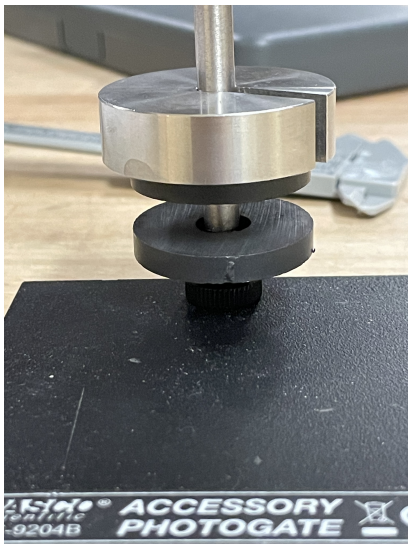
Lab 6

Punny Magnetic Force Title



Physical Models: Magnet Interaction

Analysis Tools: Nonlinear Fitting, Chi Squared

Experimental Systems: Ring Magnets, Weights, Packing Foam

Equipment: Ruler, Calipers, Mass Scale, Ring Stand

Safety Concerns: The magnets are fragile and can break into sharp pieces, so handle them carefully. Don't move the magnets too quickly around electronic devices. In principle, that could induce an electric current and ruin electronics. You should also be mindful of your fingers when magnets are attracting.

Introduction

Often times in physics we consider how a field and the corresponding force between two objects depends on the distance between them. For example, for the electric and gravitational field outside a spherical charge

or object, we find

$$\mathbf{F}_E = \frac{kq_1q_2}{r^2}\hat{r} \qquad\qquad \mathbf{F}_G = -\frac{Gm_1m_2}{r^2}\hat{r} \tag{6.1}$$

Both of these forces decrease as r^{-2}. But other types of force-distance relationships are possible. For example, the force of gravity increases as r^1 inside a spherical object, forces between atoms in a gas decrease as r^{-7}, and the force between two electric dipoles decreases as r^{-4}. In this week's lab, we're going to use our fitting techniques to form and evaluate a model to describe the force between two magnets.

The χ^2 test we learned about last week also applies to testing nonlinear models as well. If we assume that the force follows a **power law**, the model would take the form $F = Kr^\alpha$, where K is a coefficient we don't care about that doesn't depend on distance. Taking a log of both sides of this equation implies that

$$\ln F = \alpha \ln r + \ln K = \alpha \ln r + B \tag{6.2}$$

where $\ln K = B$. Then our power law takes the form of a line that isn't through the origin, which we can test using a modified χ^2 analysis.

Part 1

With what you know about force laws and electric and magnetic fields, you can make a prediction about how the force between two magnets will decay with distance. Your goal in this part of the lab will be to collect force-distance pairs to test your first guess of the power law exponent α.

Quick Check: Place one magnet on the stand by threading the stand through the hole in the magnet. Try holding a separate magnet direct over the magnet currently on the stand. Can you find which sides of the magnet you're holding attract or repel the placed magnet?

Now insert this magnet onto the stand making sure the side you found repels the top side of the magnet already on the stand. What happens when you let go of this magnet?

Designing Your Experiment: You can use the force balance between the magnetic force and the weight of the upper magnet to measure how the force and distance of the magnet are related.

- Write down your prediction for how the force between two magnets changes with distance.
- How will you measure the distance between the magnets? Try to find the best way to account for both systematic and random uncertainties in your experiment.
- You have several weights at your table with very different masses. What range of forces will you test?
- Remember that the magnets themselves have a mass that must be considered in finding the force between the magnets. How will you find it?
- You should plan on testing your model for the magnetic force using the modified χ^2 introduced in class.

Check in with Another Group: Talk about how you're going to perform your experiment, as usual.

Conducting Your Experiment: Carry out your planned experiment.

Forming a Conclusion: Was your power law exponent indistinguishable from your data?

- Did your prediction seem to hold equally well at all distances between the two magnets?
- Were there any ambiguities in this experiment that made data collection or evaluating the model difficult?

Check in with Another Group: Follow up as usual with another group after you analyze your results.

Part 2

In this part of the lab, we'll refer you to the Flowchart from earlier in this course. Here you will refine your previous experiment or test different aspects of the force between two magnets, modifying your prediction and methods as needed.

Designing Your Experiment: Some ideas of things you can test in this experiment are described below. Evaluate the results of Part 1 and decide which of the following (or something else) you should perform:

- How does the magnetic force between two magnets change if an object is placed between them? Is there a shielding effect like we saw while testing radioactivity?
- How would the force between magnets change if the number of magnets is increased?
- What were some sources of uncertainty in your previous experiment? Think of a way that you can change your procedure so that they won't apply anymore.
- Was there a region in your last experiment where the force depended on distance closer to your expectations? Concentrate on a larger or different set of forces and examine if and how the exponent changes.
- If your Part 1 predicted exponent did not agree with your data, do you think your trendline should be steeper or flatter to agree with your data? How would this affect your predicted exponent?

You can also test any other ideas you would like about the force between two magnets here.

Check in with Another Group: Talk about what you will do in this section of the lab.

Conducting Your Experiment: Carry out your planned experiment.

Forming a Conclusion:

- How did your results differ from what you found in Part 1? In what way?
- Did your modifications change whether or not your results agreed with your experiment? What do you think were the reasons for this?
- Did the same limitations apply as you found in Part 1, or were you able to successfully reduce your uncertainty?

Check in with Another Group: Follow up as usual.