**Lab 3: Charged and Minty Particles**

Note: Physics in the virtual lab follows a limited set of models. Most of these models are based on the real world, but none are exactly accurate. It’s impossible to perfectly simulate real-world physics, and many rules have been deliberately changed for this and other VR labs.

**Explore the Simulation**

**(VR headset operators) Launch the Simulation**

1. Note the reference diagrams on the inside of the headset box’s lid.
2. Make sure the Oculus headset is connected to the Desktop PC with the braided USB cable.
3. Power on the Oculus headset by pressing and holding the button on the right side of the headset for 3 seconds.
4. In the headset, you will see a message “Allow access to data”. Select “Allow” using either hand controller.
5. Click “Create Guardian” and follow directions to set ground level. (If prompted to, select “Stationary Boundary” and confirm.
6. Locate the Apps menu: In the navigation bar around waist level, at the far right, there should be a grid of 9 dots. Click that button to open the Apps menu.
7. From the Apps menu open the NOMR app (it should be at the top left of the screen).
8. Have a lab-mate open the “Students” folder on the desktop of your lab computer.
9. Open the PHYS 231 folder and double click *Quest\_Mirror-Shortcut*.
10. In the headset, you may be asked to allow USB debugging. Click “Always Allow”. On the desktop, close and re-open *Quest\_Mirror*.

You should now be in the virtual lab, and the screen should be mirrored on the Desktop PC. If you have any difficulties your TA should be able to help you.

**Familiarize yourself with the VR lab environment by completing the following steps:**

* 1. **Enter the code “1856”** into the keypad and press Submit to load today’s lab setup.
		1. Press buttons by pointing at them and clicking the trigger on your controller.
	2. Create a new positive charged particle by pointing at the button labeled “Positive” and clicking the trigger.
	3. Point at the newly created charged particle and hold down the grip button to hold the particle and move it around your space.
	4. While holding the particle, push the controller thumbstick away from you to push the particle away. Move the thumbstick toward you to pull the particle toward you. This will work for every movable object in the simulation.
	5. Anchor the particle by pointing at it and pressing the trigger. This locks the particle at a point in space and is visually represented by a cage around the particle. To un-anchor the particle, point at it and press the trigger again.
	6. Pause physics in the simulation by clicking the button labeled “Pause Physics.” This pauses the motion of all free particles, allowing you to configure an experiment. Clicking the same button again will resume physics.
	7. Delete the particle by holding down the B or Y button, pointing at it, and pressing the trigger.
	8. Reset the lab, deleting all charges and tools, by clicking the “Reset” button.

**Electrically Charged Particles**

Take turns exploring the simulation. Try creating multiple electric charges. Try mixing charge types. Try adding more than two charges to the simulation. Discuss with your group how these simulated electric charges interact with each other. *Does your model for the interaction between electric charges align with your observations of the simulated charges?*

**Modeling Force**

A goal of today’s lab is to develop and test a model describing the force between two electrically charged particles in the VR lab. To do so, you will design an experiment to answer the following question:

*How does the force between two electrically charged particles depend on those particles’ charge and on the distance between those particles?*

**Tools Available for Experimental Design**

 Before testing a model, we must first understand the tools available to use in experiments.

**Create a measuring tape.** Create two particles and anchor them nearby. Measure the distance between the particles. Discuss the following questions with your group:

* *What is the uncertainty associated with your measurements?*
* *Is this random uncertainty or instrumental uncertainty?*

**Create a force meter.** Attach a positive charge to the force meter by placing the charge on the spiky end of the meter (note: the orange end of the force meter is always anchored). Place the other anchored charge near the force meter. If nothing happens, you may need to resume physics in the simulation. Discuss the following questions with your group:

* *How are the magnitude and direction of a measured force indicated by the force meter?*
* *What is the uncertainty associated with your measurements?*
* *Is this random uncertainty or instrumental uncertainty?*

Remove the positive charge attached to the force meter and replace it with a negative charge. Discuss the following questions with your group:

* *How does the force meter indicate an attractive force versus a repulsive force?*
* *What does a negative value on the force meter mean?*

Grab the particle that is not currently attached to the force meter and move it around. Discuss the following questions with your group:

* *Why does the force meter’s value change as the particle pivots about?*
* *Does the force meter measure the net force acting on the particle attached to it?*

**Check in with an instructor regarding your understanding of the available measurement tools** before proceeding too far into your experimental design.

**Designing an Experiment**

Discuss with your group and decide on your model for how charged particles interact in the VR lab. You will use that model as a basis for your hypothesis.

Now, discuss with your group how you will experimentally observe the interactions you are interested in. Be sure to consider:

* What differences exist between your model and another model for interactions between charged particles that you learned about in class?
* How many distinct experiments do you need? How many measurements do you need to take in each experiment to obtain your result?
* What is the independent variable and the dependent variable in each experiment? Are there any control variables in each experiment?
* Based on your model, what is your predicted outcome for each experiment?
* You will have to make some assumptions, so be clear what assumptions you are making in your experimental method and in your predictions.
* How will you analyze your data from each experiment to determine if your prediction is correct?

Execute your experimental design, then proceed to the next section.

**A New Particle**

In a simulation, we are not bound by the constraints of working with real world physics. A new particle (dubbed the Minty Particle) has been invented and programmed into the simulation. **To access minty particles, enter code 1550 into the keypad and press Submit.**

Explore the behavior of these minty particles. You do not have access to quantitative tools while working with minty particles; **focus on making and recording qualitative observations.**

* + How do two minty particles interact with each other? Three? More?
	+ How do minty particles behave at extremes? Short distance? Long distance? How does a system of many minty particles interact with each other?
	+ What other features of minty particles’ behavior do you find to be significant?

Before accessing quantitative tools with minty particles, you will need to submit a preliminary model of the interactions between minty particles, as described in the next section.

**DUE mid-lab - Individual - Preliminary Minty Model**

**Minteractions**

Based on your observations of minty particles, what inferences can you make about the rules that govern their behavior? Brainstorm a possible preliminary mathematical model that describes your observations. Write it in a separate document, not shared with your group, and explain your reasoning in a few short sentences.

I’m interested here in creative thought that is well supported. There are many good possibilities here, and there is no expectation that you need to “guess the right model”.

You will be graded pass/fail. You’ll pass if your work is distinctly yours; that is, your work is in your own words, not anyone else’s. The model may be the same, but your submission should be **your** work.

Submit your inferences, model, and reasoning to the Canvas assignment “[Preliminary Minty Model](https://canvas.uw.edu/courses/1482129/assignments/6702624).” When every member of your group has submitted, ask your TA for the **Quantitative Minty Code**.

Design Your Experiment

Your aim now is to develop a quantitative empirical model of the interactions between minty particles using data from an experiment. To design an experiment, you can design-by-analogy using the previous experiment as a template for modeling an interaction between particles. You will have access to the force and distance measurement tools you used with electric charges, and you can create as many minty particles as you need.

Your experimental design should answer the following questions:

* What are the independent, dependent, and control variables in this experiment?
* How many data points do you plan to take and for what values of your independent variables?
* What sources of random & instrumental uncertainty are present in your experiment?

Discuss your experimental design with an instructor and then conduct your experiment!

Develop a Quantitative Empirical Model

Using the data that you gathered from your experiment, your goal is to develop a model for minty particle interactions. Use the table below as a guide to develop your model (the Coulombic model for electric charge interactions is described as an example).

|  |  |  |
| --- | --- | --- |
|  | **Charged Particles****(example)** | **Minty Particles** |
| **Symbolic Representation** | $$\rightharpoonaccent{F}=\frac{kq\_{1}q\_{2}}{r^{2}}\hat{r}$$ |  |
| **Verbal Representation****Define all relevant quantities** | * The force between two particles with charges $q\_{1}$ and $q\_{2}$ is proportional to each charge and has a constant $k$.
* The force falls off with the square of the distance between the charges $r$.
* The force acts in the $\hat{r}$ direction, along the line connecting the two charged particles. Note: $\hat{r}$ is a unit vector that only indicates the direction.
 |  |

As you develop your model, keep in mind:

* You are conducting a quantitative hypothesis-generating experiment. Unlike the model testing experiment you conducted for Coulomb’s law, there is no known model that you are testing. The only “right” answer is the one you make the best case for.
* It’s normal practice in physics experimentation to revise your experiment and collect additional data as you learn things and make decisions.
* An equation symbolizes information but does not necessarily capture everything about the model (such as assumptions that you might be making or limitations of the model). Describe any assumptions you are making and the limits over which you believe the equation is valid.
* One experiment can’t fully flesh out a model. The best model for the minty particle interactions is the one that your group feels best describes them, out of all your group’s ideas.

**Make sure to turn off the Oculus headset by holding the power button (on the right side of the headset) before putting them away in the box.**

DUE next week

Due at 11:59pm on the day before your lab section next week.

**Minty particles:** You’ll write a **full report as a group** with introductions, methods, data analysis, and discussion/conclusions for your quantitative empirical model of the interactions between minty particles.

In addition to meeting the criteria in the [report rubric on Canvas](https://canvas.uw.edu/courses/1482129/assignments/6702619), make sure to address the following questions in your report:

* List the significant qualitative features of minty particles’ behavior.
* Using a plotting tool like Google Sheets or Excel, create a plot of your data with uncertainties, linearized according to the model you proposed for minty particle interactions.
* Add a trendline to the linearized plot.
* What is your model for the interactions between minty particles in the VR environment?
* Does your model explain each of the qualitative features of minty particles’ behavior that you listed? Does your model agree with your qualitative observations?
* Over what regime does your model apply? Can it be used to predict behavior that you don’t currently have the ability to observe?

**Electric charges:** As an **appendix to your minty particles report,** include an analysis of your data for electric charges. This appendix must include:

* A linearized graph with error bars and a trend line;
* Reported intercept and slope values for your best-fit line, with uncertainties;
* Description of the physical significance of the slope and intercept values;
* Interpretation of the uncertainties of the slope and intercept.