爱上科学
Science

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爱上科学

INTRODUCING • 物理系列
PHYSICS

神奇的磁场

MAGNETISM 双语版

[英] Graham Bateman 编
孙宇 译
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内容提要

《爱上科学》系列科普丛书为读者全面讲述了科学知识和原理，以通俗的文字、生动的图表为特色，每本书介绍一个或几个主题。从日常生活中有趣的现象出发，引导和培养读者学习的兴趣，拓宽读者的视野，同时还可以帮助读者学习英语词汇、练习英语阅读。丛书包括物理、化学、生物、科技与发明这4个系列。适合对科学知识感兴趣的广大科普爱好者阅读。

本书是物理系列中的一本。物理系列解释和说明了物理学知识及其发展史，包含物理学发展史上许多重大的物理发现以及著名的物理学家。本书用通俗生动的语言展示物理学的魅力，引发读者对物理学的兴趣和探索，同时包含丰富有趣的物理小实验。

本书从日常生活中有趣的磁学现象出发，生动地解释其背后的磁学原理，同时展示了磁场和磁力在生活生产中的许多用途。书中含有“科学词汇”栏目，提取每章重点词汇。同时还有“试一试”栏目，包含丰富有趣的家庭小实验，有助于提高大家的动手能力。

丛书编委会

丛书序

这是一个科技新时代，我们曾经认为遥不可及的科学，时刻围绕在我们身边。你是否曾经怀疑过所谓的“2012，世界末日”，或者好奇过在地下高速飞驰的地铁，抑或每天都在关注着PM2.5……这说明科学已然走进了你的生活。学习科学，分享科学，爱上科学，让我们共同聆听来自科学的声音。

《爱上科学》系列科普丛书是一套引进版系列科普丛书，译自英国大型出版商棕熊图书（BROWN BEAR BOOKS）有限公司出版的著名系列科普图书《Facts At Your Fingertips》，其独特的科学解读视角、生动的科普画面、优美的图文设计，得到了欧洲读者的青睐，尤其是得到了欧洲青少年的极大欢迎。本丛书为读者全面地讲述了各个领域的基础科学知识和基本事实，以精彩的主题、通俗的文字、生动的画面为特色，从我们身边的素材和现象出发，激发和培养读者学习的兴趣。

丛书涵盖物理、化学、生物、科技与发明四大系列。物理系列阐释和说明了物理学知识及其发展史，包含对物理学发展史许多重大的物理发现以及著名的物理学家的介绍。化学系列主要阐释现代化学的基本概念，涵盖化学反应、有机化学、生物化学、金属、非金属、分子、原子、物态等多方面内容。生物系列主要阐释生命科学的基本概念，并探讨有关生物学的各个方面，包括植物学、微生物学、动物和人类、遗传学、细胞生物学以及生命形式等。科技与发明系列主要介绍各种科技成果以及相关发明，覆盖多个领域，包括建筑、交通、医学、军事、能源以及航空航天等，指导读者认知和学习各种科学技术，拓宽视野，引发思考，提升创新能力以及发明意识。

本丛书还具有中英双语的独特设计，让读者在阅读中文时，能对照性地阅读英语原文，为他们提高科学领域的英文阅读能力以及扩展科学类英语词汇量提供了很好的帮助。

丛书中还有“试一试”栏目，该栏目包含了丰富有趣的家庭小实验，为大家在生活实践中验证科学知识提供了更多的选择。

学无止境，让我们一起爱上科学！

目 录 CONTENT

《爱上科学——神奇的磁场》一书介绍了物理学研究的基本过程和实际意义。长久以来，人类对于“磁石吸铁”的现象非常着迷，但是直到近代，物理学家才解释了这一现象的科学原理。在本书中，我们会首先介绍磁体的特性与用途，之后我们会探索电与磁之间的密切关系，即电流能够产生磁场，而变化的磁场又能产生电流，这一现象的发现对于今天的生活至关重要。小到电铃，大到无污染的电动汽车，许许多多的设备都用到了电磁学。我们所使用的电能基本上都是依赖于由强力磁铁作为核心的发电机来产生的。最后，本书还描述了不同种类的电池是如何产生与储存电能的。

本书包含了大量的插图、照片、话题相关方面的细节，还介绍了许多著名的物理学家和“科学词汇”的定义，这些都大大拓展了本书的覆盖范围。“试一试”专题列出了一些实验，这些实验可以作为读者自己实践研究的第一步。

MAGNETIC MATERIALS

A magnetic rock called lodestone has a power that seemed magical to early people. It can point to the north and guide a traveler even when all landmarks are hidden by night or in bad weather. Early explorers used this "magic" on sea voyages.

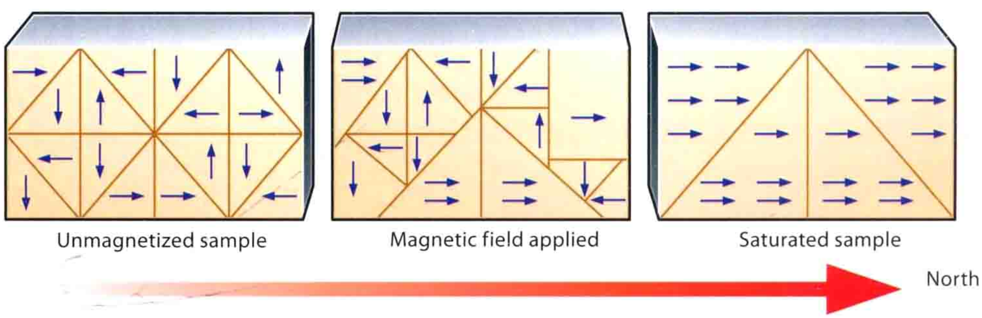
Among the earth's many types of rock is a very unusual one, first recognized as early as 2700 B.C. by Chinese scholars. This rock, called lodestone (or magnetite, to give it its modern name), contains iron. It attracts other metals, and pieces of it will either attract or repel each other depending on how they are oriented.

Lodestone demonstrates another amazing property when it is set up so that it can turn freely. It will then turn until it is pointing roughly north–south. This magnetic "compass" may have been used by navigators as early as the 3rd century a.d. in China. Certainly it was in widespread use by European sailors in the 12th century.

A magnetic needle enabled this portable sundial to be aligned north–south to take a correct reading. The instrument doubled as a magnetic compass.

MAGNETIC DOMAINS

Tiny areas in a piece of iron, called domains, are like individual magnets. Applying a magnetic field lines up these magnets. The metal is said to be saturated when all the domains have their magnetism lined up.



SCIENCE WORDS

- **Atom:** The smallest part of a chemical element that can exist on its own. It has a central nucleus, surrounded by electrons.
- **Domain:** A small region in a magnetic material in which the magnetic fields of individual atoms all point in the same direction, making the domain into a single small magnet. In the unmagnetized material, fields of different domains point in different directions, canceling one another out.
- **Lodestone:** A naturally magnetic iron ore, formerly used to make magnetic compasses. It is one of only two minerals that is naturally magnetic; the other, pyrrhotite, has only weak magnetism.

Supplies of lodestone were limited. But it was possible to use a piece of lodestone to make a large number of magnetic needles for use in compasses. By stroking an iron needle with the lodestone many times, always in the same direction, the iron became magnetized.

In the 20th century, this effect was explained by the French physicist Pierre-Ernest Weiss (1865–1940). Individual atoms of iron and other elements present in a piece of metal are like miniature magnets. The metal is divided into regions called domains in which all the atoms line up. The magnetism of the atoms adds together, making each domain into a tiny magnet. But the atoms in different domains point in different directions, so that overall the piece of metal does not behave like a magnet. Repeated stroking with a piece of lodestone causes the atoms to turn. Eventually they all point in the same direction, and their magnetism adds up to make the whole piece of metal a strong magnet. When all the atoms are lined up and the magnetism cannot become any greater, the piece of metal is said to be saturated.

TRY THIS

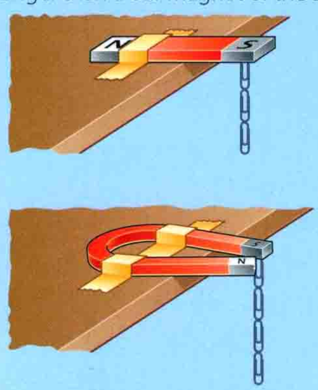
How much pull?

Magnets vary in strength, usually depending on how large they are. One way to measure the strength of a magnet is to see how much it will lift up.

What to do

Using masking tape, tape down a bar magnet near the edge of a table, with one end sticking out over the edge. Add paper clips to the end, building up a chain of clips hanging down. What is the maximum number of clips the magnet will hold up? Repeat the procedure, this time using a horseshoe magnet. How many clips will this magnet hold up?

The first clip is held by magnetism. The clip is made of steel, which is a magnetic material. When it is in contact with the magnet, this clip also becomes a magnet. The new paper-clip magnet holds up the second clip. That also becomes a magnet, and so on, all along the chain of paper clips. The number of clips held up is a measure of the strength of the magnet. Generally, a horseshoe magnet is stronger than a bar magnet of the same overall length.



Test the strength of a magnet by seeing how many paper clips it will hold up.

对于古代人类来说，有磁性的石头（磁石）仿佛有着魔力。在黑夜或者恶劣的天气里，人们无法看到任何地标，但是磁石依然能够指向北方，来给人们导航。早期的探险家在航海中就用到了这种“魔力”。

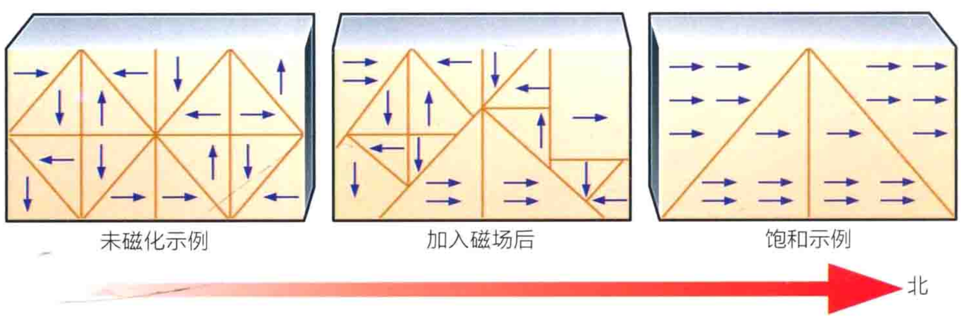
在地球上，众多石头种类中，有一种石头非常特殊，它在公元前 2700 年就被中国学者发现了。这种含有铁的石头名叫“磁石”（在今天，我们称它为“磁铁矿”）。磁石会吸引其他的金属，磁石的碎片将会根据它们的位置互相吸引或者互相排斥。

磁石还有另一个奇妙的特征：如果将磁石合理地设置好，使它可以自由转动，磁石就会自动发生旋转，直到最终指向大致的南北方向。早在公元 3 世纪，中国的航海家们就开始使用这种磁性“罗盘”了，而在公元 12 世纪，罗盘在欧洲水手间也被广泛使用。

这个携带式日晷需要根据磁针来调整，使晷针呈南北指向以便能够正确地读数。这个设备同时还是一个磁性指南针。

磁畴

铁块中被称作“磁畴”的微小单元就像各自独立的磁体，磁场可以让这些磁体整齐地排列起来。当所有的“磁畴”里的磁力都指向同一方向，我们就称这块金属饱和了。



科学词汇

- **原子**：指能够单独存在的组成化学元素的最小微粒。它有一个由电子环绕的原子核。
- **磁畴**：指磁性材料内部的一个区域。在这个区域内，每个单独原子的磁场都指向同一方向，从而使“磁畴”成为一个单独的小磁体。在未磁化材料内，不同“磁畴”的磁场指向不同方向，磁力相互抵消。
- **磁石**：指天然形成的磁铁矿，以前被用来制作指南针。磁石是地球上唯一两种具有天然磁性的矿物质之一，另一种叫作磁黄铁矿，它的磁力较弱。

磁石的储量是有限的，但是人们可以利用一大块磁石去制作数量众多的指南针里所使用的小磁针。通过将铁针与磁石在同一方向上摩擦数次，铁针就会被磁化。

在 20 世纪，法国物理学家皮埃尔•欧内斯特•外斯（1856—1940 年）解释了这一现象。一块金属内的单独的铁原子或其他元素的原子就好比微型磁体，金属被分割成叫作“磁畴”的几个区域，在“磁畴”内，所有的原子排列成队。原子的磁性相互叠加，使每个“磁畴”变为一个小型磁体。但是在不同“磁畴”内的原子指向不同的方向，因此整块金属并不像磁体一样。反复不断地在一块磁石上摩擦会使原子转向。最终，所有原子会指向同一方向，它们的磁性会叠加起来，整块金属就成为一个强磁体了。当所有的原子都排列成队，磁力达到最大值就不会再增加了，我们就称这块金属“饱和”了。

试一试

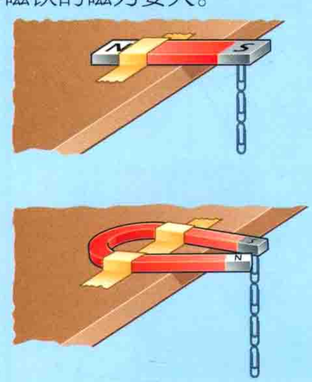
拉力究竟有多大？

磁体各自磁力不同，通常取决于磁体的大小。测量一个磁体的磁力方法之一就是来观察它能够提起多重的物体。

实践步骤

使用胶带，将一块条形磁铁粘贴在桌子的边缘，让它的一端伸出桌子。在磁铁末端放上回形针，让它们组成一条向下悬挂的链条。磁铁最多能够悬挂多少曲别针？重复这个过程，这次用 U 型磁铁试试，看看 U 型磁铁最多能够悬挂多少曲别针？

在曲别针链条顶端的那个曲别针是被磁力吸引住的。曲别针是钢制材料，属于磁性材料的一种。当它与磁场接触时，回形针会变为磁体。而这个新的回形针磁体会吸住下一个回形针，被吸住的回形针又会变为磁体，这样循环下去，最终形成回形针链条。磁铁吸住回形针的数量是衡量磁铁磁性的一种方法。通常情况下，总长度相同的 U 型磁铁比条形磁铁的磁力要大。



通过磁铁吸附的回形针数量来测量磁铁的磁性强度。

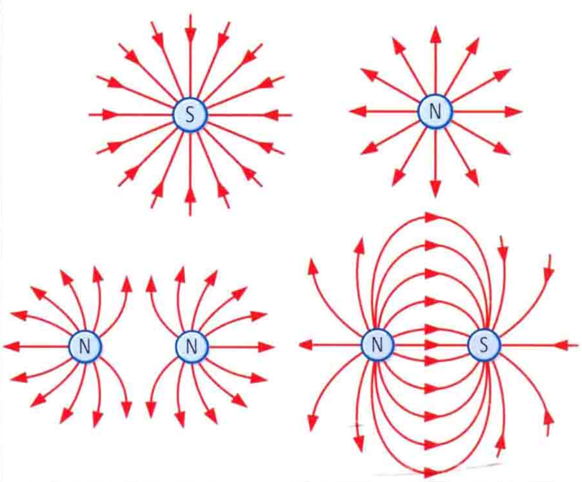
MAGNETIC POLES AND FIELDS

Surrounding a magnet and extending into nearby space is a "sphere of influence" called a magnetic field.
How another magnet is affected by the first magnet depends both on this magnetic field and on the second magnet's own properties.

A piece of lodestone or other magnet will attract small metal objects to itself. The way they arrange themselves around the magnet reveals to us important facts about magnetism. Iron filings—tiny metal grains produced when a block of iron is filed or machined—show this especially clearly. They cluster around the two ends of a bar magnet, but not toward its middle.
If the magnet is in the shape of a horseshoe, the filings cluster at the ends of the two "legs," but not around its middle. Every magnet has these two "attractive ends," called its poles.

ONE OR TWO POLES

These fields are produced by one or two magnetic poles. Such poles always occur in linked pairs; but if they are widely separated, they can be regarded as single poles.



Iron filings scattered around the poles of a bar magnet reveal the magnetic field around them. Each filing orients itself in the direction of the field at its location, and together they trace a dramatic picture of the whole magnetic field.

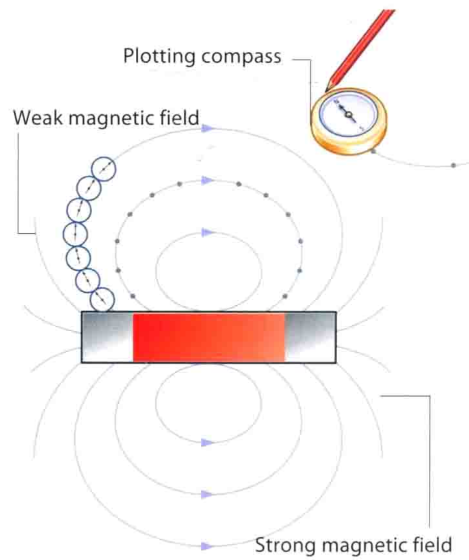
One of the poles of a magnet is attracted to the north and the other to the south. This is the reason why a compass needle swings until it is pointing north–south. The north-seeking pole is called the magnet's north, or N, pole; the south-seeking pole is the south, or S, pole.

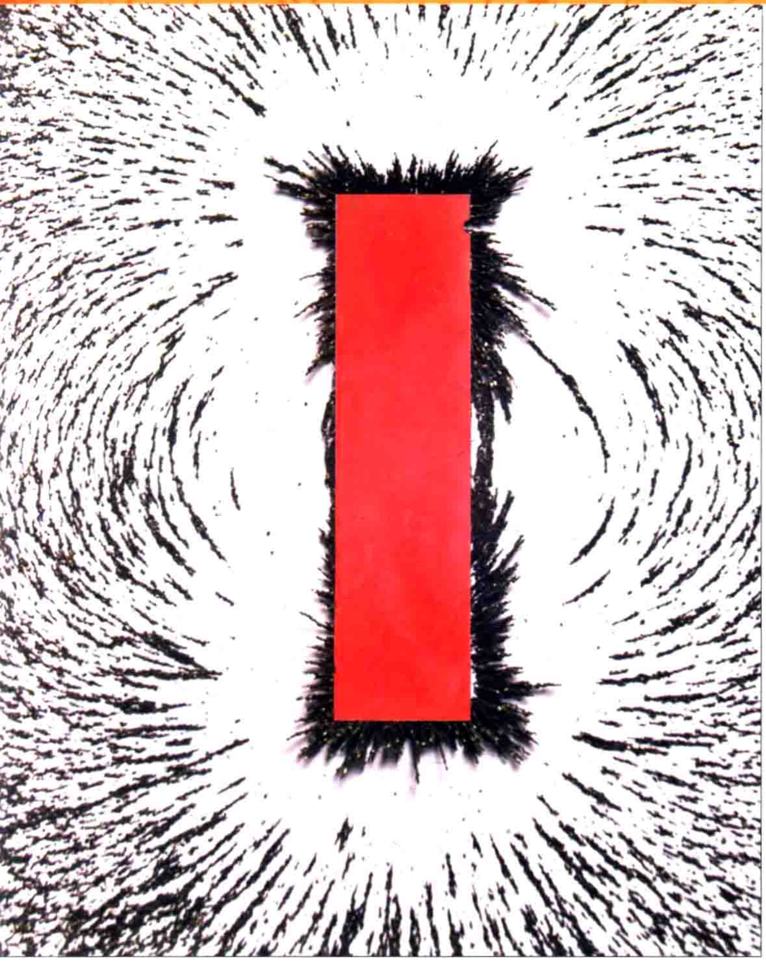
Attraction of opposites

When the two north poles of a magnet are brought close to each other, they can be felt to repel each other. The closer together they are, the harder is the mutual push. The same happens if the two south poles are brought close to each

PLOTTING THE FIELD

Trails of dots marking successive positions of the head and tail of the compass needle trace out field lines.





other. But when a north pole is brought close to a south pole, a force of attraction can be felt. Again, the force is stronger the closer the poles are to each other.

The field can be "mapped" with the aid of a small compass. If it is brought close to a magnet, the needle of the compass points toward or away from the nearest pole of the magnet. If the nearest pole is a south pole, the north-seeking end of the needle points toward it.

If the compass is moved toward the other end of the magnet, the effect of the north pole gradually increases, and the needle turns until its south-seeking end points toward the north pole.

To map the field, put the magnet on a piece of paper and place the compass anywhere on the paper. Mark the two ends of the needle with pencil dots. Then move the compass until the tail of the needle is just over the dot that marks the previous position of the head of the needle. Mark the new position of the head of the needle, and again move the compass until the tail of the needle is at that position. Continue repeating this process.

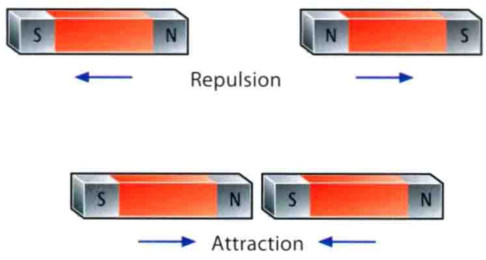
The result is a chain of dots that can be joined up smoothly to make a curved line. At every point along this line the direction of the line is the direction of the compass at that point, which is the direction of the force that would be experienced by any magnetic object at that point. The curved line is called a line of force or a field line. The region in which magnetic forces are experienced is the magnetic field. Field lines indicate the north–south direction.

Picturing the field

The magnetic field can also be made visible in a striking ay with the aid of iron filings. If a sheet of paper is placed over a magnet and iron filings are shaken over the paper, many cluster directly over the poles. But some lie scattered over the rest of

FORCES BETWEEN MAGNETS

Two bar magnets suspended on strings will push each other apart or pull each other together depending on whether like poles (two N or two S) or unlike poles (N and S) are closest to each other.



在磁体周围，存在一个“势力范围”，并且会扩大到附近的空间，我们称为“磁场”。一个磁体如何被另一个磁体作用取决于两方面，一方面是这个磁体的磁场，另一方面是另一个磁体的自身属性。

一小块磁石或者其他磁体会吸引轻小金属物件。这些围绕在磁体旁边的小金属物件的排列形式，将会为我们揭示磁力的重要信息。铁屑——即加工一大块铁时产生的金属颗粒——将会把这个现象表现得特别清晰。铁屑在条形磁铁的两端聚集，而不是聚集在磁铁中部。如果是U型磁铁的话，铁屑会聚集在磁铁的两端，而不是分布在磁铁中部。每个磁体都有两个“吸引端”，我们称为“磁极”。

磁体的一个磁极指向北方，另一个磁极指向南方，这就是指南针为何会指向南北方向。指向北方的磁极叫作磁铁的北极，或者N极；指向南方的叫作南极，或者S极。

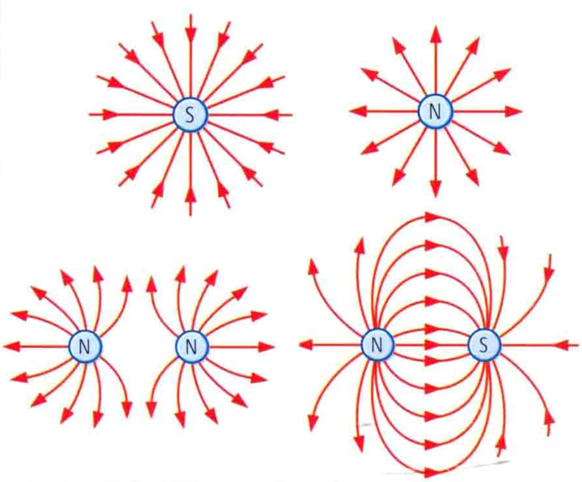
异极相吸

当两个磁体的北极相互靠近时，我们能感觉到它们在相互排斥，距离越近，排斥力就越大。当两个南极相互靠近时也是如此。但是，当一个北极靠

分布在条形磁铁磁极周围的铁屑揭示了它们周围的磁场。每一个微小的铁屑都被调整到了该点磁场的方向，这些微小的铁屑一起描绘了整个磁场的图案。

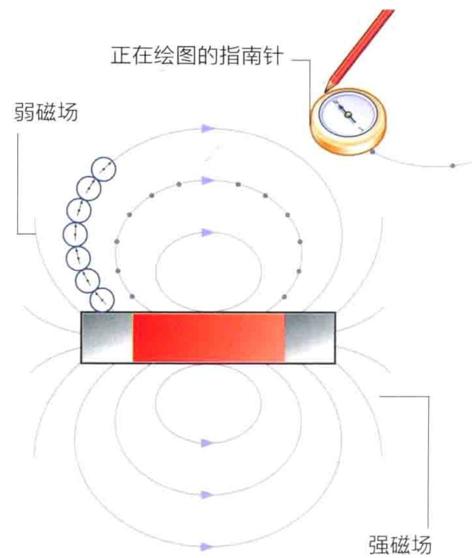
一个或两个磁极

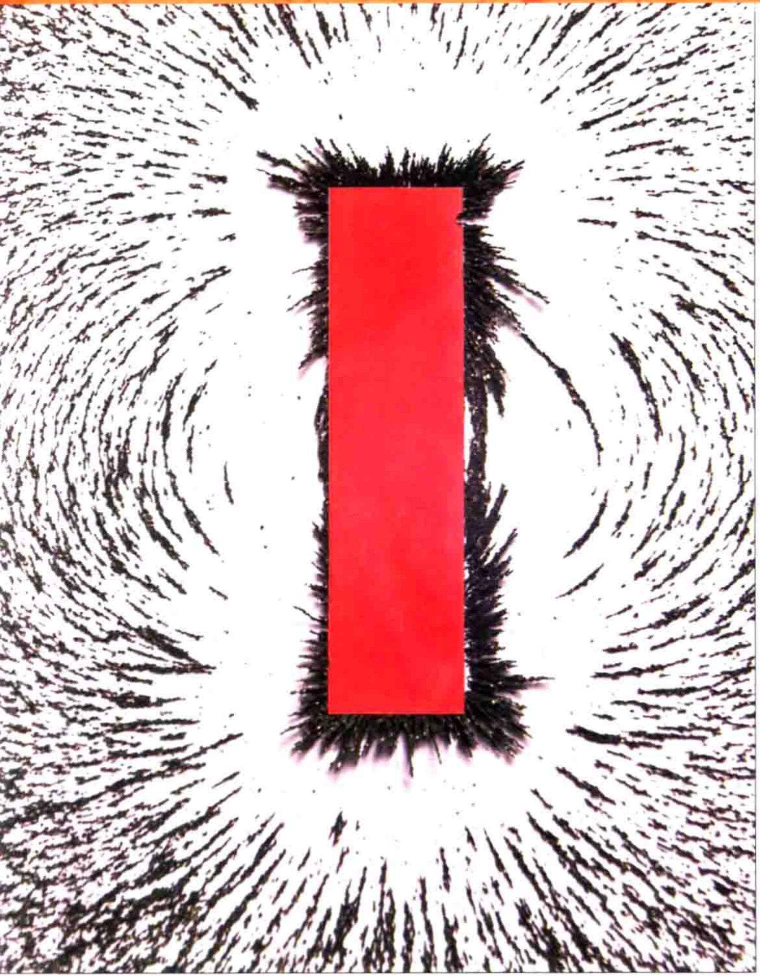
下图所示是由一个或两个磁极产生的磁场。磁极总是成对出现，但是，如果一对磁极之间相距很远，我们就可以把它们视为单磁极。



绘制磁场

连续的轨迹点记录了指南针头部与尾部之间磁场线的位置，从而描绘出了磁场线。





近一个南极时，我们能感觉到它们之间的吸引力，同样，距离越近，吸引力越大。

借用一个小指南针，我们可以绘制出磁场图。当我们将指南针靠近磁体时，指南针的指针会指向或者背离磁体最近的磁极。假如最近的磁极是南极，指针的北极端将会指向它。如果将指南针移到磁体的另一端，北极的影响将会逐渐增加，指针将会旋转直到它的南极指向磁体的北极。

要想绘制一个磁场，可以将一个磁体放在一张纸上，把指南针放在纸上的任意位置，然后用铅笔画点记录下指针两端的位置。再移动指南针，直到指针的尾部正好落在上一次指针头部位置的铅笔记录点上。记录下现在指针头部的新位置，然后继续移动指南针，让尾部再和这次的头部记录点重合。不断重复这个过程。

最终的结果是，一连串的点平滑地连接起来形成了一条曲线。曲线上的任意一点，曲线的方向就是在这点上指南针指向的方向。这条曲线被称为“磁力线”或“磁感线”。测试到磁力的这块区域就是“磁场”，磁力线表明了磁场由北到南的方向。

画出磁场

借助铁屑，磁场也可以变得清晰可见。如果将一张纸放在磁场中，抖动纸上的铁屑，许多铁屑在磁极汇聚成簇，另一些散布在磁体周围的剩余区域，形成曲线。这些曲线从一个磁极连接至另一个磁极，形成了一条条单独的纹理，它们根据一个特定的方

磁体之间的作用力

两个悬挂在线上的条形磁铁会根据互相靠近的磁极是同极（两个 N 极或两个 S 极）还是异极（一个 N 极和一个 S 极），来互相排斥或者互相吸引。

TRY THIS

Field of force

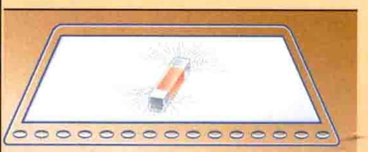
The region around a magnet in which it attracts metal objects is called its magnetic field. The field is invisible, yet it can be shown. This project shows you how to reveal the existence of a magnetic field and discover its shape.

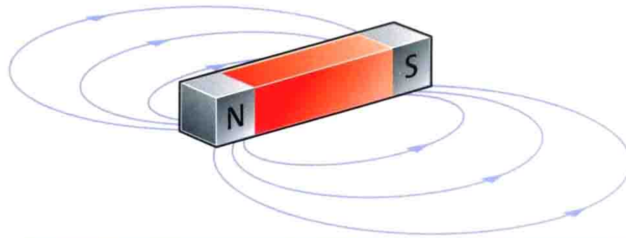
What to do

Put some iron filings in a cup and sprinkle them thinly onto a piece of writing paper. Carefully slide the paper into a clear plastic pocket, and tape closed the open edge of the pocket (this keeps the filings from spilling and possibly sticking to the magnet). Put the magnet on a table, and place the pocket on top of it. The filings will arrange themselves in a pattern that corresponds to the magnetic field of the magnet. Repeat the procedure with another shape of magnet if you have one. You can even use the same method to find the shape of the magnetic field between two magnets.

The iron filings line themselves up along the lines of force that make up the magnetic field. The field is strongest near the poles (ends) of the magnet, which is why the filings concentrate at these points. If you use two magnets, you can see how their magnetic fields combine.

The iron filings inside the plastic pocket will reveal the magnetic field.





Field lines, or lines of force, are imaginary lines showing the force that the magnet would exert on an imaginary north magnetic pole. At each point the direction of the field line shows the direction of the force.

the area around the magnet and arrange themselves in curved lines. The lines run from one pole to the other. They are formed as each individual grain lines up in a certain direction. Each grain acts like a tiny magnetic compass and points in a definite direction. Together they give a vivid picture of the form of the field, and even of its strength, for the lines crowd together near poles, where the field is strongest. The more the field lines spread out, the weaker the field is.

The direction of the field at a point is defined as the direction of the force that would be experienced by the north pole of another magnet at that point. According to this definition, the field lines run outside the magnet from its north pole toward its south pole. Entering the magnet near the south pole, they return toward the north pole, each forming a closed loop. Field lines do not normally meet or cross one another.

Poles apart

Every magnet has two opposite poles: no isolated pole is known to exist. (Physicists have made searches for subatomic particles that are single magnetic poles, but such "monopoles" have never been discovered.) This makes working out the laws of the magnetic field difficult. It is easier to see what is happening with a very long bar magnet, with the poles far apart. The magnetic effects of each pole can then be studied while the influence of the other one is ignored.