

# Introduction

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## [1] Instructions

Please make a copy of this document and share it with me ([zain.eris.kamal@rutgers.edu](mailto:zain.eris.kamal@rutgers.edu)) and your teammates. You will write your answers in the **blue boxes** as you go.

To start, please write your names and NetIDs in the box below:

<b>Name</b>	<b>NetID</b>
...	...
...	...
...	...

*\*If you're visiting from another section, please include your instructor's email address next to your name! Additionally, please email me over the weekend to remind me to send your grade to your instructor.*

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## [2] Pre-Lab Reflection

[1] When it comes to topics, lectures, homeworks, recitations, etc. in this unit...

- What do you understand well?
- What are you struggling with?
- Where do you think you have the most room to improve?

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[2] So far, in class you've studied **electrostatics** — in your own words, how would you define electrostatics?

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### [3] Conceptual Overview

Helpful resources (I'll send more via email in the coming week):

-  Polarization and Charging by Induction

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### [4] Available Equipment

- 0.01 g electronic scale
- 3 copper spheres on plastic rods (one with a standing base)
- charging rod + fake fur
- ring stand + meter stick

# Activity 1: Electrostatic Forces on a Scale

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## [0] Preface (Please Read!)

### [0.1] Activity Overview

In this activity you will repeat the same three-step loop many times:

1. **Setup / Goal** — The manual will tell you what to do, or what to accomplish. Don't do it yourself yet, just read!
2. **Prediction** — You write *what* you think will happen and *why*.
  - Charge diagrams are very helpful! I made a [Google Slides template](#) — if you'd like, feel free to make a copy to collaborate with your team and put screenshots straight into your lab report.
3. **Do + Reflect** — You run the setup, record what happened, and explain how your thinking should change.

Please note — **you will NOT lose points if your predictions are wrong!** To earn points, you must:

1. Making a physics-based prediction (words + diagrams), and
2. Using observations to correct/refine your reasoning.

Also, you may include more than one prediction if there's disagreement within your group! Feel free to make bets on vending machine snacks :)

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### [0.2] Tips for Success

- Moisture is your enemy. If nothing seems to work, it might be humidity, not you.
- Touching a copper sphere with your finger grounds it (it can remove net charge).
- If two spheres touch, charges can redistribute. Avoid contact unless a step tells you to touch.
- Always hold spheres by the plastic rod, not the copper.
- For consistency, try to keep the same distance between spheres whenever you are comparing trials.

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### [0.3] Set up the scale so it measures only the electric interaction

Actions:

- Remove the standing sphere from the scale. Turn the scale on. Set units to g.
- Place the standing copper sphere (on its base) on the scale.

- Tare / Zero the scale **with the standing sphere on it.**
- After taring: the scale now reads  $\Delta m$  (change in the apparent mass) caused by any additional vertical forces on the standing sphere.

Interpretation (use this all lab):

- If the scale reading becomes positive ( $\Delta m > 0$ ), the standing sphere is experiencing an extra downward force.
- If the scale reading becomes negative ( $\Delta m < 0$ ), the standing sphere is experiencing an extra upward force.

In your own words: what physical quantity is the scale actually measuring here? Draw/include a free-body diagram.

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### [1] Experiment 1 — Neutral + Neutral (“Null test”)

Actions:

- Ground both spheres: touch each copper sphere briefly with your finger (while holding the plastic rod).
- Use the ring stand (or a steady hand) to hold the second sphere directly above the standing sphere.
- Bring the top sphere close (start ~1-2 cm gap), without touching. Watch the scale.

[1.1] Prediction: What will happen to the scale reading ( $\Delta m$ ), and why? Include a charge diagram (what charge distributions exist on each sphere?).

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Now go ahead and do it!

[1.2] Observation: What happened? If the reading changed, list at least two plausible reasons (experimental, not “physics is broken / human error”).

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## [2] Experiment 2 — Charged (top) + Grounded (bottom)

Actions:

- Ground both spheres again (touch each copper sphere briefly).
- Charge the top sphere using the rod/fur (charging by contact is OK).
- Ground the standing sphere one more time (so it starts neutral).
- Bring the charged top sphere to the same distance as before (no touch).

[2.1] Prediction: Will the scale reading become positive, negative, or stay  $\sim 0$ ? Explain using a charge-separation diagram on the standing sphere.

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Now go ahead and do it!

[2.2] Observation: What happened? Record the sign of  $\Delta m$  (and an approximate value if it's steady).

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[2.3] Reflection: If the standing sphere started neutral, why was there still a force? What must have happened inside/on the standing sphere?

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## [3] Experiment 3 — Charged (top) + Neutral isolated (bottom)

Actions:

- Ground both spheres.

- Charge the top sphere again.
- Do NOT ground the standing sphere after this point. (Keep it neutral and isolated.)
- Bring the charged top sphere to the same distance.

[3.1] Prediction: Compared to Experiment 2, will the magnitude of the attraction be stronger, weaker, or about the same? Why?

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Now go ahead and do it!

[3.2] Observation: Compare the sign and “size” of  $\Delta m$  to Experiment 2.

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[3.3] Reflection: What role did grounding play in Experiment 2? What does grounding allow the sphere to do that an isolated sphere cannot?

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#### **[4] Experiment 4 — Contact event**

Actions:

- Start with the top sphere charged and the standing sphere neutral/isolated (like Experiment 3).
- Bring the top sphere down until it briefly touches the standing sphere, then separate them back to the same distance as before.

[4.1] Prediction (two-part):

- a. At the moment of contact, what happens to charge on each sphere?
- b. After you separate them, do you predict attraction, repulsion, or  $\sim 0$  force?

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Now go ahead and do it!

[4.2] Observation: After separation, what is the sign of  $\Delta m$ ? Does that indicate attraction or repulsion?

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[4.3] Reflection: What does this tell you about “charging by contact” between identical conductors?

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### [5] Experiment 5 — Goal: engineer repulsion on purpose

Goal: Create a setup where the scale reading indicates repulsion (standing sphere pushed downward).

Allowed tools: grounding (touching), charging rod/fur, and contact between spheres (if part of your plan).

[5.1] Prediction/Plan: Write a step-by-step procedure that will reliably produce repulsion between the two spheres. Include charge diagrams after each major step.

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Now go ahead and do it!

[5.2] Observation: Did your procedure produce repulsion? What was the sign of  $\Delta m$ ?

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[5.3] Debug/Reflect: If it didn't work, identify the most likely failure point (e.g., accidental grounding, accidental contact at the wrong time, not enough charge, distance too large, etc.) and write your revised procedure.

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## **[6] Conclusion**

[6.1] Pretend you're speaking to someone who is struggling with this topic, and hasn't done this lab yet. Explain how you can get attraction or repulsion between spheres using (i) grounding, (ii) charging by contact, and (iii) keeping objects isolated. Include one diagram.

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## Activity 2: Build an Electrometer

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## Activity 2 — Build an Electrometer

Goal: You are given one copper sphere with an unknown net charge. Your job is to design and carry out a procedure that calculates its net charge  $Q$  (in Coulombs or nC) using only the equipment at your station. In other words, build a homemade *electrometer*.

[1] Describe a step-by-step method to determine the unknown net charge on the given sphere.

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[2] Follow your procedure, and show one sample calculation clearly.

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[3] Reflection: If your estimate is wrong by a factor of 2, what single mistake is most likely responsible? If it's wrong by a factor of 10?

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# Conclusions

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## [1] Post-Lab Reflection

[1] Concept Mind Map: Create a mind map that connects the key ideas from this lab. You can use paper, or a shared whiteboard website like [excalidraw.com](https://excalidraw.com). Your map must include (at minimum):

- Charge
- Electric force
- Normal force / scale reading
- Grounding
- Charging by contact
- Charging by induction / polarization
- Conductors vs insulators
- Coulomb's law.

Draw arrows with brief labels explaining the relationships (e.g., “causes,” “depends on,” “measured by,” “changes when...”).

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[2] Look back at what you wrote in the “Pre-Lab Reflection” (go to the “Introduction” tab and scroll to the second section). Has your understanding changed/improved? What are you still uncertain about?

*Note: this will never count against you or your grade — it's solely for me to get a better idea of what your needs are so I can become a better instructor :)*

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[3] How could I improve this lab? Please be honest!!

*For reference, here's the [original lab manual](#) — you may also give feedback on how my activity compares to the original activities.*

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## [2] Lab Submission Form

Please complete this Google Form once you finish the lab (**one submission per group**):

<https://forms.gle/eEzySKSJGKXfFYKx5>

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### [3] Cleanup

Please clean up your table, then take a picture and paste it below:

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If your table is dirty, I'll deduct one zillion points :)