

# Magnets, Magnetic, and Electrostatic Fields unit Activities

## Most of these use PhET and one uses lab equipment

*To see how these activities fit into my course, use my school website. Plans fluctuate depending schedule changes and students' need.*

[http://jeffcoweb.jeffco.k12.co.us/high/evergreen/science/loeblein/phys\\_syl/syllabus\\_p.html](http://jeffcoweb.jeffco.k12.co.us/high/evergreen/science/loeblein/phys_syl/syllabus_p.html)

### Table of Contents

Sample Unit Schedule .....	2
Learning Goals .....	3-4
Magnet and Electrostatics inquiry lab .....	5-12
Faraday Electromagnetic Lab PhET Activity 1 and 2 .....	13-24
Electric Field Hockey and Charges and Fields.....	25-27
Balloons and Static Electricity and John Travoltage as a demo.....	28-29

**The PhET activities can also be found in the PhET Teaching Ideas in Microsoft office format if you would like to edit them go to:**

Faraday Electromagnetic Lab 1: [http://phet.colorado.edu/teacher\\_ideas/view-contribution.php?contribution\\_id=13](http://phet.colorado.edu/teacher_ideas/view-contribution.php?contribution_id=13)

Faraday Electromagnetic Lab 2:

College version: [http://phet.colorado.edu/teacher\\_ideas/view-contribution.php?contribution\\_id=161](http://phet.colorado.edu/teacher_ideas/view-contribution.php?contribution_id=161)

High school version: [http://phet.colorado.edu/teacher\\_ideas/view-contribution.php?contribution\\_id=14](http://phet.colorado.edu/teacher_ideas/view-contribution.php?contribution_id=14)

Electric Field Hockey [http://phet.colorado.edu/teacher\\_ideas/view-contribution.php?contribution\\_id=43](http://phet.colorado.edu/teacher_ideas/view-contribution.php?contribution_id=43)

Balloons & Static Electricity & John Travoltage as a demo <http://phet.colorado.edu/en/contributions/view/2847>

All of my activities are posted under the Creative Commons - Attribution license

(<http://creativecommons.org/licenses/by/3.0/>), so please acknowledge that they were developed by Trish

Loeblein, PhET Team and Evergreen HS, and provide a link back to the main PhET website

(<http://phet.colorado.edu>).

## 10-11 Honors Physics Semester 2 Unit 3 Magnetic and Electric Forces and Fields

(Chapters 20.1-20.4, 24.1-24.6, 25.1-25.2)\*

*How do magnets act? What is electric charge? How are charged objects like magnets? How do they differ?*

2/23 Lab 1: Magnets and Magnetic fields  
Do: read 24.1-24.2

2/25 Notes: Magnetic domain and Magnetic Force  
Lab1: Finish Magnets and Magnetic fields  
Do: Magnets and Magnetic fields homework worksheet, Stop and Think 24.1-24.2,

### CSAP weeks 2/28-3/11

2/28 Lab 2: Magnets using Faraday's Electromagnet Lab 1 PhET  
Do: read 24.3 Stop and Think 24.3, p822 concept question (1,6,7)

3/1 or 3/2 Quiz: Magnet essay question

Lab 2: finish Magnets using Faraday's Electromagnet Lab 1 PhET

Lab3: Magnets using Faraday's Electromagnet Lab 2 PhET

Lab 5: Discuss generator project: get magnets, light, and wire, research, draw plans, and plan to get supplies, Read Generator rubric

Do read 24.4-24.5 Stop and Think 24.4 concept question p 823 (17,19) problems p824 (1,3,5,23)

3/4 Lab 4: Introduction to Static Electricity using Electric Field Hockey & Charges & Fields PhET  
Do: read 24.6, Stop and Think 24.5, read 25.1-25.2 to get an understanding of generators or use online tools (record references for generator project),

3/7 Lab5: Start wind powered generators: (-10 points if you do not have your supplies)  
Do: read p 649-658, p677 questions (1,3, 5,7) p679 problem (1)

3/8 or 9 Lab5: Work on generators  
Do: read p660 (Coulomb's law), p679 problem (9,11)

3/11 Lab 5: Finish generators and paper

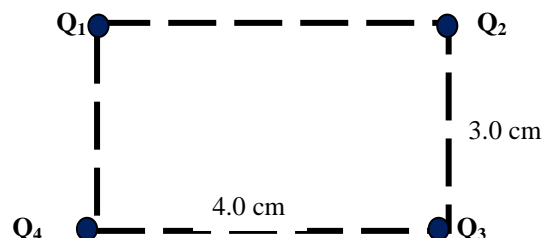
3/14 Present generators  
Notes: review essay on gravity, magnets, electricity, Gravity and Orbits clicker question

3/15 Notes: Review Coulomb's law, Electric forces and fields demos, calculation of net electric force in 1 & 2 dimensions

Do: read p661- 663, p677 questions (9,11) problem p 679 (14,16, 47)

Find the force on  $Q_1$  in the diagram to the right

Given:  $Q_1 = -4\text{nC}$   $Q_2 = 3\text{nC}$   $Q_3 = -5\text{nC}$   $Q_4 = -2\text{nC}$



3/16 Notes: Electric Field

Lab 6: Use Interactive physics to verify situations with three spheres in 1 & 2 dimensions (each person will turn in IP sketch and handwritten work) **turn in before class on 3/17**

Do: read 664-667 MC p824 (31-37), p 678 (23-29) Stop and Think 20.1-20.4

3/18 Clicker questions PhET: Faraday, Electric Field Hockey  
Do: Stop and Think 20.1-20.4 p677 questions (13) p680 problems (19, 25)

3/21 Test

## **Learning Goals Electric and Magnetic Forces and Fields**

### **Chapter 17: Electric Forces and Fields Chapter 21: Magnetism**

#### **17-1: Electric Charge**

- Understand the basic properties of electric charge
- Differentiate between conductors and insulators
- Distinguish between charging by contact, charging by induction, and charging by polarization

#### **17-2: Electric Force**

- Calculate electric force using Coulomb's law
- Compare electric force with gravitational force
- Apply the superposition principle to find the resultant force on a charge and to find the position at which the net force on a charge is zero

#### **17-3: The Electric Field**

- Calculate electric field strength
- Draw and interpret electric field lines
- Identify the four properties associated with a conductor in electrostatic equilibrium

#### **21-1: Magnets and Magnetic Fields**

- For given situations, predict whether magnets will repel or attract each other
- Describe the magnetic field around a permanent magnet
- Describe the orientation of Earth's magnetic field

#### **21-2: Electromagnetism and Magnetic Domains**

- Describe the magnetic field produced by the current in a straight conductor and in a solenoid
- Explain magnetism in terms of the domain theory of magnetism

#### **21-3: Magnetic Force**

- Given the force on a charge in a magnetic field, determine the strength of the magnetic field
- Use the right-hand rule to find the direction of the force on a charge moving through a magnetic field
- Determine the magnitude and direction of the force on a wire carrying current in a magnetic field

#### **Faraday's Electromagnet Lab 1: Introduction to Magnets PhET Activity**

- Predict the direction of the magnet field for different locations around a bar magnet and electromagnet

## **Learning Goals Electric and Magnetic Forces and Fields**

### **Chapter 17: Electric Forces and Fields Chapter 21: Magnetism**

- Compare and contrast bar magnets and electromagnets
- Identify the characteristics of electromagnets that are variable and what effects each variable has on the magnetic field's strength and direction
- Relate magnetic field strength to distance quantitatively and qualitatively
- Compare and contrast the fields of gravity and magnets qualitatively

### **Faraday's Electromagnet Lab 2: Induction PhET Activity**

- Identify equipment and conditions that produce induction
- Predict how the current will change when the conditions are varied
- Compare and contrast how both a light bulb and voltmeter can be used to show characteristics of the induced current

### **Electric Field Hockey, Charges, and Fields: Introduction to Static Electricity PhET Activity**

- Determine the variables that affect how charged bodies interact
- Predict how charged bodies will interact
- Describe the strength and direction of the electric field around a charged body
- Use free-body diagrams and vector addition to help explain the interactions

# Magnets and Magnetic Fields

## I. Magnets

A. Investigate the objects that you have been given (magnets, metals, wood, etc.). Separate the objects into three classes based on the way the objects **interact** with each other.

1. Experiment to figure out how objects within a class interact with each other, and how objects from different classes interact. Based on the way they interact, come up with a **name for each of the classes**
2. Make a table like the one below with larger spaces for writing. Instead of writing Class 1, Class 2, or Class 3, write the names you gave to the different classes. In the table, **write descriptions of the interaction** between members of the same and different classes. Below the table, list the objects in each of your classes.

	Class 1	Class 2	Class 3
Class 1			
Class 2			
Class 3			

3. Do all metals interact the same way? Are they all in the same class?
4. Explain how you sorted materials that have magnetic properties.

B. The parts of a permanent magnet that interact most strongly with other materials are called the *poles* of a magnet.

1. How many poles does each of your magnets have? Explain how you found them.
2. How many different *types* of poles do you have evidence for so far? Explain.
3. Using three magnets, find a way to distinguish one *type* of pole from another.

C. From the items you have been given, obtain a permanent magnet and an object that is attracted to the magnet but not repelled. Imagine that you do not know which object is the magnet.

1. Using only these two objects, find a way to determine which object is the permanent magnet.
2. Summarize your experiment

D. Talk about how an uncharged pith ball suspended from a string can be used to test whether an object is charged.

1. *Predict* what you think will happen when an uncharged pith ball is brought near one of the poles of the magnet. Explain.
2. Test your prediction and record your results.

## Magnets and Magnetic Fields

3. Based on your observations above, predict what will happen when the pith ball is brought near the other pole of the magnet. Test your prediction and record.
  4. Does your evidence show that there a *net charge* on the north (or south) pole of a magnet? Explain.
- E. A paper clip is attached to a string and suspended from a straw. It is then placed so that it hangs inside an aluminum-foil lined cup as shown.
1. Predict what will happen to the paper clip when a charged balloon is brought near the cup. Explain in terms of the electric interaction inside the foil-lined cup.
  2. Obtain the equipment and test your prediction. Discuss this experiment with your partners.
  3. Predict what you would observe if the paper clip were outside the cup. Explain your reasoning, and then check your prediction.
  4. Bring a magnet near the cup and observe what happens to the paper clip inside the cup. Record your observations.
- F. Based on your observations in parts D and E above, would you say that a magnetic interaction is the same as or different from an electrical interaction? Explain.

## II. Magnetic Fields

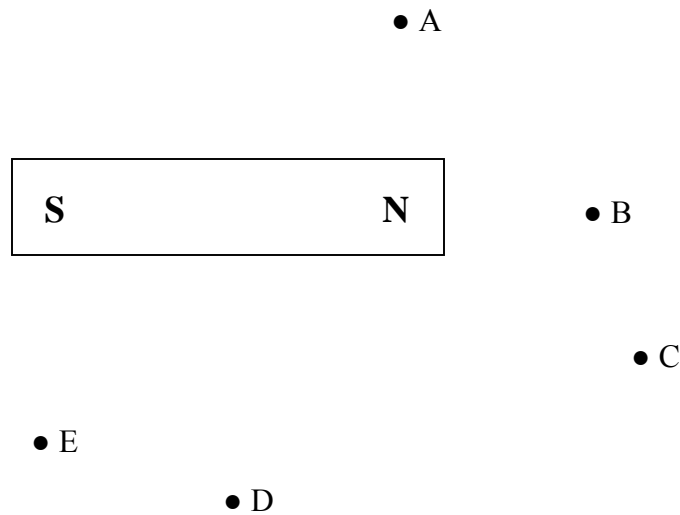
We have observed that magnets interact even when they are not in direct contact. We also know that there can be a gravitational field between objects that are not touching each other. For magnetic interactions, we similarly define a magnetic field.

- A. Obtain a compass from an instructor.
1. Use the compass to explore the region around the stack of magnets tied together. Describe the behavior of the compass needle both near the poles and all around the magnet.
  2. To which class of objects from section I does the compass needle belong? Explain.
  3. Move the compass far away from all other objects. Shake the compass and describe the behavior of the compass needle.
  4. Does the needle behave as if it is in a magnetic field?

## Magnets and Magnetic Fields

5. We can account for the behavior of the compass needle by supposing that it interacts with the Earth and that the Earth belongs to one of the categories from section I. To which class of objects from section I do your observations suggest the Earth belongs? Explain how you can tell.
6. We define the north pole of a magnet as the end that points toward the arctic region of the earth when the magnet is free to rotate and is not interacting with other nearby objects. On the basis of this definition, is the geographic north pole of the Earth a magnetic north pole or a magnetic south pole?
7. Use your compass to identify the north pole of an unmarked bar magnet.

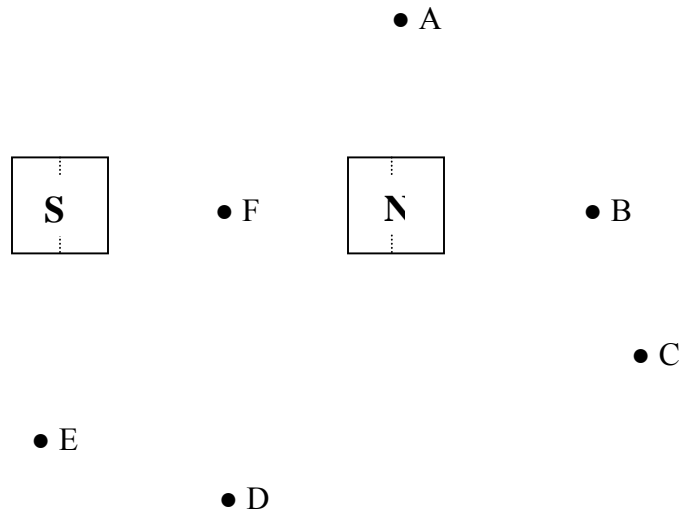
**B.** Copy the figure below. Sketch which way you think a compass would point if placed at each letter.



1. Place the stack of magnets tied together on the rectangle. Use a compass to test your ideas about which direction a compass will point and make changes to your drawing if necessary.
2. Discuss with your partners how the interaction of the compass with the magnet may depend on the distance from the bar magnet and the location around the bar magnet. Devise a method by which you can determine the approximate relative magnitudes of the magnetic field at each of the marked locations. Explain your reasoning.
3. We *define* the direction of the magnetic field at a point as the direction in which the north end of a compass needle points when the compass is placed at that point. Make arrows on your enlargement into magnetic field *vectors* (i.e., draw them so that they include information about both the magnitude and direction of the field).

## Magnets and Magnetic Fields

4. Break the stack in half and investigate the breaking points. Describe how many north and how many south poles result.
5. What does your observation suggest about how a bar magnet would behave when broken in half?
6. Copy the drawing below and draw the magnetic field vectors at the six locations A – F when **just the right half** of the stack of magnets is present.



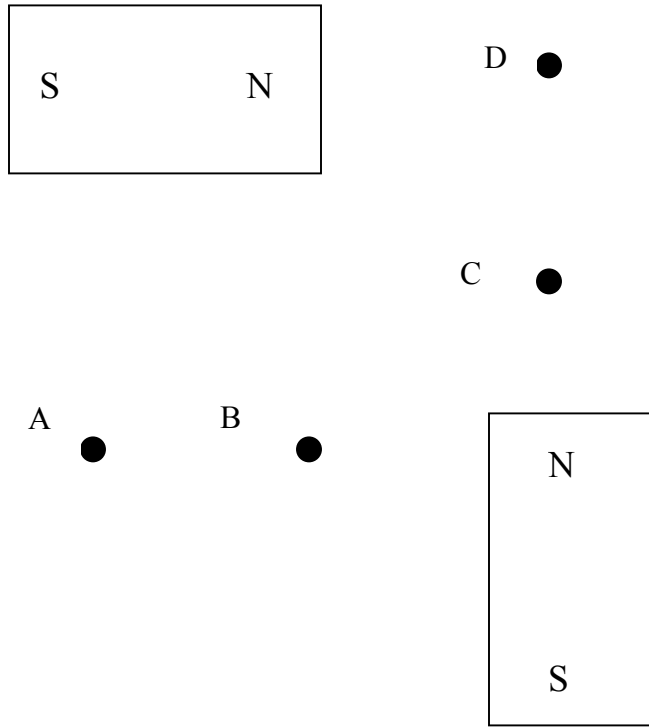
7. Using a different colored pen, draw the magnetic field vectors when just the left half of the stack of magnets is present.
8. Compare the field vectors for the two half stacks of magnets to the field vectors for the whole stack.
9. From your observations, what can you infer about the direction of the magnetic field inside a bar magnet? Explain.
10. Sketch magnetic field vectors for a few points inside the magnet.
11. Does the magnetic field of a bar magnet always point away from the north pole and toward the south pole of the magnet? Explain.
12. What can you infer about the strength of the magnetic field inside the magnet as compared to outside the magnet?



## Magnets and Magnetic Fields Homework

Answer the questions below on the basis of your experience with charges and magnets.

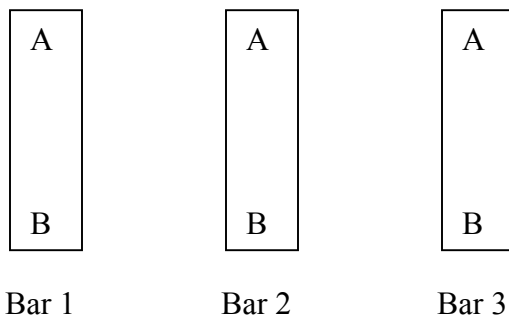
1. Two **identical** magnets are placed as shown.
  - a. Using one colored pencil, sketch the approximate magnetic field vectors at the four labeled points if just the horizontal magnet were present.
  - b. Use another color to sketch the field vectors if just the vertical magnet were present.
  - c. In a third color, show what the field vectors would look like if both were present.
  - d. Make a key to show what your different colors mean.



Explain how you determined the field vectors for the case when both magnets are present.

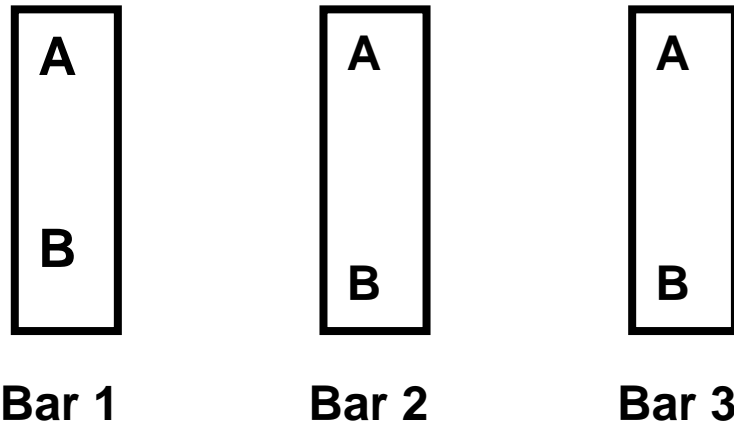
## Magnets and Magnetic Fields Homework

2. Three metal bars, labeled 1, 2, and 3, are marked A and B on either end as shown.



The following observations are made by a student:

- End 1B repels end 3A
  - End 1A attracts end 2B
  - End 2B attracts end 3B
- a. To which of your three classes from section I of the lab could bar 1 belong? Explain your reasoning and the characteristics that define each of your classes.
- b. To which of your three classes could bar 2 belong? Explain your reasoning.
- c. Would end 2A attract, repel, or neither attract nor repel end 3A if the two ends were brought near one another? If it is not possible to tell for certain, what are the possibilities? Explain.



**Three metal bars, labeled 1, 2, and 3, are marked A and B on either end as shown.**

The following observations are made by a student:

- End 1B repels end 3A
- End 1A attracts end 2B
- End 2B attracts end 3B

a. To which of your three classes (magnetic, magnetize-able, nonmagnetic), could bar 1 belong?

b. Explain your reasoning and the characteristics that define each of your classes.

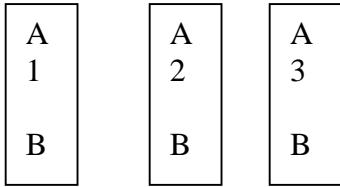
c. Would 2A attract, repel or not either 3A?

Quiz Left Name \_\_\_\_\_

The number 1 bar A end is attracted to the number 2 bar at both the A and B ends.

The number 2 bar repels the number 3 bar when placed A end to A end.

Identify what type of material each bar is and explain your reasoning including a possible magnetic pole combination.

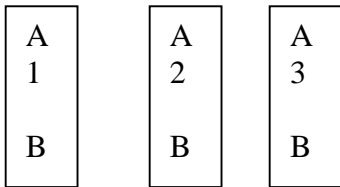


Quiz Right Name \_\_\_\_\_

The number 1 bar A end is attracted to the number 2 bar at both the A and B ends.

The number 2 bar repels the number 3 bar when placed A end to A end.

Identify what type of material each bar is and explain your reasoning including a possible magnetic pole combination.



Lesson plan Introduction to magnets using *Faraday's Electromagnet Lab 1*  
50 minute class .

Learning Goals: *Students will be able to*

1. Predict the direction of the magnet field for different locations around a bar magnet and electromagnet.
2. Compare and contrast bar magnets and electromagnets
3. Identify the characteristics of electromagnets that are variable and what effects each variable has on the magnetic field's strength and direction.
4. Relate magnetic field strength to distance quantitatively and qualitatively
5. Compare and contrast the fields of gravity and magnets qualitatively

Background: This year, I decided to try changing the traditional order for electricity and magnetism. Normally, we study static electricity before magnetism. We started with a having the students do a lab about magnets from *Tutorials in IntroductoryPhysics*<sup>1</sup> . This lab has little instructor direction and comes late in the year, after we have developed the skills for investigation, lab design, writing and reasoning.

*Faraday's Electromagnet Lab* Introduction:

I will not demonstrate the sim. We will be using the *Bar Magnet* and *Electromagnet* tabs for this activity and the other tabs later. I think we'll get through most of the first 3 steps on the first day and I'll mention the step 5 is homework to be done before we meet again.

Lesson: I will review that a compass points along the direction of a magnetic field. The activity is planned for my honors physics students to take about 90 minutes.

<sup>1</sup> McDermott, Shaffer and the Physics Education Group, Department of Physics, University of Washington. Prentice Hall 2002, p103

Student Directions: Introduction to magnets using *Faraday's Electromagnet Lab* 1  
<http://phet.colorado.edu>

Learning Goals: *Students will be able to*

1. Predict the direction of the magnet field for different locations around a bar magnet and electromagnet.
2. Compare and contrast bar magnets and electromagnets
3. Identify the characteristics of electromagnets that are variable and what effects each variable has on the magnetic field's strength and direction.
4. Relate magnetic field strength to distance quantitatively and qualitatively
5. Compare and contrast the fields of gravity and magnets qualitatively

1. Investigate *Faraday's Electromagnet Lab* paying attention to what you can change and what tools you can use to make measurements. We will be using the *Bar Magnet* and *Electromagnet* tabs for this activity and the other tabs later.

2. Read the first four learning goals and design experiments using the simulation that would help you learn these specific things. You do not have to write the procedures, but be prepared to explain to the instructor or another student your designs. Write a document that gives evidence that you can meet the learning goals. (*Include illustrations drawn by hand.*)

3. Pretend you and your lab partner are designers for the PhET simulations and want to make a simulation for students to investigate gravity fields. Think about what you know about gravity and what kinds of experiments a student might want to do to learn about gravity. You may have to refresh your memory by using the text. Draw a design, by hand, for a gravity simulation. Explain why you included each component and explain at least one experiment that a student could do.

4. Assume the 5<sup>th</sup> learning goal is a test question. Talk about what you would include to get full credit. Then have **each** person write his own paragraph on separate papers.

5. To check your writing, each person will meet with a person from a **different** group. Read each others paragraphs and talk about your reasoning. Type **one** new paragraph that you both agree is well done and print 2 copies so you can each have one to turn in with the other parts of the lab.

Lesson plan *Faraday's #2 using Faraday Law (Flash) and Electromagnet Lab(Java):*  
Induction

50 minutes

Learning Goals:

Students will be able to:

- Identify equipment and conditions that produce induction
- Compare and contrast how both a light bulb and voltmeter can be used to show characteristics of the induced current
- Predict how the current will change when the conditions are varied.

Background:

We will have studied electricity and had an introduction to magnets. About three weeks before, we will have done the activity called Introduction to Magnets that I wrote using *Faraday's Electromagnet Lab*. There will be a class discussion about their current understanding. I will define induction and demonstrate induction in common ways using an overhead meter and also a light bulb as indicators. They will be using the *Pickup Coil*, *Transformer* and *Generator* tabs of the sim. When I did this activity last year, the Flash version was not online. Many students did not do well on the essay question and I think there were too many concepts introduced at once and I had a sub that day. This lesson starts with the Flash version after the demos (the sub did not do the demos last year). I also wrote myself the following note: I have been thinking about how I might get the students to reason about what is the underlying cause of induction. I think I will have a class discussion on the next day after the activity. I will project the sim as an aid. Using the Flash sim with the "Show Field lines" may help solve the issue.

Demo equipment: magnet, variety of coils, power supply, overhead galvanometer, little demo light bulb, generator model

*Sim* Introduction:

1. *Faraday Law*: Show that the magnet can be moved to the left of the coil.
2. *Faraday's Electromagnet Lab* I will demonstrate turning off the *Show Field*, *Compass*, *Field meter* and *Electrons* so the window looks like real lab equipment and relate the window to the demo equipment that I used.

Lesson:

After the discussion and demos, have the students use the lab sheet for guidance..  
The activity is planned for my honors physics students to take about 50 minutes.

Post Lesson:

Clicker questions:

1.

Class discussion: Project *Faraday's Electromagnet Lab* (have *Faraday Law* minimized)

1. Guide the students to understand more about induction by using the *Transformer* and *Generator* windows. Talk about applications both of these. (In the college version, this is part of the student directions.)
2. Discuss what is causing the electrons to move (inducing the current) using the *Show Field* in both sims. My students have difficulty understanding how the fields

Lesson plan *Faraday's #2 using Faraday Law (Flash) and Electromagnet Lab(Java)*:  
Induction

50 minutes

interact. I may have them talk in pairs about what they think is happening and then write down their ideas. Then, we'll share. (In the college version, this is part of the student directions.)



Student Directions: *Faraday's #2 using Faraday Law (Flash) and Electromagnet Lab(Java):*  
Induction

Learning Goals: Students will be able to:

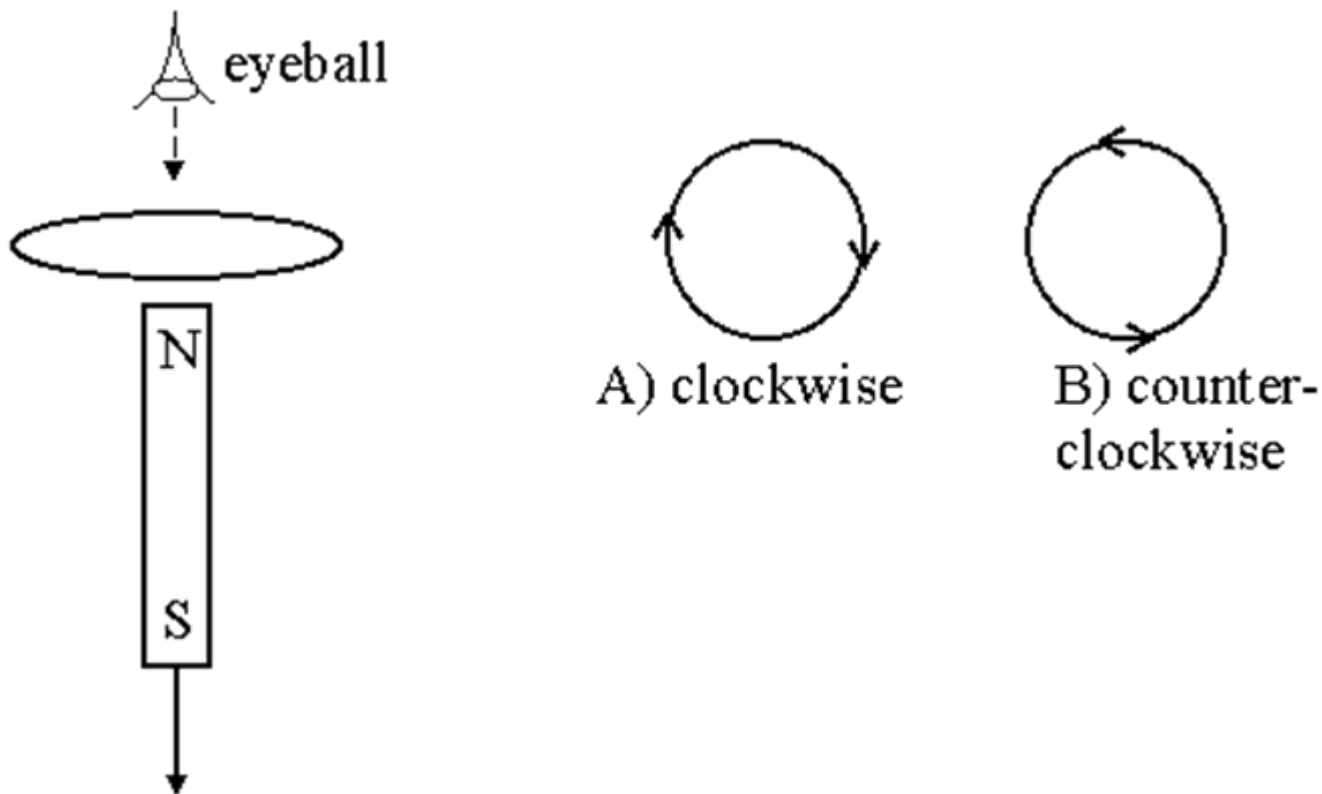
- Identify equipment and conditions that produce induction
- Predict how the current will change when the conditions are varied.
- Compare and contrast how both a light bulb and voltmeter can be used to show characteristics of the induced current.

**Directions: Start a Word document to turn in with the proper header/footer.**

1. Open the *Faraday Law* simulation and discover what you can about induction. Make a list of ways to cause induction.
2. What made you think that induction had occurred?
3. Open *Faraday's Electromagnet Lab*. Investigate using the window called *Pickup Coil*. See if you can discover more things that effect induction and add them to your list.
4. In this simulation, there is another way to show that induction is happening. Explain why this method may not have been used in the simpler simulation.
5. Describe in your own words what induction means.
6. Write a comparative paragraph to meet the third learning goal. Make sure to consider the strengths and weaknesses of each as an indicator of current.
7. Design an experiment to determine how the size and direction of the induced current will change when the conditions are varied. Collect data, make observations and record your information in a table.
8. Write a summary that demonstrates that you can meet the first two learning goals.

## Direction of induced current

A bar magnet is positioned below a horizontal loop of wire with its North pole pointing toward the loop. Then the magnet is pulled down, away from the loop. As viewed from above, is the induced current in the loop clockwise or counterclockwise?



Answer: The B-field from a bar magnet points out of the North pole. As seen from above, the field through the loop is out (toward the observer). As the magnet is pulled away, the flux is *decreasing*. To fight the decrease, the induced B-field should *add* to the original B-field, and also be out (toward the observer). The induced current will be (B), counterclockwise, in order to make an induced B-field out.

## Magnet

Two bar magnets are brought near each other as shown. The magnets...

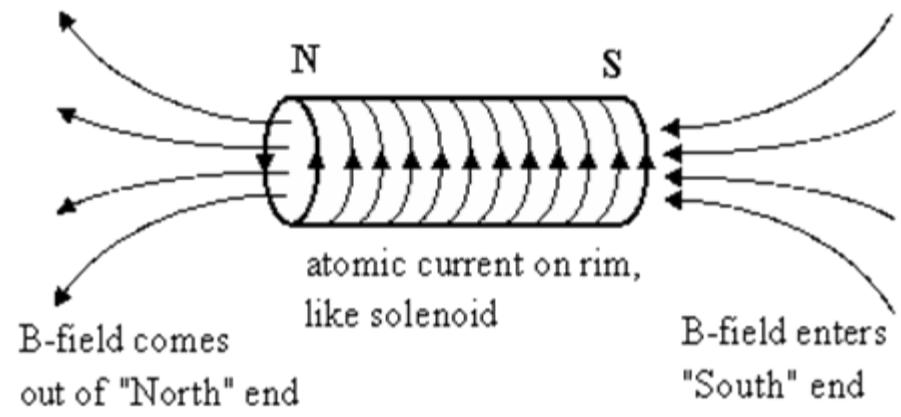
A) attract

B) repel

C) exert no net force on each other.



# Cool image of magnetic fields on bar magnet

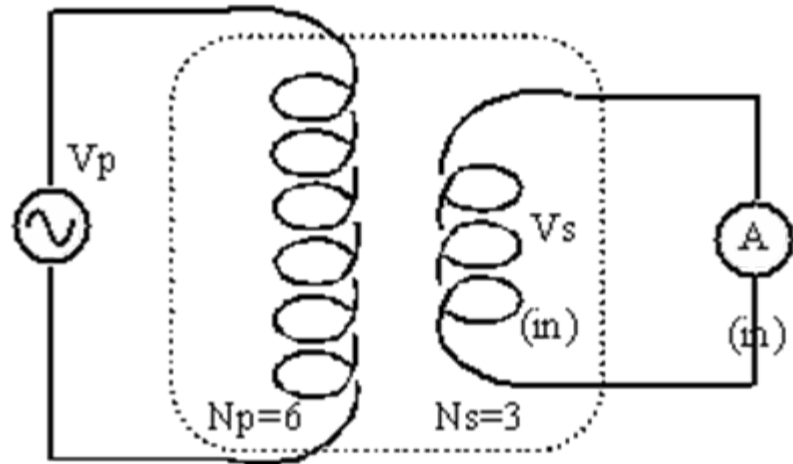


## Transformer

You have a transformer with  $N_p=6$  primary windings, and  $N_s=3$  secondary windings, as shown.

If  $V_p=120$  V AC, what is the current measured by the ammeter "A" in the secondary circuit?

- A) 120 A
- B) 60 A
- C) 240 A
- D) Nothing is measured because the fuse in the ammeter blows!



# Answer

The fuse in the ammeter blows! The secondary voltage is 60 VAC (it's a step-down transformer). The internal resistance of the ammeter is zero. So the ammeter current is  $I = V/R = 60 \text{ V}/(0 \text{ ohms}) = \text{infinite current}$ . The fuse will blow.

A solenoid is constructed with  $N$  loops of wire tightly wrapped around an iron-filled center. Due to budget cuts, the current that ordinarily runs through this solenoid is cut in half. As a result, the inductance of the solenoid is

- A. unchanged.
- B. quartered.
- C. halved.
- D. doubled.
- E. quadrupled.



Lesson plan for *Electric Field Hockey* and *Charges and Fields*: Introduction to Static Electricity  
<http://www.colorado.edu/physics/phet> Time for activity 80 minutes

Learning Goals: Students will be able to

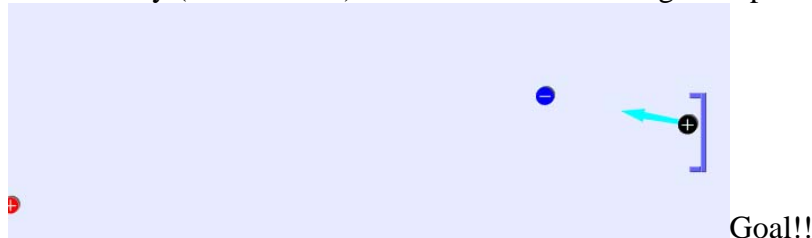
- Determine the variables that affect how charged bodies interact
- Predict how charged bodies will interact
- Describe the strength and direction of the electric field around a charged body.
- Use free-body diagrams and vector addition to help explain the interactions.

Background:

We will have briefly studied gravity last semester. We drew force diagrams to explain motion, but the concept of field as a vector is not developed. We will have studied magnets and done some qualitative investigations addressing magnetic fields. The students will have had several opportunities to add vectors, but it has been a few months.

I will do some traditional static electricity demonstrations and use the lesson plan that uses *Balloons and Static Electricity* and *John Travoltage*. (I have the demonstrations posted on the *PhET educational resources*) I have a couple of balloons that I can readily charge. We will discuss how the mass of the balloons could be varied. (Put sand in them perhaps). Also I use two scotch tape strips; I stick them to the table and then rip off, the pieces repel well and you can reverse one so they attract. I'll use my demonstration electroscope to help them how charge might be measured, but mine is very gross. I have a large glass and plastic rod to rub on some pieces of clothing to use on the electroscope.

*Electric Field Hockey* Introduction: Talk about an air hockey table and mention that this sim is like looking down on one. Instead of hitting the puck, this sim makes it move by using charged bodies like the charged balloons. I want to have them use the *Practice* mode for testing their ideas about how charge affects motion. Show them the difference between *Clear* (everything is zeroed) and *Reset* (the puck is brought back to starting point with same charges). I think having the *Trace* tool on is helpful. Point to the *Puck is Positive* option. The *Antialias* feature is just a programming tool; if you turn it on the resolution is better, but the program runs more slowly (less realistic). Demonstrate how using multiple charges can be used to make a goal.



Just a note: Static electricity and inertia is affecting the puck.

*Charges and Fields* Introduction:

It's important to realize that once you place a charge, it is fixed. The E Field sensors are like the like the puck from the *Field Hockey*, but it measures like the electroscope rather than responding with motion. I would recommend leaving the resolution (**Show lo res** and **Show hi res**) off for those most part to speed up investigations.

Lesson:

Go over the following problems:

- Draw the free body diagram for a file cabinet being pushed by a person.

Lesson plan for *Electric Field Hockey* and *Charges and Fields*: Introduction to Static Electricity  
<http://www.colorado.edu/physics/phet> Time for activity 80 minutes

- If the file cabinet is being pushed with 30 N and the friction force is 20, what is the net force?
- Find the resultant force if the cabinet is being pushed with 20 N north and 30 N east, assuming there is no friction.
- How does the resultant change if we do consider the friction?

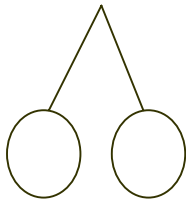
Then, have the students use the lab sheet for guidance. The activity should take my honors physics students about 80 minutes.

## Introduction to Static Electricity

Learning Goals: Students will be able to

- Determine the variables that affect how charged bodies interact
- Predict how charged bodies will interact
- Describe the strength and direction of the electric field around a charged body.
- Use free-body diagrams and vector addition to help explain the interactions.

1. You rub balloons in your hair and then hang them like in the picture below. Explain why you think they move apart and what might effect how far apart they get.



2. Test your ideas using *Electric Field Hockey* in the **Practice** mode. Make a table to record your observations about what affects the direction and speed of the puck. Your table should demonstrate that you have run controlled tests with all the variables.

3. Reflect on your ideas from question #1 and your data from question #2. How do your observations support, dispute or add to your ideas about what affects how charged bodies interact?

4. As you put charges onto the playing area, arrows appear on the puck.

- What do you think the arrows on the puck are illustrating?
- How do the arrows from the positive charges compare and contrast to the ones from the negative balls?
- Do you think the puck is positively or negatively charged? Explain
- Investigate how you can use the arrows to predict the motion of the puck.

5. Open *Charges and Field*. In this simulation, a little different model is used: the little yellow “E field sensors” are like the hockey puck but they are on a high friction surface, so they stay in place allowing for measurements. Collect data by turning on **Show Numbers & Tape Measure**.

- Investigate to see if your answers to #4 still make sense using this model. Write how the results of your investigation support or change your ideas.
- Determine the relationship between distance and the strength of the electric field around a charged body. Use Excel to document your data, graph and determine the equation for the relationship.
- Determine the relationship between amount of charge and the strength of the electric field around a charged body. Use Excel to document your data, graph, and determine the equation for the relationship.

6. Write an explanation of how you can predict the motion of a charged hockey puck that is moved by other charged pucks. Explain using examples and drawings that include:

- How to use free body diagrams and vector addition.
- How negative and positive charges compare and contrast.

Lesson plan for *Balloons and Static Electricity* and *John Travoltage* as a demo

<http://www.colorado.edu/physics/phet>

40 minute activity

Learning Goals: Students will be able to describe and draw models for common static electricity concepts. (transfer of charge, induction, attraction, repulsion, and grounding)

Background:

This will be part of an introduction to the chapter on static electricity. I will have balloons, wear a sweater and have a demo size electroscope. Two balloons need to be tied on strings hanging to demonstrate repulsion like the sim. (I hang them on a ring stand because I don't have easy access to Helium)

We will briefly review atomic structure before beginning the lesson.

Helpful hints:

Before class, open *Balloons and Static Electricity* and select the SHOW NO CHARGES on and leave the other settings on default. Also open *John Travoltage* and minimize it.

You can use the *Balloon* sim to show repulsion, but it is a little tricky. You have to lightly charge one balloon, quickly charge the other. Then you can make the first one move by repulsion. If the balloon touches the wall, you won't be able to make it move by repulsion. You can grab it and place it somewhere else. Small charge seems to work better for me than large amounts. I recommend practicing this before you do it in class. The effect of the wall is always present even if you uncheck WALL.

**Lesson:**

1. Rub a balloon on your sweater and stick it to the sweater.
2. Say “**Write down what you think is happening.**” Have a few students share their thinking as part of the class discussion.
3. Display the *Balloons and Static Electricity* sim with the charges hidden. Rub the balloon on the sweater and have it stick on the sweater like you did with the real objects. Then turn on the SHOW ALL CHARGES and say “**Write observations and include drawings**” and then repeat the demo using the sim. Hit RESET to do this several times.
4. Say “**Reflect on your answer to #2, write down how your thinking has changed.**” Have a class discussion. Include in the discussion the vocabulary: charge transfer and electric attraction.
5. Show how a real balloon can stick on the wall. Say “**Write what you think is happening.**” Follow with sharing and discussing.
6. Repeat the demo using the sim with the charges on. Say “**Write observations with drawings of what happens**” and then repeat the demo. Hit RESET to do this several times.
7. Say “**Reflect on your answer to #5, write down how your thinking has changed.**” Have a class discussion. Include in the discussion the vocabulary: induction; compare with charge transfer and electric attraction.

Lesson plan for *Balloons and Static Electricity* and *John Travoltage* as a demo

<http://www.colorado.edu/physics/phet>

40 minute activity

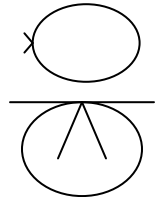
8. Have the two balloons tied to strings hanging from the ceiling. Rub them on your sweater and let them hang showing repulsion. Say “**Write what you think is happening.**” Follow with sharing and discussing.

9. Say “**Write observations with drawings of what happens**” and then repeat the demo. This demo is a little tricky. *See notes in Helpful Hints.* Hit RESET to do this several times.

10. Say “**Reflect on your answer to #8, write down any new ideas that you have.**” Have a class discussion. Include in the discussion the vocabulary: electric repulsion; compare with charge transfer, induction and electric attraction.

11. Show how an electroscope is used to measure charge by rubbing the balloon and bringing it near the scope. My scope will show a difference between rubbing more than less.

12. Draw an electroscope and a balloon like the picture on the right. Say “**Draw this on your paper and sketch what you think is happening to make the electroscope parts move apart.**” Then have a student draw his model on the board and follow with a class discussion.



13. Touch the electroscope to ground it. Demonstrate several times and say “**Draw what you think is happening.**”

14. Bring up *John Travoltage*. Rub John’s foot on the floor to demonstrate charge transfer. Talk about the similarities and differences in the two models represented by the sims. Touch his finger to the door knob to show grounding. Make sure that they understand that this is commonly called grounding. Say “**Discuss with your partner what is happening when he touches the knob.**” Repeat the demo several times.

15. Our text has several illustrations about these ideas, so I’ll have the students open their books and I’ll have them look at them. There are questions in our text that will ask for writing descriptions and drawing models that I will assign.