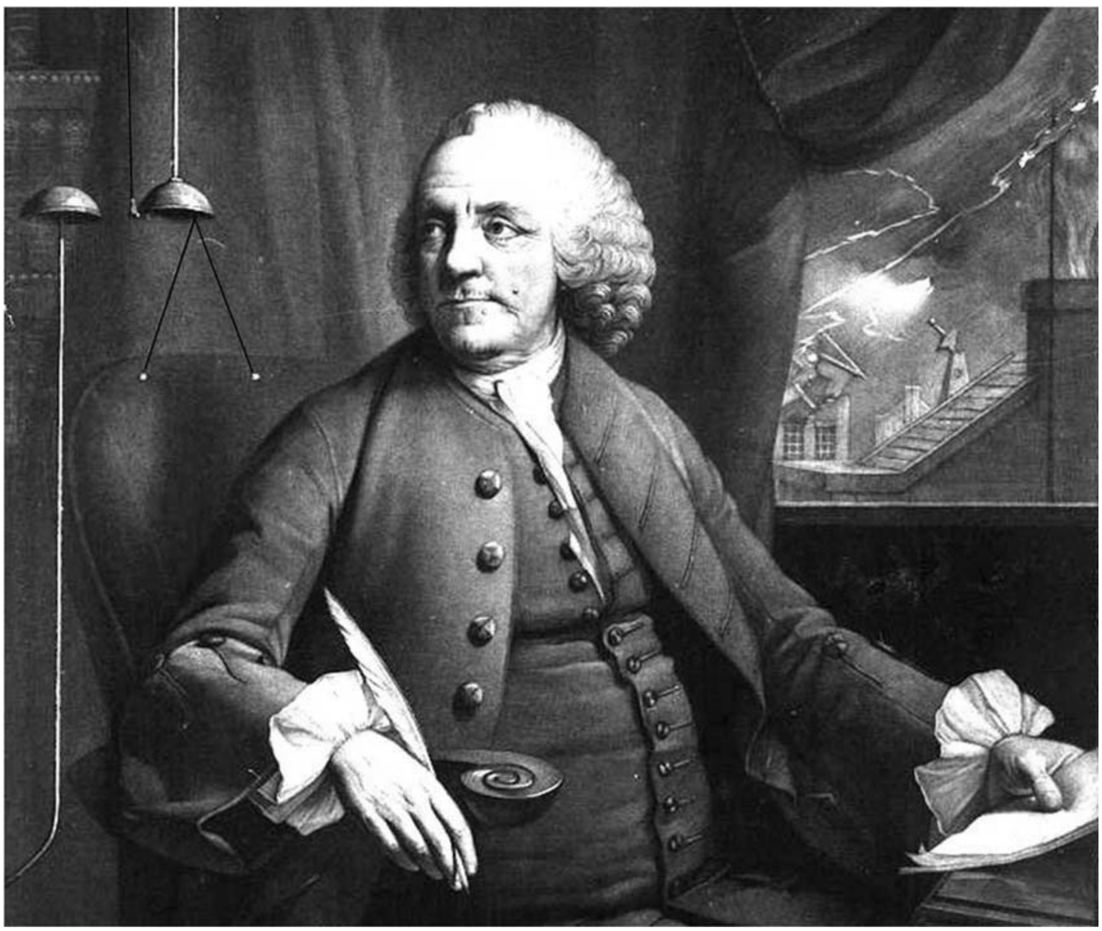
Laboratory Manual for General Physics II
PHYS 1602L

Spring 2020



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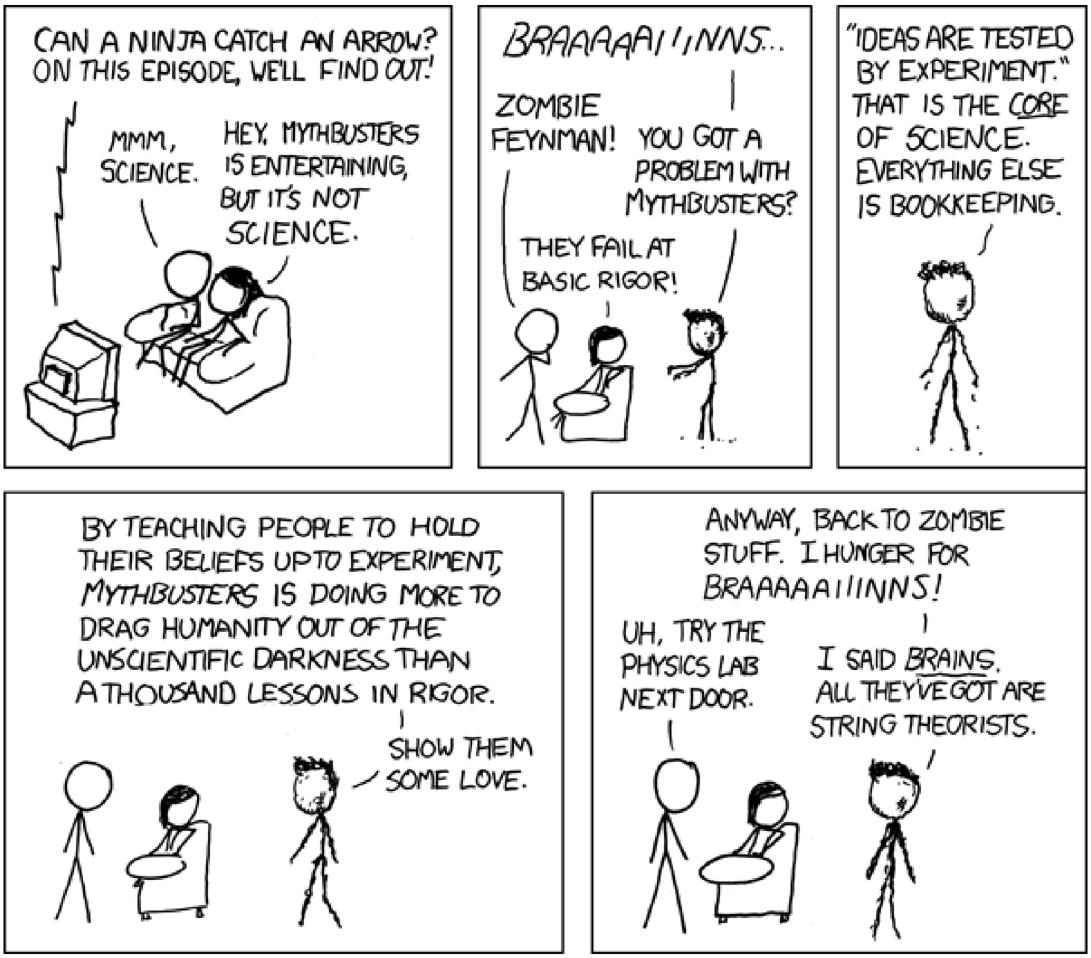

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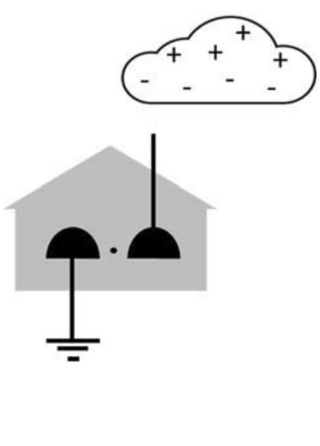

Cover image: *Detail of Franklin with his electric bells from Edward Fisher's mezzotint, after a painting by Mason Chamberlain. Franklin used this device to detect oncoming thunderstorms. How this worked is illustrated in the diagram on the left.*

Safety note: DO NOT INSTALL THIS DEVICE IN ANY HOME! There are far safer methods of detecting electrical storms than grounding a lighting bolt through your living room.

General Physics Laboratory II

PHYS 1602L

(Prior to the Fall of 2015, this lab was referred to as PHYS 118B.)

Contents

Introduction

The Sermon

The speed of light is 2.99792458 × 10^8 m/s. This is not science.

The Wikipedia entry on Newton's 2^{nd} law of motion is not science.

Nor is the periodic table of the elements.

Science is not a collection of facts. (Not even true facts!) Rather, science is a **process** for figuring out what is really going on. *What is the underlying principle here? How does this relate to some other observation?* If you are not involved in such a process, you are not doing science. A brilliant, dedicated, A+ student memorizing a list of equations is not doing science. A baby dropping peas on the floor to see what happens: now *that's science!!* (Does oatmeal fall too? Let's find out!!)

This is a science lab. I expect you to do some science in it.

"*Yeah, yeah, Dr. Charnock, I've heard this sermon before*."

Perhaps so, but I have seen too many brilliant and dedicated students who have learned to succeed in their other science classes by learning **lots of stuff**. So, they come into physics planning to memorize every equation they encounter and are completely overwhelmed. **You cannot succeed in physics by learning lots of stuff.** There are simply too many physics problems in the world; you cannot learn them all.

Instead, **you should learn as little as possible!**[*] More than any other science, physics is about fundamental principles, and those <u>few</u> principles[†] must be the focus of your attention. Identify and learn those fundamental principles and how to use them. Then you can **derive** whatever solution that you need. And that **process** of derivation is the **process** of science.

"OK, thanks for the advice for the class, but this is a lab!"

It's still about fundamental principles. Look, each week you will come to lab and do *lots of stuff*. By following the instructions and copying (. . . oh, I mean *sharing* . . .) a few answers from your lab partners, you can blunder through each lab just fine. The problem is that the following week you will have a quiz, and you will not remember everything you did in that lab the week before.

When you are doing each lab, consciously relate your experiments to the underlying principles.

How did I measure this? Which principle am I applying? Why are we doing this?

On the subsequent quiz, instead of having to **remember what you did**, you can apply the principles to **figure out what you did**. Trust me. It really is easier this way.

[*] . . . but not less.
[†] F = ma, conservation of energy and momentum, oscillations and waves, trigonometry. You will learn a few more in the second semester.

GOALS AND OBJECTIVES

Physics is about the real world, not some idealized Platonic world that only exists in your head.* The purpose of this lab is to relate the theories and equations you are learning in the classroom to reality. Hopefully, we'll convince you that all that physics stuff actually does work. Of course, reality can be messy, and along the way you will learn to deal with experimental uncertainty, loose cables, bad sensors, sticky wheels, temperamental software, temperamental lab partners, your own awful handwriting, and the typos in this lab book.

Welcome to experimental physics!

xkcd.com

CORRELATION WITH LECTURE

Most of the topics covered in the lab will also be covered in your lecture, although not necessarily in the same sequence or at the same time during the semester. Given the scheduling (and re-scheduling) of the different lecture sections (some are MWF and some are TR), and the different lab sections (the first lab is Monday at 1 PM, the last is Thursday at 4 PM), *perfect correlation of lecture and lab topics is not possible*. The TA will provide a brief overview of the physics concept being explored in the lab during the first part of each lab section.

Occasionally, to improve the correlation with the lecture, the order of the labs may be changed from the sequence in this lab book. If so, you will be informed by your TA. **Check your email regularly.**

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* That's the Mathematics Dept. Walk over to Bldg. 3.

PREPARATION

Prior to coming to lab, you should read over each experiment. Furthermore, for each laboratory, you must complete a *pre-lab* activity printed at the beginning of each lab in this manual. The pre-lab should be completed before the lab and turned in at the **beginning** of the lab. See the course syllabus for more details. In some labs, you may also be required to complete experimental predictions and enter them in your lab manual before you come to lab. Your TA will discuss this with you when necessary. Bring the following to each lab:

- Your complete lab manual secured in a 3-ring binder, including your previous graded labs.
- Your completed pre-lab.
- A scientific calculator. Graphing calculators are nice but not necessary. For some calculations, you may find a spreadsheet (such as Excel), Matlab, or some other computer based tools more appropriate. You are welcomed and encouraged to use such tools, but you still need a calculator.
- A pen, pencil and an eraser.

Often, the pre-lab includes online media for you to watch. Direct URL links are printed in the text, but clickable links may be found here:

`https://my.vanderbilt.edu/physicslabs/videos/`

xkcd.com

PROCEDURE IN THE LABORATORY

In the laboratory, you will need to be efficient in the use of your time. We encourage a free exchange of ideas between group members and among students in the section, and we expect you to share both in taking data and in operating the computer, but **you should do your own work (using your own words) in answering questions in the lab manual and on the review questions handed out in lab.**

HONOR CODE

The Vanderbilt Honor Code applies to all work done in this course. Violations of the Honor Code include, but are not limited to:

- Copying another student's answers on a pre-lab, lab questions, review questions, or quiz;
- Submitting data as your own when you were not involved in the acquisition of that data; and
- Copying data or answers from a prior term's lab (even from your own, in the event that you are repeating the course).

GRADING

Your lab reports will be graded each week and returned to you the following week. Grades (including lab and quiz grades) will be posted on Brightspace.

- ***Mistakes happen!*** Check that the scores on Brightspace are correct. If you don't do this, *no one will.*
- Retain you lab reports so that any such errors can be verified and corrected.
- Details of grading may be found on the online syllabus.

MAKING UP MISSED LABS

For details, I refer you to the syllabus (see below), but the main points are . . .

- **All** labs must be completed.
- If you know ahead of time that you will miss a lab, you must email both Dr. Charnock and your TA no later than the Friday before you will miss the lab.

  forrest.t.charnock@vanderbilt.edu

  In that email, include

  - Your lab (1601L, 1602L, 1501L, or 1502L)
  - Section number
  - TA name
  - A brief explanation of why you are missing lab.
- If arranging a make-up ahead of time is not possible, email us as soon as possible.
  - If you are abducted by aliens, whip out your phone and compose an email describing your predicament while the tractor beam is lifting you into the air. Make sure to hit SEND before the iris door closes or the message won't go out.[*] Update us on your situation as soon as you are returned to Devil's Tower.
- You must be pro-active in making up labs.
  - Do NOT passively wait for someone to tell you what to do.
  - If you do not receive a reply from Dr. Charnock within 24 hrs, ***email him again***. Repeat as necessary.[†]

[*] Aliens rarely share their Wi-Fi passwords.
[†] Luke 18:1-5

SYLLABUS: available online

`https://my.vanderbilt.edu/physicslabs/documents/`

The Greek Alphabet

The 26 letters of the Standard English alphabet do not supply enough variables for our algebraic needs. So, the sciences have adopted the Greek alphabet as well. You will have to learn it eventually, so go ahead and learn it now, particularly the lower case letters. (Just be glad you don't have to learn Cyrillic.)

Alpha	A	α
Beta	B	β
Gamma	Γ	γ
Delta	Δ	δ
Epsilon	E	ε
Zeta	Z	ζ
Eta	H	η
Theta	Θ	θ
Kappa	K	κ
Lambda	Λ	λ
Mu	M	μ
Nu	N	ν
Xi	Ξ	ξ
Omicron	O	o
Pi	Π	π
Rho	P	ρ
Sigma	Σ	σ
Tau	T	τ
Upsilon	Y	υ
Phi	Φ	ϕ or φ
Chi	X	χ
Psi	Ψ	ψ
Omega	Ω	ω

Useful Physical Constants*

Speed of Light (exact)	c	$2.99792458\times10^{8}\ \frac{m}{s}$
Elementary charge (exact)†	e	$1.602176634\times10^{-19}C$
Electron volt (exact)†	1 eV	$1.602176634\times10^{-19}\ J$
Plank's constant (exact)†	h	$6.62607015\times10^{-34}\ Js$
	$\hbar = h/2\pi$	$1.054571818\times10^{-34}\ Js$
Permeability of free space (exact)	μ_0	$4\pi\times10^{-7}\ \frac{Wb}{Am}$
Permittivity of free space (exact)	$\varepsilon_0 = \frac{1}{\mu_0 c^2}$	$8.854187187187...\times10^{-12}\ \frac{C^2}{Nm^2}$
Universal gravitational constant:		$G = 6.67408(31)\times10^{-11}\ \frac{m^3}{kg\ s^2}$
Avogadro's Constant (exact)†	N_A	$6.02214076\times10^{23}\ mol^{-1}$
Boltzmann's Constant (exact)†	k	1.380649×10^{-23} J/K
Universal gas constant	R	$8.3144598(48)\ \frac{J}{mol\ K}$
Absolute zero		0 K = −273.15°C
Acceleration due to gravity at Vanderbilt‡:		$g = 9.7943(32)\ \frac{m}{s^2}$

* Unless otherwise stated, values are from NIST (physics.nist.gov/cuu). The number in parentheses is the standard uncertainty of the final digits of the main number.
For example, 6.67408 ± 0.00031 = 6.67408 (31)

† As of May 20, 2019, this exact value is adopted by the General Conference on Weights and Measures (GCWM)
‡ Dr. Medford Webster, Vanderbilt University

Name______________________________________ Section______ Date_____________

Pre-Lab Preparation Sheet for Lab 1:
Electrostatics
(Due at the beginning of lab)

Read over the lab, then watch the following videos. Hyperlinks to these and other videos may be found at

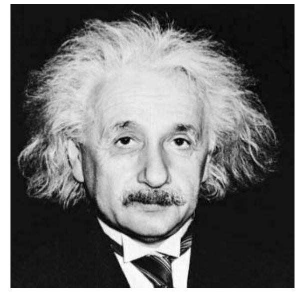
`my.vanderbilt.edu/physicslabs/videos/`

What's in a candle flame?	`www.youtube.com/watch?v=a7_8Gc_Llr8`
Electric sparks from falling water:	`www.youtube.com/watch?v=Rwa26CXG1fc`
Kelvin's Thunderstorm:	`www.youtube.com/watch?v=rv4MjaF_wow`

1. Electrostatic precipitators are used to remove smoke particles from the exhaust of power plants. From the first video above, how do they work?

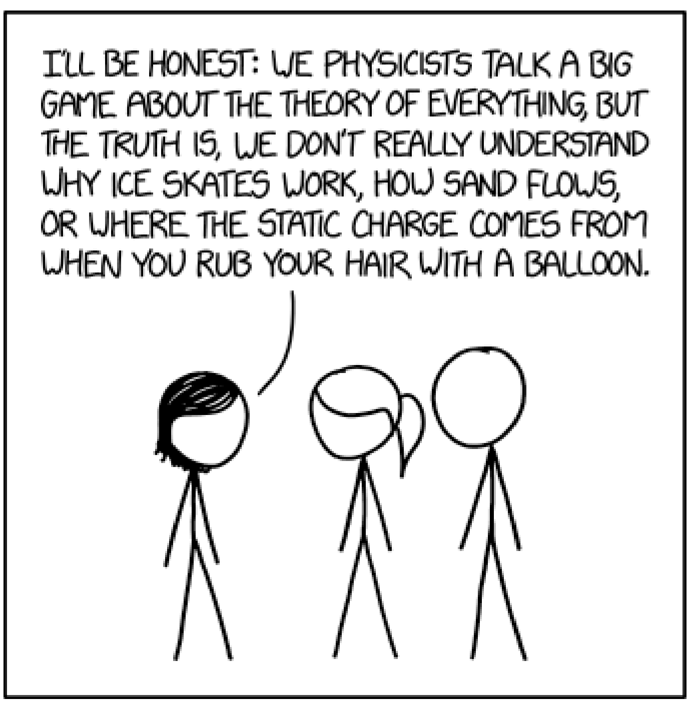
2. Consider the electrostatic generator of the 2nd video. What force is doing work to produce electrical energy?

3. Define the triboelectric effect. (On back.)



For this first lab, you will need an efficient electrostatic generator. Fortunately, you probably have half of one conveniently located on top of your head. However, to work well, it needs to be very clean. So, before coming to this first lab**, please wash your hair using little or no conditioner** or styling products. The frizzier, the better.

This is by no means a requirement, but the lab will go more smoothly. And, it's quite the rage among natty physicists.



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Name ______________________ Date __________ Partners ________________

TA ________________ Section _______ ________________

Lab 1: Electrostatics

"Electricity is really just organized lightning."
--*George Carlin*

Objective:
To understand electrostatic phenomena in terms of the basic physics of electric charges.
To experimentally distinguish positive and negative charges.
Properties of conductors and insulators.

Equipment:
Braun electroscope, polar electroscope, Faraday cage
Fur, Saran Wrap, two rubber balloons, tissue paper
Electrophorus

Introduction

Electrostatic theory, while profound, is quite simple. Many otherwise mysterious phenomena can be understood by applying a few simple principles:

1. Electrical charges come in two types: *positive* (+) and *negative* (-).
2. Like charges repel. Opposite charges attract.
3. Electrical charges cannot be created or destroyed, but may be separated and moved.
4. If an object is observed to be electrically neutral, equal amounts of + and – charges are present. If it is positively charged, a surplus of + charges are present. If it is negatively charged, it has a surplus of – charges.
5. There are two types of materials:
   a. *Insulators*: electrical charges are frozen in place in the material.
   b. *Conductors*: electrical charges may freely move throughout the volume of the object like a gas in a container.

Franklin himself thought of these charges arising from an excess or deficiency of a single electric fluid. Today, we understand the charges are due to particles of protons (+) and electrons (-). *Usually*, it is the electrons (that is, the negative charges) that move around; however, it is often useful to think of positive charges moving as well. A negative charge moving to the left is equivalent to a positive charge moving to the right.

Triboelectricity

First, you must move some electrons around to produce a net electric charge. You can do this with the *triboelectric effect*.*

6. Vigorously rub an inflated balloon with your over dry, frizzy, unconditioned hair.†

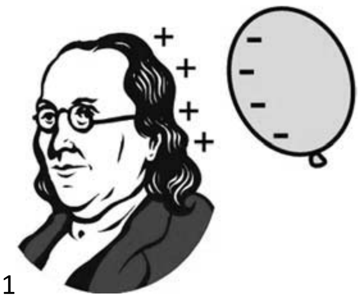


Fig 1

7. Tear off a few small pieces of tissue paper. Hold the balloon next to the chaff and observe the effect.
8. Touch the balloon to the electroscopes and observe the effect.

Some materials (such as hair) have a slight tendency to give up electrons. Other materials (such as rubber) tend to pick up a few extra electrons. Hence, if you rub a balloon with hair, electrons will be transferred, and a net electric charge will appear on each. When Ben Franklin did this, he declared the hair to have a "positive" charge and the rubber to have a "negative" charge.‡ Today, following Franklin's convention, we declare electrons to have a negative charge.

The Triboelectric Series ranks different materials by their tendency to give up or absorb electrons.

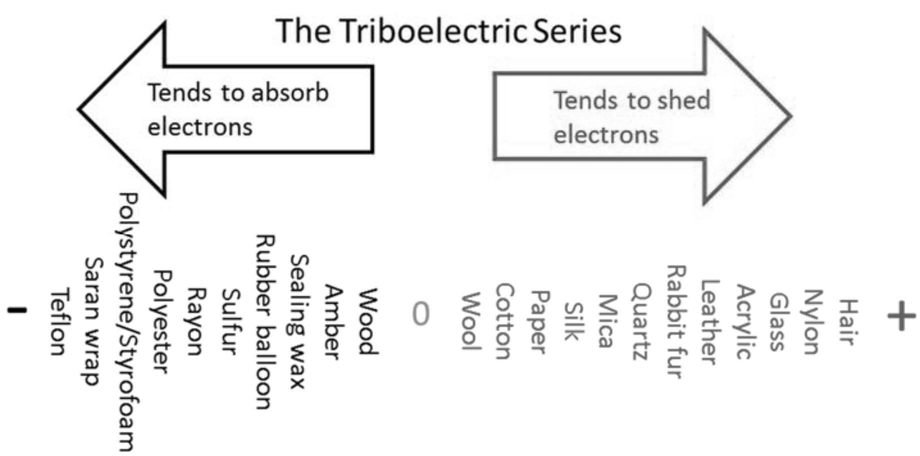


Fig 2

* *Tribo* is from the Greek term for rubbing.
† If you are follicly challenged, use the fur.
‡ An unfortunate choice in retrospect. Electrical currents would be a little more intuitive if Franklin had declared the rubber (and hence, electrons) to be positive.

For any two materials brought in contact, you can estimate the sign and relative strength of the triboelectric effect by the relative position of materials on the series. For instance, hair is to the right of rubber on the series; hence, when rubbed against rubber, hair will acquire a positive charge. Rub hair against hair and nothing happens.

9. If hair is rubbed against Styrofoam, would you expect a stronger or weaker effect? What type of charge would appear on the Styrofoam? What charge on the hair?

10. What would be the sign of the charges on each of the following items if they were rubbed against each other:
    a. Cotton _________ + Nylon _________
    b. Fur _________ + Rubber _________

11. From Fig. 2, do artificial fabrics tend to be more or less more prone to static cling? Explain.

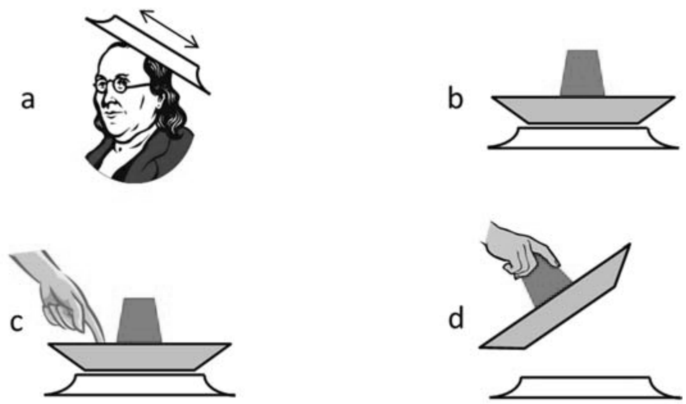
12. Charge two balloons by rubbing them with hair or fur. What is the charge on these balloons? Observe and describe the force between the balloons.

13. Re-charge one of the balloons by rubbing it with Saran wrap. What is the charge on this balloon? Observe and describe the force between it and the balloon charged using hair.

14. Charge the Styrofoam plate by rubbing it with your hair. Observe and describe the force between the Styrofoam and the negatively charged balloon. What is the charge on the Styrofoam?

The Electrophorus and Electrostatic Induction

The electrophorus is a simple device for easily generating and transferring electrostatic charges. It consists of an insulating plate (the Styrofoam plate) and a conductive plate (the aluminum pie pan) with an insulated handle.* The cartoon below illustrates how to use the electrophorus to charge the metal plate. Initially, the aluminum plate is uncharged.



Charging an electrophorus

Fig 3

a. Rub the **underside** of the Styrofoam plate with an appropriate material† to produce a large negative charge on the plate.
b. Place metal plate on top.
c. Touch the metal plate to remove excess charge.
d. Remove the metal plate with the insulated handle.

Notice that charge cannot move from the Styrofoam to the aluminum.

15. Experimentally determine the charge on the aluminum plate. Describe your procedure, and explain your reasoning.

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* We use the term *electrophorus* because that sounds much more impressive than *picnic supplies*.
† Refer to the triboelectric series above.

16. Now, determine exactly how the aluminum plate is charged. Initially, the aluminum plate has no charge.
    a. After the aluminum is placed on the Styrofoam, what is the net charge on the aluminum?

    b. How are the + and – charges on the aluminum distributed?

    c. What happens when you touch the aluminum?

17. For each step, add + and – symbols to the cartoons in Fig. 3 to illustrate the distribution of charges on the plates. Discuss these distributions with your lab partners and finally with your TA

Charging an Electroscope by Contact

Static charges on insulators are *sticky*, that is these charges do not easily move to other objects. Static charges on conductors are much more promiscuous.

An electroscope is used to detect an electric charge. By tapping an electroscope with charged aluminum plate, charge will move from the plate to the electroscope.

You will be using several different electroscopes. While the Braun electroscope is more sensitive to small charges, its reaction time is slow due to the relatively large mass of its needle. Be patient with it. The others react more quickly, but may be less sensitive.

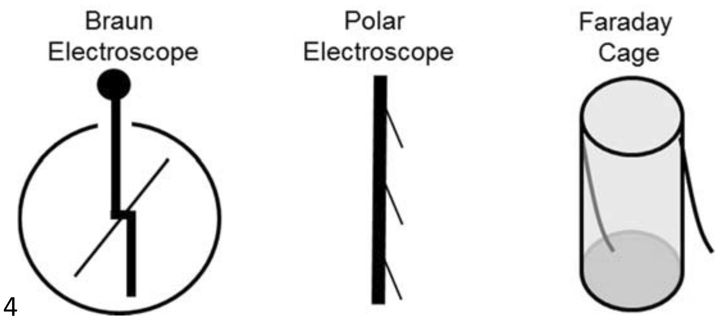


Fig 4

18. Verify that there is no charge on each device by touching them with your finger. This is called *grounding* the device. Any excess charge on the device will dissipate through your body to the ground.*
19. After charging the aluminum plate, touch the aluminum plate to the each of the electroscopes, and then remove the plate. Using the principles above, explain why is the needle or foil leaves deflected?

* The human body is essentially a bag of salt water and therefore a fairly good conductor.

Polar Electroscope

20. Recharge the plates of your electrophorus.
21. Ground the polar electroscope to verify that it has no charge. Then, alternately bring the Styrofoam and aluminum plates close (but not touching) the top of the polar electroscope, then pull it away. Let no charge move between the electroscope and the plates. Describe the effect. Is there any difference in the reaction of the electroscope to the two plates?

22. Tap the charged aluminum plate to the electroscope, then remove the plate. Describe the effect. What is the net charge on the electroscope?

23. Bring the charged aluminum plate close, but not touching, to the top of the charged electroscope. Describe the effect this has on each of the foil leaves. You may find a sketch useful. Explain your observations using the principles listed at the beginning of this lab.

24. Bring the charged Styrofoam plate close, but not touching, to the top of the charged electroscope. Describe the effect this has on each of the foil leaves. Illustrate your results and explain your observations using the principles listed at the beginning of this lab.

The Faraday Cage

25. Touch the Faraday cage to verify that it is discharged.
26. Recharge the electrophorus
27. Transfer three doses of charge from the electrophorus to the Faraday cage. Describe the effect on both of the foil leaves. (Note that there is a leaf inside the can.)

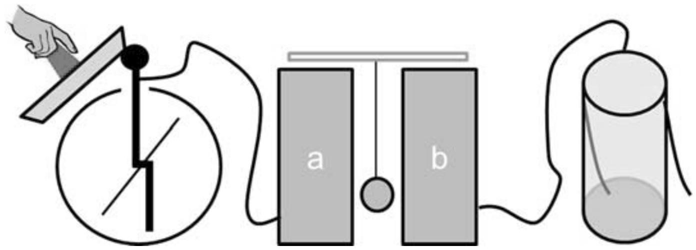
28. Exactly where on the cage does the charge reside? Applying the principles above, think of an intuitive explanation for this and discuss it with your TA.

29. What is the electric field inside the cage?

30. Have one member of your group wrap a cell phone with foil. Have another member make a call to the wrapped phone. Explain the result.

Franklin's Bells

31. Attach an electroscope to each side of the Franklin Bells (that is, the soda cans) as shown below. Each bell should be about 0.5 cm from the clapper. Ground each electroscope to ensure the system is neutral.



32. Using the electrophorus, transfer enough charge to the electroscope for the bells to start ringing.
33. When the motion stops, briefly ground one of the electroscopes with your finger.
34. Using the principles from the introduction, explain what you observed.[*]

[*] With one bell attached to a lightning rod and the other grounded, Franklin used his bells to detect approaching electrical storms; thus letting him know when he could perform his experiments. His bells are illustrated on the cover of this lab book.

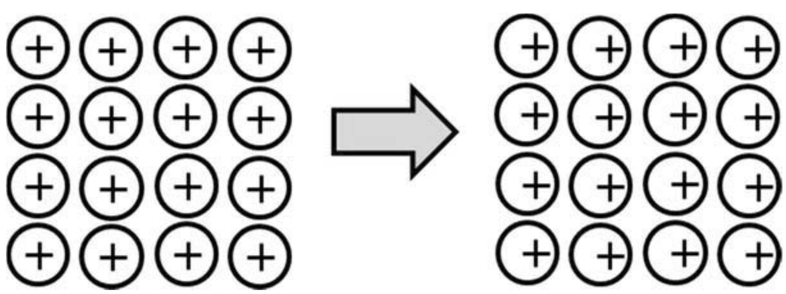
> *"I was one night awaked by loud cracks on the staircase. . . I perceived that the brass ball, instead of vibrating as usual between the bells, was repelled and kept at a distance from both; while the fire passed, sometimes in very large, quick cracks from bell to bell, and sometimes in a continued, dense, white stream, seemingly as large as my finger, whereby the whole staircase was inlightened (sic) as with sunshine . . . ."*

Wisely, Franklin also invented fire insurance.

Induced Polarization of Insulators

35. Charge the electrophorus.
36. Hold metal plate close to, but not touching, the hanging wooden dowel.
37. Hold the insulating plate close to, but not touching, the hanging wooden dowel.
38. Describe the effects below.

Even though electrical charges are not free to move through the insulating wood (unlike a conductor), the wood can still be slightly polarized. Model each atom in the wood as a positive nucleus surrounded by a negative shell of electrons. In the presence of an external electric field, the electrons will be slightly pulled one way and the nuclei are pulled the other way. This polarizes each atom, and hence the entire object, by having just a little more positive charge on one side, and a little more negative charge on the other.



Name_______________________________________ Section______ Date_____________

Pre-Lab Preparation Sheet for Lab 2:
Geometric Optics – Reflection and Refraction

(Due at the beginning of lab)

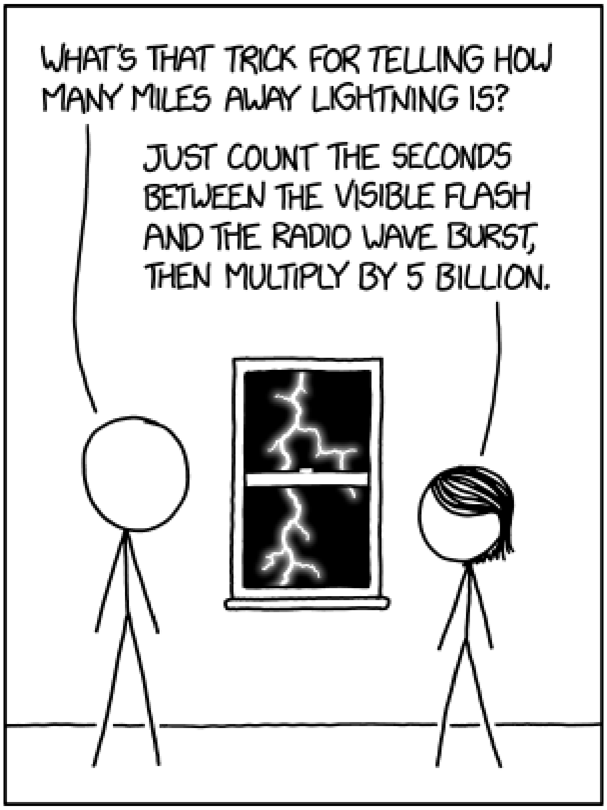
Watch the following videos,

`https://www.youtube.com/watch?v=FOwDgpKTqdY`

Then read over Lab 2, and answer the following questions.

1. The refractive index of titanium dioxide (aka white pigment) is 2.614, one of the largest of any material. What is the speed of light in TiO_2 ?

2. What is the critical angle for an TiO_2 to air interface?


WHAT'S THAT TRICK FOR TELLING HOW MANY MILES AWAY LIGHTNING IS?
JUST COUNT THE SECONDS BETWEEN THE VISIBLE FLASH AND THE RADIO WAVE BURST, THEN MULTIPLY BY 5 BILLION.

xkcd.com

Name ______________________ Date __________ Partners ______________________

TA ________________ Section _______ ________________________

Lab 2: Geometric Optics – Reflection and Refraction

All that is now
All that is gone
All that's to come
and everything under the sun is in tune
but the sun is eclipsed by the moon.

--Pink Floyd, *Dark Side of the Moon*

Objectives

To understand Snell's law, reflection, refraction, and total internal reflection

Equipment

2 equilateral prims	1 right angle glass prism
1 right angle acrylic prim	Light box
Clear plastic cup half filled	Aluminum block
Protractor and ruler	Paper towels

Introduction

Waves may travel at different speeds in different media. When a wave travels from one medium into another with different wave speeds, two things will occur:

1. Part of the wave will *reflect* off the interface. The reflected angle is equal to the incident angle.

$$\theta_i = \theta_r \tag{1}$$

2. Part of the wave will transmit into the 2nd medium, but its direction of travel will be bent or *refracted*. The angle of the transmitted wave is given by Snell's Law

$$\frac{\sin\theta_i}{\sin\theta_t} = \frac{v_i}{v_t}\ , \tag{2}$$

where v_i and v_t are the speeds of the incident and transmitted waves.

This is true of all waves: sound waves, light waves, tsunamis, . . . *any kind of wave*.

When dealing with light waves, we define a value called the *index of refraction*:

$$n \equiv \frac{c}{v} \ , \tag{3}$$

Where v is the velocity of light in a particular material, and c is the velocity of light in a vacuum $\left(2.998\times10^{8}\,\frac{m}{s}\right)$. Hence, we can write Snell's Law as

$$\frac{\sin\theta_i}{\sin\theta_t} = \frac{n_t}{n_i} \tag{4}$$

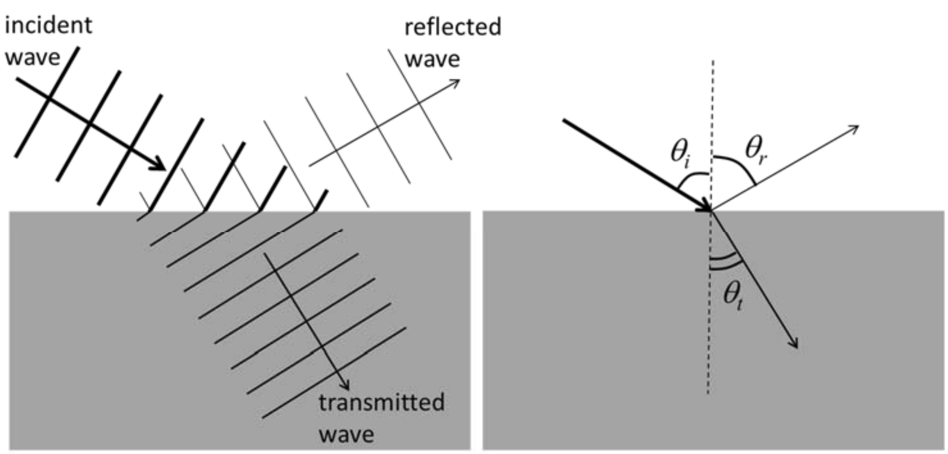
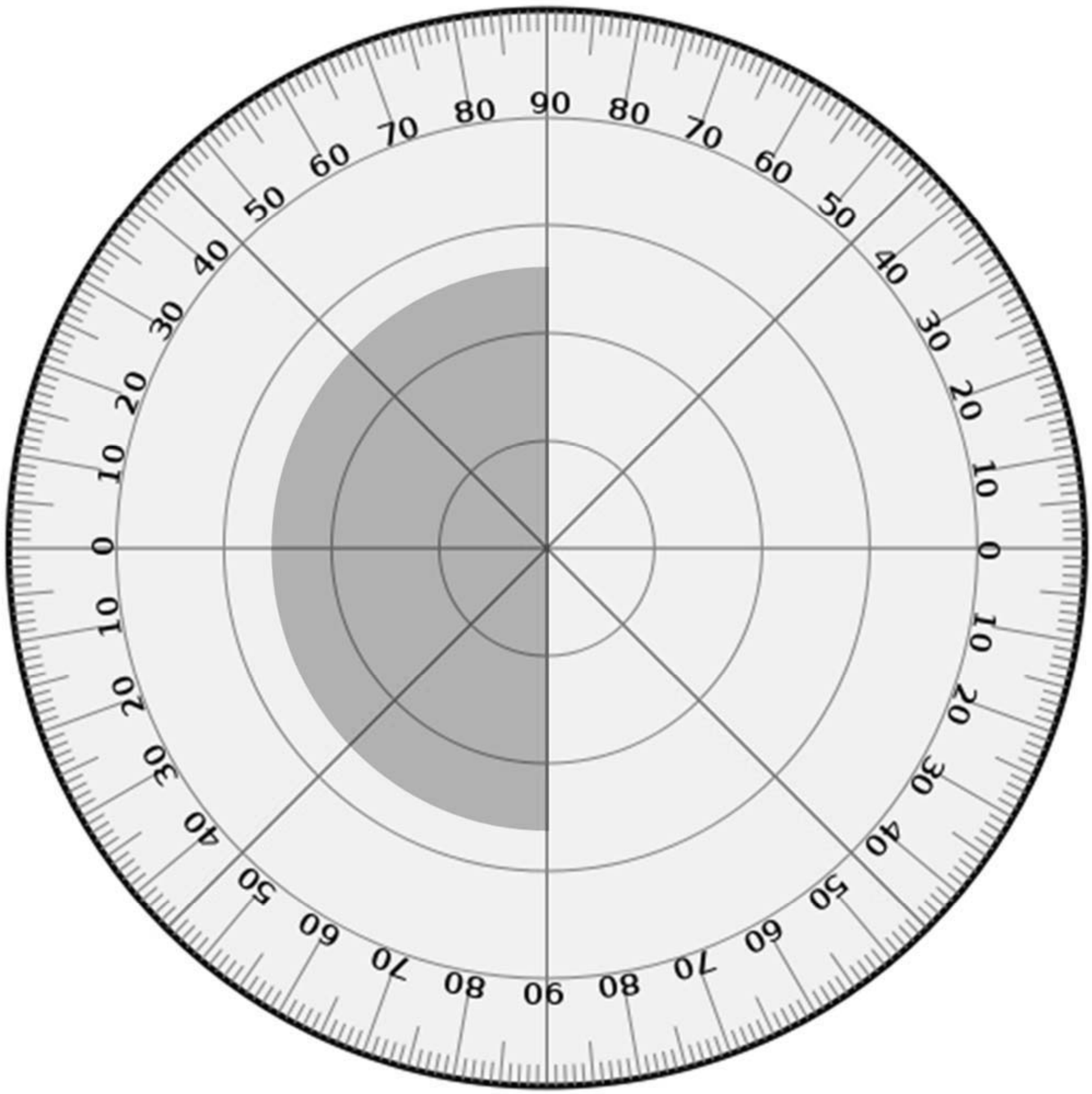


Figure 1

Exercise 1: Reflection and Refraction

1. Place the semi-circle of glass on the printed protractor. Adjust the light box so that a single beam of light is produced. Shine the beam on the center of the flat surface with the incident angle θ_i (listed in Table 1A) and measure the corresponding reflected θ_r and transmitted θ_t angles. (See Figure 2.) Fill in Table 1A below.
2. Next, reverse the semi-circle as illustrated in Figure 2B. Again, Measure the angles and fill in Table 1B below.

Figure 2



3. Using Excel, plot $\sin(\theta_i)$ vs. $\sin(\theta_t)$ for both tables. From this plot, determine the index of refraction of glass.

4. You will notice that light may be bent toward the normal or away from the normal. (See the figure below.) What determines the direction?

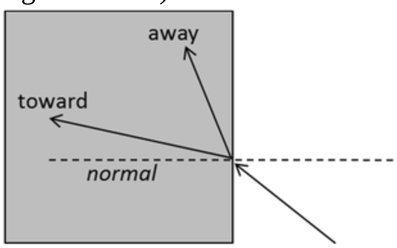


Figure 3

For some of your measurements, there was no transmitted light beyond a particular angle. Instead, all of the light is reflected off the interface. This condition is called *total internal reflection* and occurs because the transmitted angle θ_t cannot be larger than 90°. The minimum incident angle at which this occurs is called the *critical angle* θ_c.

5. Carefully measure the critical angle of glass.

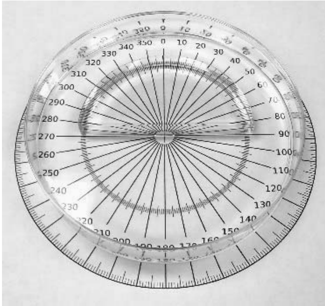
6. At the critical angle, what is the transmitted angle θ_t ?

7. What are the required conditions for total internal reflection?
    a. Explain in English:
    b. Derive an expression for θ_c.

8. Similarly use the water lens to measure the index of refraction for water via multiple refractions and the critical angle.

9. Compare your value for the index of refraction of water to the accepted value.

Snell's Law still applies if the glass block is placed in water.



10. Submerge the glass block in the water. Measure the critical angle of the glass / water interface.

11. From this, calculate the index of refraction of water. Compare your result with the commonly accepted value.

θ_i	θ_t	$\sin(\theta_i)$	$\sin(\theta_t)$
0°			
10°			
20°			
30°			
40°			
50°			
60°			
70°			
80°			

Table 1A: Air to glass

θ_i	θ_t	$\sin(\theta_i)$	$\sin(\theta_t)$
0°			
10°			
20°			
30°			
40°			
50°			
60°			
70°			
80°			

Table 1B: glass to Air

Exercise 2: A glass of water

You should find a clear plastic cup on the table. The bottom of the cup is painted white.

12. Fill half with water, and place it on the black surface of the table.
13. Looking straight down into the cup, observe the reflections on the side.
14. Place a dry finger against the side of the cup and observe the effect on the reflection.
15. Place a wet finger against the side of the cup and observe the effect on the reflection.
16. Decribe the phenomenon, then write a complete explanation of the phenomenon.

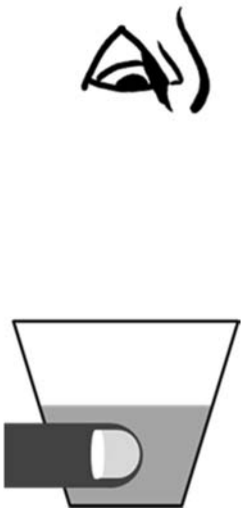


Figure 4

Exercise 3: Dispersion

17. Using Google, study the cover art for Pink Floyd's *The Dark Side of the Moon*. Then, attempt to reproduce it with an equilateral prism.* Which color is bent the most? The least?

18. What does this imply about the speed of light and the index of refraction of the different colors in glass? Which color is the fastest? Slowest?

19. Using a 2nd prism, can you recombine the colors? Can you separate them more?

* This is best done while humming *The Great Gig in the Sky*.

20. Position the aluminum block after the 1st prism so that only red light can pass. Then send the single color through the 2nd prism. Does the 2nd prism have any effect on the color or dispersion of the red beam? How about blue light?