E&M Laboratory 1106, Spring 2025

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https://www.physics.smu.edu/tneumann/110X_Spring2025/

Lab 2 — Static Electricity — Electric forces and charges Max. points: 56

Your preparation: Work through before coming to the lab

- Read through chapter 21 and 22 (Electric charge) Halliday, Resnick, and Walker [1], in particular to understand the topics of electric charge, Coulomb's law, electric field and electric field lines
- Learn about the triboelectric effect and tribocharge [2].
- Prepare by reviewing the lab measurement and report section below and the equipment overview and further introductory material on https://www.physics.smu.edu/tneumann/110X_Spring2025/schedule-em/ (available later this week).

Pre-lab: Upload to Canvas before coming to the lab

A reminder: Upload your answers as a text document (exported as PDF) to Canvas before the lab begins (Canvas uploads are no longer possible after the lab starts!).

Pre-lab 1 9 points

- (2 points) Look up and, in your own words, explain the Triboelectric effect.
- (3 points) Give three examples where tribocharge accumulation can cause problems or is actively prevented.
- (2 points) In your own words, briefly describe how a Van de Graaff generator achieves very high voltages.
- (2 points) Generally, being inside our cars is considered to be safe in the presence of lightning strikes. Explain why that is the case. Also argue why or why we would not be safe in a tuned lightweight car that is entirely made out of carbon fiber.

Lab measurements and report: submission by end of class

In this lab we use an electric field detector to study static electric fields of various electrically charged objects.

A reminder: All measurements and steps must be followed in order and must be fully documented (using Excel spreadsheets for tables and plots and a text document for the text answers). The final report must be uploaded to Canvas *by the end of the class* (Canvas will stop accepting uploads 10 minutes after the class ends). If you have not fully completed your report, you must upload the documents as far as you have completed them for grading.

Measurement 1 *Charging rods* 20 points

We first study the field of a charging rod (PVC pipe), charged by rubbing with a microfiber cloth. For each measurement, first remove any residual charge by holding a grounding wire in one hand and wiping the rod slowly with a slighly moist paper towel. Confirm with the detector that the charge of the rod is vanishing. If necessary, wipe a grounding wire along the rod.

1. (6 points) Vigorously rub the microfiber cloth along the length of the PVC pipe so that it becomes warm. This will create static electricity on the pipe. Place the PVC pipe carefully centered on a sheet of graph paper (as demonstrated by your instructor). Using the static field detector take note if the charge of the rod is positive or negative.

   Use the static field detector to sample points around the rod where the number of LEDs lighting up on the field detector is two. Mark at least 10 points and connect those points with a line to create an equi-field line, i.e. a line showing where the field-strength is equal.

   One person in your group should move the static field detector, while the other group members should mark the position of the detector's tip on the graph paper.

   Everyone in your group should repeat the measurement, so that you have N measurements for N group members. Use a new sheet of graph paper for each member in your group and label it by name.

   Before proceeding, include a photo of the field map where you probed with the static field detector in your report. (Alternatively, label the sheet with your name and the measurement number and give it to your instructor at the end of the lab)

2. (6 points) Repeat the measurement using the acrylic rod and new sheets of graph paper. Each of your group's members should use the static field detector once with a new sheet of graph paper.

   Before proceeding, include a photo of the field map where you probed with the static field detector in your report. (Alternatively, label the sheet with your name and the measurement number and give it to your instructor at the end of the lab)

3. (2 points) Combine your N measurement sheets for the PVC rod on one piece of paper, you should have three curves. Estimate the average spread between the three different curves in cm and record it.

   Before proceeding, each one of you must include a photo of the combination sheet in their report. (Alternatively, label the sheet with your name and the measurement number and give it to your instructor at the end of the lab)

4. (6 points) Each one of your group should work with their field map that shows the equi-field line corresponding to 2 lit up LEDs with the charged PVC rod. Using the charged PVC rod,

sample points around the rod where the number of LEDs lighting up on the field detector is four. Mark at least 10 points and connect thoise points with a line. Label the line with the number 4. Repeat this procedure with 6 and 8 and 10 LEDs so that there are five lines in total on your field map.

Also create a field map with equi-strength lines at 4, 6, 8 and 10 LEDs for the acrylic rod and label them.

Include photos in your report of *your* two field maps for acrylic rod and PVC rod. (Alternatively, label the sheet with your name and the measurement number and give it to your instructor at the end of the lab)

Measurement 2 *Static electricity for moving an aluminium can and a pith ball* 6 points

Static electricity can have a macroscopic effect and can cause objects to repel or attract following Coulomb's law describing the force between charged particles. We study the effect of static electricity on an aluminium can and a pith ball.

1. (2 points) Remove any residual charge of the aluminium can with the grounding wire and confirm that it's neutral with the static field detector.

   Lay the aluminium can on its side on the table and bring a charged acrylic rod near its side. Perform the same experiment using a charged PVC rod. Record in each case whether the can is attracted or repelled.

2. (4 points) Pith balls are balls coated with a conductive material that enhances their electrostatic performance. We use a pith ball suspended by a thing thread to study charge transfer.

   Remove any residual charge from the pith ball with the grounding wire and confirm that it's electrically neutral with the static field detector.

   a) Bring a charged acrylic rod next to the ball at a distance greater than the length of the thread. Observe the motion of the ball, but do not let the ball touch the rod.

   b) Let the charged acrylic rod touch the ball and observe the motion of the ball.

   In a few sentences describe your observation and discuss the difference between a) and b).

Measurement 3 *Adhesive tape* 11 points

We study the triboelectric effect. Cut two pieces of $15\,\mathrm{cm}$ adhesive tape and create non-stick handles by folding over about $1\,\mathrm{cm}$ each.

1. (2 points) Press the tapes on the table and rapidly remove them. Do the tapes repel or attract? Give a brief explanation.

2. (2 points) Record the charges of both tapes with the static field detector. Describe if this confirms the attracting or repulsing tapes.

3. (5 points) Cut two more tapes and mark one with "B" for bottom and one with "T" for top. Place the "T" tape over the "B" tape and the "B" tape on the table, and rapidly remove both tapes together from the table. Then separate the "B" and "T" tapes.

Use the static field generator to determine the charge sign of the ”T” and ”B” tapes and record it. Write a brief (a few sentences) explanation of your findings when compared to removing the tapes individually off the table.

4. (2 points) You measured the charge sign of ”T” and ”B”. Explain why the top and bottom tapes have a certain charge depending on their position. Compare the situation with one single tape.

Measurement 4 *Superposition principle* 4 points

The total electric force acting on a charge due to multiple other charges can be obtained from the vector sum of forces exerted by each of the individual charges. We study this this by combining two charged rods. You will have to swiftly and carefully handle the rods as to not bleed off any charge.

1. (2 points) Charge two acrylic rods. Bring the first near the static field detector so that it shows a strength of 2 or 3. Take note of the approximate distance.

   Then take the second rod and bring it to the same distance and take note of the strength the field detector reports.

   Now hold both rods together and bring them near the static field detector to the same distance and again take note of the strength the field detector reports.

   Remove all charge from the rods, reset the static field detector and repeat the measurement two more times, taking note of your measurements.

2. (2 points) Briefly argue why your measurements confirm the superposition principle or why not. If not, what is the reason?

Measurement 5 *Charge separation rods* 6 points

We will now work with the charge separation rods. When bleeding of any charge off the rods, confirm this with the static field detector.

1. (3 points) Bleed of any charge of both charge separation rods and place them such that their metal ends touch each other. Bring a charged PVC rod close to the end of one rod without making contact. Separate the two charge separation rods and then move the PVC rod away.

   Use the static field detector to probe around both rods and record your observation qualitatively. Explain the effect you see.

2. (3 points) Again, bleed of any charge of both charge separation rods and place them such that their metal ends touch each other. This time, let a charged PVC rod touch one end of one charge rod (making contact). Remove the PVC rod and separate the two charge separation rods.

   Use the static field detector to probe around both rods and record your observation qualitatively. Explain the effect you see.

References

[1] D. Halliday, R. Resnick, and J. Walker. *Fundamentals of Physics*. Fundamentals of Physics. John Wiley & Sons.

[2] URL: https://en.wikipedia.org/wiki/Triboelectric_effect#Examples.