Lab 2. Resistive Paper Electrostatics Analog

Name:________________________________ Date:________________________________

Figure 1: Setup of the experiment

Introduction

Figure 1 shows the set up of the experiment. The capacitance per unit length of the two-
dimensional structures are to be obtained from measurement. The capacitance per unit
length of the structure can be found by

\[ \varepsilon \ast \frac{R_{SQ}}{R_{MEASURED}} \]  \hspace{1cm} (1)

where \( R_{SQ} \) is the resistance per square and \( R_{MEASURED} \) is the resistance measured between
two electrodes.

The capacitance per unit length of the two-wire line is

\[ \frac{\pi \varepsilon}{\cos^{-1}\left(\frac{2}{r_w}\right)} \frac{F}{m} \]  \hspace{1cm} (2)

and

\[ \cos^{-1}(x) = \ln(x + \sqrt{x^2 - 1}) \]  \hspace{1cm} (3)

Here \( r_w \) is the radius of the wire and \( s \) is the separation between the centers of the two wires.
Laplace’s equation is satisfied for steady current flowing in a resistive medium. Thus a resistive sheet can be used as an analog to plot the equipotentials and electric field lines, and to determine the capacitance, for a two-dimensional electrostatic field configuration.

**Procedure**

1. You will paint 3 sheets as shown in Figure 2 and 3. Paint the patterns onto the resistive sheets with conductive paint. The shaded areas are to be painted. The width of the lines is about 1cm. Use the compass if necessary. The smallest unit of the resistive sheet grid is 1cm. Put a cardboard below the resistive sheet when painting. Allow enough time to dry the paint.

2. Use an ohmmeter, measure the resistance of a square(#1 in Figure 2) of the resistive paper with its two opposite edges coated with paint.

\[ R_{SQ} = \] \(\Omega\)
Should the measured value of $R_{SQ}$ depend on the size of the square?

3. (a) Use the resistive sheet with pattern #2 shown in Figure 3. It is the cross section of a coaxial line. Use thumbtacks to attach copper strips to the inner and outer electrodes. Ground the outer electrode and apply 10 volts to the inner electrode.

(b) Use the digital voltmeter and probes to find and the 5 volt equipotential line on the resistive sheet and mark it with a pencil.

Is it a circle?

Is it right in the middle between the inner and outer electrodes?

(c) **Disconnect the voltage source!** Measure the resistance between the inner and outer electrodes:

$$R_{COAX} = \Omega$$

(d) From Eq. (1), the capacitance C per unit length of the coax is

$$C = \frac{F}{m}$$

(e) Calculate the capacitance per unit length of the coax line of pattern #2 analytically.

The computed value of C is

$$C = \frac{F}{m}$$

4. Repeat steps 2 for the two-wire structure (pattern #3). Plot a few equipotentials (including 2.5V, 5V and 7.5V). Determine C from your measurement,

$$C = \frac{F}{m}$$

and compare with

$$C = \frac{F}{m}$$ from Eq. (2).

5. Method of images. Use pattern #4. Connect the electrode on the left circle with 5 volts and the conducting plane with the ground. Replot the 2.5 volt equipotential. Does the method of images yield the same equipotential line as found in the two-wire line?

6. Connect the stepped conductor with 10V and the plane conductor (pattern #5) with ground. Plot a few equipotential lines (2.5V, 5V, 7.5V) between the stepped conductor and the plane conductor.

**Things to turn in**

Lab result and three sheets with equipotential lines marked.