EECS 16A Spring 2016 — Designing Information Devices and Systems I
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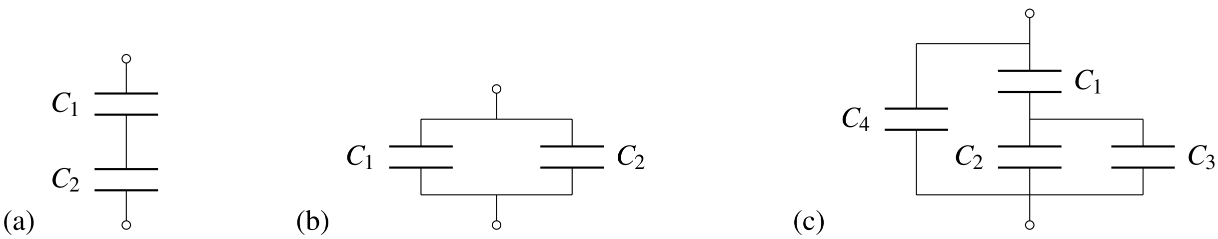
1. Lecture Review

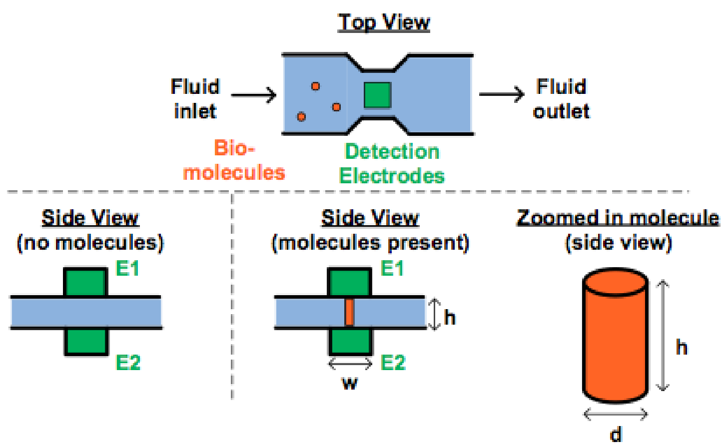
2. Derive Series and Parallel Caps!

Derive C_{eff} for the following diagrams.



3. Biomolecules Part 2

Recall the biomolecules setup from Discussion 5A.



As shown in Fig. 1 above, the detector works by flowing a liquid that may or may not contain the biomolecules through a region in the device that has electrodes on the top and bottom of the liquid channel. The electrodes (E1/E2 in Fig. 1) are chemically "functionalized" (using e.g. some appropriately designed antibodies) so that if the specific bio-molecule of interest is present in the fluid sample, one or more of the molecules will get physically trapped between the two electrodes (bottom right of Fig. 1). After all of the fluid has been cleared out of the device (i.e., so that if there are bio-molecules present, there is only air in between the two electrodes E1/E2), we can then figure out whether or not one or more bio-molecules were trapped by measuring the resistance between the two electrodes, the capacitance between the two electrodes, or both.

(a) Now let's assume that the bio-molecules aren't conductive at all (i.e., $\rho = \infty \Omega\text{m}$), and so we will instead try and detect the change in capacitance caused by the presence of trapped bio-molecules.

Assuming that the electrodes are square (from the top view) and have a side length $w = 10\mu$m, that h is still 100nm, and that the permittivity of the bio-molecule is $\varepsilon = \varepsilon_r \cdot \varepsilon_0 = 10 \cdot 8.85 \cdot 10^{-12}\frac{\text{F}}{\text{m}}$, what is the capacitance between E1 and E2 if no bio-molecules are present?

(b) Using the same parameters as the last part, a molecule height of 100nm, and a molecule diameter of 10nm, what is the capacitance between E1 and E2 if a single bio-molecule is trapped? How about if $N_{\text{molecules}}$ are trapped?

(c) Given your answers to the previous parts, design a circuit that will output a voltage > 2.5V if less than 5 molecules are trapped.

(d) We may not know in advance whether the bio-molecule will be conductive, and so we might want to build our detector circuit so that it is capable of measuring either the resistance or the capacitance between E1/E2. Design a circuit that will output a voltage that is proportional to the resistance between E1/E2 (if measuring resistance), or output a voltage that is inversely proportional to the capacitance between E1/E2 (if measuring capacitance). Note that you can assume that if your circuit is configured to measure capacitance, the resistivity of the bio-molecule is infinite (i.e., you will always be measuring either purely resistance or purely capacitance).