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ABSTRACT

By using this instructional module the participants should be able to: (1) predict the behavior of two magnets prior to their being placed close to each other; (2) identify and describe the magnetic forces acting on a bar magnet that is free to rotate; (3) demonstrate a method for determining the lines of force in a magnetic field; (4) identify the positions of the poles of a magnet given the lines of force in a magnetic field and the geographic orientation; (5) construct one or more inferences to explain data shown in lines of force around magnets; (6) describe how the data support an inference about magnetic lines of force. In order to identify the present standing of the participants, a pre-appraisal is administered prior to presenting this module. By immediately scoring the pre-appraisal, the instructor is able to identify which sections of this module need heavier emphasis. The module contains instructional activities, rationale, references, materials list, and duplicated materials. The population for which this instructional program has been found to be effective includes preservice and inservice elementary school teachers. (BR)

THE MEANING OF DATA

Magnets and Magnetic Fields

1st Experimental Edition

The Research & Development Center
For Teacher Education

THE UNIVERSITY OF TEXAS
AUSTIN

THE MEANING OF DATA

<u>Magnets and Magnetic Fields</u>

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THE MEANING OF DATA

Magnets and Magnetic Fields

Gene E. Hall

Science Education Center
and
The Research and Development Center for Teacher Education
The University of Texas at Austin

I. PERFORMANCE OBJECTIVES:

At the end of this session the participants should be able to:

1. Predict the behavior of two magnets prior to their being placed close to each other;
2. Identify and describe the magnetic forces acting on a bar magnet that is free to rotate;
3. Demonstrate a method for determining the lines of force in a magnetic field;
4. Identify the positions of the poles of a magnet given the lines of force in a magnetic field and the geographic orientation;
5. Construct one or more inferences to explain data shown in lines of force around magnets;
6. Describe how the data support an inference about magnetic lines of force.

II. RATIONALE:

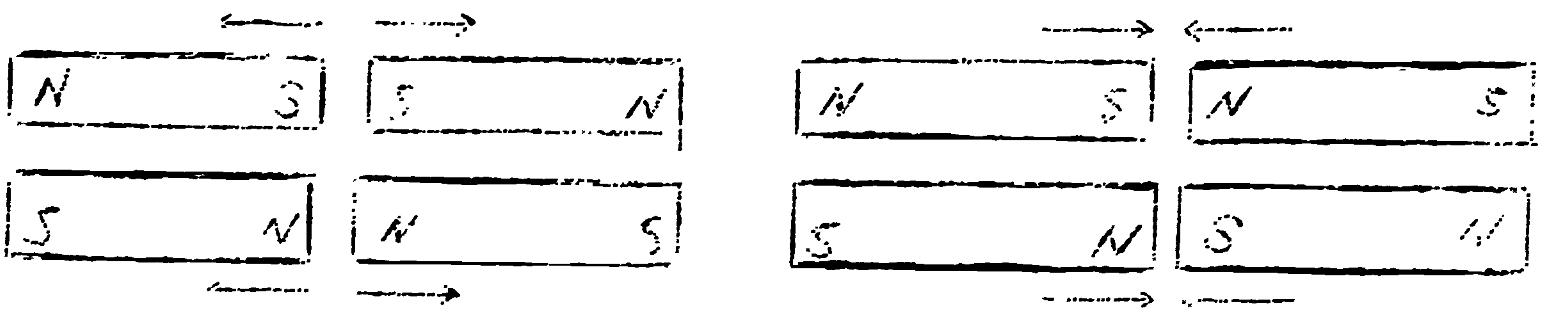
The inferences that are drawn from data can be of extreme importance to participants, not only in science classes but in other subject area classes as well as in everyday life. Being an expert collector of data is not of much value if meaning cannot be made from the data once it has been collected.

This module entails work with magnets and magnetic fields. Probably all of the participants will have worked with magnets; however, it is doubtful that many will have a great deal of clarity in their understanding of magnets and magnetic fields.

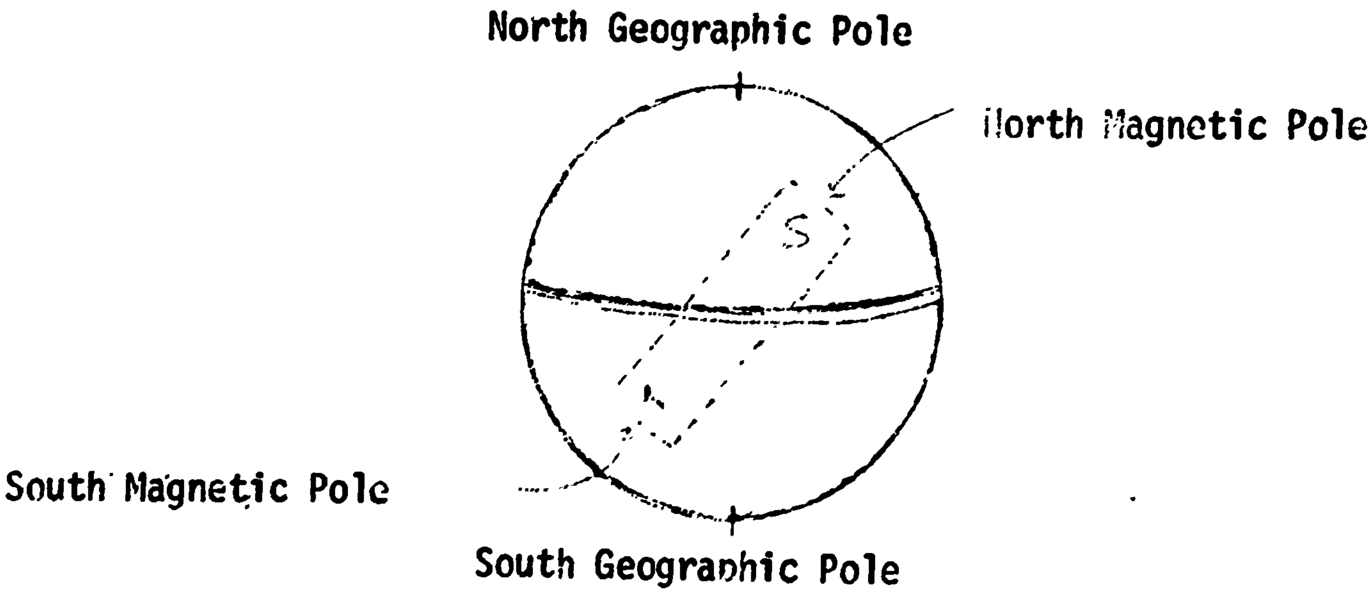
It cannot be overemphasized that prior to teaching this module the instructor should have a firm understanding of the observable properties of magnets, including the operation of a compass. Any misstatements or confusion on the part of the instructor may lead to confusion for the participants.

The two areas on a magnet where the magnet is the strongest are called poles. P convention the poles are labeled N and S. The N-pole is the pole of the magnet that will point toward northern Canada when it is free to rotate. In other words, the N-pole of a magnet is the north-seeking pole. Conversely, the S-pole of a magnet is the south-seeking pole, or that end of the magnet that will point toward Australia. It may be of some help to reserve the terms "north" and "south" for geographic labels and use "N" and "S" only when talking about the poles of a magnet.

When two magnets are placed together, like poles repel while unlike poles attract.



A compass is nothing more than a small magnet that is free to rotate. As you know, the north-seeking pole of a compass will point toward northern Canada. This happens because the earth has the properties of a magnet. Since opposite magnetic poles attract and the north-seeking pole of the compass points in the general direction of the north geographic pole of the earth, the S magnetic pole of the earth must be in northern Canada, while the N magnetic pole of the earth is near Australia. Depending on where you are on the surface of the earth, the compass needle does not always point directly at the north geographic pole. This is due to the fact that the S pole of the earth's magnetic field is not exactly at the north pole of the earth, but near Hudson Bay. The following diagram may help visualize the relationship between the earth's geographic and magnetic poles.



In summary then, the N-pole or north-seeking pole of a compass points toward northern Canada, while the S-pole or south-seeking pole of the compass points toward Australia.

As you know from experience, magnets can affect certain metals without coming into direct contact with them. To explain this phenomenon, the concept of a magnetic field has been described. This magnetic field and the effects of the field on another magnet (e.g., a compass) are to be explored in this module.

In order to identify the present standing of the participants, the pre-appraisal is administered prior to presenting this module. By immediately after presentation having the participants score the pre-appraisal, it is then possible for the instructor to identify which sections of this module need heavier emphasis. Since later portions of this module depend upon information developed by the participants in earlier activities of the module, it is impossible to skip activities. However, the relative time spent upon each activity can be varied depending upon the background experiences of the participants and their score on the pre-appraisal. The objectives are related to the appraisal task and the instructional activities in the following manner:

Objective	Appraisal Task	Instructional Activity
1	1	Introduction
2		1
3		2
4	2	3
5		3
6	3	3

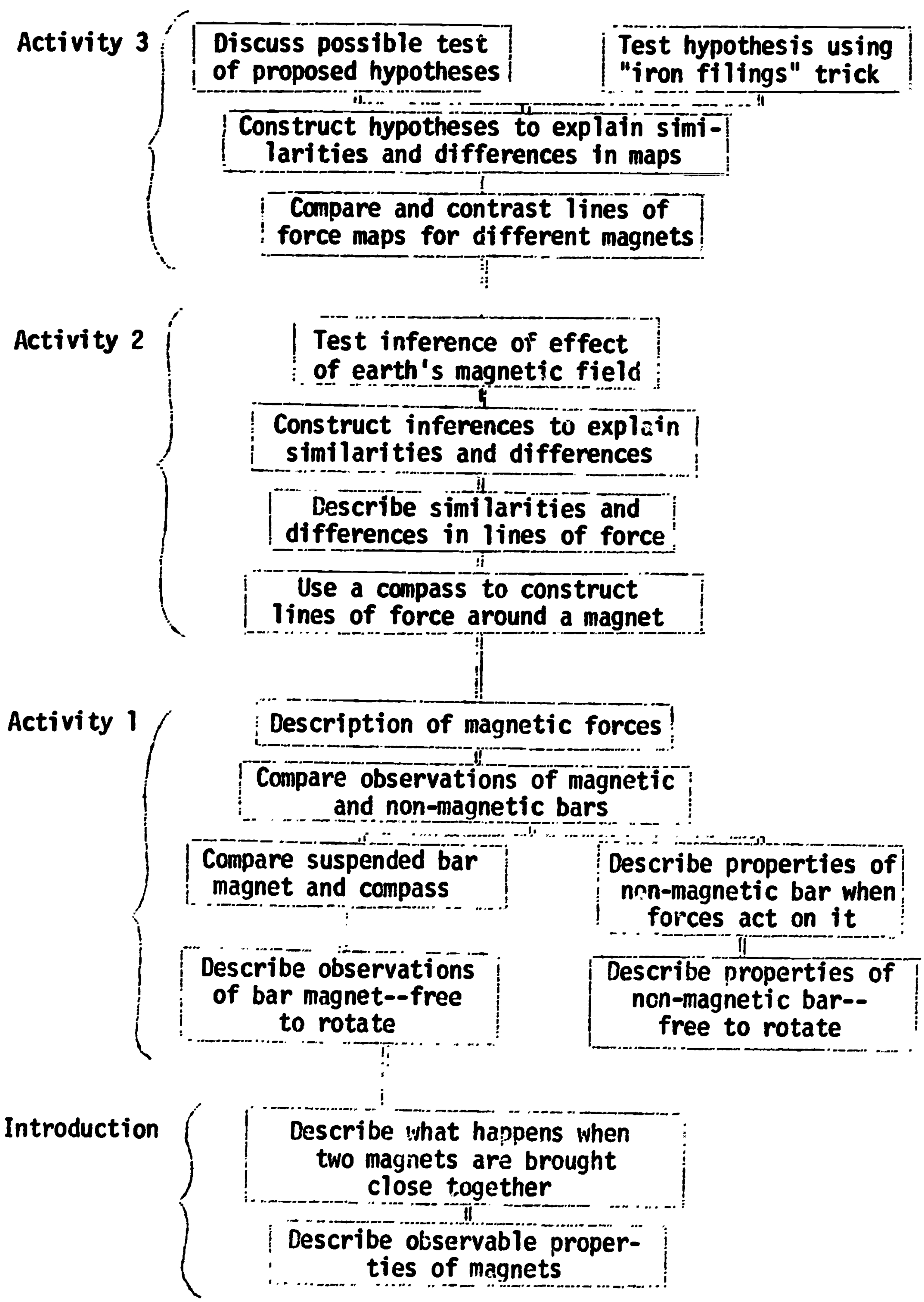
During the module the participants will become more familiar with magnets by using a compass to collect data about a magnet and then describing the meaning of the data.

In the first activity, after being introduced to compasses, participants will plot the lines of force for a portion of the magnetic field of the earth. In addition, the meaning and effect of lines of force will be explored.

In the second activity, the participants will explore the strong local magnetic field of a magnet after observing that this field is strong enough to deflect a compass brought near the magnet. The participants will then plot the lines of force for a magnet using their compasses.

The population for which this instructional program has been found to be effective includes pre-service and in-service elementary teachers who teach science.

The instructional activities of the module are based on this sequence:



III. REFERENCES:

AAAS Science - A Process Approach Commentary for Teachers. Washington, D. C.: American Association for the Advancement of Science, 1968.

AAAS Science - A Process Approach, Part 6, 4th Experimental Edition. Washington, D. C.: American Association for the Advancement of Science, 1968.

Rogers, Eric M. Physics for the Inquiring Mind. Princeton: Princeton University Press, 1960.

IV. MISCELLANEOUS NOTES:

A. This module will include subquestions at times. These questions are identified by a small lette followed by a parenthesis e.g., a) . The subquestions are to be used as leading questions if the initial question does not get a desired response.

B. Bar magnets should be stored with opposite poles together, while horseshoe magnets should be stored with a piece of soft iron, such as a nail, across the poles.

C. Do not throw or drop compasses and other magnets since the magnetic properties will be drastically reduced.

D. The following is one method for remagnetizing a magnet: In series connect a long coil of wire to a d.c. source, such as a car battery, and a switch. Place the material to be magnetized in the coil, then quickly close and reopen the switch. The short passage of current through the coil will magnetize the material placed in the coil.

E. Weak magnets can be made by rubbing appropriate materials with a magnet. One pole of the magnet should be used and the stroke repeated several times.

Evaluation Data:

At the time of printing, evaluation data with regard to this module is quite limited. The time periods required for this instructional module would include:

A. Planning for instruction: Approximately three hours.

B. Teaching: 90-150 minutes.

Suggested time periods for this module are as follows:

A. Pre-Appraisal	10 minutes
B. Introduction	10 minutes
C. Activity I	35 minutes
D. Activity II	50 minutes
E. Activity III	20 minutes
F. Post-Appraisal	10 minutes
Total	135 minutes

V. MATERIALS LIST:

Pre-Appraisal	MD #1 (one per participant)

Section I

Introduction and Activity 1	One (1) bar magnet that has the N-pole marked with paint Nonmetallic support (e.g. spring scale, tripod) and 30 cm. length of string One (1) non-magnetic bar with 20 cm. of string attached at each end One (1) compass per group
Activity 2	(Per Group) Two (2) large pieces of paper (1 meter x 1 meter) One (1) compass One (1) felt tip pen For each group, place a magnet on the center of the paper. Use a different shape magnet and/or a different orientation of the magnet for different groups.
Activity 3	One (1) piece of white cardboard (8½ x 11) One (1) magnet Iron filings
Post-Appraisal	MD #2 (One per participant)

VI. INSTRUCTIONAL ACTIVITIES

Pre-Appraisal (Time: Approximately 10 minutes)

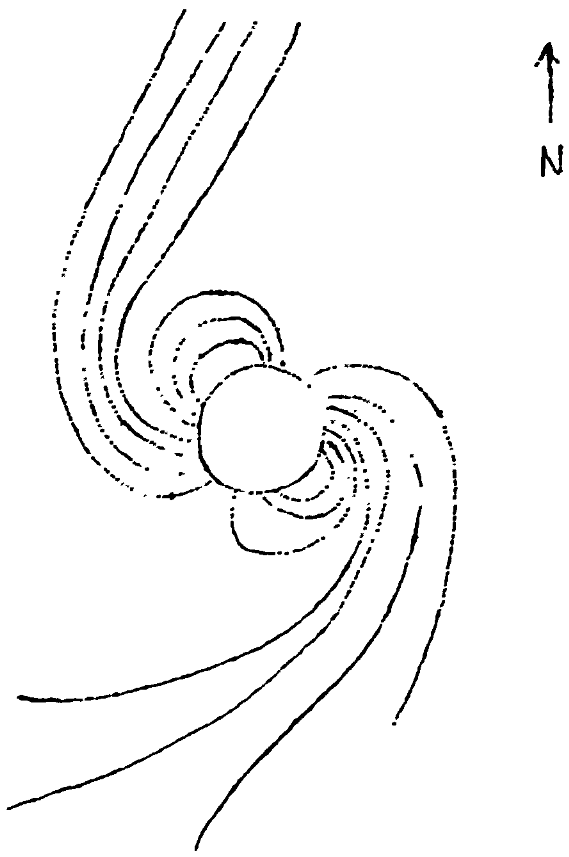
(Directions: Hand out the Pre-Appraisal--MD #1--to the participants. Ask them to complete both items. Allow five minutes for this task and then discuss the answers with the participants. Record the number of people receiving correct responses to the items on the board. You can also ask them about their confidence in responding.

If 80% or more of the group did not respond satisfactorily, then The Meaning of Data Module should be presented.)

Pre-Appraisal

1. Describe three properties of magnets.

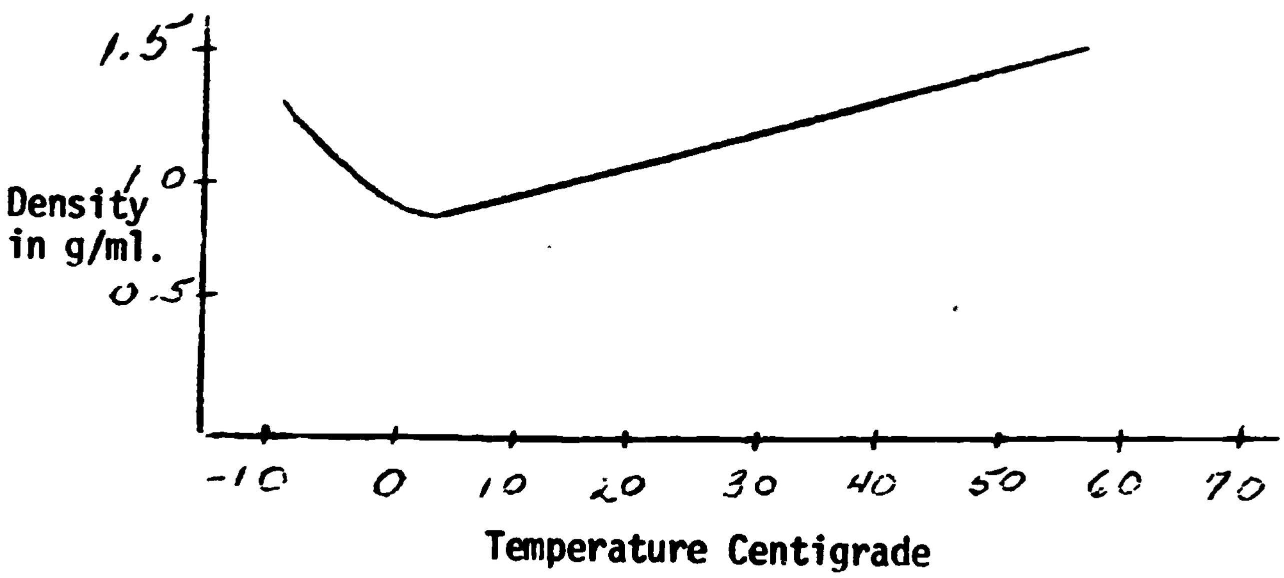
2. Figure 1 is a map of the lines of force around a bar magnet. Draw the orientation of the bar magnet, marking which pole is the N-pole.



3. Describe how the data support your placement of the magnet.

Pre-Appraisal cont'd.

4. The following graph (Figure 2) was constructed from data gathered in a laboratory study of a certain substance Zeq.



What does the graph tell you about the substance Zeq?

Introduction (Instruction time: Approximately 10 minutes)

Before the session begins, identify locations around the room where the participants can work in groups of from three to five. The work stations should be free of magnetic metals so that the compass needles will not be distracted. Tape the large sheets of work paper to the work surfaces.

1.	Write down three things that you know about magnets.

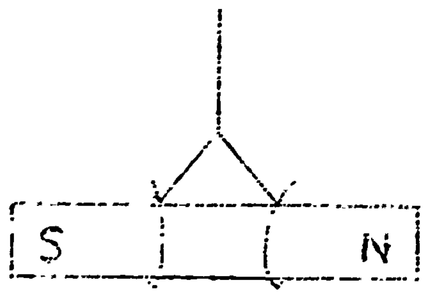
Then discuss their knowledge of magnets.

Probably the discussion will bring out that magnets have two poles, opposite poles attract, like poles repel, etc. If all of these principles do not come out, do not volunteer them. The participants may feel that they already know all there is to know about magnets. However, as the lesson unfolds, they will probably find new information.

Activity 1 (Instruction time: Approximately 35 minutes)

Use the bar magnet that has one pole marked with paint so that the class can readily identify it. With a thread, suspend the bar magnet from a spring scale tripod or other non-metallic support.

So that the suspended magnet will not tilt, use a short string to tie the bar in two places; then by making a cradle, attach the string from the tripod to the cradle.



Make certain that there are not magnetic materials near the magnet. Set the magnet into a gentle oscillation. Once the oscillation stops...

2.	In which direction does the N-pole (marked pole) of the magnet point?

Toward the northern part of the classroom.

3.	If I set the magnet into motion again, do you think that once it stops the N-pole will again be pointing toward the northern part of the room? What reason do you have?

Do it.

4. What happened?

Since the N-pole of the magnet points toward the north, it could be called the "north-seeking pole." That is, the pole of the magnet that points toward the north geographic pole.

Hand out one compass to each group.

5. Write down three things about the compass.

Discuss their observations and inferences about the compass.

6. a) How is the suspended magnet similar to or different from a compass?

A compass needle is also a suspended magnet.

7. Why do you suppose a compass needle and the suspended magnet point north?

Probably they will say that the earth is a magnet, and opposite poles attract. Try and have the participants propose the idea of a force acting on the magnet. If this fails...

8. a) Do you think that there could be forces acting on the magnet to make it point north and south?

Substitute a piece of wood for the bar magnet. Attach a piece of string at each end of this bar. Name a participant to hold each of the strings.

9. By manipulating the strings that are tied to the wooden bar, can you simulate the action of the magnetic bar?

Once the participants do this...

10. How could this action be related to your observations of the magnetic bar? Could you develop an inference to explain the behavior of the magnetic bar?

The participants will probably suggest that magnetic forces were acting on the magnetic bar.

11. How many magnetic forces were acting on the bar? How many directions?

If the participants do not come up with the inference of there being two forces, then do the following: Have the participants face each other with the bar between them.

12. a) While A does not pull on his string, B pull lightly on your string. What happens?

The bar rotates so that it is pointing toward each participant. In addition, the bar is pulled closer to B.

13. a) This time, both A and B pull lightly on your strings. What happens?

The bar should rotate but not be displaced toward either participant. The participants should observe that the bar oscillates some before pointing directly at participants A and B. It may be necessary to repeat this procedure in order to gather additional observations.

14. a) When using the magnetic bar, the bar was not displaced either way. How does this relate to the wood bar with A and B pulling on it?

15. a) Did the magnetic bar move farther north or south?

The magnetic bar must have had equal and opposite forces pulling on it.

16. b) Okay. At this point, let's review the data we have with respect to magnetic and non-magnetic bars.

Magnetic bars line up in a north-south orientation, with the N-pole or north-seeking pole pointing north, while nonmagnetic bars line up in the direction of the pulls exerted on it.

17. What shall we call these factors?

For the magnetic bar, "magnetic forces."
For the non-magnetic bar, "AB forces" or "people forces" or...

Following this discussion...

18. What can you say about the space around a magnet?

    a) Are there magnetic forces there?
    b) In other words, do magnets affect objects without physically being in contact with them?

Yes.

19. How could you find out more about the space around a magnet?

Permit all sorts of answers to be considered. Ask the participants about the feasibility of different approaches.

20. a) Do you think that would work?
    b) What exactly would that tell us?
    c) Etc.

Activity 2 (Instruction time: Approximately 50 minutes)

Give each group a magnet, placing it on the center of the paper and orienting each magnet so that no two have the same orientation.

21. Draw an outline of the magnet on the paper so that if it is moved the original placement can be found again.

If the idea of using a compass to observe the space around a magnet has not occurred...

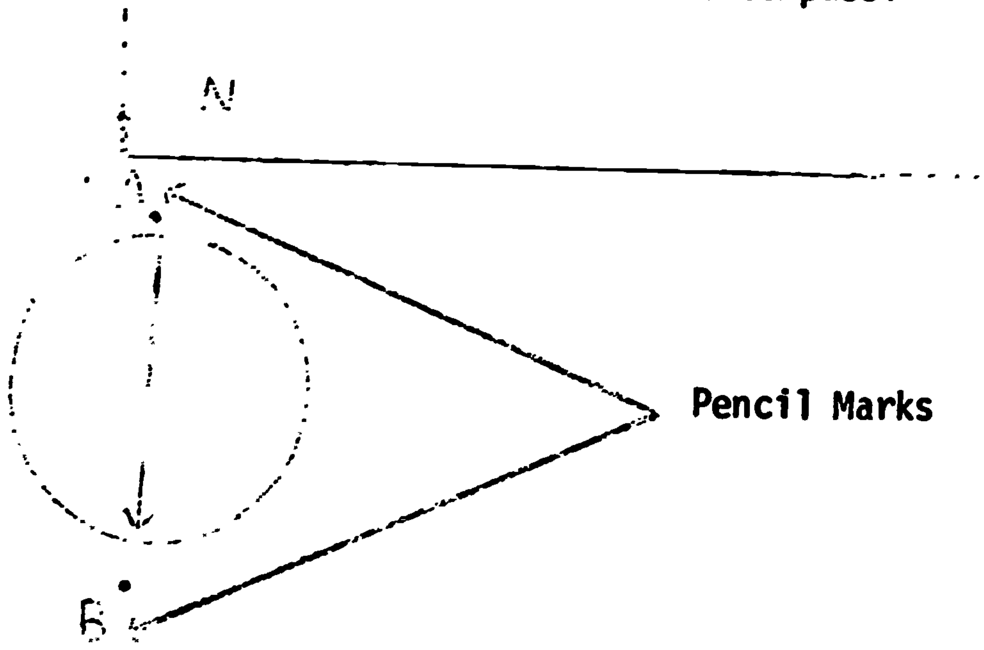
22. Do you think that a compass could be used to gather information about the space around a magnet?

23. How?

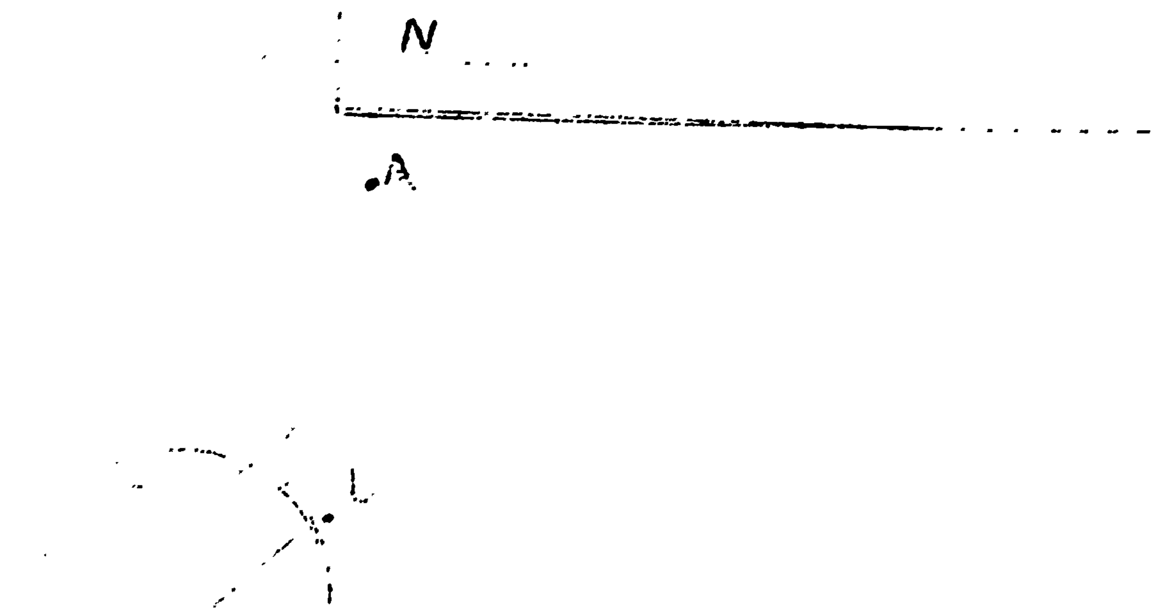
24. What would happen?

In other words, the compass will line up parallel to the lines of force of the magnet. By placing the compass at different points around the magnet, the direction of the lines of force at the point can be observed.

Procedure for constructing lines of force. Place the compass very close to, but not touching, the magnet. The compass may be placed next to any part of the magnet, although a point near one of the magnetic poles will probably be easiest at first. Using a pencil, or other non-magnetic marker, mark on the paper the direction the compass needle points by making a dot on each side of the compass.

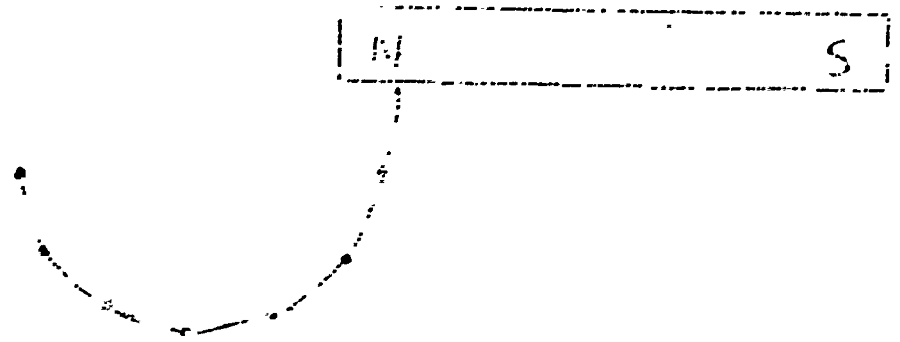


Next, move the compass out from the magnet, adjusting its position until the compass is adjacent to pencil mark B and the compass needle points toward the pencil mark B. Be sure that the end of the compass needle that was pointing toward the magnet is now pointing toward pencil mark B.



Now mark the direction that the compass needle is pointing toward. Repeat the procedure until the compass is again adjacent to the magnet or until you are reasonably sure that the compass needle will continue to point away from the compass for some distance.

Following this procedure will result in a series of dots which can then be connected together, the resulting line represents one line of force.



25. How should we record the results?

Mark where the ends of the needles point.

26. Should you place the compass just anywhere, or could we make it a little more systematic?

The method employed should be systematic by placing the compass "head to tail," in other words, "North pole to South pole." Draw a magnet and compass on the board to aid in describing the procedure to be followed. You should move from group to group demonstrating the procedure if necessary since it is crucial that the participants be working correctly.

27. Is the procedure clear?

__Note__: This activity may require more guidance by the instructor than has been usual for other modules. The instructor should check to see that the participants work carefully and correctly in the construction of the maps of the magnetic fields or the data will be meaningless.

28. Can you think of any variables that we haven't controlled that should be considered?

   a) Do you think that it would be okay to use a ball point pen to record with?
   b) Are there any other magnetic objects around that would affect the record?
   c) We have observed that the compass points North and South. Do you suppose this will affect our results?

"c)" should lead to the participants recording on their papers the direction of magnetic north.

29. Are there any other variables to be considered or remaining unanswered questions? Okay, begin the construction of the map of the lines of force.

30. After you have completed one series of points, use the felt pens to connect the points together. Do not make your lines just from the ends or sides of the magnet, but all around.

Do not encourage interaction between the groups at this time. After the maps are completed, post the maps on the walls so that all of the participants may compare them.

31. What sort of reaction do you have to the charts?

   a) How are they different?
   b) How are they alike?

Continue this discussion until the participants observe that lines near the magnets are similar, while the lines farther away are different and also that some lines return to the magnet while others just go away.

32. Why are the patterns different?

Accept any and all answers writing them on the board.

33. What could we call the lines that you have made?

   a) How about "magnetic lines of force"?

If the participants do not suggest it...

34. Earlier you suggested that the earth is a magnet (has a magnetic field). Do you suppose that this magnetic field had any effect on the data?

35. How could we test this inference?

If the participants do not suggest it...

36. Do you suppose that we could use a similar approach to that you used in constructing (pointing) these maps?

The participants all probably conclude that a similar procedure to that used before would work.

37. What do you think the maps will look like?

a) Do you think that each group will have similar maps?
b) Your location in the room will (not) effect the map?

Accept whatever discussion is forthcoming.

38. Okay. Go ahead and construct your maps of the local lines of force for the earth's magnetic field.

The lines of force recorded should be long, parallel north-south lines.

Activity 3 (Instruction time: Approximately 20 minutes)

Interpreting the Data

Review the first two activities with the class.

39. In the first activity we explored the concept of lines of force using a bar magnet and a non-magnetic bar. In the second activity you used a compass to plot lines of force for a magnet. We concluded that it was reasonable to infer that there could be magnetic forces working on the magnet like there were student forces working on the magnetic bar. Activity 2 concluded with you constructing maps of the lines of force for the earth.

40. Now, let's look at the maps that we have posted around the room.

First, taking one map for study discuss the individual lines and the resulting patterns using such questions as:

41. a) Where does this line go? Where does this one go? Etc.
    b) Why do you think this line goes where it does?
    c) This line that runs off the paper, where will it eventually go?
    d) Does anyone else have a different idea?

42. Let's look at another pattern or map:

    a) How is this pattern similar to the first?
    b) How is this pattern different from the first?
    c) Why do you think they are different?
    d) Why do you think they are similar?

Briefly explore the other patterns, listing similarities and differences.

43. As you remember, a hypothesis is a generalization statement which covers all cases of a class of events, even those cases for which you did not make observations. What are some hypotheses or generalizations that could be made from the maps of local lines of force that we have here?

44. a) What could you say about the direction and pattern of the lines of force around the magnet?
    b) What could you say about the similarities (differences) of a magnet and the earth?
    c) What could you say about the space around a magnet and our earth?

Hopefully from the maps the participants will suggest several hypotheses for discussion.

The one hypothesis that should be explored is that the lines of force from the N-pole of the magnet that do not return to the magnet will eventually point toward the geographic north pole, while the lines of force leaving the S-pole will eventually point toward the south geographic pole.

When a hypothesis is presented, you should ask the class for ways of testing the hypothesis.

You could also explore their degree of confidence in the hypothesis.

45. a) Have you tested all of the magnets?
    b) What variables of other magnets might affect your hypothesis?

Shape, size, strength, etc.

After completing the discussion, you could point out that the old "iron filings sprinkled on paper" trick results in a similar phenomenon to the lines of force maps.

Demonstrate the old "iron filings sprinkled on paper" trick and ask the participants to write out a short description of what they think happens.

46. How do you suppose the old "iron filings sprinkled on paper" trick works?

The iron filings act as tiny magnetic bars or compasses. By tapping the paper the friction is reduced and the filings can rotate, lining up parallel to the lines of force at the point each filing is at.

Post Appraisal (Instruction time: Approximately 10 minutes)

(Directions: Hand out MD #2.)

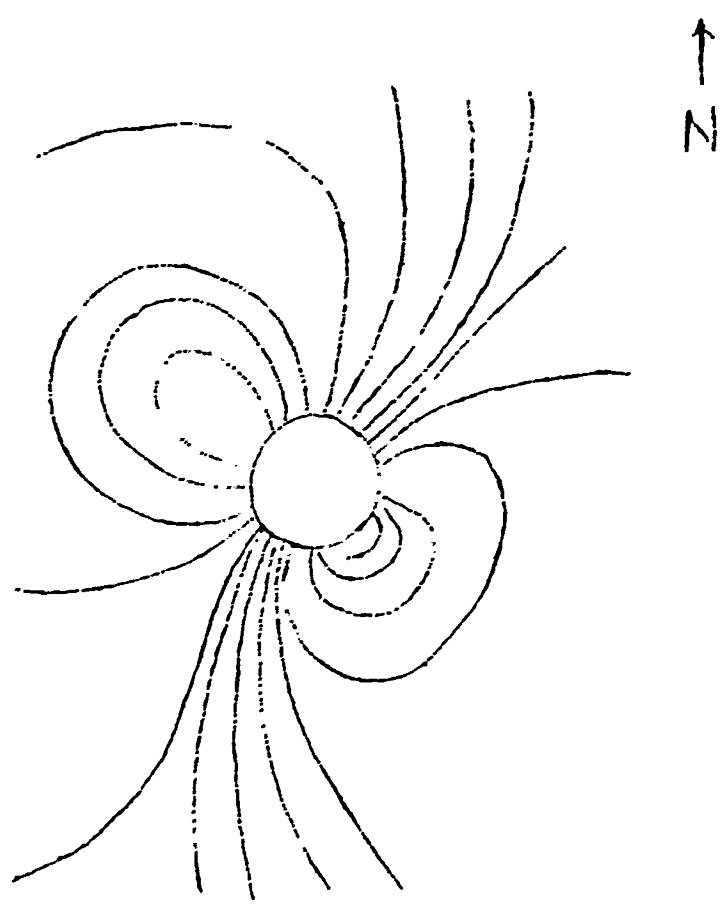
47. Complete both parts of the Appraisal (MD #2).

If you wish, and time permits, discuss the Appraisal checking to see if the participants achieved the objectives. You can also discuss their reactions to the just completed instructional period.

Post-Appraisal

1. Describe three properties of magnets.

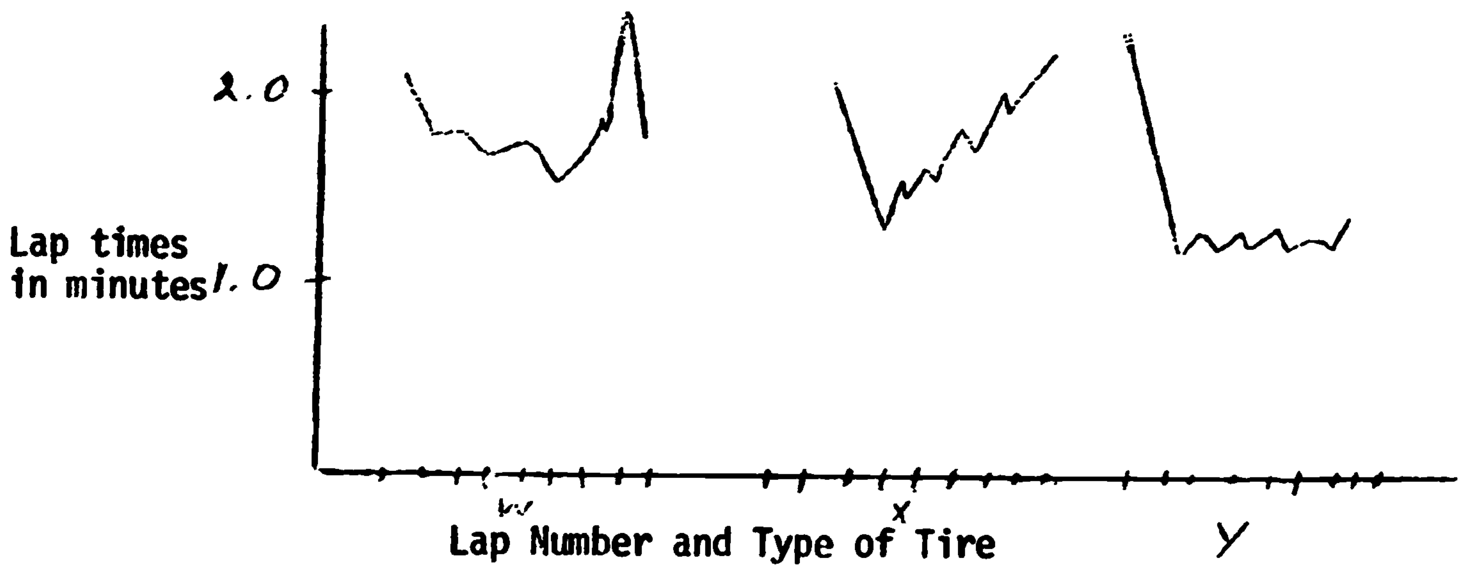
2. Figure 3 is a map of the lines of force around a bar magnet. Draw the orientation of the bar magnet, marking which pole is the N-pole.



3. Describe how the data support your placement of the magnet.

Post-Appraisal cont'd.

4. Figure 4 is the graphical representation of the lap times of a race car during three practice sessions. Lap time is the time it takes the car to make one complete trip around the racetrack. For each practice session the race car was equipped with different tires (w, x, or y).



As team manager and if the driving conditions were the same, which set of tires would you recommend that the driver use during the race?

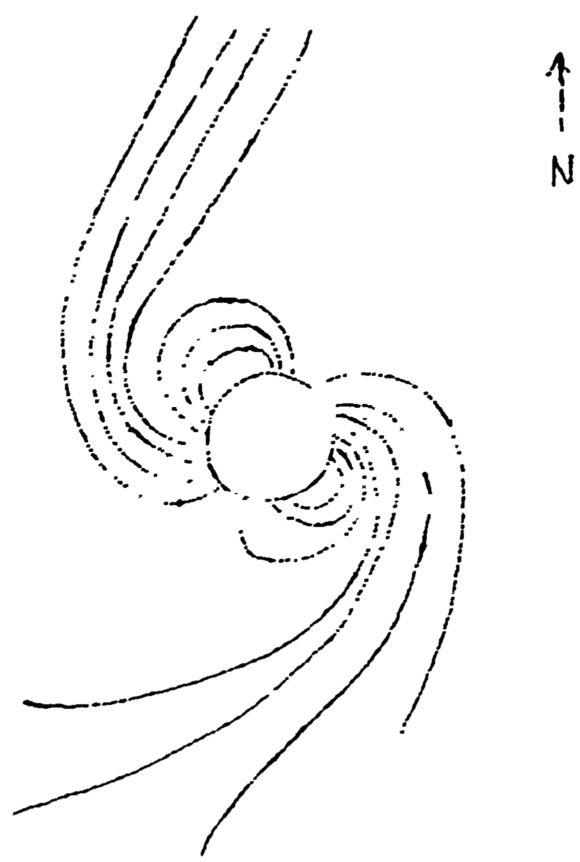
Justify your decision.

Duplicated Materials -- Without Answers

Pre-Appraisal

1. Describe three properties of magnets.

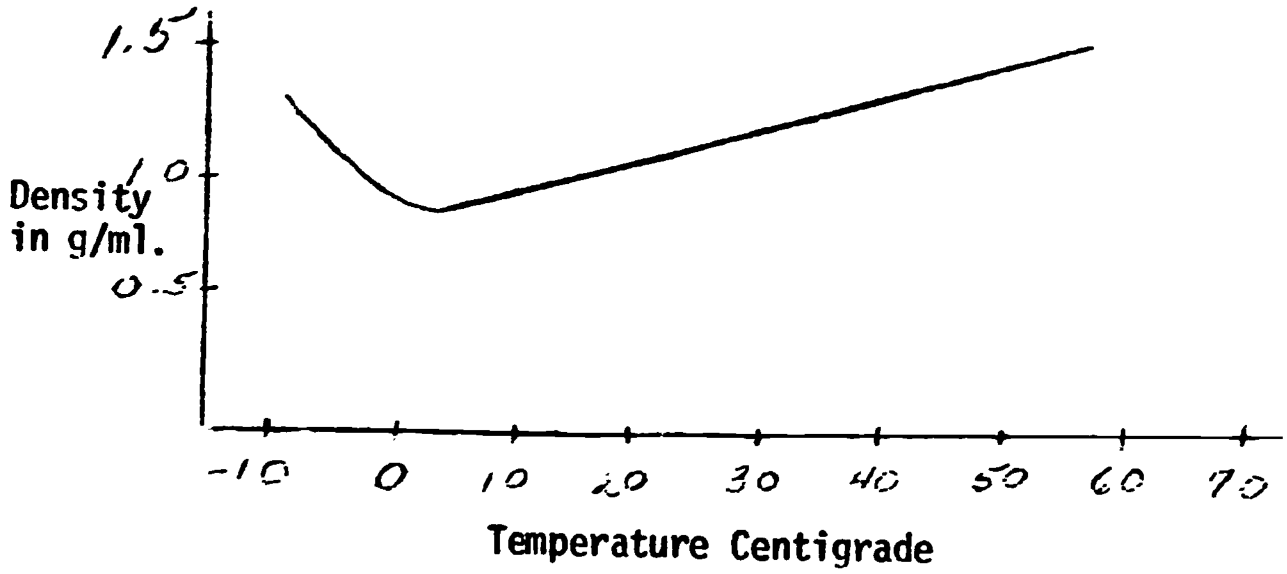
2. Figure 1 is a map of the lines of force around a bar magnet. Draw the orientation of the bar magnet, marking which pole is the N-pole.



3. Describe how the data support your placement of the magnet.

Pre-Appraisal cont'd.

4. The following graph (Figure 2) was constructed from data gathered in a laboratory study of a certain substance Zeq.

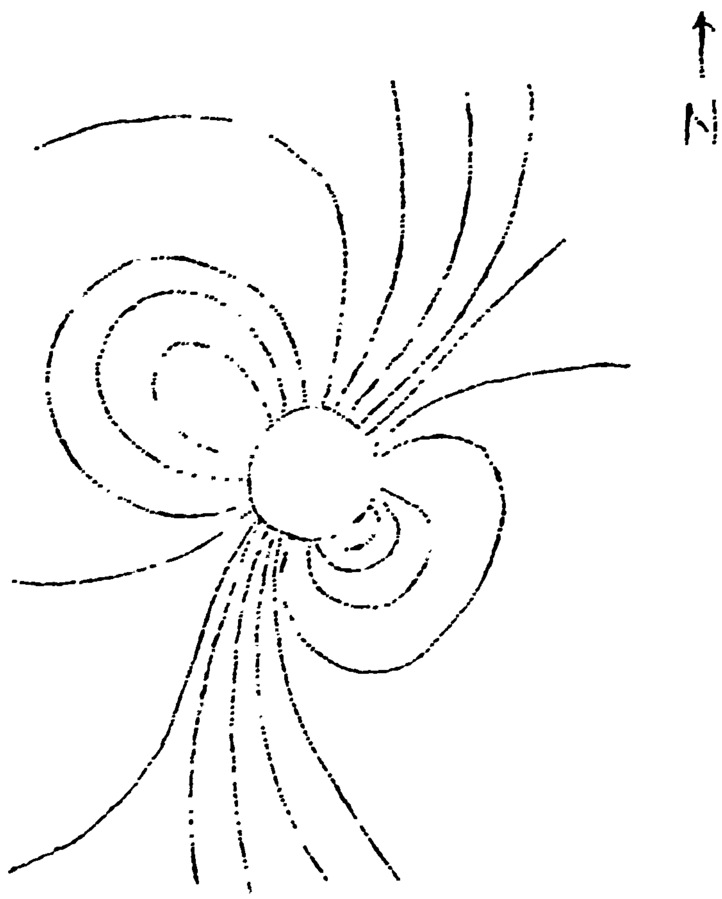


What does the graph tell you about the substance Zeq?

Post-Appraisal

1. Describe three properties of magnets.

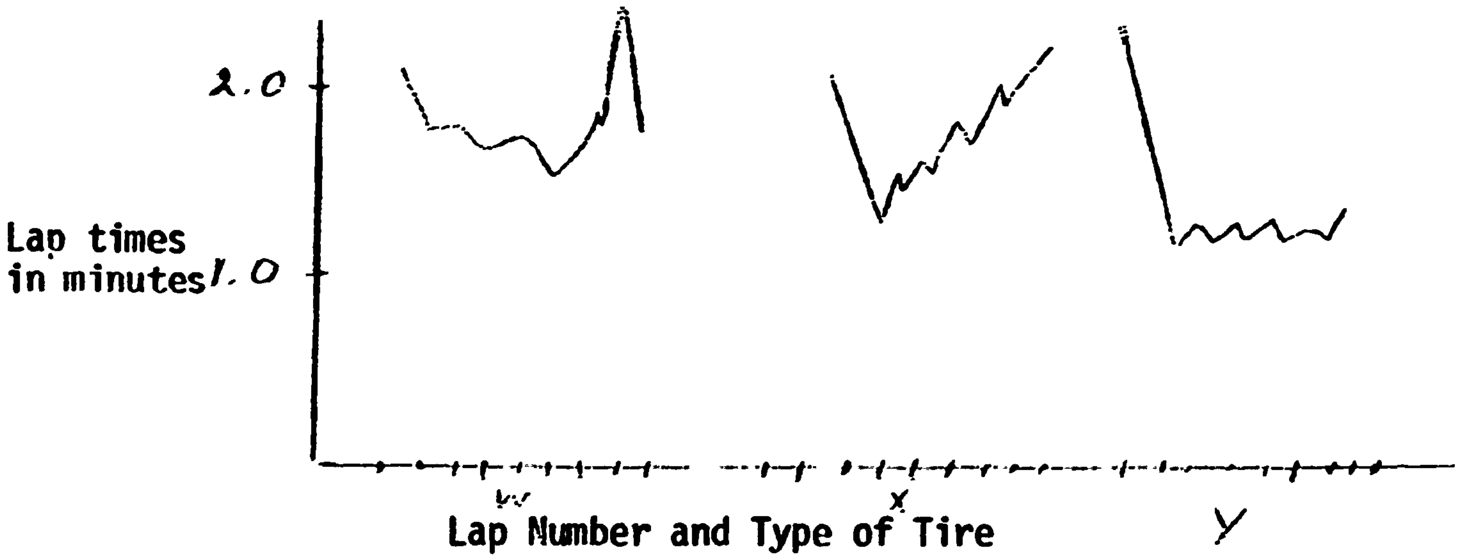
2. Figure 3 is a map of the lines of force around a bar magnet. Draw the orientation of the bar magnet, marking which pole is the N-pole.



3. Describe how the data support your placement of the magnet.

Post Appraisal cont'd.

4. Figure 4 is the graphical representation of the lap times of a race car during three practice sessions. Lap time is the time it takes the car to make one complete trip around the racetrack. For each practice session the race car was equipped with different tires (w, x, or y).



As team manager and if the driving conditions were the same, which set of tires would you recommend that the driver use during the race?

Justify your decision.

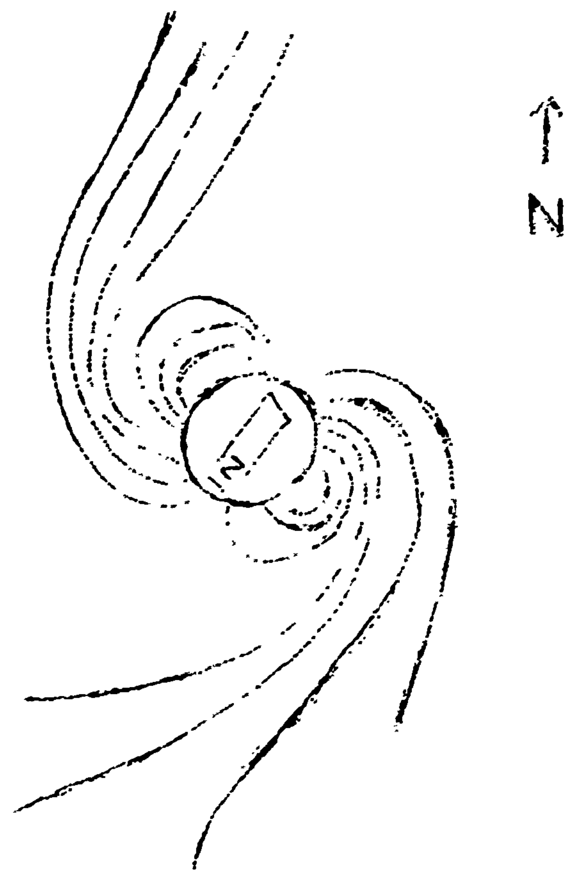
Duplicated Materials -- With Answers

Pre-Appraisal

1. Describe three properties of magnets.

   Made of certain metals (all metals will not work)
   Have two poles
   Opposite poles attract

2. Figure 1 is a map of the lines of force around a bar magnet. Draw the orientation of the bar magnet, marking which pole is the N-pole.



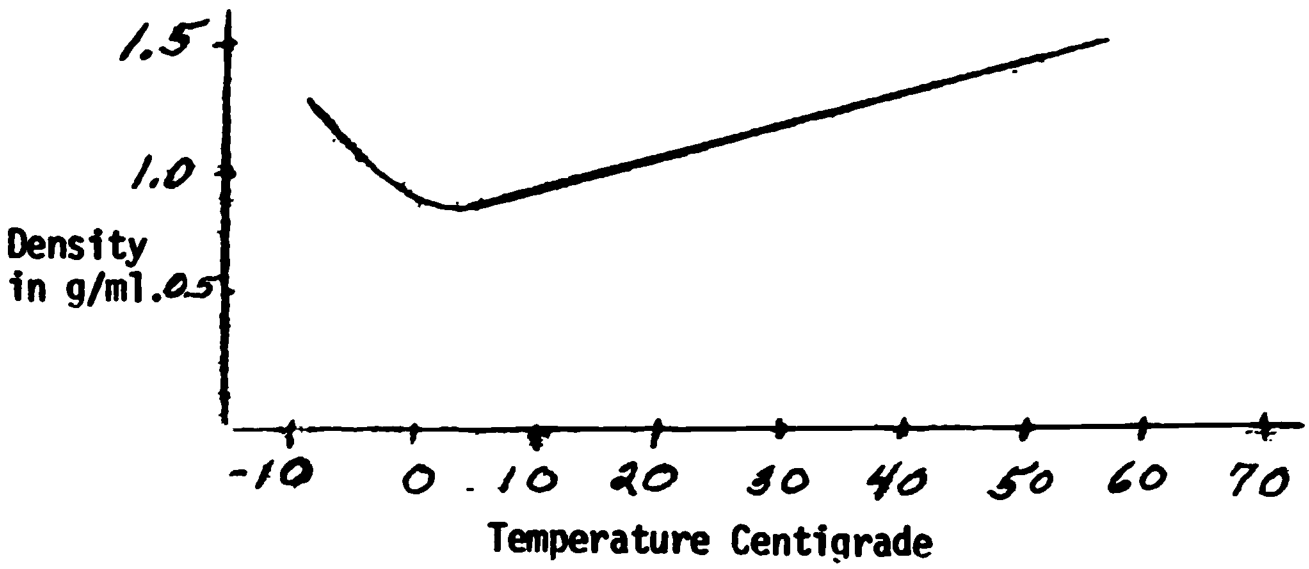
3. Describe how the data support your placement of the magnet.

   The lines of force that lead away from the N-pole of a magnet point toward the north magnetic pole.

   The lines of force that lead away from the S-pole of a magnet point toward the south magnetic pole.

Pre-Appraisal cont'd.

4. The following graph (Figure 2) was constructed from data gathered in a laboratory study of a certain substance Zeq.



What does the graph tell you about the substance Zeq?

Zeq is least dense at approximately zero degrees centigrade.

Above zero degrees, density increased directly with temperature.

Or

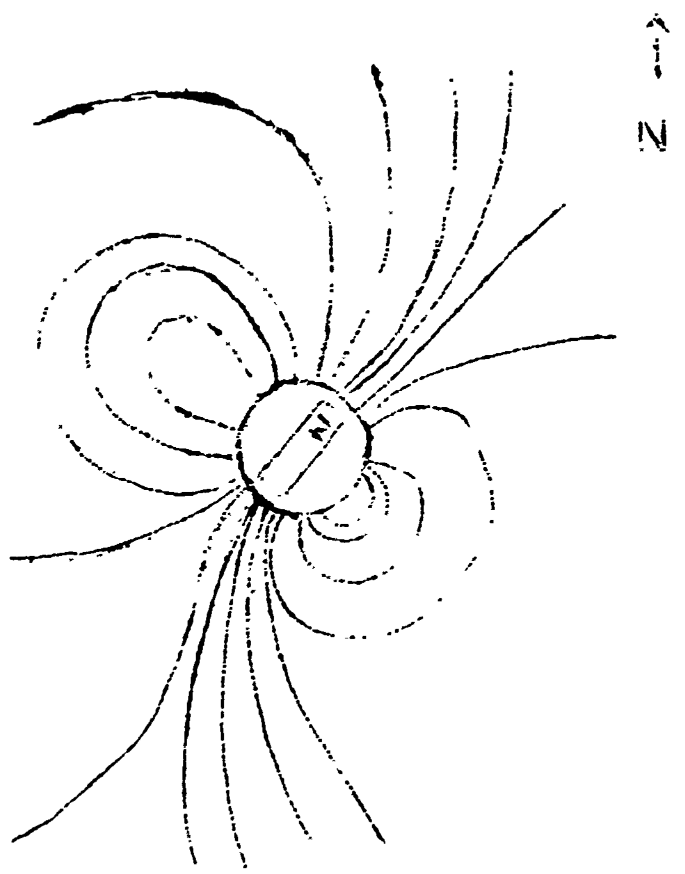
In other words, the hotter the substance, the more dense it is.

Post-Appraisal

1. Describe three properties of magnets.

   Made of certain metals (all metals will not work)
   Have two poles
   Opposite poles attract

2. Figure 3 is a map of the lines of force around a bar magnet. Draw the orientation of the bar magnet, marking which pole is the N-pole.



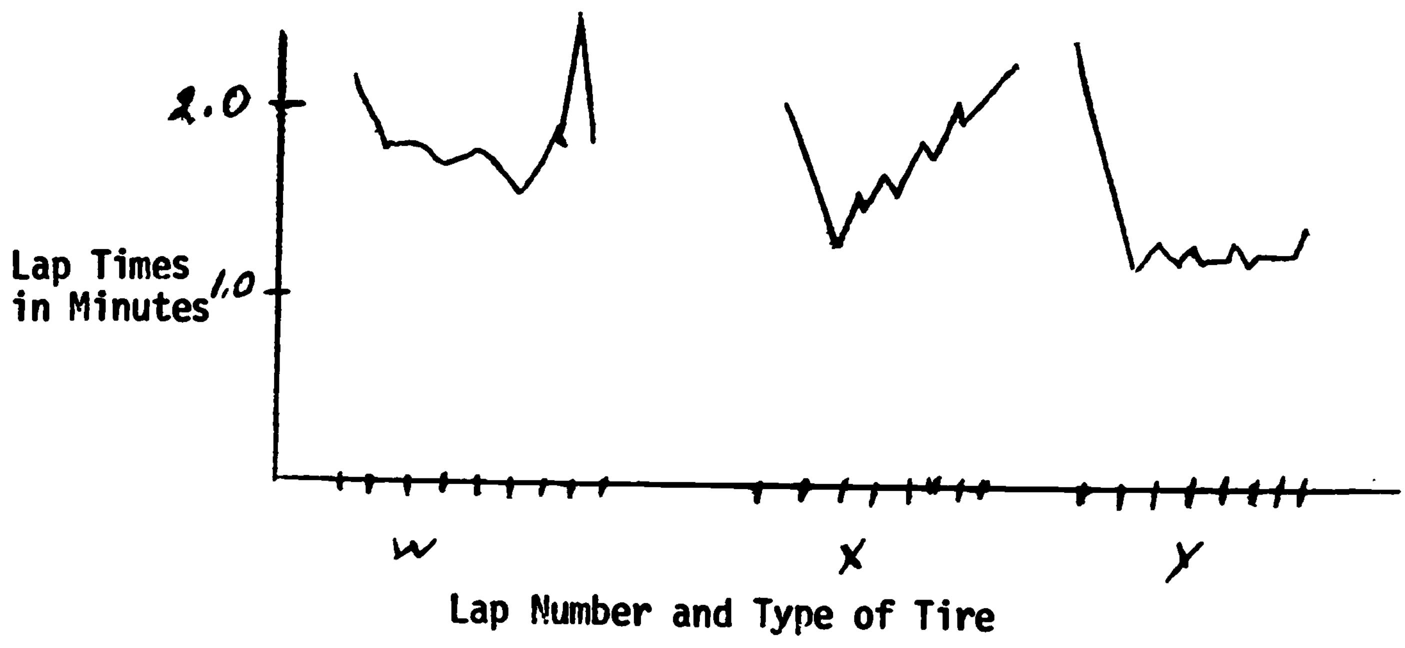
3. Describe how the data support your placement of the magnet.

   The lines of force that lead away from the N-pole of a magnet point toward the north magnetic pole.

   The lines of force that lead away from the S-pole of a magnet point toward the south magnetic pole.

Post-Appraisal cont'd.

4. Figure 4 is the graphical representation of the lap times of a race car during three practice sessions. Lap time is the time it takes the car to make one complete trip around the racetrack. For each practice session the race car was equipped with different tires (w, x, or y).



As team manager and if the driving conditions were the same, which set of tires would you recommend that the driver use during the race?

Tire Y.

Justify your decision.

Lap times improved and remained quite consistent with this tire.

Also, the fastest laps were run using Tire y.