identify the problem and (ii) suggest one way to fix it.



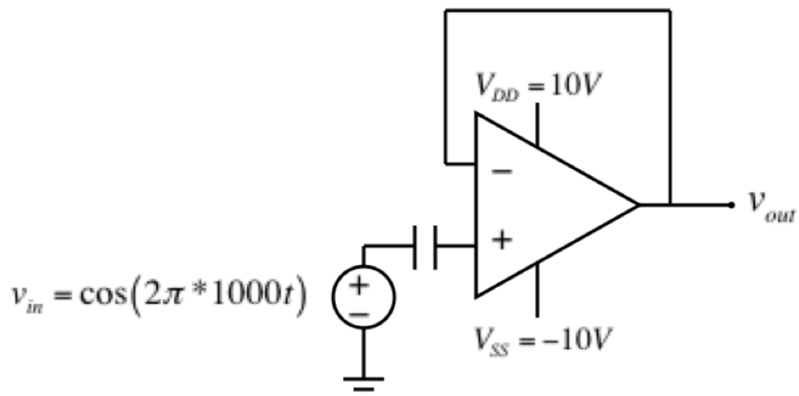
(a) Problem:

Possible solution:



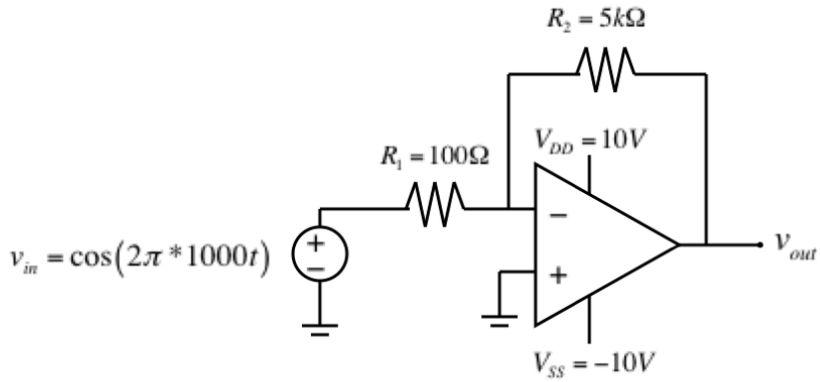
(b) Problem:

Possible solution:



(c) Problem:

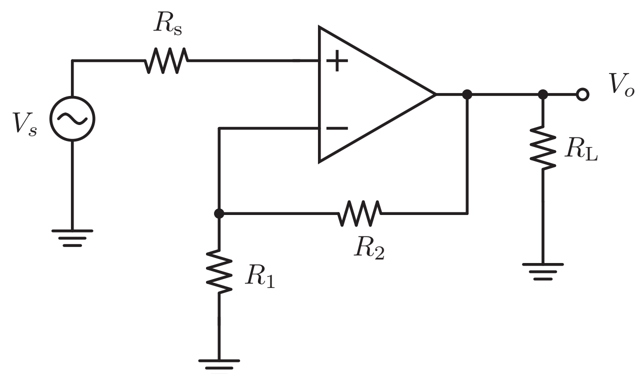
Possible solution:



(d) Problem:

Possible solution:

4. (25 points) An op-amp is configured to provide gain of 10V/V to a 1kΩ load. Model the op-amp with the following parameters:



- $R_{in} = \infty\Omega$ (ideal)
- $R_{out} = 0\Omega$ (ideal)
- $A_0 = \infty$V/V (ideal)
- $\omega_u < \infty$ Hz (not ideal: finite unity-gain frequency)
- DC offset voltage of v_{offset} (not ideal)

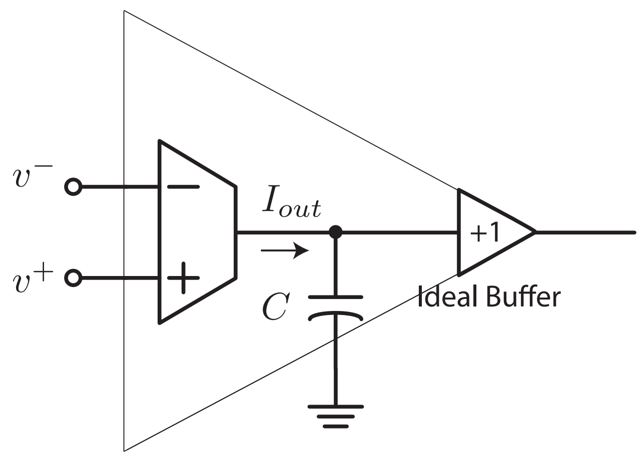
(a) (5 points) When the input voltage is set to zero, we observe an output voltage of +50mV. What is the offset voltage ? Specify the magnitude and draw an equivalent offset voltage in front of an ideal op-amp to model this effect.

(b) How does the gain vary with changes in source resistance R_s. Explain.

(c) How does the gain vary with changes in the load R_L. Explain.

(d) What's the approximate bandwidth for small signals? (-3dB bandwidth) Hint: You do not need to derive this result but simply state it from what you know about feedback amplifiers.

(e) You will now verify the results of the previous problem. Derive the complete closed-loop transfer function by modeling the op-amp with an ideal G_m, a capacitor, and an ideal voltage buffer, as shown. For this part, ignore the DC offset.



$$I_{out} = G_m \left(v^+ - v^-\right)$$