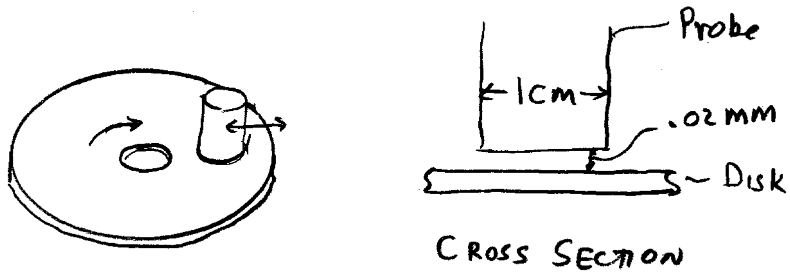
ELEC 435
Problem Set 3
Due: September 19, 2014

Homework Problems.

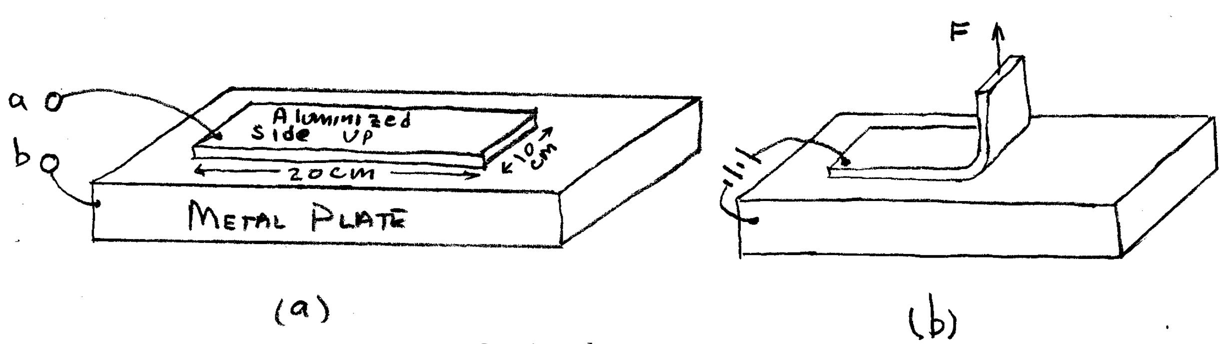
H3.1 The figure below is a plan for a system to measure the flatness of disk drive platters using a capacitive sensor. The plates of the capacitor are formed by the platter itself (which is grounded) and a cylindrical probe 1 cm in diameter with a flat end suspended 0.02 mm above the rotating platter.

- **(a)** What is the nominal value of the sensor's capacitance?
- **(b)** What is the sensitivity in pF/micron?
- **(c)** Suggest a circuit for interfacing this device to the rest of the measurement system.



H3.2 A Space Blanket is a thin (0.015 mm) sheet of Mylar (polyester) film coated with an even thinner (0.001 mm) layer of aluminum. Since a very thin gap is a requirement for a good electrostatic device, let's see what kinds of electrostatic forces we can get with a piece of this stuff. With the aluminum layer as one electrode and the Mylar sheet as the dielectric, we already have two-thirds of a capacitor. Using a rectangular strip of Space Blanket, 10 cm $\times$ 20 cm, and adding a flat metal plate for the second electrode, we could construct the apparatus shown in Figure (a) below.

- **(a)** With the piece of Space Blanket pressed firmly against the metal plate, aluminized side up (as shown in Figure (a)) what it the capacitance between terminals a and b?
- **(b)** With 100 V applied between terminals a and b, what is the total force acting to hold the sheet and the plate together?
- **(c)** If the piece of Space Blanket were rigid, the force you found in part (b) would be the force required to separate it from the metal plate. However, since the sheet is very thin, it is also very flexible, and it will "peel" off rather than lifting straight off. If you were to lift the narrow edge, as shown in Figure (b), how much force would be required to peel the sheet off of the metal plate?



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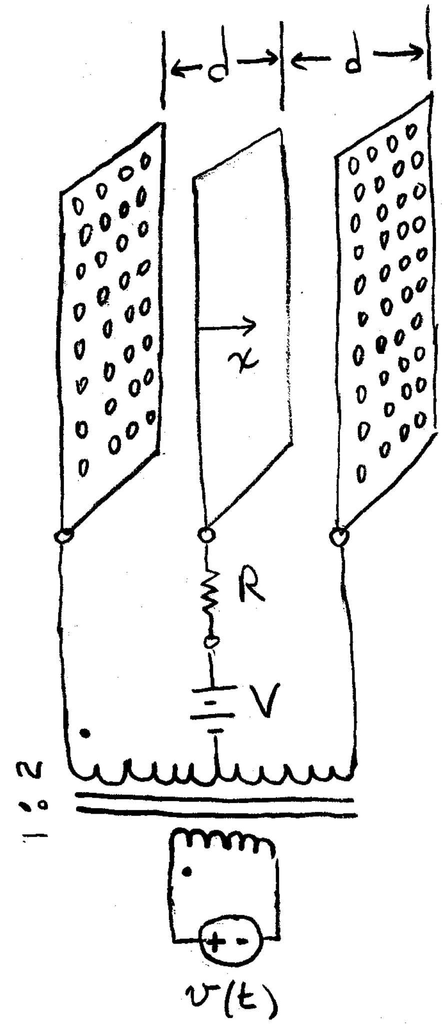
Quiz Problems.

Q3.1 The simple electrostatic loudspeaker we examined in class is subject to distortion due to the presence of v^2 in the expression for force. We were able to reduce (but not eliminate) this distortion by introducing a large bias voltage. The improved speaker on the right improves upon this by using a differential or push-pull arrangement. As before, it is assumed that the diaphragm is subject to a linear restoring force, $F = kx$, so that the resulting displacement is proportional to the force produced. The outer plates are perforated to allow acoustic waves to pass, but may be assumed to be electrically solid.



(a) First consider the case where the polarizing voltage is connected directly to the diaphragm (i.e. $R = 0$). Show that for small displacements ($x \ll d$) the force on the diaphragm is linearly proportional to the signal voltage. What is the constant of proportionality?

(b) Since the whole purpose of a loudspeaker is to move air in response to the motion of the diagram, the assumption of negligible displacement in the previous part is somewhat counterproductive. What happens if we remove this assumption (i.e. allow x to be an appreciable fraction of d) while still keeping $R = 0$? What is the useful operating range of the device?

(c) Show that we can make F, and hence x linear in v for any displacement ($|x| < d$) by making R sufficiently large. What determines how large is "sufficient?"