ELECTROMAGNETIC PROPERTIES OF MATERIALS

TEACHING AND LEARNING ACTIVITIES

ORIGINAL VERSION

MATERIALS SCIENCE PROJECT

UNIVERSITY-SCHOOL PARTNERSHIPS FOR THE DESIGN AND IMPLEMENTATION OF RESEARCH-BASED ICT-ENHANCED MODULES ON MATERIAL PROPERTIES

SPECIFIC SUPPORT ACTIONS

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ELECTROMAGNETIC PROPERTIES OF MATERIALS

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The following curriculum materials have served as a resource for this effort: McDermott, L. C. & the P.E.G., University Washington. (1996). Physics by Inquiry (Volume 1). USA: John Wiley & Sons, Inc.

We would like to thank Lillian McDermott and the Physics Education Group at the University of Washington for their continuing support.

CONTENTS

UNIT 1: INVESTIGATION WITH MAGNETS

1.1 MAGNETIC INTERACTIONS

In Magnetism, we will investigate a particular type of physical interaction. Based on our observations, we will develop a simple model that will enable us to account for the behavior of magnets and magnetic materials.

CAUTION: IN SOME OF THE FOLLOWING ACTIVITIES, WE WILL BE USING MAGNETS, WHICH CAN INFLUENCE THE OPERATION OF CLOCKS, CREDIT CARDS, TELEPHONES, COMPUTERS, AND OTHER DEVICES PRONE TO DAMAGE BY MAGNETIC FIELDS. IT IS RECOMMENDED THAT YOU DO NOT PLACE THE MAGNETS CLOSE TO THESE OBJECTS.

In chapter 1, we will develop an operational definition for a magnet and we will examine the different parts of a magnet and the interaction between magnets and other objects.

1.1.1. Experiment: Interaction of magnets between them and with various other materials.

Obtain two magnets and a set of objects made of various materials.

A. Bring the two magnets near each other and examine the interaction between them.

Record your observations.

Do the magnets need to be in contact to interact? If not, how does the distance between the magnets affect the interaction?

How do the different parts of the magnets interact?

B. Bring various objects from your set near one another and near a magnet from part A.

Describe what you observe and record the results in your notebook.

How do the different parts of a magnet interact with the various objects?

C. Arrange the objects into at least three different classes based on their interactions with the two magnets and with each other. Test other objects as well (for example, coins, pencils, paper, paper clips).

How is one class distinguished from another?

For each class, describe how its members interact with:

- **other members of the same class**
- **members of each of the other classes**

Do all the metallic objects interact in the same way?

D. **In your notebook make a table like the one below to record your observations from parts A-C. Use a word or phrase to describe the interactions.**

TABLE OF INTERACTIONS

	CLASS 1	CLASS 2	CLASS 3
CLASS 1			
CLASS 2			
CLASS 3			

DISCUSS YOUR WORK WITH YOUR TEACHER

One of the classes in the preceding experiment consists of objects that interact with one another and with other objects in the same way as the two magnets you were given. We call the objects in this class **permanent magnets**, or simply **magnets**. The interactions you studied in Experiment 1.1.1. are called **magnetic interactions**.

1.1.2. Exercise: Operational definition of a magnet

Using the Table in Experiment 1.1.1., write a series of steps that you or someone else would follow in order to identify a *magnet*. Try to be precise in the wording of your directions so that they cannot be misinterpreted by anyone.

DISCUSS YOUR WORK WITH YOUR TEACHER

The objects in your set that interact with magnets are said to be *ferromagnetic*. The prefix *ferro* means *iron* in Latin. Many objects that interact magnetically are made of iron. However, a few other materials such as nickel interact in the same way as iron and are also called ferromagnetic.

1.1.3. Experiment: Interactions

Obtain a magnet and a ferromagnetic object that is not a magnet. Both should be about the same size and mass. Close your eyes and hold them end-to-end near each other.

Can you tell which is the magnet solely on the basis of the pull that you sense between them?

We have used the term "interaction" to describe the magnetic effects between two objects. Discuss why the use of that term is appropriate.

DISCUSS YOUR FINDINGS WITH YOUR TEACHER

The materials that interact with magnets can be divided into three categories: ferromagnetic, paramagnetic and diamagnetic materials.

Ferromagnetic materials strongly interact with magnets (attraction). A lot of these objects are made of iron but there are also ferromagnetic objects made of nickel or cobalt.

Paramagnetic materials also interact with magnets (attraction) though the interaction is significantly weaker. Some examples of paramagnetic materials are aluminium and chromium.

Diamagnetic materials are repelled by magnets (often the repulsion is weak). Some examples of diamagnetic materials are copper, gold and silver.

1.2 THE PARTS OF A MAGNET

1.2.1. Experiment: Magnet's Ends

For this experiment you will need three bar magnets and a box that has five test spots on it.
The test spots are marked A through E.

Place a piece of tape on each end of the three magnets and label the ends I through VI.
Place end I next to each of the five test spots, one after the other.
Record the interactions in the table below.
Repeat this procedure for each of the remaining magnet ends.

		MAGNET 1		MAGNET 2		MAGNET 3	
		END I	END II	END III	END IV	END V	END VI
TEST SPOT	A						
	B						
	C						
	D						
	E						

A. *Are there any magnet's ends that can be considered identical?*

Explain.

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Group the magnet ends I-VI into different categories according to their interactions with the five test spots.

How many different categories can you identify?

B. *Is it conceivable that there may be another type of magnet end that is different from the types that you identified above?*

1.2.2. Experiment: Comparison between the different parts of a magnet

Investigate the different parts of one of the bar magnets used in Experiment 1.2.1.
Make rough comparisons of how each part interacts with paper clips or other small ferromagnetic objects.

Draw a sketch of the magnet and identify the different parts.
On the diagram, indicate the relative strength of each part of the magnet.

The term **magnetic pole** is used to identify a portion of a magnet that has magnetic properties like the ends of the magnets that you used in the preceding experiments. For a bar magnet, the poles are usually located at the ends of the magnet. However, magnets come in various shapes and the locations of the poles may not be obvious.

DISCUSS YOUR FINDINGS WITH YOUR TEACHER

1.2.3. Experiment: Identify the poles of a magnet

Obtain several magnets of various shapes from your instructor.
Try to identify the locations of all the poles on each of the magnets.

Are the poles of a bar magnet always located at the ends of the bar?

Outline a series of steps whereby you can (1) determine where the poles are located on a magnet, and (2) identify the type ("color") of each pole. These steps will constitute an operational definition for the term magnetic pole.

So far, we examined the behavior of small magnets and their interactions with other similar magnets and other objects. Are there any other objects of different dimensions that behave like magnets?

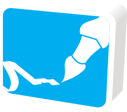
1.3 THE EARTH AS A MAGNET

1.3.1. Experiment: Alignment of Magnets

NOTE: Perform this experiment together with your classmates. If others have already begun this experiment, you can use their magnets. However, you must first determine how their color-coding scheme for poles relates to yours.

A. Obtain between six and eight cylindrical or bar magnets. Use one of your color-coded magnets from Experiment 1.2.1 to color code the poles of the remaining magnets.

Place each of the magnets in a piece of paper folded in half. Hang the folded paper sheets, using cotton string, in various parts of the classroom. Make sure that the sheets can rotate freely. While you are waiting for the magnets to stop swinging, draw a map of the room that shows the location of each magnet.



MAP OF THE ROOM

When the magnets stop swinging, record the orientation of each magnet and its poles on your map. Indicate explicitly the "color" of each pole on your map.

Is there any pattern to the alignment of the magnetic poles?

If so, describe the pattern.

Carefully consider the environment of each magnet.
List any objects with which the magnet might be interacting.

Are there any magnets that do not fit the general pattern?
If so, how might you account for the behavior of those magnets?

B. **Tape a magnet onto the table and suspend another, smaller, magnet from a string above it. Hold the suspended magnet with your hand so that each pole of the suspended magnet is above the "like" pole of the bottom magnet.**

Release the suspended magnet and describe what happens.

C. **Based on the results of the experiment above is it possible to suggest a model or a mental picture that could help to account for the behavior of the suspended magnets in part A.**

Can we think of the earth as acting like a large magnet?

On the basis of this model, explain how the situations in parts A and B are similar. (Hint: Imagine that the magnet on the table in part B was very large and the suspended magnet was very small.)

DISCUSS YOUR FINDINGS WITH YOUR TEACHER

1.3.2. Exercise: Magnetic poles

A. The poles of a magnet are usually labelled “north pole” and “south pole”. The standard convention is to label the end of a magnet that points towards the Arctic as a "north pole," and the end that points towards the Antarctic as a "south pole".

On the basis of this convention, is the magnetic pole of the earth that lies in the Arctic (North Geographic pole) a north or a south pole?

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Is the magnetic pole of the earth that lies in the Antarctic (South Geographical pole) a north or a south pole?

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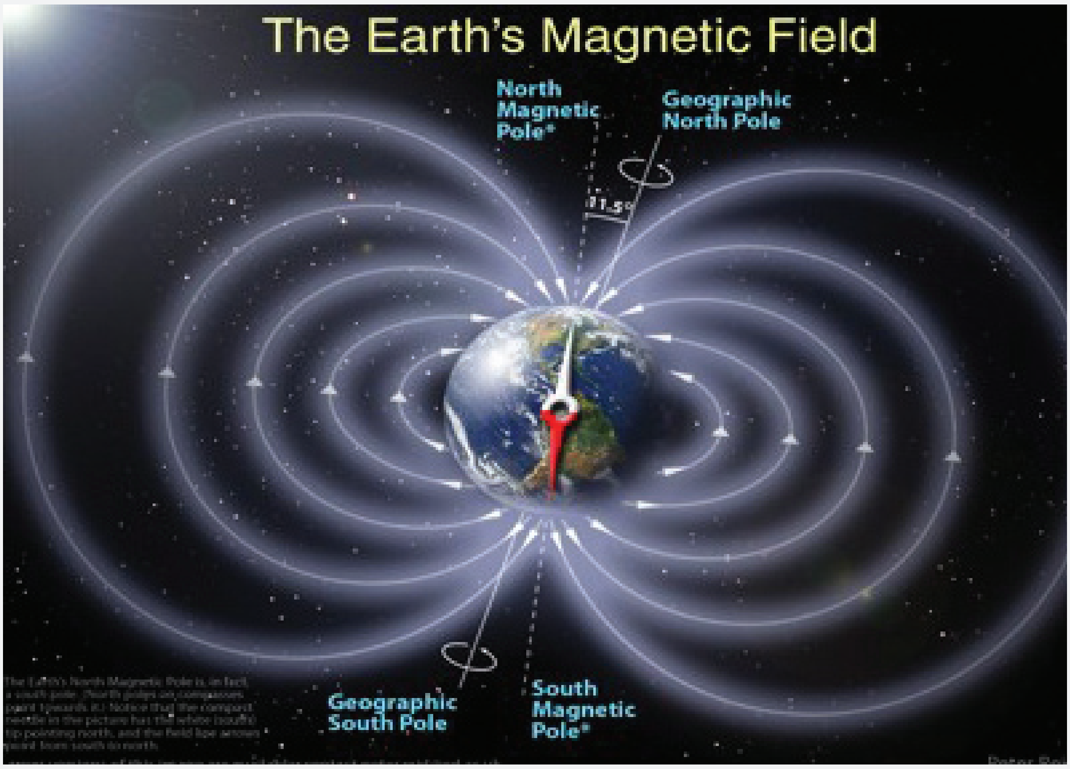
B. Mark the color-coded ends of your magnets with either an "N" or an "S" so that they are consistent with the standard convention.

We studied the earth as a huge size magnet.
How important is the size of a magnet?
This will be explored in the next chapter.

ADDITIONAL INFORMATION

MAGNETIC DECLINATION

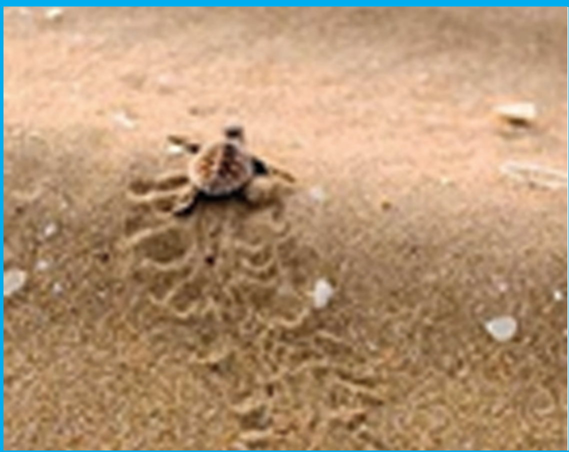
The magnetic poles of the earth are the points with the largest magnetic intensity and they are close to but not coinciding with the opposite geographic points. In contrast, the magnetic Equator of the earth is the neutral zone with the smallest magnetic intensity. At any point on the surface of the earth, when we place a magnetic needle that is free to rotate, we observe that it always ends up taking a certain direction from south to north. On the surface of the earth, the curve that links the magnetic poles of the earth is called magnetic meridian and it forms an angle [Θ], which changes with time, at each point. This angle is named the magnetic **declination**.



Extension
For more information and an interesting simulation you can visit the website:
http://phet.colorado.edu/simulations/sims.php?sim=Magnet_and_Compass.

INTERESTING READING

There are living organisms (birds, whales, turtles, etc.) that have their own biological compass, which helps them to find their orientation by making use of the earth's magnetic field. For example, pigeons have crystals of iron or magnetite incorporated in their beak, which they use as a small compass.



After coming out of the sand, turtles' younglings (which are not bigger than the human palm) find their way to the sea, which they have not seen before, and swim following their migratory roads into the oceans. When they arrive at deep waters where the formation of waves is not a reliable navigator, they use the magnetic field in order to orient themselves. They are able to cross up to 9000 miles in Northern Atlantic in this way before returning as young turtles to the coast, some years afterwards.

Extension

You can find more information at the following websites:

http://www.focusmag.gr/articles/view-article.rx?oid=150178
http://www.in.gr/news/article.asp?lngEntityID=510358
http://www.physics4u.gr/news/2007/scnews3016.html

1.4 COMPARING THE STRENGTH OF MAGNETS

1.4.1. Exercise: Strength of identical magnets

Chloe and Maria live in different cities. Each has a cylindrical magnet that is 12 cm in length and 1.0 cm in diameter. They often argue about whose magnet is stronger.

Describe a procedure that they may follow to determine who has the stronger magnet.

DISCUSS YOUR IDEAS WITH YOUR TEACHER

1.4.2. Experiment: Comparing the strength of various magnets' poles

A. **Obtain several magnets of various sizes and shapes. Use a compass to identify the north and south poles of each magnet. Label these "N" and "S."**

B. **In the first column of the table below, sketch each of your magnets. Show the dimensions of each magnet on your drawing as well as the locations of the poles.**

C. **Place a paper clip on a horizontal surface. Approach vertically a magnet and measure the maximum distance from where it is able to lift the paper clip. Repeat for both poles of all the different magnets.**

Note the distance at the table below; consider it as a way of determining the "strength" of each magnet's poles.

SKETCH OF MAGNET	“STRENGTH” OF NORTH POLE	“STRENGTH” OF SOUTH POLE

D. Base your answers to the following questions on the results of the experiment in part B. Perform additional experiments if necessary.

Is a larger magnet necessarily stronger (or weaker) than a smaller magnet?

Do the north and south poles of a magnet have essentially identical strengths? Explain your answer on the basis of your observations.

DISCUSS YOUR FINDINGS WITH YOUR TEACHER

UNIT 2: MAGNETIC INTERACTIONS AT A DISTANCE

2.1 MAGNETIC FIELDS

So far, we studied magnetic interactions with other magnets and ferromagnetic materials. We also studied the effect of the distance and the observations showed that the interaction decreases as the distance increases and vice versa. In the next chapter, we will study "interactions at a distance".

2.1.1. Experiment: Magnetic Lines I

A. **Place a bar magnet flat under a large tray or piece of paper. Carefully sprinkle iron filings over the surface of the paper. Be careful to keep the iron filings from coming in direct contact with the magnet.**

Gently tap the tray or the piece of paper several times and describe what you observe.

In which region(s) do the iron filings appear to interact:
- **strongly with the magnet?**
- **weakly with the magnet?**

Explain how you can tell in each case.

B. **Sketch the bar magnet and the pattern of iron filings.**

DRAWING

2.1.2. Experiment: Magnetic Lines II

Place a large piece of paper on a flat surface far from any magnetic or ferromagnetic materials. Tape a bar magnet at the centre of the paper and label the north and south poles. Sketch the outline of the magnet on the paper and also indicate the direction of the earth's magnetic north pole.

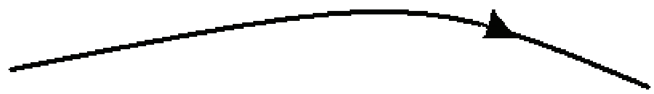
A. Take a small compass and determine which end of the needle is north. Place the compass on the edge of the paper far from the magnet and slide the compass over so that it touches the end of the magnet.

(1) Make two dots on the paper: one at the end of the compass needle next to the magnet, the second at the other end of the needle.

(2) Move the compass so that the end of the needle that was next to the magnet is now directly over the second dot that you drew above. Make a dot on the paper at the other end of the needle.

(3) Continue to move the compass as in step (2) until the compass comes back to the magnet or leaves the edge of the paper.

(4) Draw a line (not necessarily straight) through the dots. On the line, place an arrowhead to indicate the direction in which the north pole of the compass needle points. (See the example below.)



B. Repeat part A, starting with the compass touching a different part of the magnet. Repeat this procedure at least 6 more times on each side of the magnet.

C. Describe the pattern of lines that you have obtained in parts A and B.

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How does the pattern compare to the pattern of iron filings around a magnet? (See Experiment 2.1.1)

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D. Imagine that you were to remove the magnet from the paper and to repeat parts A and B without the magnet.

What would be the pattern of the lines that you drew in this case? Explain.

Remove the magnet and check your answer.

Is the pattern that you obtained in parts A and B due only to the bar magnet? If not, where do you think the pattern is mostly due to the bar magnet alone? Explain your reasoning.

The continuous curved lines drawn using the procedures outlined in Experiments 2.1.1 and 2.1.2 are called *magnetic field lines*. Magnetic field lines depict the magnetic field, which is the space around the magnet that interacts with other objects.

DISCUSS YOUR WORK WITH YOUR TEACHER

E. *How does the magnetic field concept help you explain the alignment of the magnets in Experiment 1.3.1?*

Are there any other observations that you have made, which could be explained using the magnetic field concept?

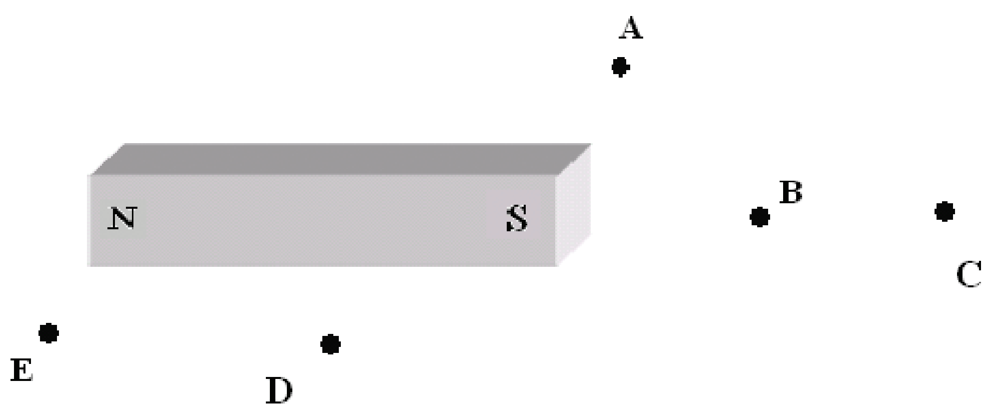
What is the role of concepts such as the magnetic field in science? Why are they useful in science? In order to answer this, it is useful firstly to answer the question "What is the main goal of science?"

F. Visit the following webpage:
http://phet.colorado.edu/simulations/sims.php?sim=Magnets_and_Electromagnets
Run the simulation.

What is the shape of the magnetic field around the bar magnet?

What do you observe when you move the compass to different places around the magnet? Is the direction of the compass different?

Select the box next to the item "Show field meter". Move the magnetic field meter that appears on your screen to different places around the magnet.
Note in the figure below the meter readings for each of the points.



The intensity of the magnetic field is measured in either Tesla or Gauss. In our case the simulation meter reads in Gauss.

Is there any relation between the meter readings from the simulation and your observations from Activity 1.2.2? If yes, what is the relation between them?

DISCUSS YOUR WORK WITH YOUR TEACHER

We say that the pattern of iron fillings or compass needles illustrates the magnetic field of a magnet or group of magnets. The magnetic field indicates how an object made of a magnetic material will behave when placed near a magnet.

The ability of magnets to act without physical contact is a surprisingly effect. Many people have pondered whether "action at a distance" is possible without a physical agent or a medium to conduct the effect. Even though our experiments do not answer this question, the magnetic field is a useful concept that helps us predict magnetic interactions.

2.1.3. Experiment: Pattern of the Magnetic Field between two magnets

A. For the following arrangement of two magnets, sketch your prediction for:

- **the pattern that you would obtain if you were to place compasses in the region between and around the magnets.**
- **the pattern that you would obtain if you were to sprinkle iron filings over the magnets.**

Explain your reasoning in each case.

DRAWING WITH COMPASSES

DRAWING WITH IRON FILINGS

B. Obtain two magnets and check your answer.

The pattern of iron filings and the pattern of compass needles near a magnet help us visualize how a magnet interacts with other objects. As you have seen in Experiment 2.1.3, these patterns for a single magnet can also be used to predict magnetic effects when more than one magnet is present. In this case, the effect of the individual magnets does not change, but the effect from each must be taken into account. The resulting iron filing or compass needle pattern reflects the additive effects of all the magnets.

2.1.4. Experiment: Pattern of the Magnetic Field for magnets of different shape

Obtain several magnets that are not bar magnets. Make an iron filing pattern for each magnet.

Make sketches of the patterns that you obtain. Indicate the region(s) where the magnetic field's strength is the greatest.

SHAPE OF MAGNETIC FIELD FOR EACH MAGNET

DISCUSS YOUR FINDINGS WITH YOUR TEACHER

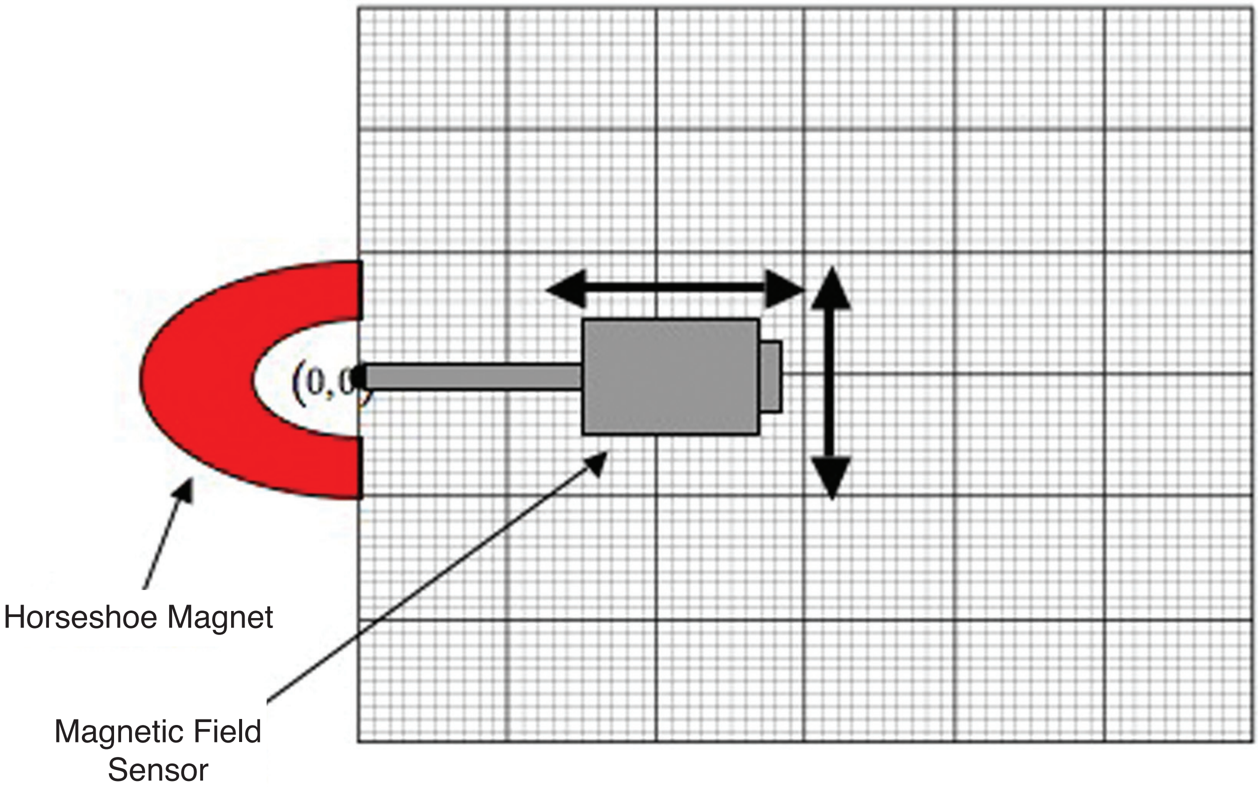
2.1.5. Experiment: Measuring the intensity of Magnetic Fields with Sensors

ASK THE TEACHER TO HELP YOU CONNECT THE MAGNETIC FIELD SENSOR, SO THAT YOU CAN BEGIN WITH THE ACTIVITIES.

In your PC find and open the program “Data Studio”. Select the button “Create Experiment”. From the sensor’s list select “Magnetic Field Sensor”. Activate the field-meter to be able to take measurements. Select “Start” to start obtaining measurements.

Place the magnetic field sensor away from any source that creates a magnetic field (i.e., magnets, personal computers, current carrying wires) and press the button “TARE” that is on the sensor. This procedure aims at the calibration of the sensor.

Obtain some graph paper and tape it on the labs’ counter. Then tape a horseshoe magnet at one end of the graph paper, as in the figure below. Place the magnetic field sensor between the two edges of the horseshoe magnet (reference point) and write down the magnetic field intensity value. Continue performing this measurement procedure while placing the sensor in different positions for each measurement. Make a table of the intensity of the magnetic field for each position the sensor was placed. (Note: When you want to move the sensor forward or backward the button on the sensor must be in the position “AXIAL”, whereas when you want to move the sensor to the right or to the left the button on the sensor must be in the position “RADIAL”.)



Use the table you made and group the values of intensity for the magnetic field in groups of 10 contiguous values. Afterwards, give a different tone of a specific color to each group, for example Gray, and map the magnetic field of a horseshoe magnet.

UNIT 3: A MODEL FOR MAGNETIC MATERIALS

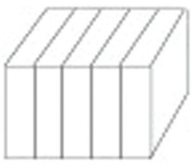
3.1 BREAKING AND STACKING MAGNETS

During the previous chapters we realized that not only permanent magnets have magnetic properties, but also other ferromagnetic objects when they are close to a magnet or have been close to a magnet for a reasonably long time. In the following chapters we are going to develop a model accounting for how materials acquire magnetic properties.

3.1.1. Experiment: Magnetic Stack

Obtain a set of small magnets that are assembled into a magnetic stack as shown below.

Explore the magnetic properties of the stack. Identify the similarities and differences between the behavior of the stack and that of a bar magnet.



Does the stack behave as though it were a single large magnet?
If so, locate the north and south poles and indicate the locations on a diagram.
If not, how does the behavior of the stack differ from that of a single magnet of the same size and shape?

3.1.2. Experiment: Breaking a magnet

In this experiment we will examine what happens when a magnet is broken into smaller pieces. However, rather than actually break a magnet we will use the magnetic stack from Experiment 3.1.1.

A. *What justification can you give for regarding the magnetic stack as a large unbroken magnet?*

B. Break the stack of magnets in half. Examine both ends of each half of the stack.

Does each half have a north and a south pole? If so, where are the poles located?

C. **The original stack consists of several individual magnets, each with its own north and south poles.**

Do the poles of the individual magnets appear to act like poles when part of the stack? Explain.

3.1.3. Experiment: Studying Magnetic Stacks

Use the small magnets from the preceding experiments for this experiment.

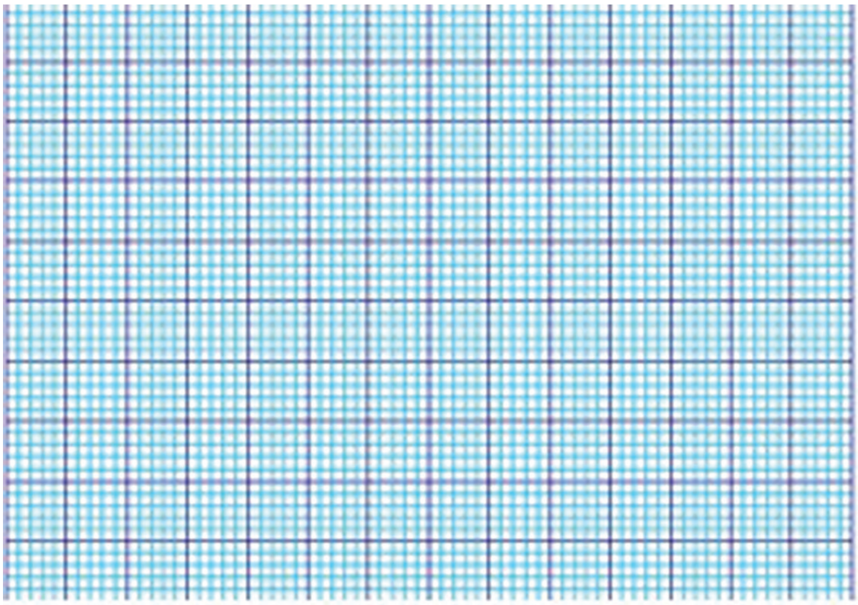
A. **Measure the strength of each pole of a magnet using the procedure from Experiment 2.1.5 and record your results in the first line of the table below.**

B. **Get a second magnet and measure the strength of each pole, as before. Then, place the two magnets together to form a magnetic stack. Repeat the experiment, this time measuring the strength of the poles of the magnetic stack. Record your results.**

C. **Keep adding to the stack a magnet each time. In every stage, measure the strength of the individual magnet and the strength of the resulting magnetic stack. Record your results.**

No. OF MAGNETS	MAGNETIC FIELD INTENSITY FROM ….cm AWAY FROM EACH INDIVIDUAL MAGNET		MAGNETIC FIELD INTENSITY FROM ….cm AWAY FROM THE POLES OF THE MAGNETIC STACK	
	NORTH POLE	SOUTH POLE	NORTH POLE	SOUTH POLE

D. **Open an excel sheet and plot a graph of the Intensity of the Magnetic field of the magnetic stack versus the no. of magnets in the stack. Name your file and save it.**



Describe how the strength of the stack changes as magnets are added, one at a time.

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Is the strength of the stack at each stage equal to the sum of the strengths of the magnets that form the stack? Explain how you can tell from the graph.

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Can the strength of the stack increase infinitely (i.e., could you make the stack as strong as you like just by adding magnets?) or does the strength seem to approach a limiting value? Explain.

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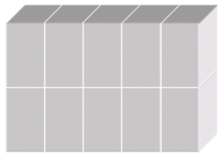
DISCUSS YOUR FINDINGS WITH YOUR TEACHER

3.2 A MODEL FOR MAGNETIC MATERIALS

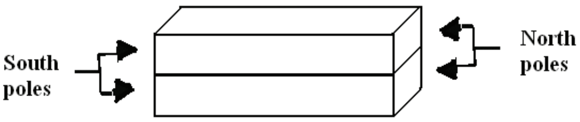
3.2.1. Exercise: Behavior of Magnetic Stacks

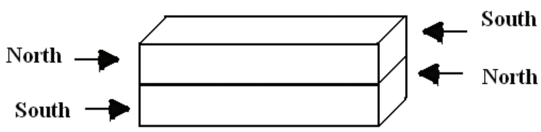


A. How should the ten magnets (shown in the figure on the right) be arranged so as to form the "strongest" possible magnetic stack?

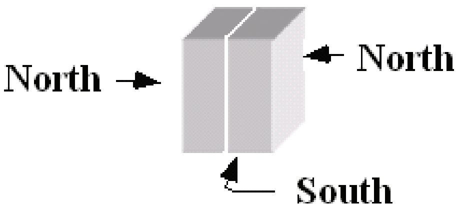
To determine the best arrangement, try first the following configurations of two magnets.

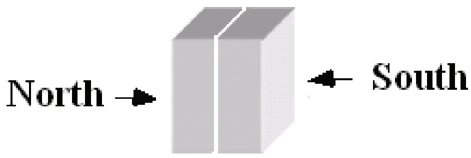
- **Parallel assembly:**





- **Series assembly:**





Measure the intensity of the magnetic field using the sensor.

Which of the two magnetic stacks forms the strongest magnet in each of the cases shown above? Explain your answer.

Draw how you would arrange the 10 magnets in the magnetic stack so as to attain maximum strength.

B. In chapter 3.1, you observed that when a magnet is broken into smaller pieces, each piece is a magnet with its own north and south poles.

Describe how the poles of the small magnet pieces are arranged within the magnet as a whole.

DISCUSS YOUR WORK WITH YOUR TEACHER

As you have been working through this module, you may have begun to develop a mental picture of how magnets behave that helps you to make sense of your observations. In this section we draw on our observations to construct a scientific model for magnetic materials that we can use to account for our observations and predict how magnets will behave in new situations.

Some important observations that we have made include the behavior of magnets when they are broken or stacked, and how a magnet can be made from a ferromagnetic object. These observations are consistent with a model in which a magnet is regarded as a collection of many smaller pieces, each of which acts like a tiny magnet. The magnetic interactions of a bar magnet can be thought of as the cumulative effect of many interactions arising from the small magnetic pieces composing the bar magnet.

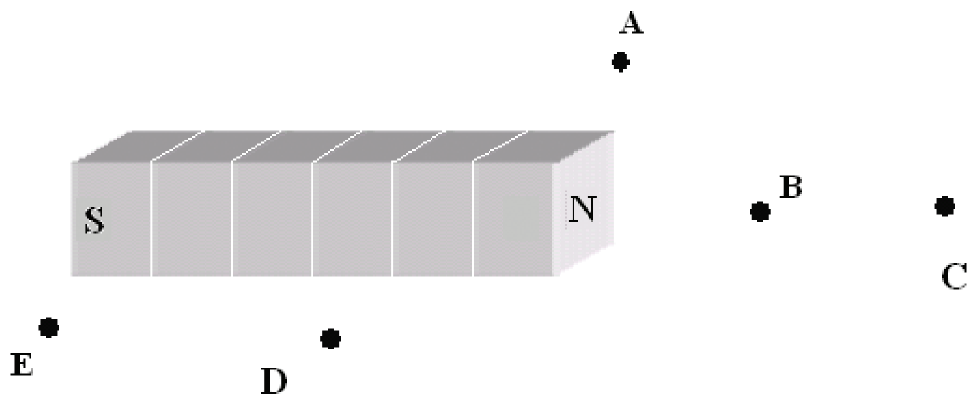
3.2.2. Experiment: Magnetic field lines inside a magnet

In 3.2.1, you drew a map of the magnetic lines of a bar magnet using a compass. In this experiment we study what our model for magnets predicts about the way a compass needle would behave if it was possible to place it inside a magnet.

In this experiment we will explore how a set of compasses behave when placed near a bar magnet.

A. **Obtain some small magnets and place them together to form a magnetic stack that has the same size as the bar magnet you were using in the previous experiments. All the magnets should have the same orientation. Place the magnetic stack on an A3 piece of paper.**

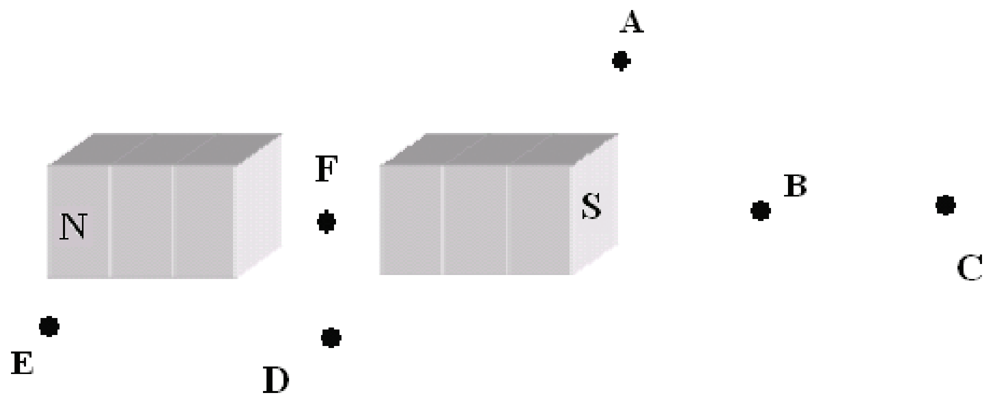
Use a compass to find the direction of the magnetic field at the points A-E. Draw an arrow to show the direction of the field at each point.



How does the direction and strength of the Magnetic field at each of these points compare with that of a bar magnet of the same size and strength?

B. **Remove some of the magnets from the middle of the magnetic stack, enough so that a compass can fit in the resulting gap.**
Use the compass to find the direction of the magnetic field for each of the points, as before.

Does the Magnetic field of the magnetic stack changes considerably when a few of the magnets are removed?



C. **Use the compass to investigate the direction of the magnetic field at point F. Compare the direction of the Magnetic field at points F and D.**

Compare the strength of the magnetic field at points F and D.

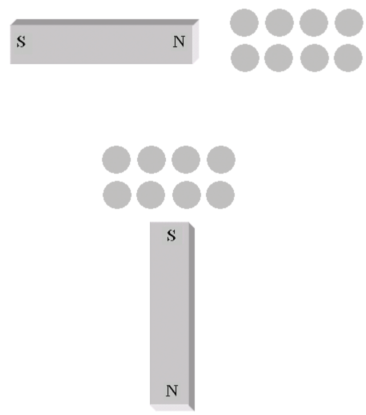
D. **What are the conclusions drawn from this experiment regarding the strength and direction of the magnetic field inside a bar magnet.**

Explain if your answer shows any similarities with the magnetic model developed so far.

Some of the observations you have made in this module concern the interaction of magnets with materials that we classified as ferromagnetic. We found that objects made of ferromagnetic materials can become magnetized when placed near a magnet. We have also observed that the centre of a magnet, which is not a pole, is attracted to the poles of other magnets. These facts suggest that permanent magnets are made of ferromagnetic material. This close relationship between those objects we call "magnets" and those we call "ferromagnets" must be taken into account in any model that we develop.

3.2.3. Experiment: Behavior of ferromagnetic materials

In this experiment we will explore how a set of compasses behave when placed near a bar magnet.



A. Obtain between 6–12 small compasses and place them close together.
Do all your compasses initially point in the same direction?

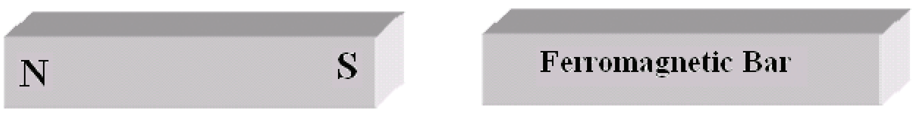
B. Bring the north end of a bar magnet up near the set of compasses as shown in the two figures at right. Carefully sketch the alignment of each compass for each location of the magnet.

C. Repeat part B with the magnet reversed.

Thus far, we have been thinking of magnets as consisting of many small magnetic pieces. We can think of ferromagnetic materials in this same way. We can account for interactions between magnets and objects made of ferromagnetic material by thinking of the small magnetic pieces in the ferromagnetic material as being free to rotate like a compass needle when other magnets are near.

3.2.4. Experiment: Magnetic field between a magnet and a ferromagnetic bar.

A. A bar magnet is placed next to a ferromagnetic bar, as shown below.



Predict the pattern of the magnetic field for this arrangement. Assume that the ferromagnetic bar is not magnetised initially.
Explain your reasoning.

Check your answer using a compass or iron filings.

How does the magnet affect the small magnets that form the ferromagnetic bar?

B. **Use the model for magnetic materials that you have developed in this chapter in order to explain your observations from the previous experiment.**

C. **Use the model for magnetic materials in order to predict how your observations will change in the previous experiment (3.2.5 A) if the ferromagnetic bar was reversed (right end where the left is and the other way around).**

Explain your reasoning.

D. **Check your prediction, use iron fillings or a compass.**

How is your prediction different from your observation?

E. **In many activities of this unit, we represented the magnet as a collection of smaller pieces, each of which acts like a tiny magnet.**

Are there any observations that you have accounted for using this representation?

F. *How is the development of models, like the one representing the magnet as a collection of many tiny magnetic pieces, connected with the main goal of science?*

Explain your answer.

Until now, we have been thinking of magnets as consisting of many smaller magnetic pieces. We can think ferromagnetic materials in this same way. We can account for interactions between magnets and ferromagnetic objects by thinking of the small magnetic pieces in the ferromagnetic material as being free to rotate like a compass needle when other magnets are near.

3.2.5. Exercise: When a ferromagnetic material has magnetic properties

Use the model for ferromagnets to account for the following phenomena. Explain your reasoning in each case.

A. A ferromagnetic object that is not magnetized is attracted to a magnet.

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B. Ferromagnetic objects that are not magnetized are not attracted to one another.

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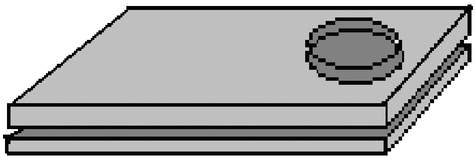
DISCUSS YOUR IDEAS WITH YOUR TEACHER

3.2.6. Experiment: How different materials influence the magnetic field?

Obtain two small plastic sheets (Corriflute) and tie them together using tape, letting a small gap between them, like in the figure below. Fix a small disk-shaped magnet at the top surface using again some tape.



Approach at the bottom surface some paper clips.

What do you notice?

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What could be the influence of placing sheets of several materials between the plastic sheets? Which materials will affect the configuration and how?

Explain your predictions.

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Place sheets of several materials or thin objects between the plastic sheets.

Which types of materials cause the paper clips to fall?

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How can you explain your observations considering the model for magnetic materials and the interaction of those materials with the magnetic field?

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DISCUSS YOUR IDEAS WITH YOUR TEACHER

3.2.7. Exercise: Explaining phenomena

Below are some observations you may have made while conducting experiments in this module. Use the model that has been developed thus far to account for these observations. Explain your reasoning in each case.

A. A compass needle near a magnet may reverse polarity.

B. A pole of a strong magnet may attract both poles of a weaker magnet.

C. A heated ferromagnet becomes a magnet when it is cooled in a magnetic field.

DISCUSS YOUR IDEAS WITH YOUR TEACHER

3.2.8. Exercise: Magnetisation - Demagnetisation

Use your model for magnetic materials to answer the following questions. Explain your reasoning.

A. *How might you account for one magnet being stronger than another?*

B. *What will happen to a strong magnet that is repeatedly dropped ?*

C. Suppose that you had a source of a very strong magnetic field.

How could you use the magnetic field to make a magnet out of a ferromagnetic object?

Do you think there is a limiting value to the maximum attainable strength of a magnet that could be made out of a particular object?

DISCUSS YOUR FINDINGS WITH YOUR TEACHER

3.2.9. Exercise: Judging the Model for Magnetic Materials

Discuss with the other members of your team the model for magnetic materials that has been developed until now.

Are there any additional observations that you have made so far that you can account for by using the model?

Did you make any observations that cannot be accounted for by this model?

DISCUSS YOUR IDEAS WITH YOUR TEACHER

UNIT 4: INVESTIGATION WITH ELECTROMAGNETS

4.1 MAGNETIC FIELD CREATED BY CURRENT-CARRYING WIRE

During the previous chapters, we studied magnetic fields created by magnetic materials. In the following chapters, we will study magnetic fields created around current-carrying wires.

4.1.1. Experiment: Shape, intensity and direction

Use a ring stand and a clamp to hold a piece of cardboard horizontally as shown. Then pass the thread wire through a hole in the cardboard and connect the wire to a battery and a switch. Do not close the switch yet.

CAUTION: WHENEVER YOU CLOSE THE SWITCH, THE WIRE AND BATTERY MAY BECOME HOT. KEEP THE SWITCH OPEN FOR ALL BUT THE BRIEF PERIODS DURING WHICH YOU ARE MAKING OBSERVATIONS.

Place several small compasses on the cardboard around the wire.

A. Draw a diagram to show the orientation of the compasses before closing the switch. If the north poles of all the compasses are not aligned, determine why not and adjust your setup accordingly.

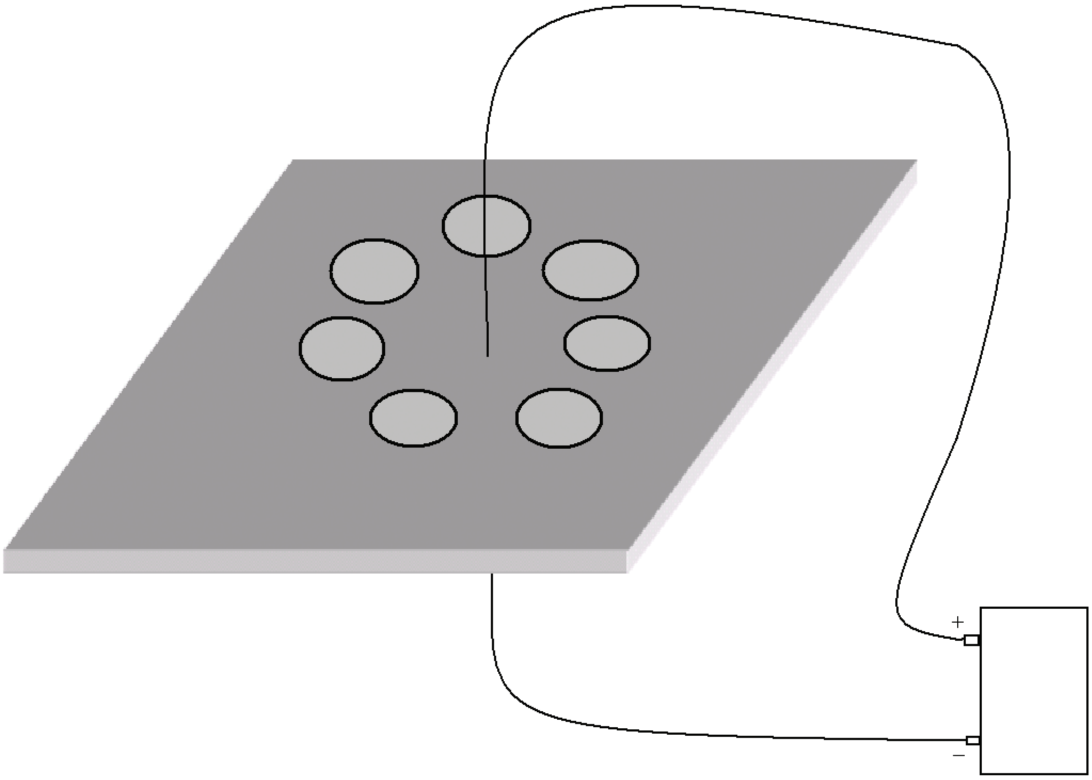


DIAGRAM (OPEN SWITCH)

B. **Hold the wire vertically as shown. Close the switch *briefly* and observe the behavior of the compasses needles. After you open the switch, record your observations.**

DIAGRAM (CLOSED SWITCH)

We say that there is a magnetic field due to a current-carrying wire. Explain how you can tell.

How does the strength of the magnetic field due to the current carrying wire vary with the distance from the wire? Explain how you can tell.

C. Make a sketch that shows the magnetic field lines near the current-carrying wire.

Explain how you decided to draw the lines as you did.

What are the differences between the field lines that you drew and those of a bar magnet.

Explain how you took into account the magnetic field of the earth.

Compare the magnetic field for a current-carrying wire to the magnetic field of other magnets, such as a horseshoe magnet or a pair of bar magnets.

Are any of the magnetic fields that you have previously studied similar to the field of a current-carrying wire?

D. Reverse the connecting leads to the battery and repeat part B.
Record your observations

Sketch the magnetic field due to the current-carrying wire in this case.

How does reversing the leads to the battery affect the magnetic field of the current-carrying wire?

DISCUSS YOUR WORK WITH YOUR TEACHER

4.1.2. Experiment: Magnetic field lines: circles or spirals

A student makes the following statement about the magnetic field of a current-carrying wire:

"The compasses are lying in a plane perpendicular to the wire so the compasses show the magnetic field lines as circles around the wire, but really the field lines of the current-carrying wire look like spirals winding up around the wire".

Design and perform an experiment to prove or disprove this student's statement.
Describe below the experiment that you will carry out in order to make that decision.

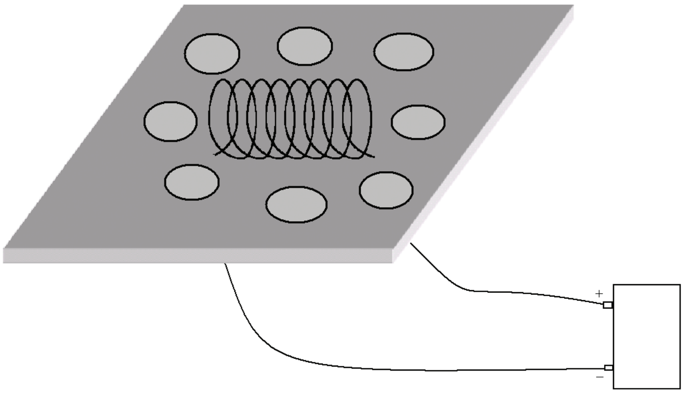
DISCUSS YOUR WORK WITH YOUR TEACHER

4.2 MAKING MAGNETS WITH A CURRENT-CARRYING WIRE

In the previous unit we studied the magnetic field of a current-carrying wire. In this unit we will investigate how the configuration of the wire affects the magnetic field.

4.2.1. Experiment: Magnetic Field of a current-carrying coil

Wrap a 20 cm piece of insulated wire around a pencil several times. Remove the pencil and place the wire coil on the cardboard from Experiment 4.1.1. Connect the coil to a fresh battery through two holes in the cardboard. Do not close the switch yet. Place several compasses around the coil as shown below.



A. Before you close the switch, sketch the coil and compasses in your notebook. Draw arrows to show the orientations of the compasses needles with the switch open.

DIAGRAM (OPEN SWITCH)

B. **Briefly close the switch. Quickly observe the orientations of the compasses needles, and open the switch. Make a sketch of the coil. Indicate the direction of the current through each winding of the coil. Draw small arrows to show the orientations of the compasses needles around the coil.**

DIAGRAM (CLOSED SWITCH)

Sketch lines to represent the magnetic field of the current-carrying coil. Base the sketch on your observations of the compasses needles.

MAGNETIC FIELD AROUND THE CURRENT-CARRYING COIL

How do these field lines compare to those of a bar magnet?

Can you identify the north and south pole of the current-carrying coil? Explain your reasoning?

C. Suppose you wanted to replace the current-carrying coil with a magnet that produces a similar magnetic field.

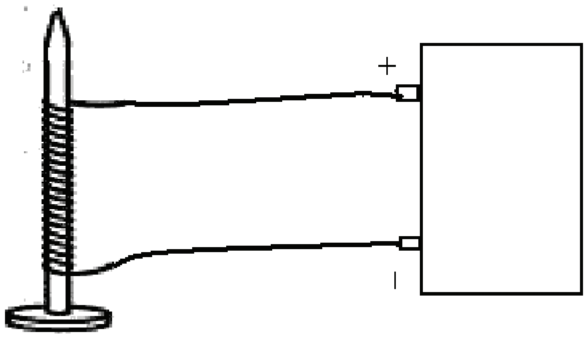
Describe the approximate location of the poles, the size, and the orientation of the magnet.

D. Reverse the leads to the battery in the circuit and repeat part B.

Describe how the magnetic field lines in this case differ from those you sketched in part B.

4.2.2. Experiment: Electromagnets

Wrap a piece of insulated wire around a ferromagnetic object (e.g., a nail) that is not a permanent magnet. Connect the wire to a battery and a switch as shown. Use a fresh battery for this experiment. Do not close the switch yet.



A. **While the switch is open, bring the nail near several paper clips. If the nail attracts paper clips, find a nail that is not magnetized.**

B. **Bring the nail near some paper clips and then briefly close the switch.**

Describe your observations.

While the switch is closed, does the nail attract paper clips? If so, how many paper clips can the nail hold?

Are the paper clips still attracted to the nail after the switch is opened? If so, does the nail pick up as many as when the switch is closed?

C. **Predict the locations of the north and south poles of the nail-coil combination while the switch is closed.** (Hint: Base your prediction on your observations from Experiment 4.1.1).

D. Wrap, anticlockwise, a piece of insulated wire around a nail, starting from the head of the nail. Use another nail and repeat the process, this time wrap the wire clockwise (head to tip).

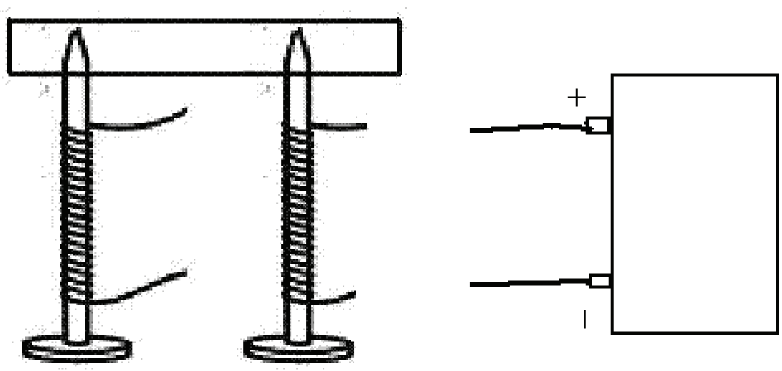
Is the polarity of the two electromagnets different? State your opinion.

E. Connect both nails with a battery and a switch. Connect the positive terminal of the battery with the coil end where the head of the nail is.

F. Briefly close the switch and determine the poles of the electromagnets using a compass.
Write down your observations.

4.2.3. Experiment: Moving a Magnet

A. Prepare two electromagnets; follow the same procedure as before. Then, nail them in a piece of wood, as shown in the figure below.



How should these electromagnets be connected with each other and with the battery, in order for the ends of the nails to have different polarity.

Draw the correct connection and then carry out the experiment.

Explain your reasoning.

B. **Take a circular magnet and identify the poles. Place the magnet on the top of the wooden surface in an equal distance between the two electromagnets.**

C. **Briefly close the switch.**

Write down your observations.

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D. **Change the direction of the current in the circuit by inverting the cables on the battery terminals. Briefly, close the switch.**

Explain the movement of the magnet.

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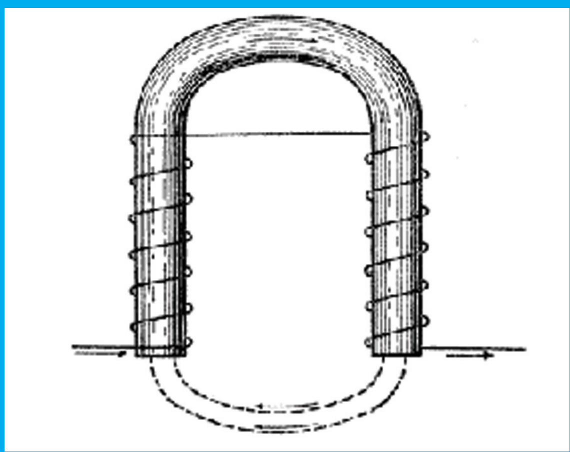
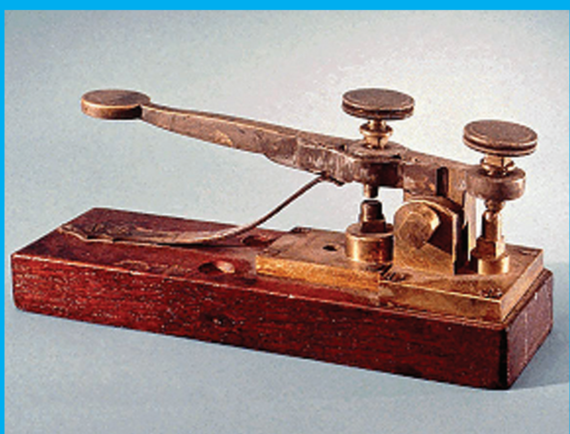
DISCUSS YOUR WORK WITH YOUR TEACHER

INTERESTING READING





ELECTROMAGNETS

An electromagnet is a device in which magnetism is produced by an electric current.

British electrician, William Sturgeon invented the electromagnet in 1825. The first electromagnet was a horseshoe-shaped piece of iron that was wrapped with a loosely wound coil of several turns. When a current was passed through the coil; the electromagnet became magnetized and when the current was stopped the coil was de-magnetized. Sturgeon displayed its power by lifting nine pounds with a seven-ounce piece of iron wrapped with wires through which the current of a single cell battery was sent.

Sturgeon could regulate his electromagnet this was the beginning of using electrical energy for making useful and controllable machines and laid the foundations for large-scale electronic communications.

Five years later an inventor called Joseph Henry - made a far more powerful version of the electromagnet. American, Joseph Henry (1797-1878), demonstrated the potential of Sturgeon's device for long distance communication by sending an electric current over one mile of wire to activate an electromagnet which caused a bell to strike. Thus the electric telegraph was born.

4.3 SCIENTIFIC INVESTIGATION WITH ELECTROMAGNETS

4.3.1. Exercise: Investigating the strength of electromagnets

John and Andrea have constructed two different electromagnets following the procedure described in the first experiment of chapter 4.2. The electromagnet constructed by John is able to attract five paper clips while Andrea's electromagnet is able to attract 8 paper clips, in vertical series each hanging below the other.

John and Andrea are discussing about what may have caused this difference in the force exerted by each of the two electromagnets.

John: "I think that the factor that influences the force exerted by the electromagnet is the number of turns of the coil."

Andrea: "You might be right… However, I believe that the crucial factor is the length of the wire used in the coil"

Do you agree with John, Andrea, both or neither? Explain your reasoning.

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4.3.2. Exercise: Identifying Variables of Electromagnets

Complete the table below with variables that might influence the magnitude of the force exerted by an electromagnet.

	VARIABLES THAT MIGHT INFLUENCE THE MAGNITUDE OF THE FORCE EXERTED BY AN ELECTROMAGNET
1	
2	
3	
4	

Choose one of the variables you identified in the table and carefully describe an experiment that will allow you to determine whether it does influence the magnitude of the force exerted by the electromagnet.

CHECK YOUR REASONING WITH YOUR TEACHER

In science, we often seek to design and conduct valid experiments that allow us to determine whether one factor influences another. Before proceeding to design an experiment it should be useful to clearly formulate the investigable question under consideration. An investigable question can be expressed in the format shown below: Does **VARIABLE A** influence **VARIABLE B?**

4.3.3. Exercise: Experimental design – Controlling Variables

Formulate the investigable question relevant to the variable you have chosen to address.

Does the variable .... influence the variable ....?

In any given experiment, some of the variables need to be **KEPT CONSTANT, MEASURED OR ALTERED.**

Fill the table below by specifying the factors to be kept constant, measured or altered so as to address your investigable question. Select the factors to be placed in each column in a manner that could lead to a valid experiment that will allow you to address the question at hand in a reliable manner.

FACTOR(S) TO BE ALTERED	FACTOR(S) TO BE KEPT CONSTANT(S)	FACTOR(S) TO BE MEASURED

CHECK YOUR REASONING WITH YOUR TEACHER.

If an experiment is to lead to valid conclusions we should ensure that we only allow one variable to vary at a time by keeping all other potentially relevant factors constant and measure just one other variable.

4.3.4. Experiment: Set up your experiment

What do you need to do in order to vary Variable A in your experiment?

How would you measure Variable B in your experiment?

How would you ensure that all other variables that might influence the outcome are kept constant?

4.3.5. Experiment: Carry out your experiment

Set up and carry out the experiment you have designed.

Use the space provided below to construct a table and record your measurements.

What do the results of this experiment suggest with respect to the investigable question you sought to address?

4.3.6. Your classmates' experiment

Read the experiment that a group of students designed to investigate if "the number of coil turns affects the strength of an electromagnet".

"To answer the investigable question, we made 2 electromagnets. The first electromagnet had 10 coil turns and the second 20 coil turns. The wire used in both electromagnets for the coils was made from the same material but the core of the electromagnets was made from different materials. In the first electromagnet we used an iron nail and in the second a stainless steel nail. Then we measured how many paper clips each electromagnet attracts and we found that the first one where an iron nail was used as the core attracts 3 more paper clips than the other one. We concluded that the no. of coil turns affects the strength of the electromagnet.

What is your opinion about the experiment you just read?
Is it a valid experiment?
Explain your reasoning.

In case you consider the experiment invalid, write down how you would revise it so as to produce reliable results for the investigable question stated above.

CHECK YOUR REASONING WITH YOUR TEACHER

4.3.7 Exercise: Second Experiment

Choose another variable from the table in Exercise 4.3.4 and formulate a second investigable question.

Design an experiment in order to address this question,

- We will alter the following variable:
- We will keep the following variables constant:
- We will measure the following variable:

CHECK YOUR REASONING WITH YOUR TEACHER

4.3.8. Experiment: Carry out the Experiment

Set up and carry out the experiment you have designed.

Use the space provided below to construct a table and record your measurements.

What conclusion could be drawn from the results of your experiment?

Provide an overview of an approach that could be generally followed in order to address investigable questions that could be stated in the form «Does variable A influence variable B?”.

The main goal of science is to generate reliable knowledge about how systems function.
Do you think that investigating questions in the form of “Does factor A influence factor B?” through the procedure you described in the previous question, serves towards achieving this goal?
Explain.

DISCUSS YOUR WORK WITH YOUR TEACHER

The main **goal of science** is to **generate reliable knowledge about how systems function**, i.e., science tries to explain and predict natural phenomena. Finding causal relations (e.g., Factor 1 influences factor 2) between factors that are involved in a natural phenomenon, constitutes a basic part of our understanding about its function and allows us to formulate relevant predictions.

UNIT 5: TECHNOLOGY PROJECT: DESIGN AND CONSTRUCTION OF A MAGNETIC LEVITATION TRAIN

5.1 DESIGN AND CONSTRUCTION OF A MAGNETIC LEVITATION TRAIN

Design is regarded as the core problem-solving process of technological development. The design process varies to some extent according to situational circumstances but it generally includes the following steps.

DESIGN PROCESS DIAGRAM

Identify the problem and possible causes.	PROBLEM	Determine the Specifications (requirements – restrictions) for its solution.
Investigate the problem and the parameters that relate to the intended solution.	INVESTIGATION	Possible Research topics include: How did others solve the problem or a similar problem (study other models, available materials, functions, cost, etc.).
Brainstorming, Short Analysis and construction designs of Initial Ideas.	IDEAS	Sometimes even the craziest idea can be adapted to form part of the solution.
Select the Best Idea and justify your rationale.	DEVELOPMENT OF BEST IDEA	Presentation of the best idea including detailed description and construction designs.
Construction design of best idea in orthographical projection including dimensions.	CONSTRUCTION DESIGNS	List of materials and tools required.
Preparation of a diagram showing the different stages of the work progress.	CONSTRUCTION	Construction of the final product (train) using the appropriate materials and taking all the necessary steps to ensure that they are adhering to the lab safety regulations.
Final product testing and collection of the results.	TESTING – EVALUATION	Evaluation of the final product in terms of aesthetics and specifications/functions. Suggest possible ways for improvement.

5.1.1. Problem

Traffic congestion in Cyprus has become a common problem in all the major cities and especially in the capital, Nicosia. The projection is that this problem will become even more influential in the next decades. The government is trying to find solutions to alleviate this problem. Following the overt encouragement of many visitors and also the European Commission, the government is exploring the possibility of creating its own trains and railway network.

The Minister of Transport has requested that you develop a model train and make a presentation of our design. Your train must be economic, must operate in a way that does not require excessive amounts of energy and, at the same time must be fast.

Your Mission

Your mission is to come up with innovative ideas for the design of a new train based on magnetic levitation. You will need to make a detailed design that synthesizes what you have learnt in order to explain how the various mechanisms of the train operate. Your construction must adhere to three specifications/functions. These are: a) magnetic levitation b) electromagnetic propulsion and c) magnetic shielding (safety measure for passengers' health protection). You will construct either three models (one for each function) or one model incorporating all three functions. Finally, you will prepare a poster and present it in public, in a way that your audience will be able to understand how each mechanism works.

According to the description given above, is the goal of the task described above aligned with the main goal of science?
Explain your reasoning.

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CHECK YOUR REASONING WITH YOUR TEACHER

5.1.2. Collection of Information

Investigate the problem and find alternative solutions that others have proposed. Describe the different possible choices and the mechanism for each one.

How did others solve the same problem or a similar problem?

Which mechanisms they used in order to accomplish the three functions/specifications (levitation, propulsion, shielding)?

What information did you find about the materials needed (cost, aesthetics, ergonomics, etc.)?

AFTER THE COMPLETION OF THIS STAGE MAKE SURE THAT YOU WILL DISCUSS YOUR PROGRESS WITH THE TEACHER. IN ADDITION RETURN TO YOUR DESIGN PROCESS AND RETHINK THE ORGANISATION AND TIMETABLE YOU ORIGINALLY PLANNED. MAKE SURE THAT YOU HAVE ENOUGH TME TO COMPLETE THE MODEL TRAIN.

5.1.3. Initial Ideas

Suggest and present three or more ideas (along with the construction designs) that can provide a solution to your problem for each of the three specifications/functions. If you lack ideas it might be useful to return to the investigation stage and collect additional information.

Describe your ideas:

DISCUSS YOUR IDEAS WITH YOUR TEACHER

5.1.4. Development of Best Idea – Construction Designs

A. Construction of wagon and rails

How will you construct your model train? Which materials will you be using for the wagon and which ones for the rails?
Which properties do these materials have to possess?

Provide orthographical projections of the model train. The designs have to include dimensions and the type of materials used for each part.

B. Magnetic Levitation

How will you succeed magnetic levitation of your wagons?
What kind of magnets will you use for this purpose?
Where and how the magnets will be placed?

C. Electromagnetic Propulsion

Which mechanism has to be used in order to succeed propulsion?
Is it possible to succeed propulsion using permanent magnets only?

D. Magnetic Shielding for passengers' health protection

How the protection of the passengers from electromagnetic radiation will be ensured?

DISCUSS YOUR IDEAS WITH YOUR TEACHER

5.1.5. Scientific or other goal?

In the following table you are given examples of research goals. Discuss with your group and categorize them in two groups according to whether they are:

(A) aligned with the goal of science (if you don't remember what this is, then go back to 2.1.2 , 3.2.5 F, 4.3.7) or
(B) aligned with a different type of goal

	RESEARCH GOALS	A OR B
1	We try to develop an electromagnetic train in order to facilitate local public transportation.	B
2	We want to understand the causes of tornados.	
3	We try to design faster airplanes.	
4	We try to improve microscopes so that we can make more detailed observations.	
5	Sometimes arteries that supply our heart with oxygen become occluded and this causes heart problems. We try to examine factors that lead to artery occlusions.	
6	It is assumed that caffeine is not healthy. Still, this has not been adequately studied so far. We try to investigate this issue in order to explain if and how caffeine affects our health.	

Explain how you thought in order to choose between A and B.

DISCUSS YOUR RESPONSES WITH THE TEACHER

A major difference between science and technology is the difference between their main goals:

- The main **goal of science** is to **generate reliable knowledge about how systems function**, i.e., science tries to explain and predict natural phenomena.
- The main **goal of technology** is to **develop solutions to human problems** and therefore improve the quality of our life.

5.1.6. Construction

A. Initial Construction stage

List the main parts of the model train that you have constructed?

Did you face any difficulties and how did you resolve them?

From which activities of the module did you draw information that helped you in the construction of the train? Specify how this information was used in the construction of the train.

B. Final construction stage

Briefly describe the stages you followed for the construction of the model train.

Write down a list of the materials you used:

DISCUSS THE PREVIOUS ACTIVITIES WITH YOUR TEACHER

5.1.7. Exercise: Investigation or Design process?

In the table below, you are given summaries of some recently published research procedures. Categorize them in two groups according to whether they:

(A) refer to an investigation (as the ones that you conducted in Chapter 7)
or
(B) refer to a different kind of procedure that is similar to the design process that you are implementing at the moment for developing an electromagnetic train.

Note: You should specifically focus on the procedure that is followed in each project rather than the project itself.

	RESEARCH PROCEDURES	A OR B
1	"…We use some especially sensitive cameras that measure the amount of light that is emitted from the bodies of five healthy men and five healthy women every one hour for 12 hours. Our results showed that the human body's brightness reaches an upper level at 4pm and a lower level at 10am. Therefore, time influences the amount of light that is emitted by the human body."	
2	"We plan to develop a vaccine that prevents heart attacks. The main specifications of the vaccine are that its ingredients will facilitate the abortion of bad cholesterol (LDL) that subsides in the arteries and is a frequent cause for thromboses and heart diseases. Next, we will test the vaccine so as to evaluate its effectiveness."	
3	"We replaced the batteries and some other parts of the Hubble telescope; we installed two new cameras and some other parts. We tried the improved version of the telescope in order to evaluate whether: (a) it allows making observations at distances larger than 10 billion light-years, (b) it can take high resolution photos of galaxies and stellar swarms in wide parts of the electromagnetic spectrum."	
4	"We studied whether the amounts of air pollution influence rainfall. We took measurements of the amounts of carbon dioxide and other polluting gases during September to May for the years 1997-2007. Also, we collected data from the Weather Service concerning the rainfall levels for the same period of time. We compared our measurements with the rainfall data."	
5	"We monitored the medical development of many women aged 25-40 for 24 years. In particular, we examined the frequencies of celebral accidents in three groups of women: The first group consisted women that drank 5-7 coffee cups daily, the second group consisted of women that drank 2-4 coffee cups daily, while the third group consisted of women that drank 1 or no coffee daily."	

Explain how you decided whether to choose A or B in each case. Your response should be stated in a generic form which is not specifically constrained to particular cases.

DISCUSS YOUR IDEAS WITH YOUR TEACHER

Beyond the difference between the main goals of science and technology, the two fields are different with respect to the procedures they adopt for achieving their goals:

- A core procedure in **science** is **investigation**
- A core procedure in **technology** is **design**

5.1.8 Testing – Evaluation

Test your model train and write down your results.

	YES	NO	PARTLY
➢ The model train solves the problem initially stated			
➢ Successful testing of:			
• Levitation			
• Propulsion			
• Shielding			

Explain briefly the process you used for testing the model train for each of the parameters, shown above.

Which difficulties did you face in the:
(A) design stage?

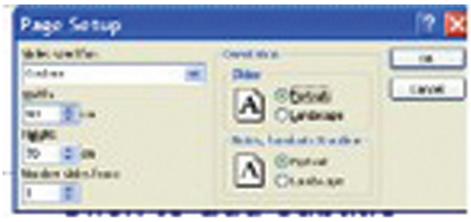
(B) construction stage?

What will you do differently if you had to make a model train from scratch again?

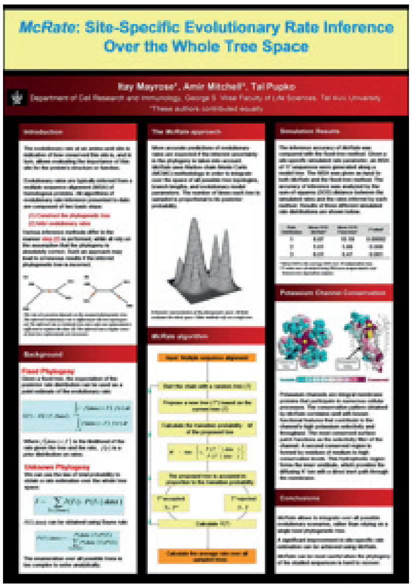
DISCUSS YOUR PROGRESS WITH YOUR TEACHER

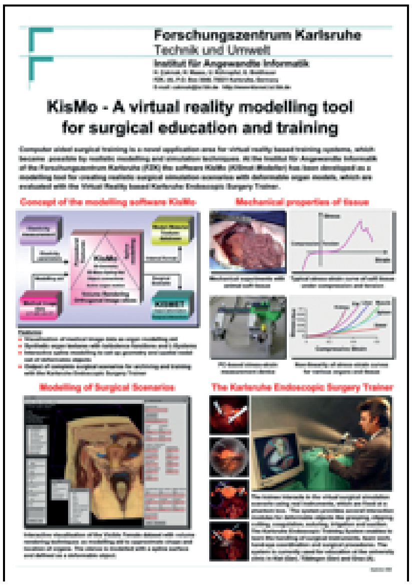
5.1.9 Creating a Poster

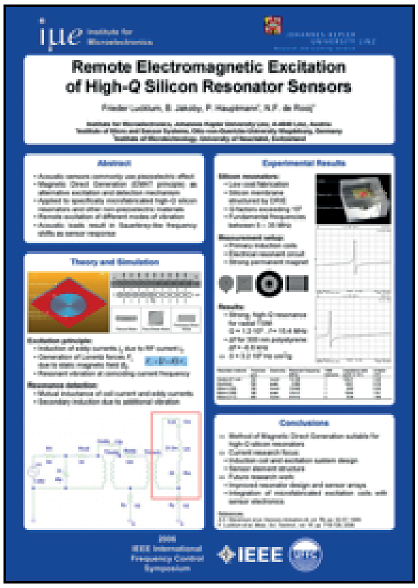
Instructions

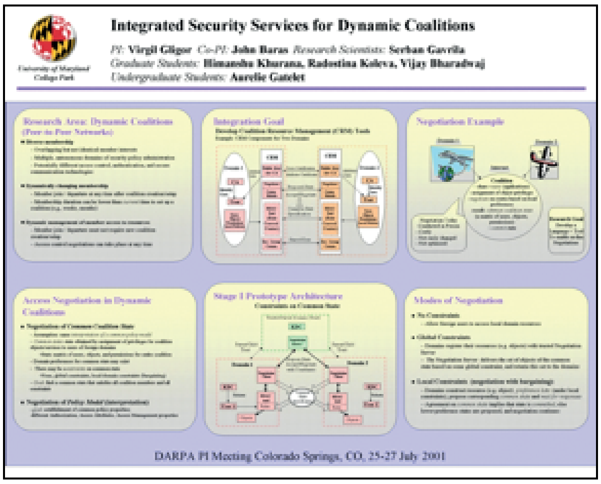
1.	Open - Microsoft PowerPoint.	
2.	From the drop window “File” select “Page Setup”.	
3.	In the option drop-box ‘select sized for’ select “custom”, as shown in the picture at the right column.	
4.	The dimensions of your poster will be 50cm x 70cm, so in the box next to width write the number 50 and for height the number 70.	
5.	Under ‘slides’ select one of the options Portrait or Landscape depending which one you prefer for your poster (examples shown in the right column).	Landscape Por- trait
6.	Press OK.	
7.	Now you are ready to create your poster!	
8.	To add text to your poster press the icon shown in the right column. This icon is found at the bottom of the program screen.	
9.	Your poster should include information for all the categories shown at the right column.	• Problem • General Information • Initial Ideas • Development of best idea • Construction designs • Explanation of the 3 functions • Passengers’ safety • Evaluation
10.	Do not forget to enter your names in the poster!	

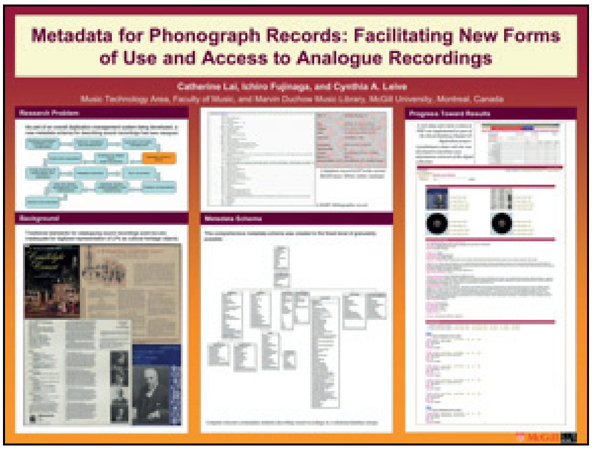
Poster Examples

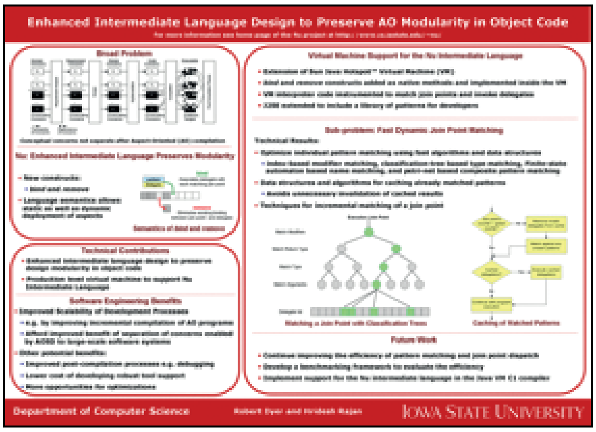












UNIT 6: LINKAGES BETWEEN SCIENCE & TECHNOLOGY

6.1 LINKAGES BETWEEN SCIENCE & TECHNOLOGY

6.1.1. Examples of Science- & Technology- oriented activities

A. Identify and describe two activities (from the whole module) which you consider falling under science and two activities that you consider falling under technology. (Hint: Remember the differences we have discussed between science and technology)

Activities that fall under science:

1. **Activity/Experiment ____ In this activity we tried to ______________________________**

____

2. **Activity/Experiment ____ In this activity we tried to __________________**

____

____

Activities that fall under technology:

3. **Activity ___________ In this activity we tried to ______________________**

____

____

4. **Activity ___________ In this activity we tried to ______________________**

____

____

6.1.2. Connection between Science & Technology

Were there any cases in which technology helped you to reach your scientific goal?
Explain and provide relevant examples.
(Hint: Has technology helped you to implement any of the activities that you have described in A1 or A2?)

....

....

....

Were there any cases in which science helped you to reach your technological goal?
Explain an provide relevant examples.
(Hint: Has science helped you to implement any of the activities that you have described in A3 or A4?)

....

....

....

6.1.3. Story examples that demonstrate the interconnection and differences between Science & Technology

Below, there are some stories that describe some research activities. Carefully read them and answer the questions.

Oersted, Faraday and electricity stations

People used to believe that there is no connection between magnets and electricity… Before 1820, iron magnets and magnetite were the only known “sources” of magnetism. This changed when Hans Christian Oersted, one not so known physics professor of the University of Copenhagen (Denmark), found that electricity and magnetism are connected.

In 1820, Oersted was giving an evening lecture where he would demonstrate heat phenomena that occur while current flows through a tube as well as some magnetic experiments. While preparing a demonstration, Oersted noticed the compass needle deflected from magnetic north when electric current from a battery switched on and off. However he did not mention anything and completed his demonstrations.

Soon after his guests had left, he started working in order to find an explanation about this “new” phenomenon. After this accidental observation, he had many questions that he needed to answer, e.g., “What causes the rotation of the compass?”, “What’s pushing the pointer of the compass?”, “If I move the wire what will happen?”, “What will happen when current flow increases?”

One year later, after intensive investigations, Oersted published his findings, showing that an electric current produces a magnetic field as it flows through a wire. Many colleagues read this book and were impressed by his experiments and his ideas. One of those was the English scientist Michael Faraday. Oersted had observed that a wire obtains magnetic properties when electricity flows through it. Faraday was interested to find out whether the reverse was possible, i.e., whether magnetism can lead to electricity. In order to find an answer to his question, Faraday designed and carried out many investigations. Through his experiments he observed that when a wire is rotated inside a magnet, then electric current is produced. Also, through his experiments he concluded to factors that influence how electromagnets function. In order to be able to execute his experiments, Faraday needed to invent some techniques and mechanisms that allowed him to automate the wire's circling inside the magnet and change the rotation speed in a fixed mode.

Today, electromagnetism is used for the function of many devices that unburden humans from a lot of hard hand work. Therefore, using electricity has saved us from a lot of discomfort and fatigue. The valuable electricity is produced in large factories called electricity stations. Oersted's discovery of the existence of a connection between electricity and magnetism, is the core principle for the function of the electricity station. Also, Faraday's research was the foundation for the construction of the generator, where a magnet rotates in a circuit and produces electric current.

A new huge ring was discovered around Saturn (Source: Nature magazine)

Saturn's ring system has just got a lot larger, with the discovery of a new huge ring. The new ring was discovered by the Spitzer space telescope of NASA. It is the largest known ring of Saturn. It was thought that the farthest ring of Saturn was the E ring, which stretches from a distance up to to 8 Rs (where Rs is the radius of Saturn, equal to 60,330 kilometres). However, this new ring dwarfs all the others, extending from approximately 207 Rs with a vertical thickness of 40 Rs. According to the NASA air promotion laboratory, the ring consists of ice particles and dust, while it is at an angle of 27° with respect to Saturn's equator. **Spitzer space telescope managed to discover the new ring** in the infrared spectrum despite its extremely sparse nature. (The extremely sparse nature of the ring means that it reflects very little light and is practically invisible, which is why it has previously escaped detection.)

Beyond the discovery of the ring, scientists have also observed for the first time that Iapetus, one of Saturn's moons has a hemisphere that is permanently much darker in colour than the other half. Through further research with the use of Spitzer telescope, scientists think they may be able to solve this astronomical mystery and fully explain their new observations about Iapetus' darker side.

A. Write down two research goals found in the above texts that are aligned with the goal of science and two research goals that are aligned with the goal of technology.

Scientific goals:

....

....

....

Technological goals:

....

....

....

B. *Are there any cases where the progress of technology has helped the progress of science? Explain by mentioning examples from the texts you have read.*

C. *Are there any cases where the progress of science has helped the progress of technology? Explain by mentioning examples from the texts you have read.*

Science and technology are linked in a bidirectional relationship where each field contributes towards the progress of the other:

1. ***Science* contributes to the progress of *technology*** because:
   A. It provides the knowledge background for the development or improvement of technological equipment
   B. It formulates questions that posit specific instruments, which need to be produced (i.e., the invention of specialized instruments/processes for measuring, monitoring or controlling)
2. ***Technology* contributes to the progress of *science*** because:
   A. It provides instruments and experimental techniques that facilitate the conduction of better (more valid and more reliable) experiments
   B. Technological invention generates new research questions for science to address.

DISCUSS YOUR ANSWERS WITH YOUR TEACHER

MATERIALS
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