Leybold Physik Physics Physique

Magnetik
Magnetism
Magnétisme

Magnetic Forces and Fields

588 302
Students' work sheets
(Masters for copying)

Schülerversuche Naturwissenschaften
SVN
STM
Science Teaching Modules

STM Physics
Magnetism
Magnetic Forces and Fields

Published by the LEYBOLD DIDACTIC editorial staff.
Author: W. Brauers
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Design and layout, final artwork and production:
K. R. Fecht, Büro für Text und Grafische Produktion, Bonn

Graphics: C. Harnischmacher

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General instructions on the use of STM work folders

The need for complete editorial revision of the literature in the STM series (Science Teaching Modules) describing experiments for schools was the ideal opportunity to give the series a fresh, practical orientation:

The student's worksheets form the main focus of each work folder. These are laid out as a series of reference sheets, loose-leaf pages designed for use as master copies and capable of meeting the demands of a modern educational environment.

The associated teacher's workbook is an exact replica of the worksheets. In addition to defining the actual assignments, however, it also describes the object of each experiment and includes special hints and tips on each working step in the experiment, as well as additional information, calculated sample measurements and the answers to questions asked in the students' worksheets.

How the experiments are laid out:

The structure of the worksheets is essentially the same for all experimental topics. The basic information, such as the nature of the assignment itself, the list of apparatus required, setup diagrams etc. always appear in the same place and in the same order. For additional convenience, however, the experiments are also divided up into a series of consecutively numbered working steps. Diagrams and illustrations are also numbered consecutively. Any supplementary illustrations which appear in the teacher's notes are numbered according to the decimal classification system.

Symbols used:

The following symbols are used in the students' worksheets:

⚠ Caution! hazardous for the experimenter or experimental apparatus
Follow working instructions exactly.

▶ Refer to another point

About the apparatus:

To familiarise students with the equipment they will be using, the worksheets are preceded by a detailed section describing the various pieces of apparatus.

In addition to the list of apparatus and other aids which appears before each experiment (complete with catalogue numbers in the teacher's workbook), you will also find a complete list of all the apparatus used at the end of the book (after the reference sheets), showing all the apparatus and other equipment required for the particular subject area under examination.

Each folder also contains a constantly updated list of the entire range of STM literature.

Preface

This folder contains 12 experiments on the subject of “Magnetism”. All experiments can be carried out using the **S**cience **T**eaching **M**odules (STM) equipment set MAG1 (Magnetism 1). The objectives of each experiment topic are given in the teacher’s section. The teacher can thus obtain an overview of the material to be dealt with just by reading this information in advance.

Magnetic and non-magnetic materials

Assignment: Test the magnetic properties of various objects using a bar magnet.

Apparatus:
1 Bar magnet
1 Iron yoke
1 Pointer
1 Rod, magnetizable

Setup:

1. Lay out the apparatus as shown in Fig. 1.

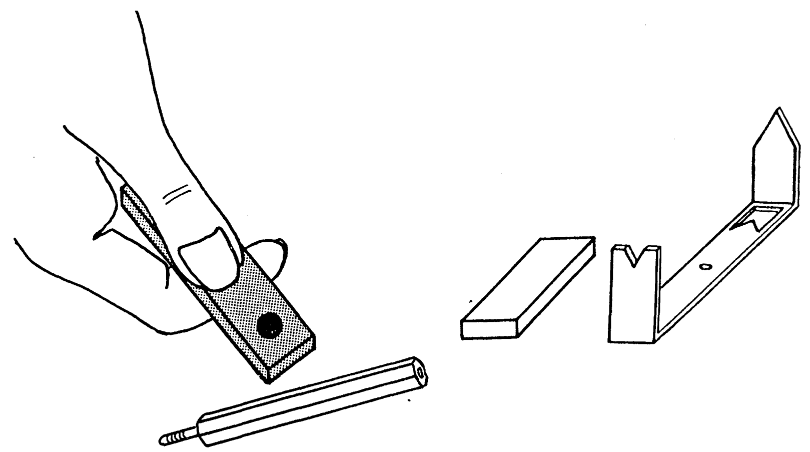

Fig. 1

Carrying out the experiment:

Experiment part 1:

A magnet attracts some objects but not others.

2. Touch the objects one after another with the marked end of the bar magnet and observe whether the object is attracted by the magnet.

Experiment part 2:

Studying the effect of the other end of the magnet.

3. Turn the bar magnet around and touch the objects one after another again.
   Write down your results in the table.
   Table

	Marked magnet end		Unmarked magnet end	
Object	attracted	not attracted	attracted	not attracted
Iron yoke				
Pointer				
Rod				

4. What objects are attracted by a magnet?

___

5. Do you see a difference in the effects of the two ends of the magnet in this experiment?

___

___

6. What are the magnetic objects you investigated made of?

___

Note:

Besides iron, cobalt, nickel and certain metal alloys are also magnetic. Materials which are magnetic like iron are called "ferromagnetic" materials.

Technical applications:

Magnets are used to separate materials containing iron from those containing no iron. Magnets are used, for example, as latches on the doors of cabinets.

Positions of the magnetic poles on a bar magnet

Assignment: Study the force of attraction at various points on a bar magnet.

Apparatus:
1 Bar magnet
1 Iron yoke
2 Magnetizable rods

Setup:

1. Lay down the rods separately.

Carrying out the experiment:

Experiment part 1:

Do different points on the bar magnet attract iron differently?

Hold the bar magnet firmly in one hand and the iron yoke in the other. Test whether the iron yoke is attracted to the bar magnet with equal strength at all points.

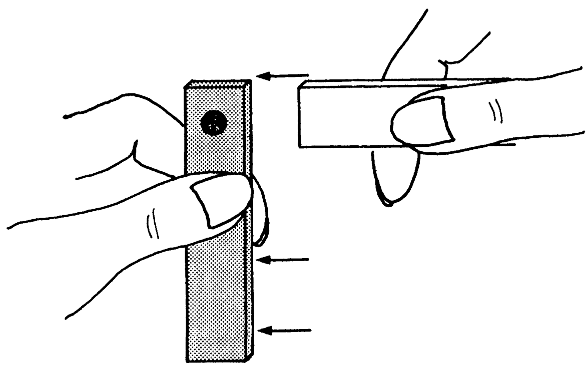

Fig. 1

Student's Sheet 2

Experiment part 2:

Where is the bar magnet's force of attraction greatest?

3. Magnetize two magnetizable rods and hang them end on end.

   Then hang them from the end of the bar magnet, as shown in Fig. 2.

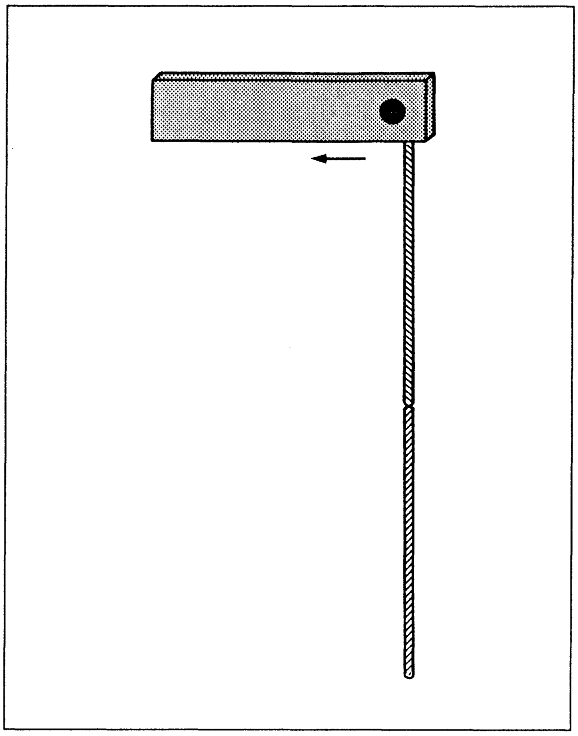

Fig. 2

4. Take hold of the top rod and slowly push it along the bar magnet to the middle.

   For this experiment to succeed, you must move the rods very carefully along the magnet; otherwise they will drop off too soon.

   It is also a good idea to make sure that the rods fall on something soft (a cloth, etc.).

   What do you observe?

   ____

   ____

5. Repeat steps 3 and 4 starting from the other end of the magnet.
6. Mark the points with the strongest force of attraction with ⊙ and those with the weakest force with ○ in the evaluation drawing (Fig. 3).

   Observations:

   ⊙ = points with strong force of attraction

   ○ = points with weak force of attraction

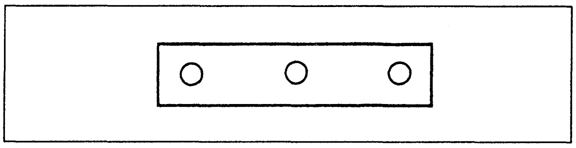

Fig. 3

Evaluation:

7. Where are the points with the greatest force of attraction, the so-called poles of a magnet?

   ____

8. How many poles does a magnet have?

   ____

9. How can we test the magnitizability of a material using a magnet?

   ____

   ____

Polarity of magnets

Assignment: Find out whether there is a difference between the poles of bar magnets.

Apparatus:
2 Bar magnets
1 Direction-finding compass
Thin thread, approx. 1 m long

Note:
The forces caused by the twist of the thread are less when a long, thin thread is used.

Setup:

The teacher should first check in which direction magnetic north lies, in order to judge whether the students' experiment conditions are appropriate.

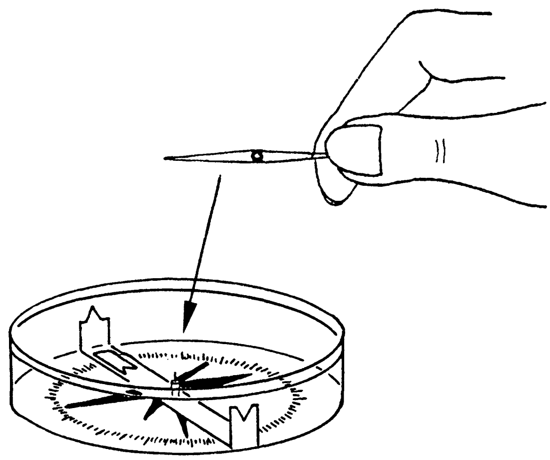

Fig. 1

1. Set the needle on the bearing tip of the compass (Fig. 1).
2. Tie the bar magnet to the thread (Fig. 2).
3. In the following experiment, no magnetizable objects may be left close to the compass or the bar magnet.

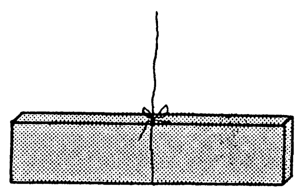

Fig. 2

Carrying out the experiment:

Experiment part 1:

4. Hold up the bar magnet by the thread.

   Wait until it has aligned itself in one direction (Fig. 3).

5. Determine the geographic direction in which the marked end of the bar magnet is pointing.

   The marked end points toward magnetic north.

6. Name the magnetic poles according to the directions in which they are pointing.

   The end pointing north is the "north pole" and the end pointing south is the "south pole".

7. Which end of the bar magnet is marked?

____

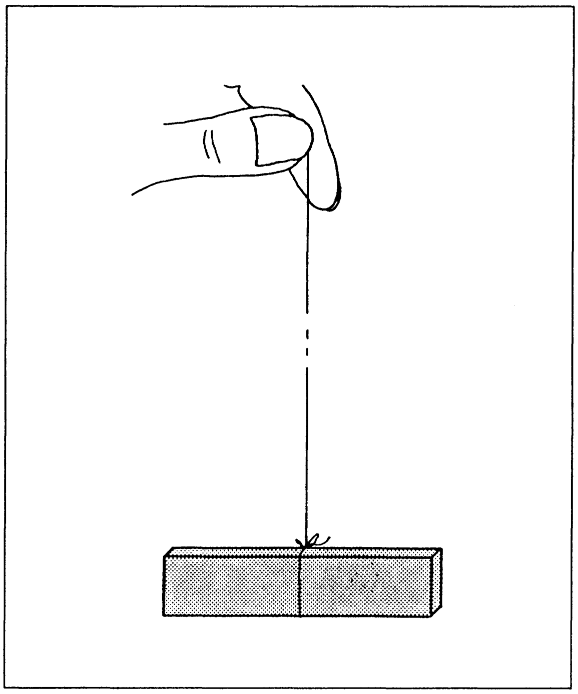

Fig. 3

Experiment part 2:

8. In which direction does the red end of the compass needle point? ▶ Fig. 4.

____

____

9. Which pole of the magnetic needle is at the end marked with red?

____

10. Which end of the bar magnet behaves like the red end of the needle?

____

____

____

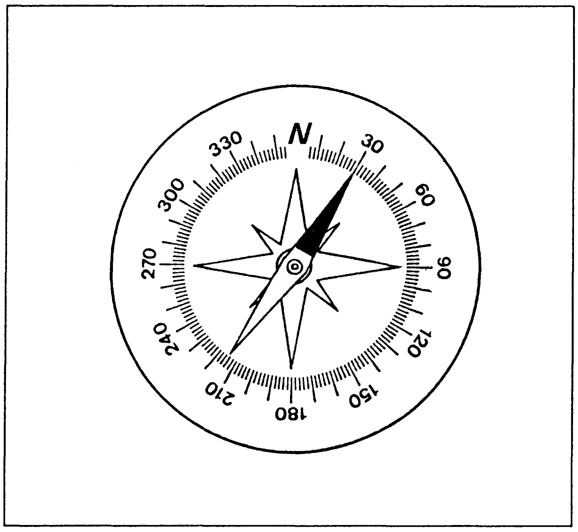

Fig. 4

11. How do we find east using the compass?

____

____

Experiment part 3:

▶ Fig. 5

12. Remove the thread from the marked magnet.
13. Move the poles of the two magnets toward each other as shown in the table.

    Cross the correct box for each case.

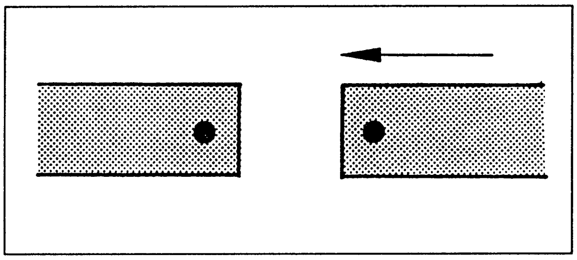

Fig. 5

Observations:

Table

Poles moved toward each other	identical poles		different poles	
	N N	S S	N S	N N
Attract				
Repel				

Experiment part 4:

▶ Fig. 6

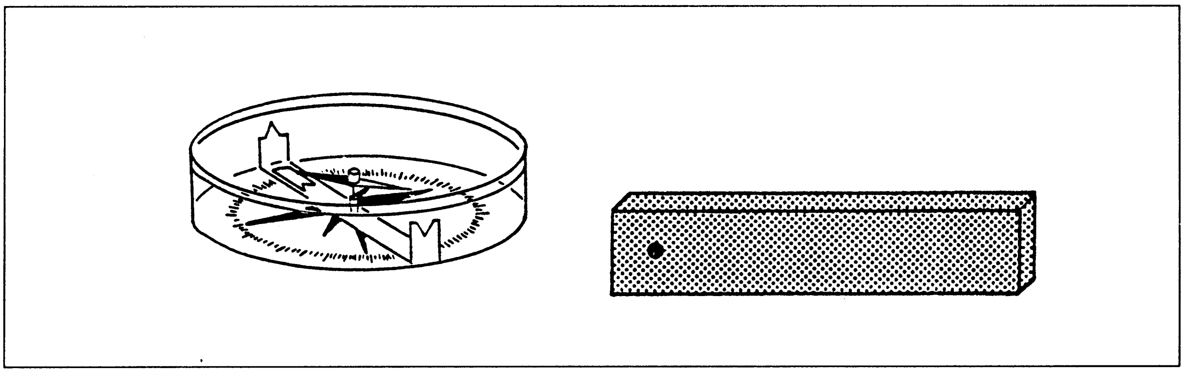

Fig. 6

14. In which direction does the red end of the compass needle point when the compass is placed near:

    a) the north pole of the magnet?

    b) the south pole of the magnet?

    The tip of the compass needle marked in red points

    a) ______________________________

    b) ______________________________

Student's Sheet 4

Evaluation:

15. We can see from the magnetic forces acting on the earth that the earth has two internal magnetic poles, one near the geographic north pole and one near the geographic south pole of the globe.

    Which of these poles is the magnetic north pole?

    ____

    Give the reason for your answer:

    ____

16. Magnetic poles can either attract or repel each other.

    State your experiment results in one sentence, using the expressions "like poles" and "unlike poles".

    ____

    This law is the basic law of magnetism.

Magnetization

Assignment: Test whether it is possible to use a permanent magnet to create other magnets.

Apparatus:
1 Bar magnet
4 Paper clips

Carrying out the experiment:

1. Hold the magnet in one hand and hang one of the paper clips from the magnet.
2. Hang another paper clip from the first one on the magnet.
3. Hang all four paper clips one after another to form a chain.
4. Hold everything over the table and carefully remove the magnet from the chain of paper clips. Do this very carefully; otherwise the chain will fall apart.
5. Test whether the paper clip that was hanging directly from the magnet can attract other paper clips.

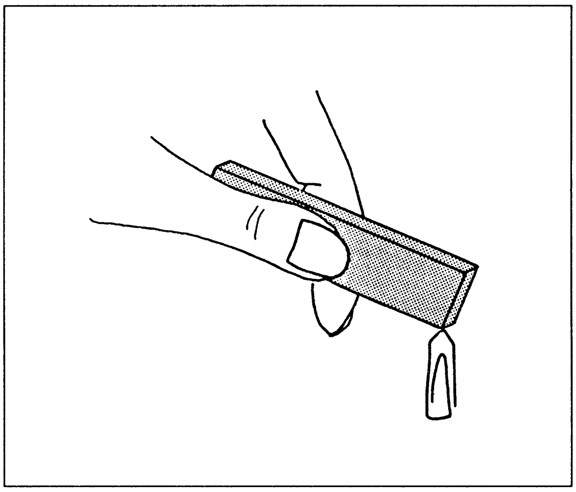

Abb. 1

Evaluation:

6. Why can a paper clip hanging from a magnet attract the next paper clip, and so on until we have a whole chain of hanging paper clips?

___

7. What happens when you remove the magnet from the chain of paper clips?

___

8. Why does the chain of paper clips fall apart when the magnet is removed?

___

Student's Sheet 2

9. What happened to the first paper clip?

____

Optional question:

Does the magnetic effect of the bar magnet become less when a lot of paper clips are magnetized?

____

Disassembling magnets

Assignment: See whether you can create a magnet with only one pole by taking a magnet apart.

Apparatus:
1 Bar magnet
1 Set of 4 magnetizable rods
1 Direction-finding compass
1 Paper clip (iron)

Setup:

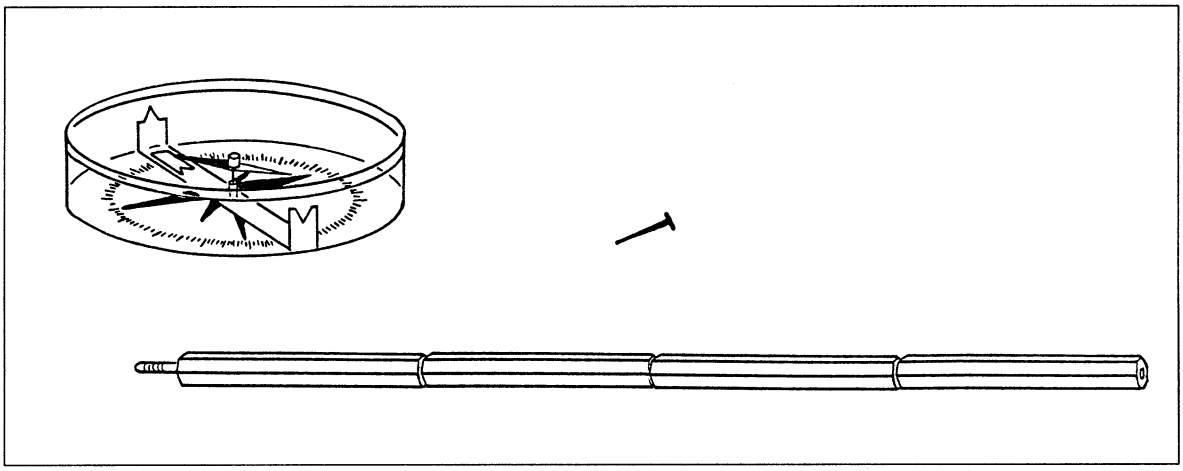

Fig. 1

1. Place the magnetic needle in the compass housing.
2. Screw the four rods together. Be sure to place the assembled rod as shown in Fig. 1!

Carrying out the experiment:

Experiment part 1: magnetizing the entire rod

▶ Fig. 2

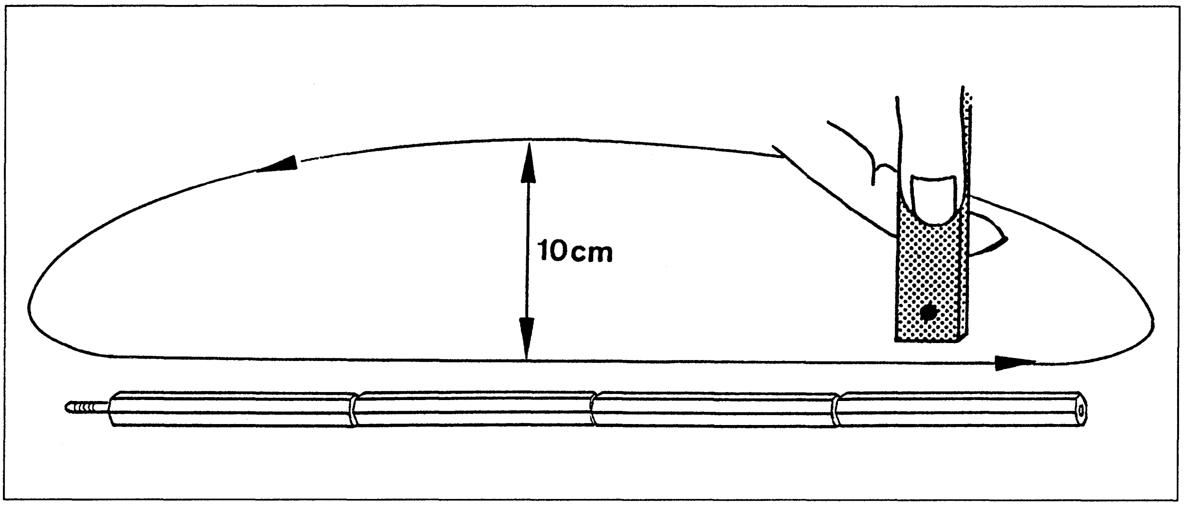

Fig. 2

3. Hold the bar magnet in your hand and move one of the poles along the rod from one end to the other. Hold the magnet close to the rod when moving in one direction, but hold it at least 10 cm away from the rod when moving it back to the starting end.
4. Repeat step 3 about 20 times.
5. Use the paper clip to test whether the rod has become magnetic.
6. Find the north pole of the rod by putting one end of the rod close to the compass needle. (Fig. 3).

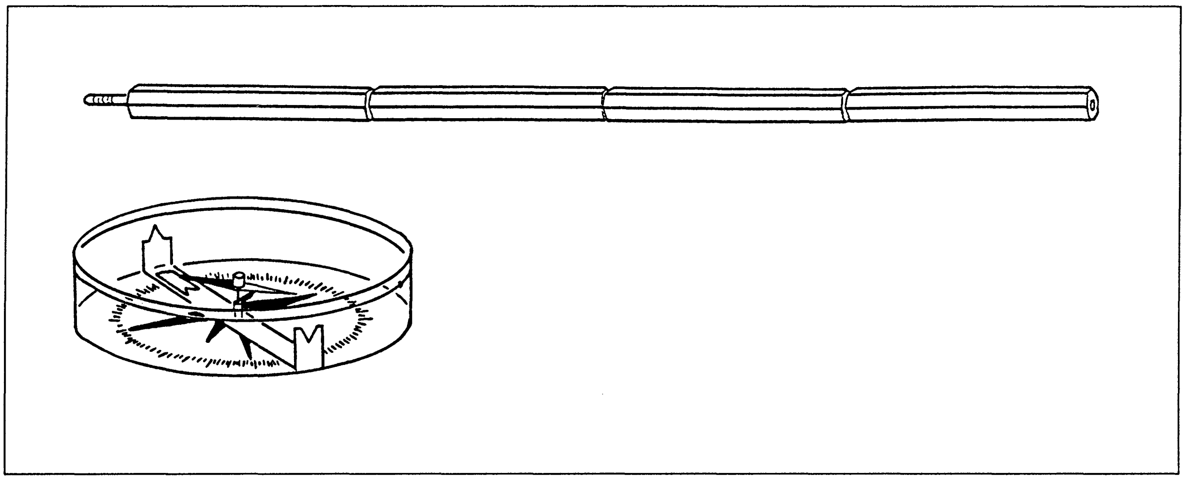

Fig. 3

How do like poles react?

____

Student's Sheet 3

7. Which pole is at the end of the four-piece magnetizable rod with the male thread when the rod is magnetized as shown in Fig. 2?

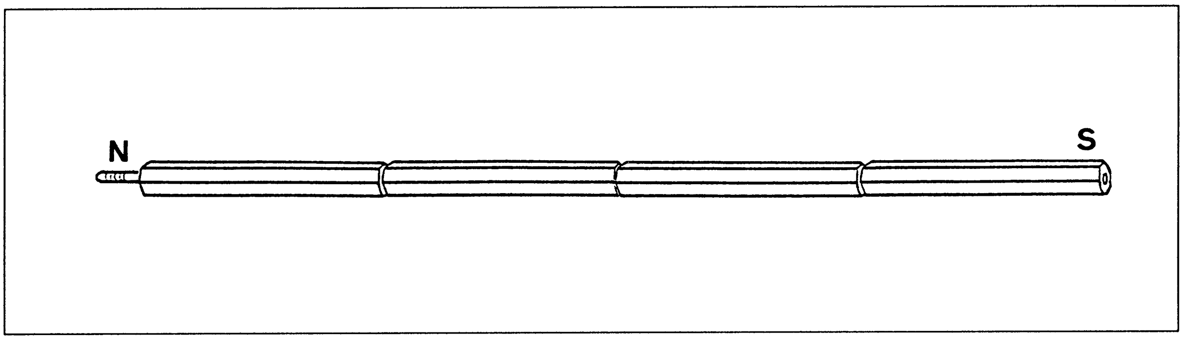

Fig. 4

Experiment part 2: disassembling a magnet:

8. Unscrew the magnetized rod in the middle.
9. Test the polarity of all four ends using the north pole of the compass needle.

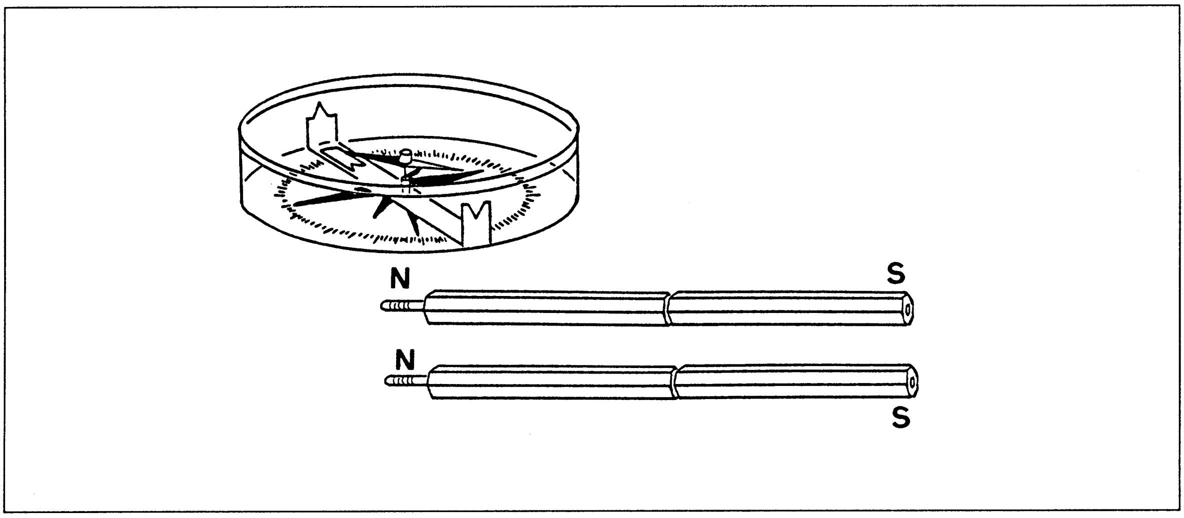

Fig. 5

Experiment part 3: disassembling the magnet parts

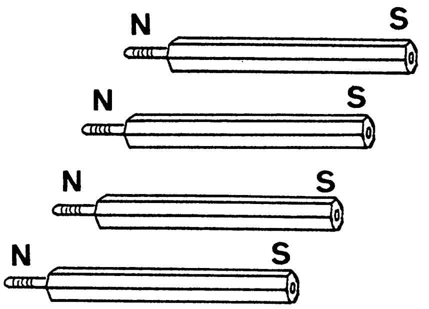

Fig. 6

10. Unscrew the two rod parts so that you have four rods.
11. Test the polarity at the ends of all four rods (Fig. 6).
    Write down your observations in the table below.
    Table

Experiment 1	
Experiment 2	
Experiment 3	

Mark the ends of the rods with N and S.
N: north pole
S: south pole

Evaluation:

12. Is it possible to separate the poles of a magnet by taking it apart?

____

13. Which poles do the separated rods have?

____

14. Why do we call magnets dipoles?

____

____

Putting magnets together

Assignment: Test whether the magnetic effect on other objects changes when one magnet is added to another.

Apparatus:
2 Bar magnets
1 Magnetizable rod
1 Sheet of paper, DIN A4 or DIN A5

Setup:

1. Draw a straight line on the piece of paper with the starting mark “0” (you can use the bar magnet as a straight edge).

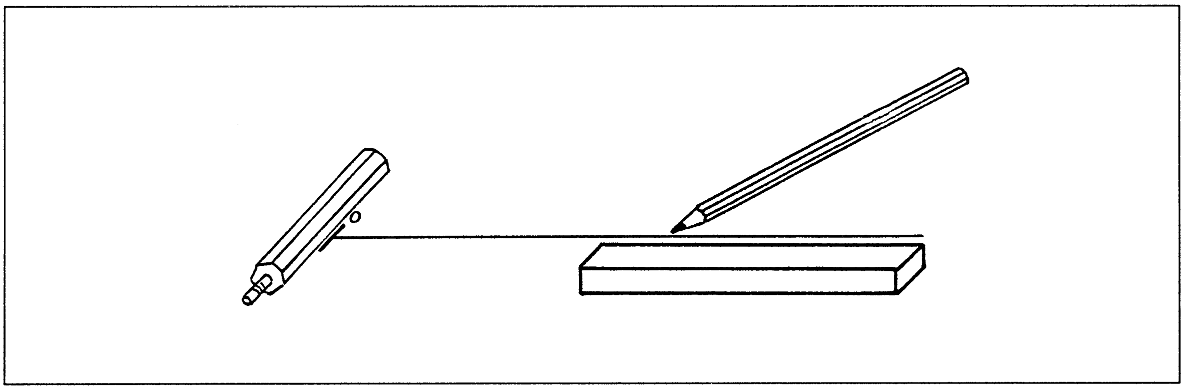

Fig. 1

Student's Sheet 2

Experiment part 1:
At what distance does the bar magnet make the iron rod move?

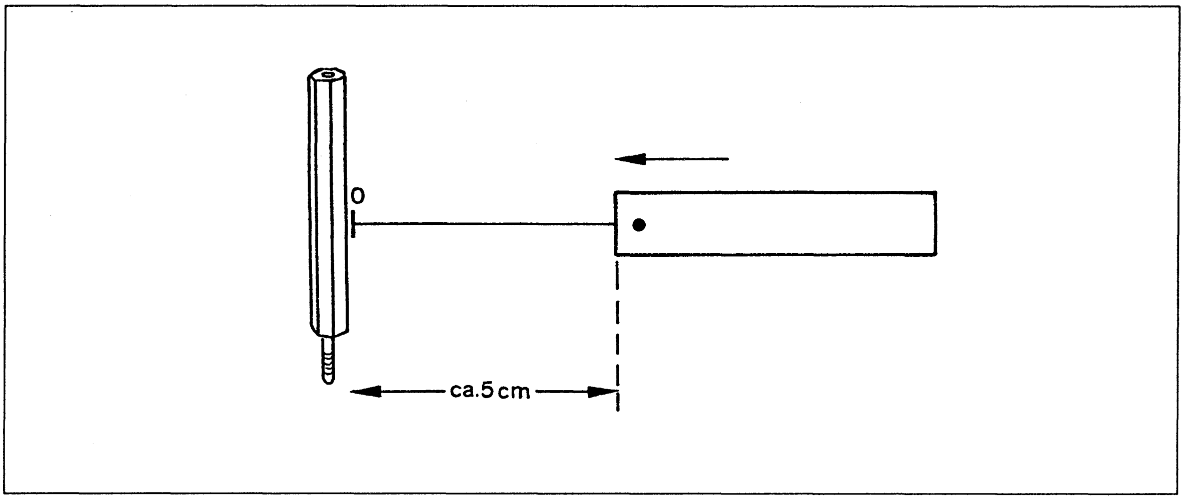

Fig. 2

2. Place the rod and the bar magnet on the piece of paper as shown in Fig. 2.
3. Slowly push the bar magnet along the line toward the rod.
4. Stop moving the bar magnet immediately and press down on it firmly when the rod starts to move. The magnet should not move when the rod bumps against it (Fig. 3).

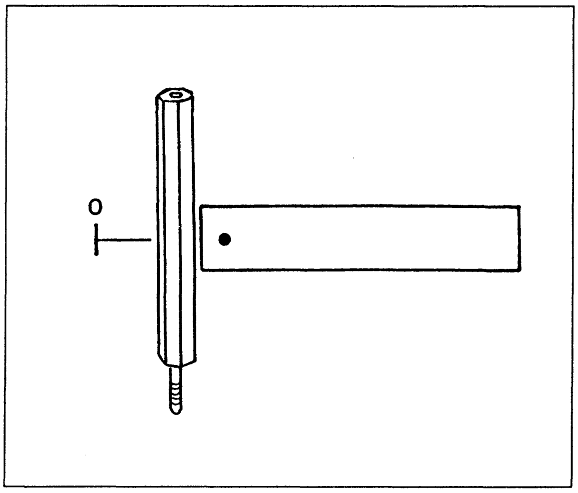

Fig. 3

5. Mark the position of the front edge of the magnet on the line.
6. Number this position "1".

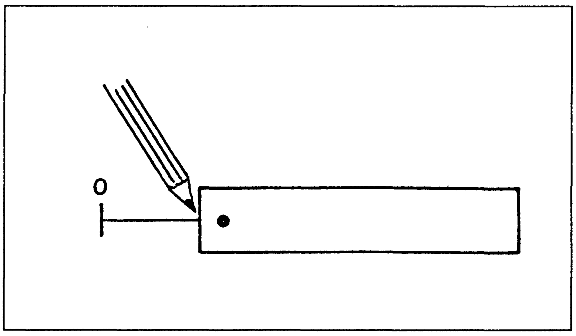

Fig. 4

Student's Sheet 3

Experiment part 2:
At what distance do two bar magnets with the opposite (attracting) poles placed together make the iron rod move?

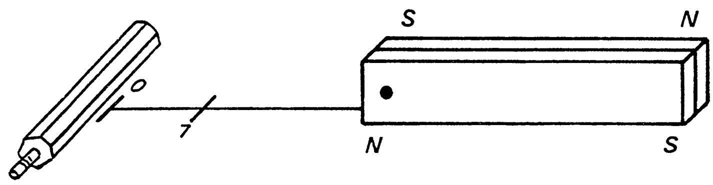

Fig. 5

7. Put the two magnets together and place them as shown in Fig. 5. Repeat steps 3 to 5 for the joined magnets.
8. Number the position of the magnets with "2".

Experiment part 3:
At what distance do two bar magnets with the like (repelling) poles placed together make the iron rod move?:

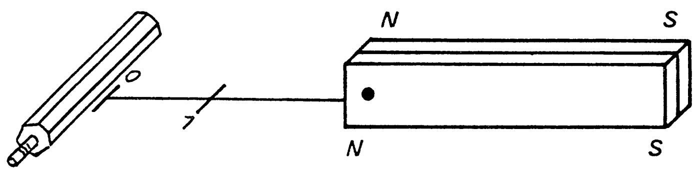

Fig. 6

9. Press the two magnets together as shown in Fig. 6.
   Repeat steps 3 to 5 for the joined magnets.
10. Mark the position of the magnets with "3".

Observations and measurements:

Mark	Pole arrangement
1	
2	
3	

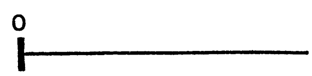

Fig. 7

Student's Sheet 4

Evaluation:

11. In which arrangement is the magnetic effect of two magnets less than that of the single magnet?

12. In which arrangement is the magnetic effect of two magnets greater than that of the single magnet?

Fig. 8 and 9 show additional experiment setups for studying the force of magnetic attraction magnets placed together.

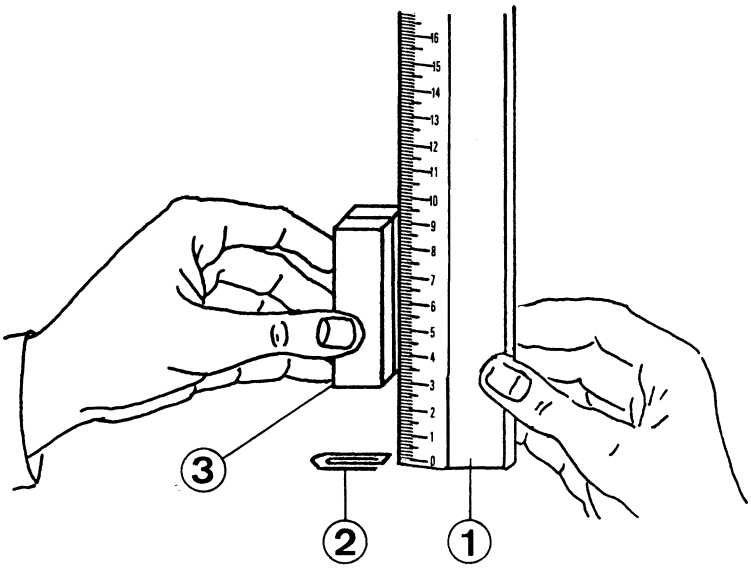

Fig. 8 **(1)** ruler, **(2)** paper clip, **(3)** two magnets placed together. The compound magnet is moved toward the paper clip. The magnetic force is greater or less, depending on the way in which the poles are placed together.

Student's Sheet 5

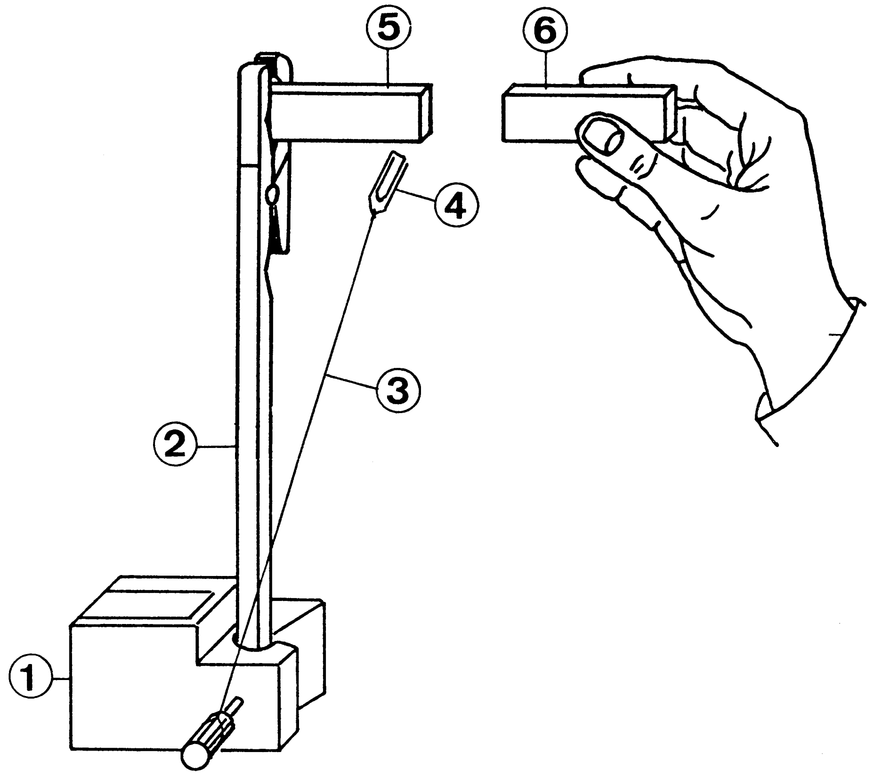

Fig. 9 **(1)** clamp, **(2)** stand rod, **(3)** thread, **(4)** paper clip, **(5)** magnet, **(6)** magnet.
Depending on the polarity, moving the magnet **(6)** closer increases or decreases the magnetic force attracting the paper clip.

Demonstrating a magnetic field with iron filings

Assignment: Show the magnetic field of a bar magnet using a sheet of paper and iron filings.

Apparatus:
1 Bar magnet
1 Shaker for iron filings
Iron filings, 250 g
1 Sheet of coarse paper

Setup:

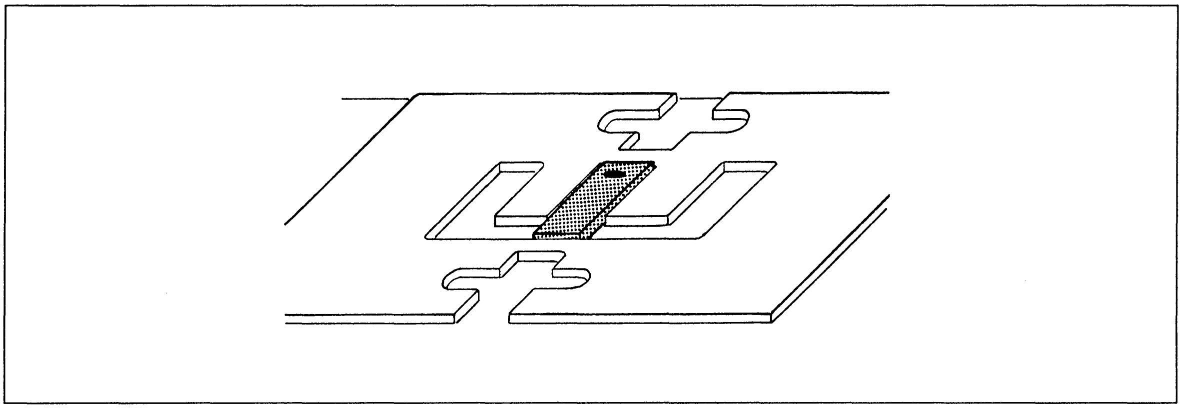

Fig. 1

1. Remove all magnets and objects containing iron from the storage tray.
2. Place the magnet in the central space in the storage tray as shown in Fig. 1.
3. Cover the magnet with a sheet of paper.

Student's Sheet 2

Carrying out the experiment:

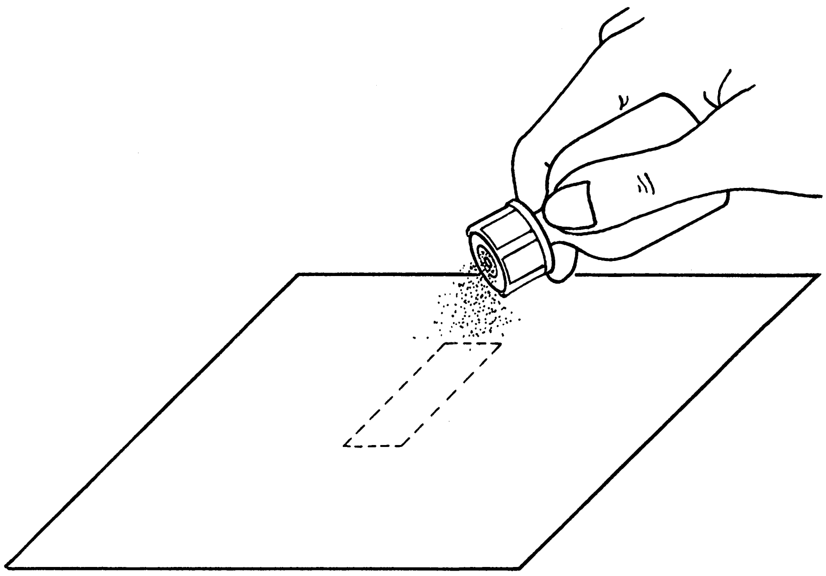

Fig. 2

4. From a height of approx. 30 cm, carefully and evenly shake iron filings over the sheet of paper until a clear pattern of the iron filings appears (Fig. 2).

   The result is often improved by lightly knocking the storage tray.

Observations:

The magnetic lines of force of a bar magnet, made visible on a sheet of paper using iron filings.

Fig. 2.1

Evaluation:

5. Describe the pattern of the lines of force at the poles of the bar magnet.

___

6. Describe the lines of force beside the bar magnet at the midpoint between the two poles.

___

___

Lines of force of a bar magnet

Assignment: Using the plotting compass, draw the lines of force of a bar magnet.

Apparatus:
1 Bar magnet
1 Plotting compass
1 Sheet of paper
1 Sharp pencil

Setup:

The following experiment assumes a flat table or bench surface on which the students can draw.

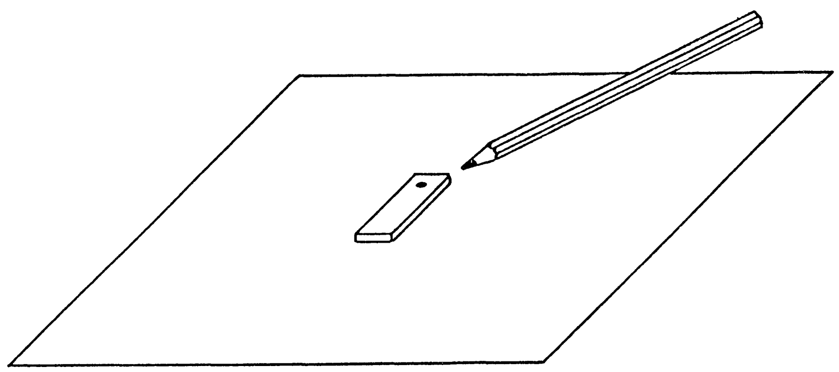

Fig. 1

1. Place the sheet of paper on the table as shown in Fig. 6.
2. Place the bar magnet in the middle of the sheet with the red mark (north pole) facing toward the top of the paper.

Student's Sheet 2

Carrying out the experiment:

3. Place the plotting compass at the top right-hand corner of the bar magnet and mark the position of the needle tip with the pencil (Fig. 2).
4. Move the plotting compass so that the back end of the needle covers the marked point, and mark the new position of the needle tip (Fig. 3).

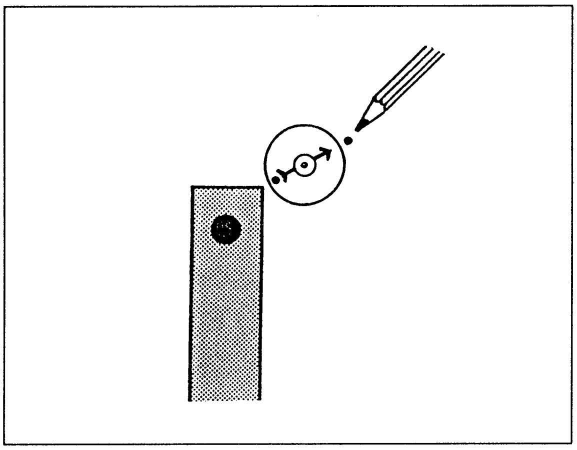

Fig. 2

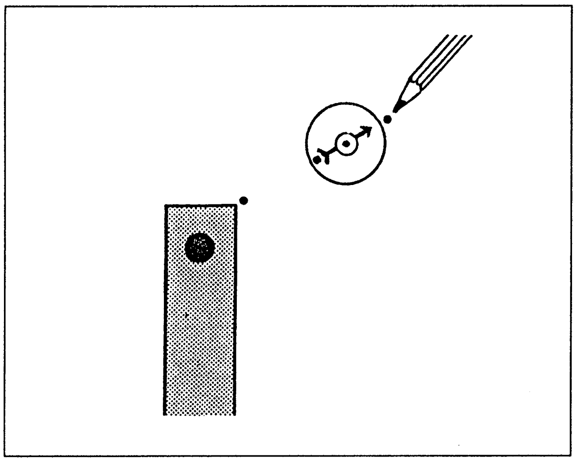

Fig. 3

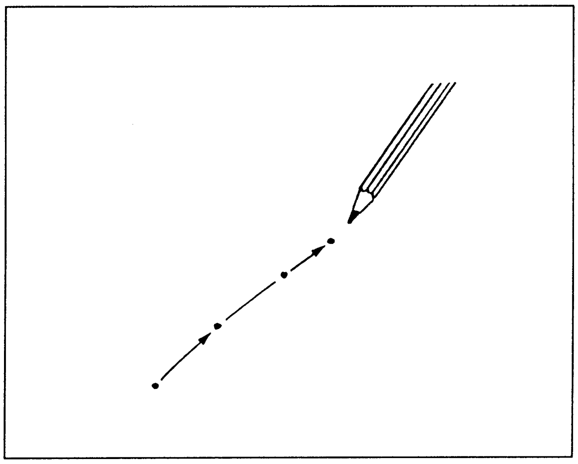

Fig. 4

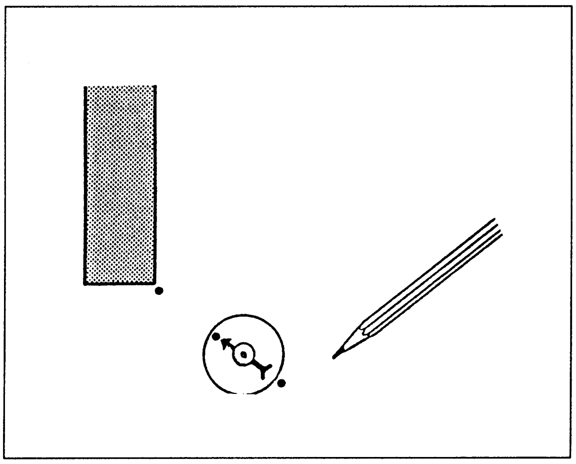

Fig. 5

5. Repeat step 4 until you come either to the edge of the paper or back to the magnet.
6. Join the points together and draw arrows to show the direction in which the compass needle pointed (Fig. 4).
7. When drawing lines away from the direction in which the compass needle is pointing, shift the compass so that the tip of the needle is on the last point marked, and then mark the position of the back end of the needle on the paper (Fig. 5).
8. Fig. 6 shows the starting points for drawing lines of force.
9. Repeat steps 4 through 7 for all the points.
10. Exchange the positions of the north and south poles. What is the same? What is different?

Student's Sheet 3

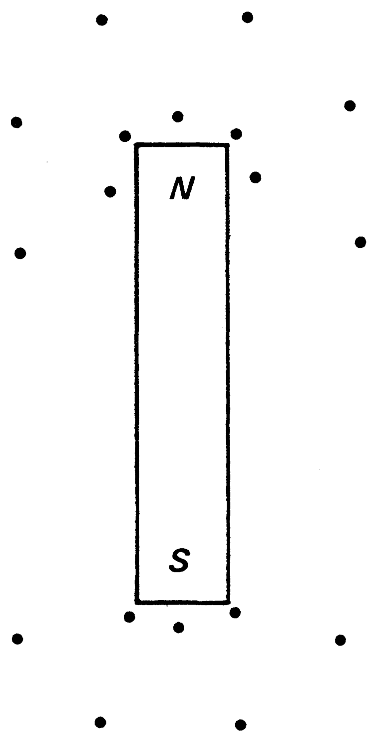

Fig. 6

Student's Sheet 4

Evaluation:

11. Describe the pattern of the lines of force at the poles.

____

12. How do the lines of force appear at the sides of the bar magnet?

____

Student's Sheet 1

Experiments on a model of the earth's magnetic field

Assignment: Study the shape of the magnetic field on the surface of a model of the earth.

Apparatus:
1 Hemisphere without magnet56
1 Bar magnet
1 Plotting compass

Setup:

Before the lesson, the teacher must:
- insert a bar magnet in each hemisphere (tool: e.g. second magnet);
- turn the cover until it latches.

The magnetic hemispheric earth model is issued by the teacher.

Carrying out the experiment:

Experiment part 1: orientation on the earth model using the compass

1. Place the plotting compass on various points of the hemisphere and observe the magnetic needle.

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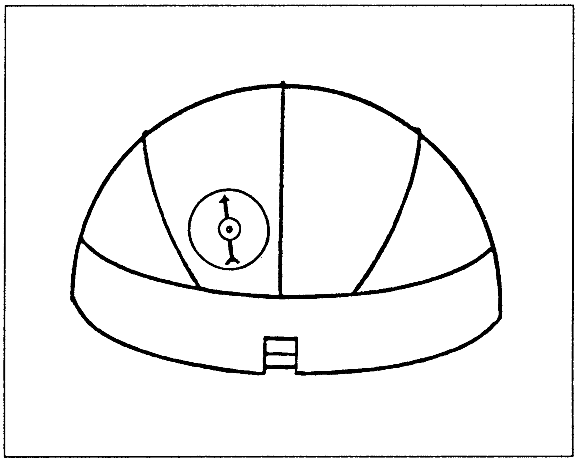

Fig. 1

2. How many magnetic poles does the model have, and where are they?

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3. Which magnetic pole does the magnetic compass needle point to?

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Student's Sheet 2

4. In which geographic direction does the compass needle point?

5. Describe the pattern of the lines of magnetic force on the surface of the hemisphere.

Experiment part 2: inclination angle:

6. Hold the plotting compass against the earth model as shown in Fig. 2.
7. At which points is the needle tangential to the surface of the (hemi-)sphere? ("Tangential" means the direction in which the needle neither points toward the model nor away from it.)

8. Where does the compass needle point toward the earth model, and where does it point away?

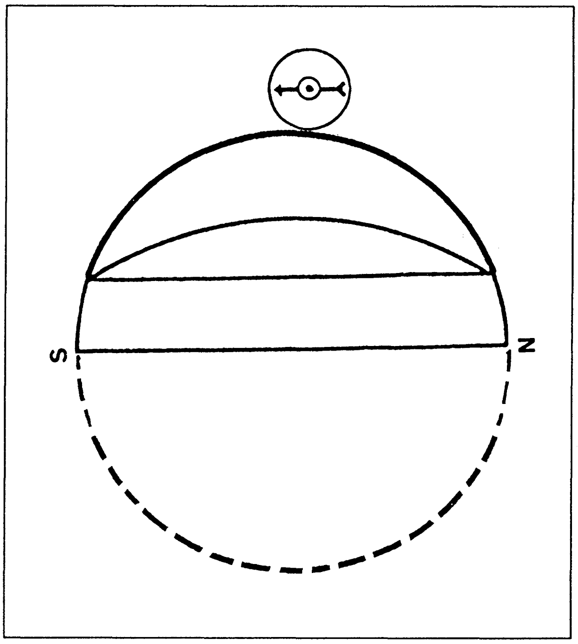


Fig. 2

9. Where is the deviation of this angle (called the inclination angle) greatest?

10. Imagine that the earth model is a complete sphere. Are there inclination angles that do not occur anywhere?

Student's Sheet 3

Evaluation:

11. What phenomena on earth can be demonstrated using the magnetic earth model?

12. What can we say about the interior of the magnetic earth model (with the help of the plotting compass) without opening it?

Note:

The compass can tell us nothing about how the magnet inside the model looks, just as it can tell us nothing about the shape of the "magnet" inside the earth.

Experiment part 3: lines of force of the magnetic earth model:

13. Place the model earth hemisphere in the middle of a sheet of paper (DIN A4) so that the magnetic south pole is toward the top of the paper.
14. Trace the outline of the hemisphere with the pencil.
15. Draw the points from Fig. 3 on your worksheet; these are the starting points for drawing the lines of magnetic force using the plotting compass.
16. Label the following points in your drawing:

Geographic north pole

Geographic south pole

Hints:

The geographic north pole and the magnetic south pole are not in the same place.

The magnetic poles of the earth are not in a fixed position; they move around. At several times in the earth's history, they have even reversed themselves completely.

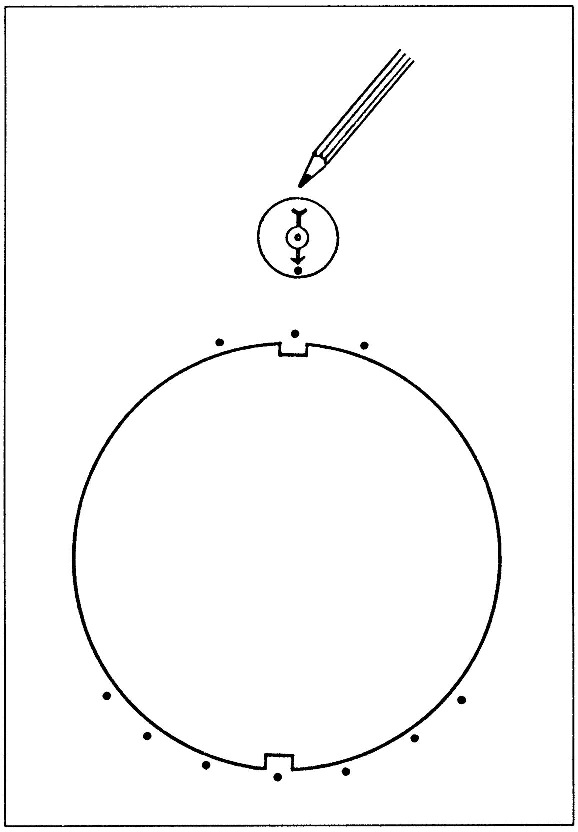
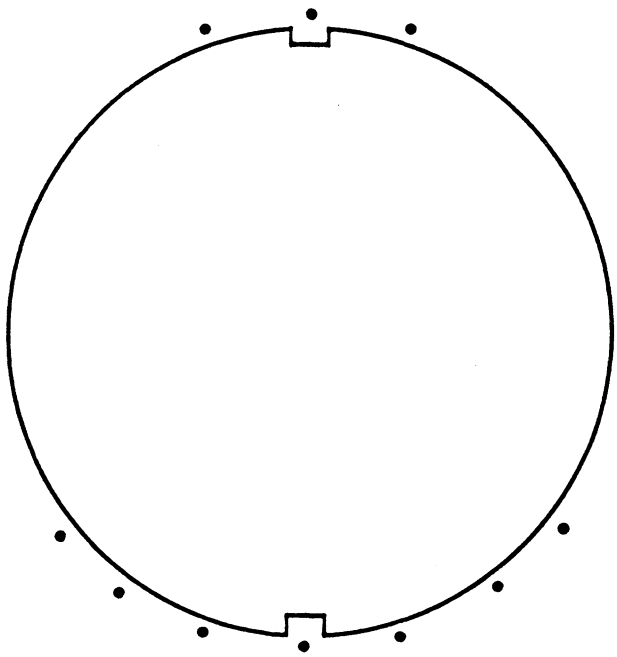


Fig. 3



Student's Sheet 1

Lines of force of a horseshoe magnet

Assignment: Assemble a horseshoe magnet and draw some of its lines of force using the plotting compass.

Apparatus:
1 Bar magnet
2 Iron yokes0
1 Plotting compass
1 Sheet of paper
1 Sharp pencil

Setup:

1. Place a sheet of paper on the table or lab bench as shown in Fig. 6.

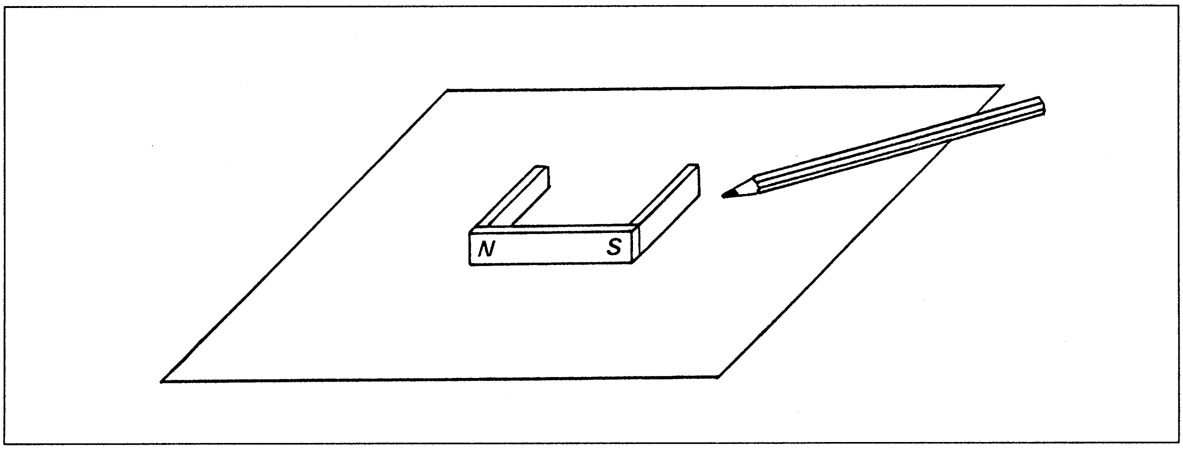


Fig. 1

2. Make a horseshoe magnet by assembling the bar magnet and the iron yokes as shown in Fig. 1.
3. Place the horseshoe magnet on the sheet of paper as shown in Fig. 1 and Fig. 6.

Carrying out the experiment:

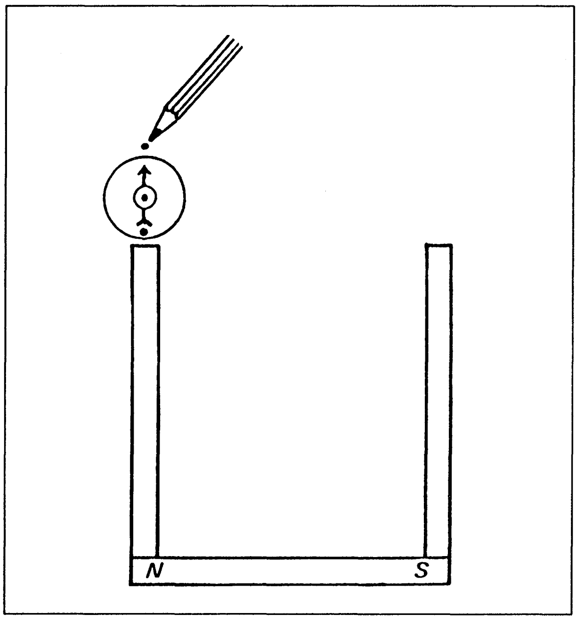


Fig. 2

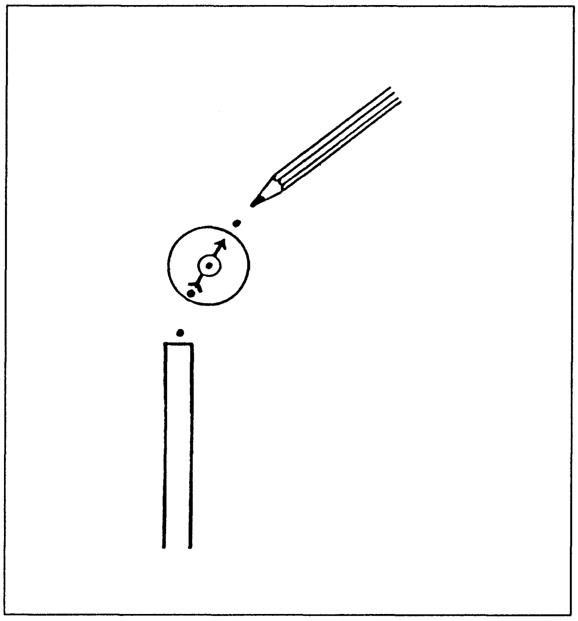


Fig. 3

4. Place the plotting compass at the midpoint of the left-hand arm of the horseshoe magnet and mark the position of the needle tip with the pencil (Fig. 2).
5. Move the plotting compass so that the back end of the needle covers the marked point.
   Mark the new position of the needle tip (Fig. 3).
6. Repeat step 5 until you come either to the edge of the paper or back to the horseshoe magnet.
7. Join the points together and draw arrows to show the direction the needle points along the line (Fig. 4).
8. When drawing lines away from the direction in which the compass needle points, shift the compass so that the tip of the needle is on the last point marked, and then mark the position of the back end of the needle on the paper (Fig. 5).
9. Draw all lines of force for the points given in Fig. 6 by repeating steps 5 through 8.
10. Does the pattern of the lines of force change when the poles are reversed? When the magnetic poles of a horseshoe magnet are reversed, the pattern of lines of force is mainly the same, but the direction of the lines of force is reversed.

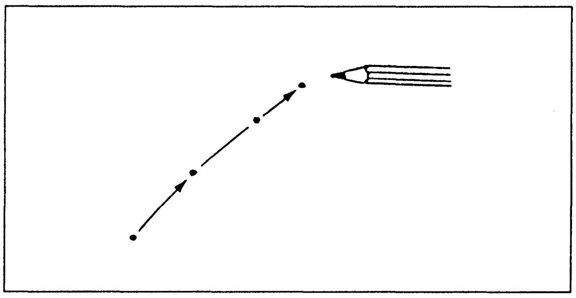


Fig. 4

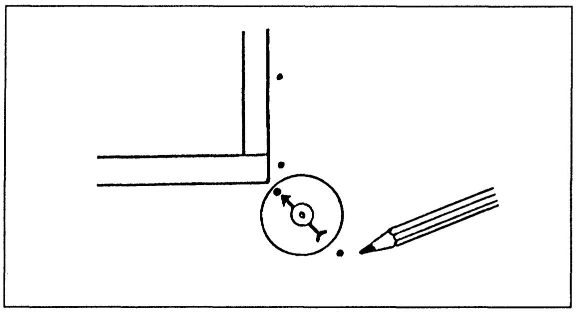
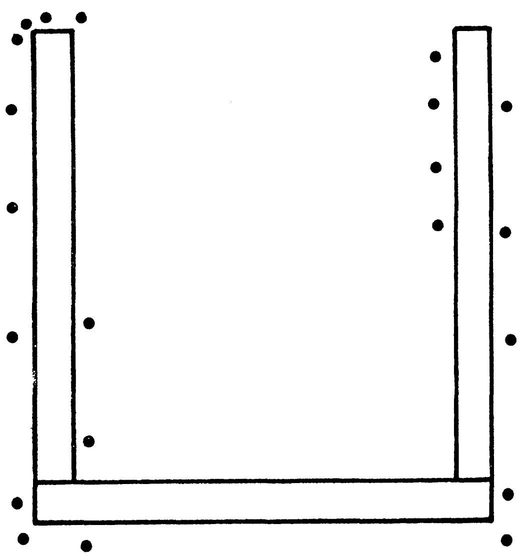


Fig. 5

Note:

If the arms of the magnet are magnetized differently, the pattern of the lines of force is not completely symmetrical to the axes.

Student's Sheet 3



Student's Sheet 4

Evaluation:

11. Give a short description of the pattern of the lines of force of a horseshoe magnet.

12. Where is the field structure particularly simple?

Student's Sheet 1

Lines of force of attracting magnetic poles

Assignment: Using a plotting compass, draw the lines of force between two magnets which attract each other.

Apparatus:
2 Bar magnets
1 Plotting compass
1 Sheet of paper, DIN A4
1 Sharp pencil

Setup:

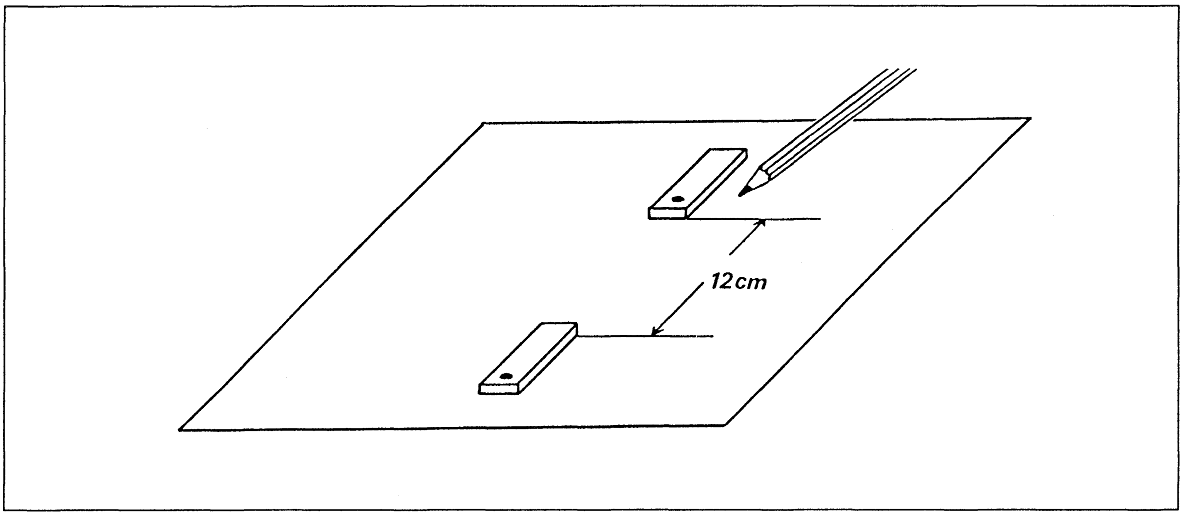


Fig. 1

1. Lay the sheet of paper on the table or lab bench as shown in Fig. 6 and arrange the two magnets as in the picture.

Carrying out the experiment:

2. Place the plotting compass so that the back end of the needle is over a marked point. Mark the position of the needle tip (Fig. 2).

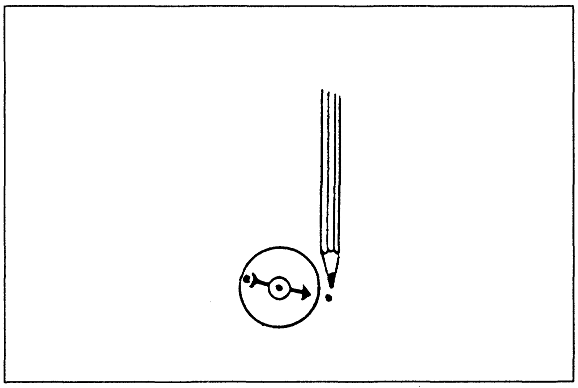


Fig. 2

Student's Sheet 2

3. Repeat step 2 until you come to one of the magnets (Fig. 3).
4. Join the points and draw arrows to mark the direction in which the needle points at each step along the line (Fig. 4).
5. When drawing lines away from the tip of the compass needle, shift the plotting compass so that the needle tip is on the last point marked; then mark the position of the back end of the needle on the sheet of paper (Fig. 5).
6. Draw the lines of force for all points marked in Fig. 6.
7. Does the picture of the lines of force change when the poles of the two bar magnets are exchanged?

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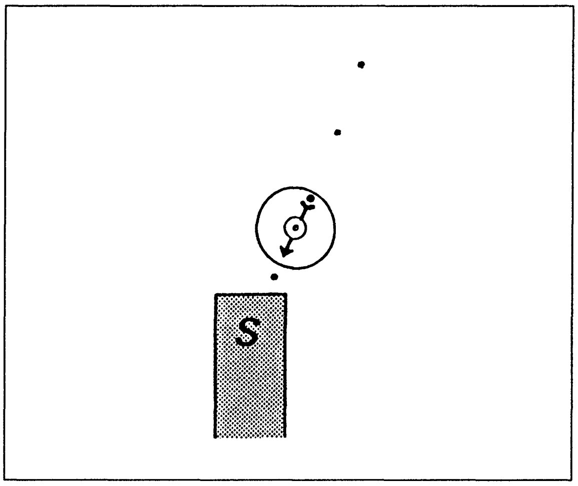


Fig. 3

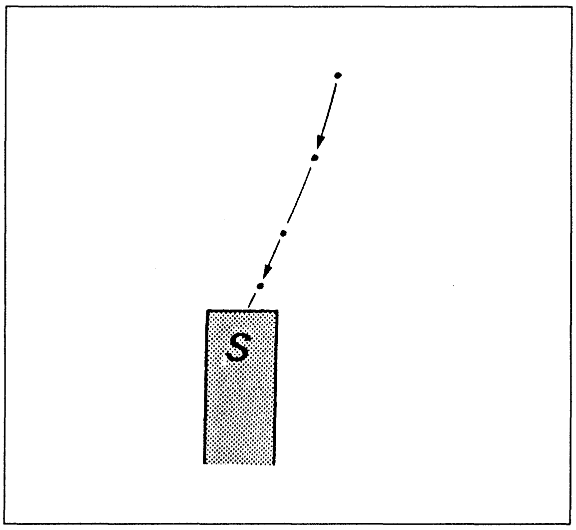


Fig. 4

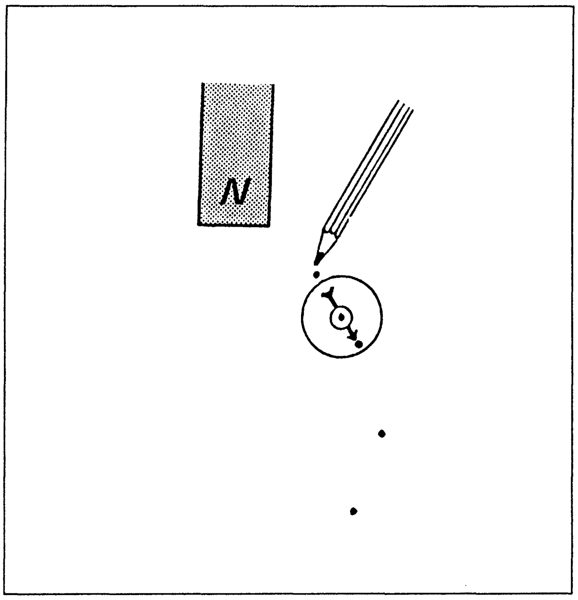
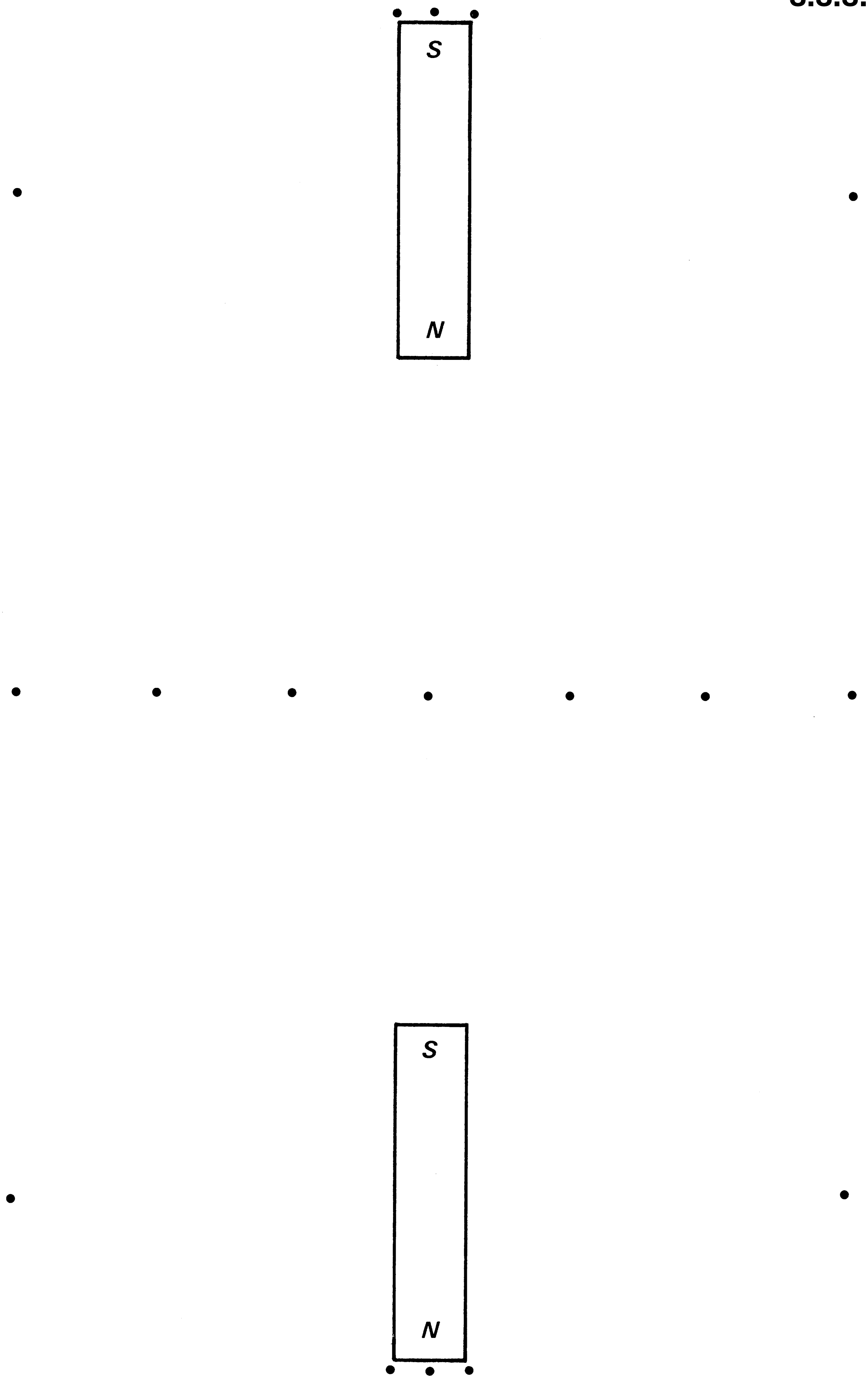


Fig. 5

3.3.3.5



Evaluation:

8. How do the lines of force run between two unlike magnetic poles?

Optional assignments:

9. How do the lines of force between two magnets attracting each other appear when one of the magnets is weakened (attenuated) by being covered with the iron yoke?

10. When two magnets move closer together because of their attraction, the pattern of the lines of force between them also changes. How does this pattern change?

Note:

From this we can conclude that the natural tendency of the lines of force is to become shorter.

Lines of force of repelling magnetic poles

Assignment: Using a plotting compass, draw the lines of force between two magnets which repel each other.

Apparatus:
2 Bar magnets
1 Plotting compass
1 Sheet of paper, DIN A4
1 Sharp pencil

Setup:

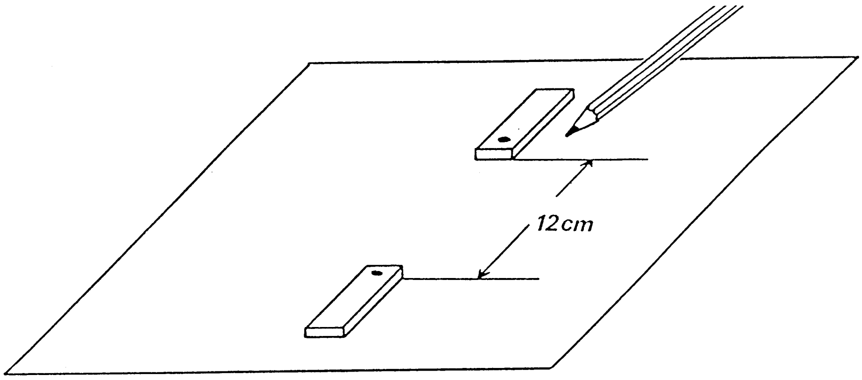


Fig. 1

1. Lay the sheet of paper on the table as shown in Fig. 5 and arrange the two magnets as shown in the picture.

Carrying out the experiment:

2. Move the plotting compass along the straight line between the two poles.
   Where does the compass needle do?

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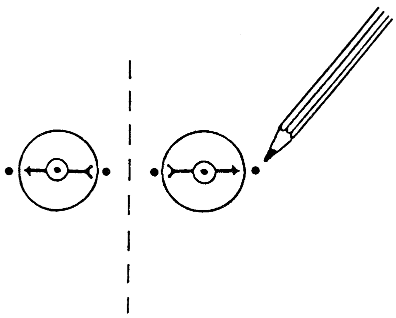

Fig. 2

Student's Sheet 2

3. Move two plotting compasses parallel to the straight line between the two poles (dotted line in Fig. 3).
4. Where do the compass needles point at a right angle to the line between the two poles? Mark the needle tip and back end positions of both plotting compasses at this point (Fig. 4):

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5. Draw the lines of force through these points from the middle to the two sides of the paper.

   The result is a straight line which divides the sheet more or less in half.
6. Mark the directions of the lines you drew with arrows in the direction of the field (in other words, the directions in which each compass needle pointed).
7. Fig. 5 shows some points which are especially good starting points for drawing more lines of magnetic force. Draw the lines of force for these points.

   The lines of force have very sharp curves in the middle of the sheet between the magnets. However, it is difficult to draw sharp curves without a great error because the needle of the plotting compass has a finite length. For this reason, do not draw any lines of force in this critical area.
8. Does the pattern of lines change when two south poles are opposite each other instead of two north poles?

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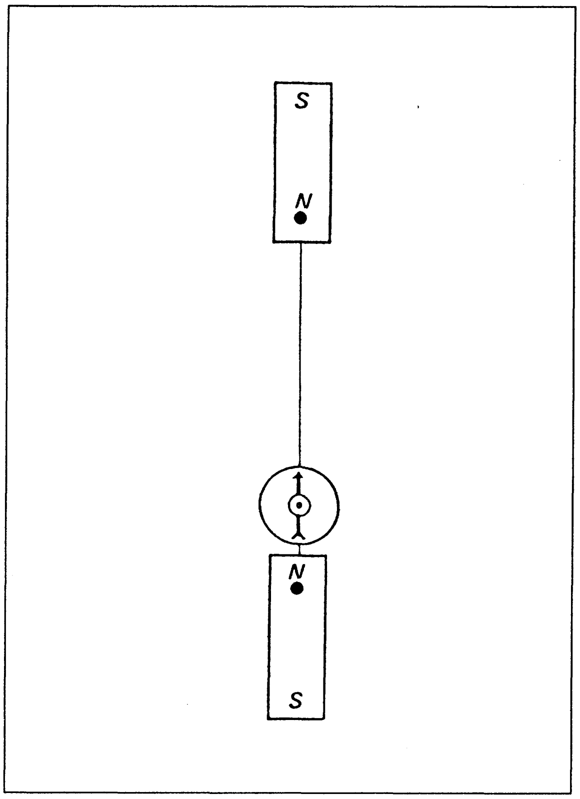


Fig. 3

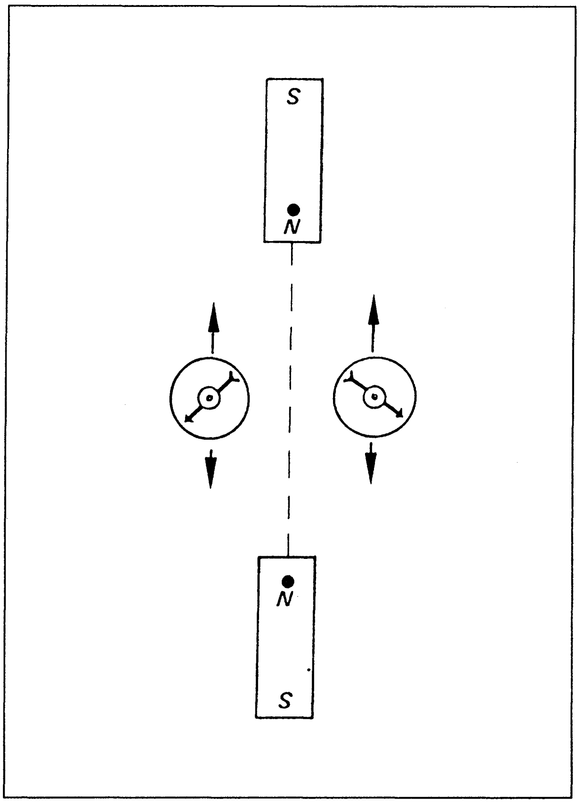
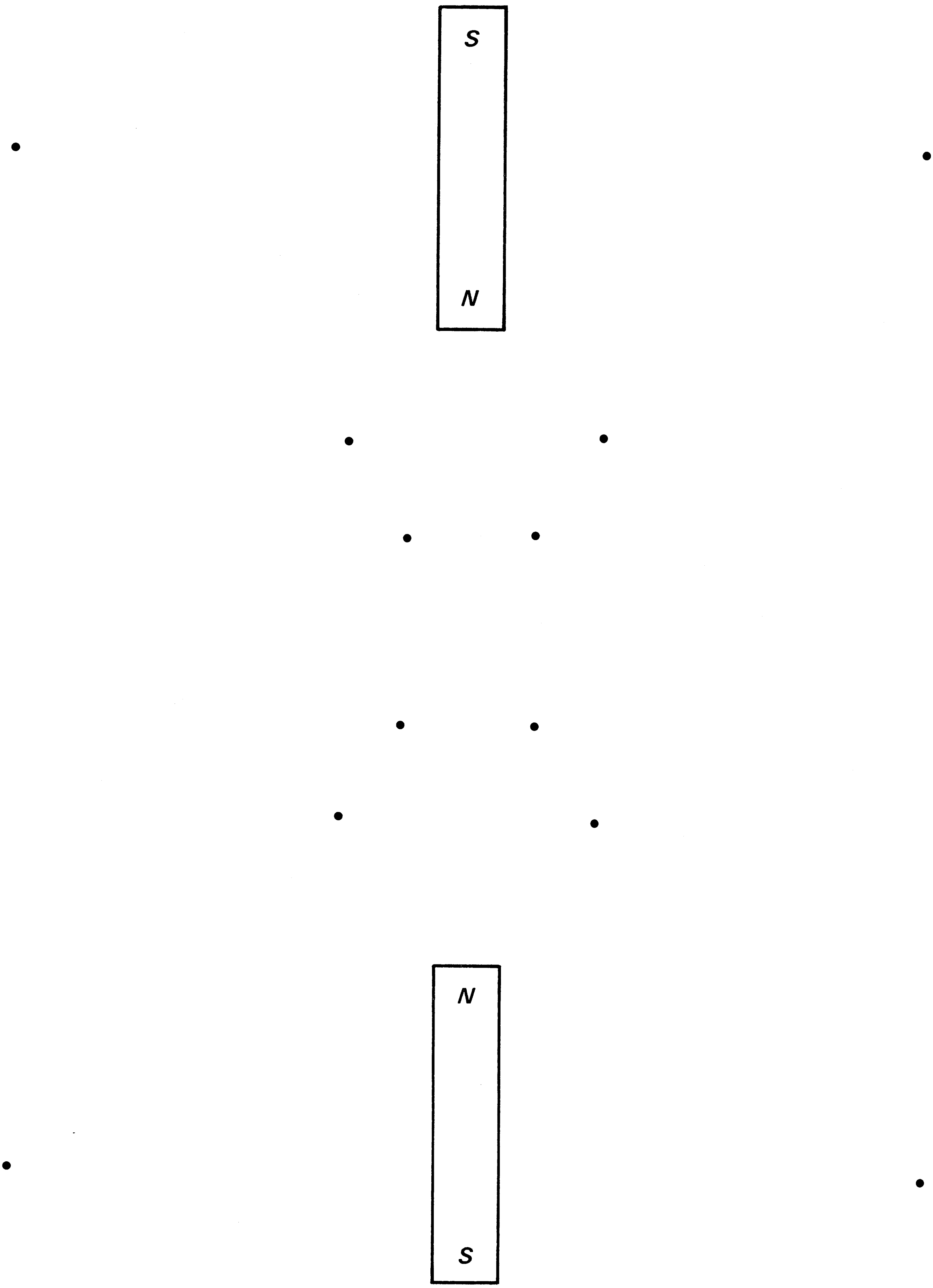


Fig. 4

3.3.3.6



Evaluation:

9. What pattern do the lines of force show when two like poles are opposite each other?

10. Where are the forces of the two magnets on a compass needle equal?

11. *Supplementary experiment assignment:*

How does the pattern of lines of force (Fig. 5) change when an iron yoke is placed on one of the magnets?

Answer (experiment result):

Interpretation: What does this mean?

List of apparatus

Maximum quantity per Cat. No.	Description	Cat. No.	Apparatus required in experiment (No. of items/lengths in cm)												Quantity supplied in STM-apparatus set
			1	2	3	4	5	6	7	8	9	10	11	12	
2	Bar magnet with north-pole mark	510 50	1	1	2	1	1	2	1	1	1	1	2	2	2
1	Pair of plotting compasses	510 53								1	1	1	1	1	1
1	Set of 4 magnetizable rods	510 54	1	1			1	1							1
1	Direction-finding compass	510 55	1		1		1								1
1	Hemisphere without magnet	510 56									1				1
1	Pair of iron yokes	510 60	1	1								1			1
1	Shaker for iron filings	514 72							1						1
1	Bottle with iron filings, 250 g	514 73							1						1
1	Storage tray with depressions for experiments	510 61													1

Additional material required for conducting the experiments:

4 Paper clips or iron nails, approx. 20 mm long
1 Sharp pencil
Sheets of paper, approx. DIN A4
1 Thin thread, approx. 1 m long