Magnetism the Big picture

J. M. D. Coey

Trinity College Dublin

I. Science rules the Earth - OK?

II. The end of an aether

III. What the ancients knew

IV. Billions of magnets for billions of people

www.tcd.ie/Physics/Magnetism

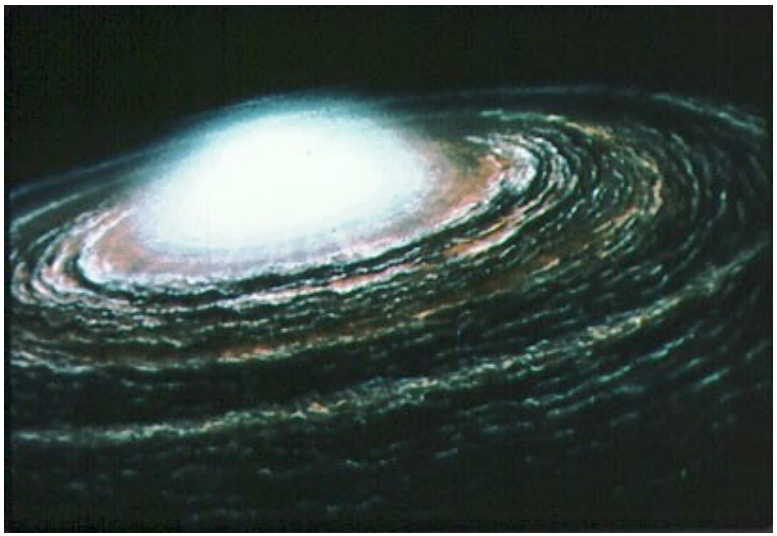
The first 3.5 Ga.

1	1	one	x
10	10	ten	
10^2	100	hundred	
10^3	1000	thousand	kx kilo
10^4	10000	ten thousand	
10^5	100000	hundred thousand	
10^6	1000000	million	Mx mega
10^7	10000000	ten million	
10^8	100000000	hundred million	
10^9	1000000000	billion	Gx giga
10^{10}	10000000000	ten billion	

1	1	one	x
10^{-1}	0.1	tenth	
10^{-2}	0.01	hundredth	
10^{-3}	0.001	thousandth	mx milli
10^{-4}	0.0001	ten thousand	
10^{-5}	0.00001	hundred thousand	
10^{-6}	0.000001	millionth	μx micro
10^{-7}	0.0000001	ten millionth	
10^{-8}	0.00000001	hundred millionth	
10^{-9}	0.000000001	billionth	nx nano
10^{-10}	0.0000000001	ten billionth	

Formation of the Earth 4.5 Ga

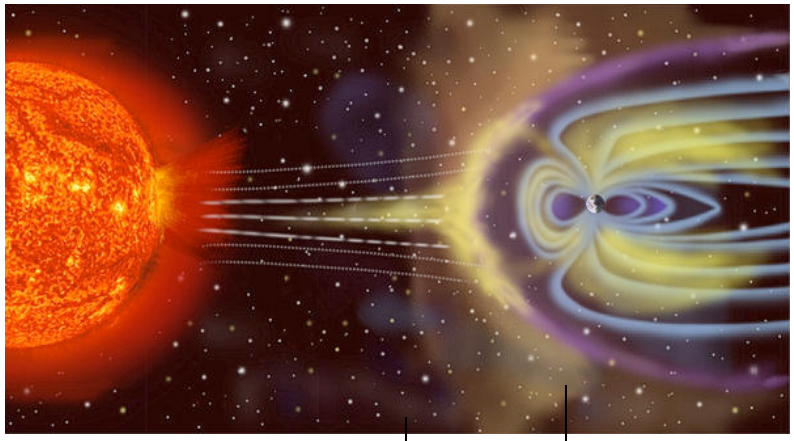
Big bang 14 Ga



Pangaea 240 Ma

Magnetotactic bacteria 150 Ma

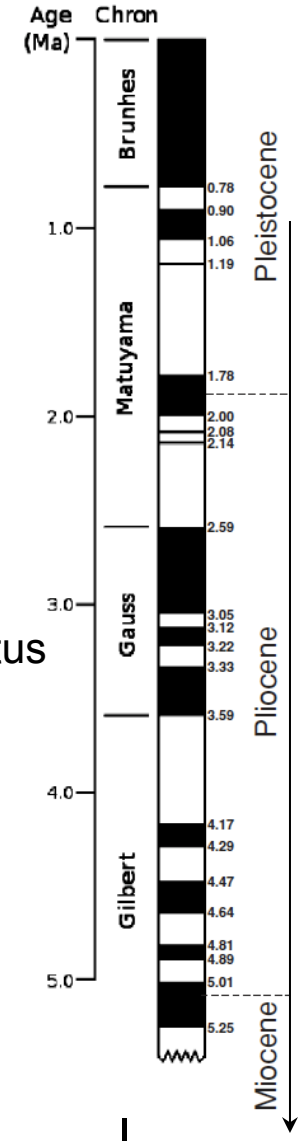
Earth's magnetic field 3.5 Ga



10 9 8 7

log *t*(a)

Homo erectus
1.8 Ma



Last reversal
700 ka

Homo sapiens
200 ka

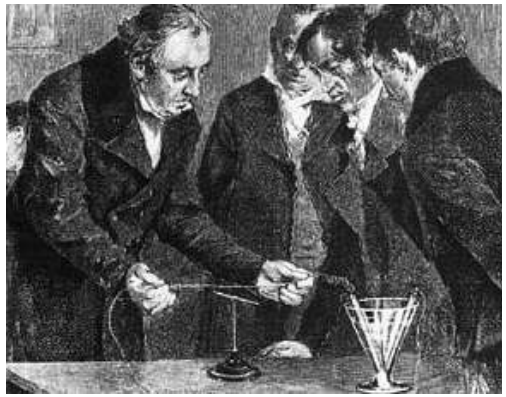
Agriculture 11 ka

7 6 5 4

log *t*(a)

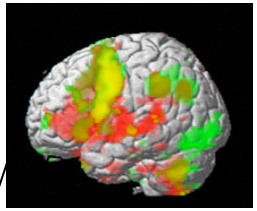
Discovery ~3 ka

Columbus
520 a



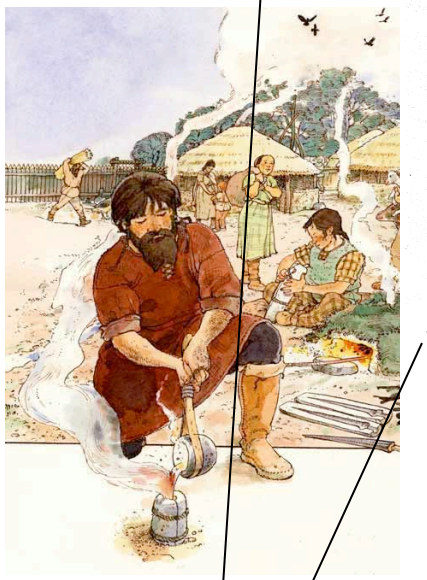
Oersted 190 a

AHM 45 a

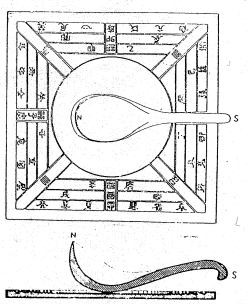


fMRI 20 a

Writing 7 ka

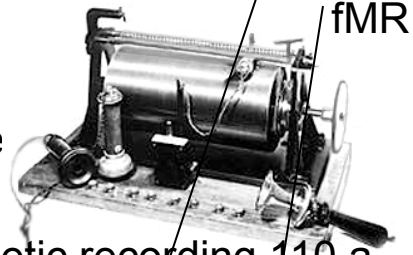


Iron metallurgy
3.8 ka

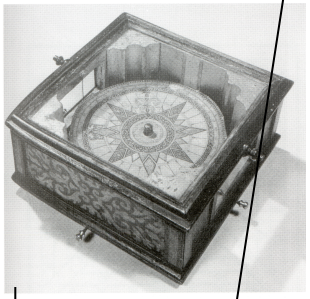


South pointer 2.2 ka

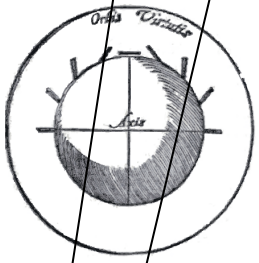
Horseshoe
250 a



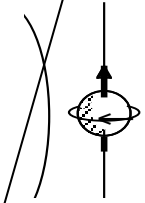
Magnetic recording 110 a



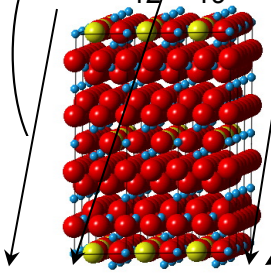
Compass 1.0 ka



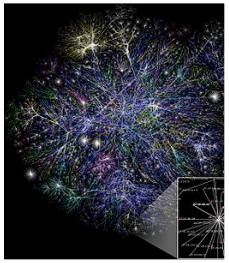
De Magnete
410 a



Spin
80 a



$BaFe_{12}O_{19}$ 55 a



www 20 a

4 3 2 1

log *t*(a)

2. What the ancients knew

- Olmecs and Sumerians
- Greeks
- Chinese
- The Compass
- Dreams
- Mines

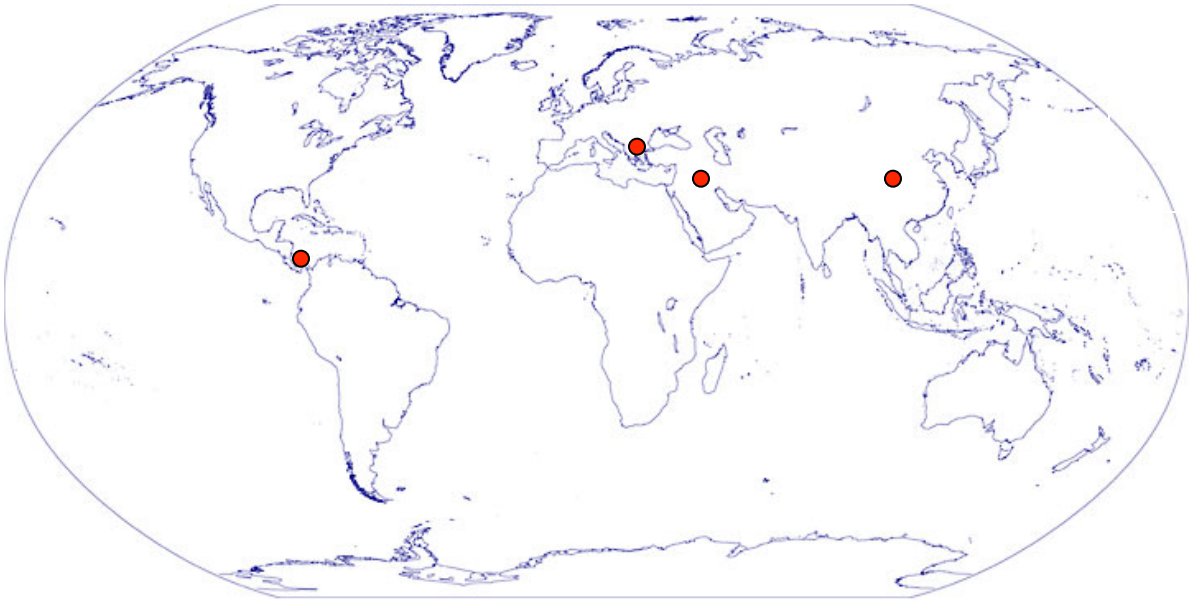
2. What the ancients knew

The mysterious behaviour of lodestones, rocks naturally magnetized by lightning strikes, and their strange love for iron was known in ancient China, Greece, Sumer and Mesoamerica. The directional property, attributed to the heavens, was used first for geomancy and then, a millenium later when occult knowledge became public, for navigation. The great voyages of discovery of Africa by the Chinese and America by the Europeans, all depended on the compass. The ancients dreamt of levitation and perpetual motion. So do we.

Child A discovers the magetic force.

The age of discoveries; -1000 to 1600

A wonder I experienced as a child of 4 or 5 years when my father showed me a compass. That a needle behaved in such a determined way did not at all fit into the nature of events. I can still remember (or at least I believe I can remember) that this experience made a deep and lasting impression on me *Albert Einstein*



Olmecs and Sumerians

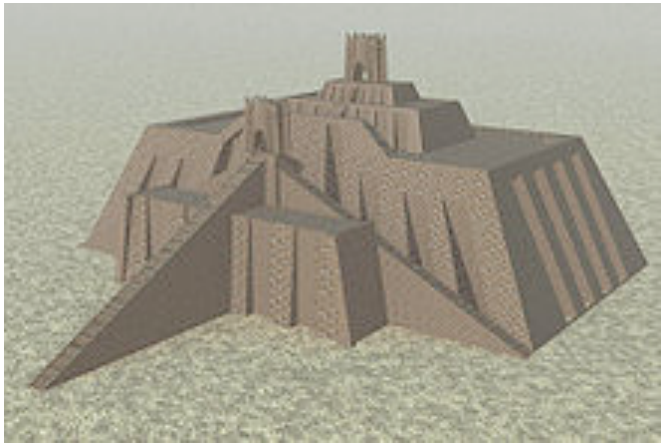
Sea turtle with a magnetic snout

Polished hematite bar

The Olmec heartland; 1400 - 400 BC

Olmecs and Sumerians

Sumer 4000 - 2000 BC



Greeks

Thales

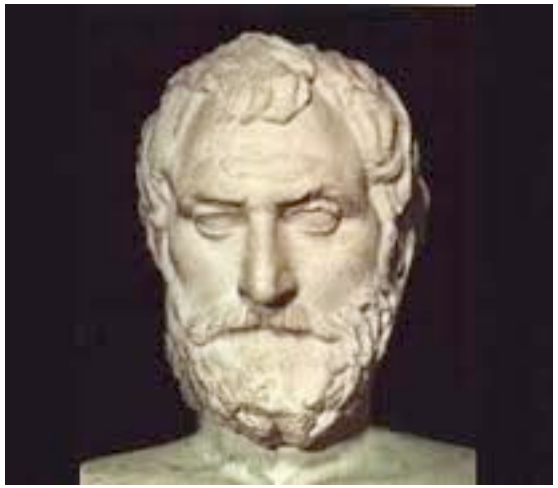
Animated

Pythagoreans

Pliny of

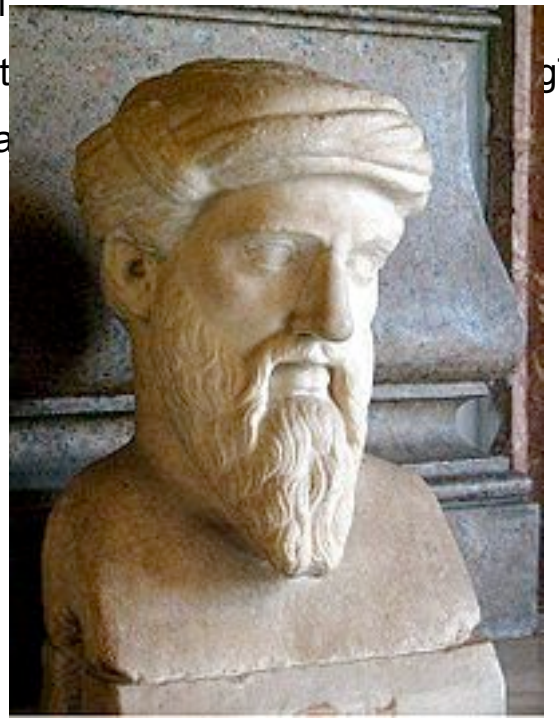
Magnet

No idea

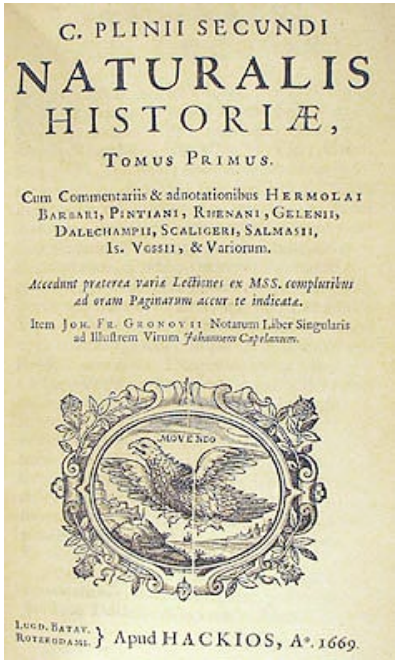


Thales of Miletus 624-545 BC

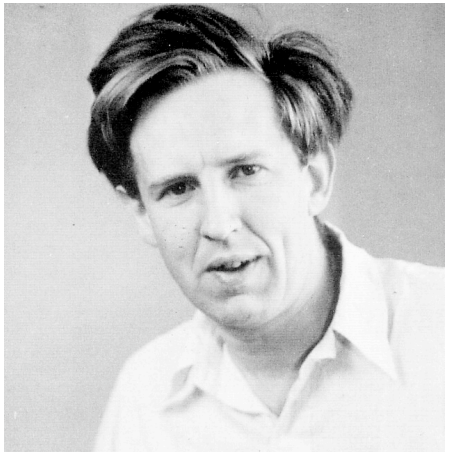
Pliny the Elder 23 - 79 AD



Pythagoras of Samos 570-495 BC




Magnetic
WHITE
LODESTONE
GENUINE
MO-JO Brand
PRICE
$1.00
EACH
3 for
$2.00
ALIVE WITH MAGNETISM
A LODESTONE has been held in High Regard by the Ancient Romans, Chinese, Mohammedans, and other people, as a Powerful Amulet and GOOD LUCK Charm; probably because the Magnetic Influence of this Stone was supposed to ATTRACT Power, Favors, and Gifts. It is said that the Ancient Romans believed that Lodestone kept Man-hood and Wife faithful, and made their Love secure. We make no claims to this effect or that the LODESTONE is LUCKY. We have taken the Genuine Lodestone, expertly prepared it, and called it WHITE LODESTONE. Two pieces of Specially Prepared WHITE LODESTONE for $1.00.
Order by No. A-208B
Price Each $1.00
3 for $2.00
HOW TO ORDER Just write Catalog Number, How Many, and Price. No Need to write a long letter. The company pays postage when you send full amount of money with order. If you want your order C.O.D. you pay Postman Amount of order plus few cents postage when he delivers your package. On C.O.D. orders for over $3.00 send 20% deposit. Write your name and address plainly.

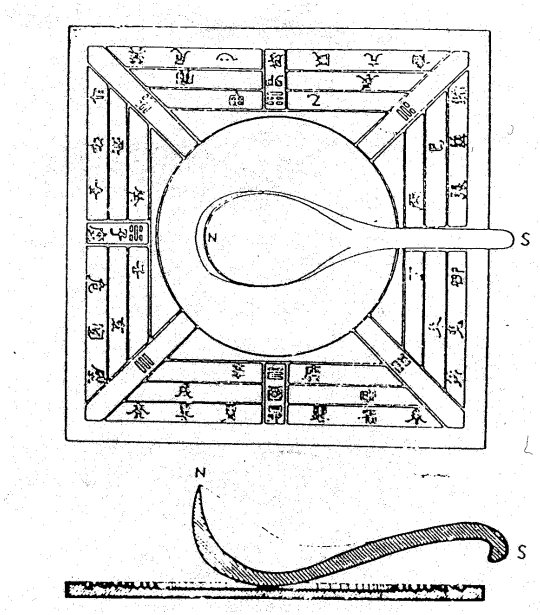


The Greeks knew the magnet attracted iron, and the attracted iron would attract other bits, and so on. But what they did not know was that there was any relation between the magnet and direction. This is one of the greatest discoveries: in fact *I would say without doubt, that it is the greatest discovery, in view of the difficulty in making it, in the whole of physics*. Because it was one of those things that could not be predicted. No one was in a position to say that if you take a magnet and suspend it freely, it will point north and south. First of all, why should you suspend a magnet freely? There was absolutely no reason to do so. Then why should it point north and south? What id ther north and south that concerns a magnet? There is no *a priori* connection between the two. *J. D. Bernal; The Extension of Man*

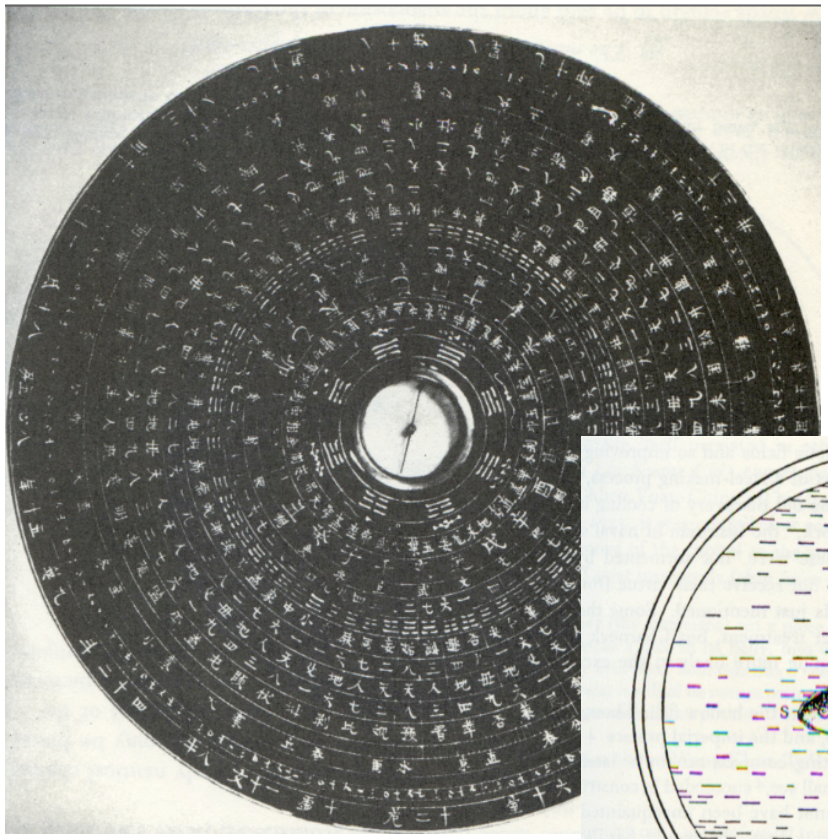
Chinese

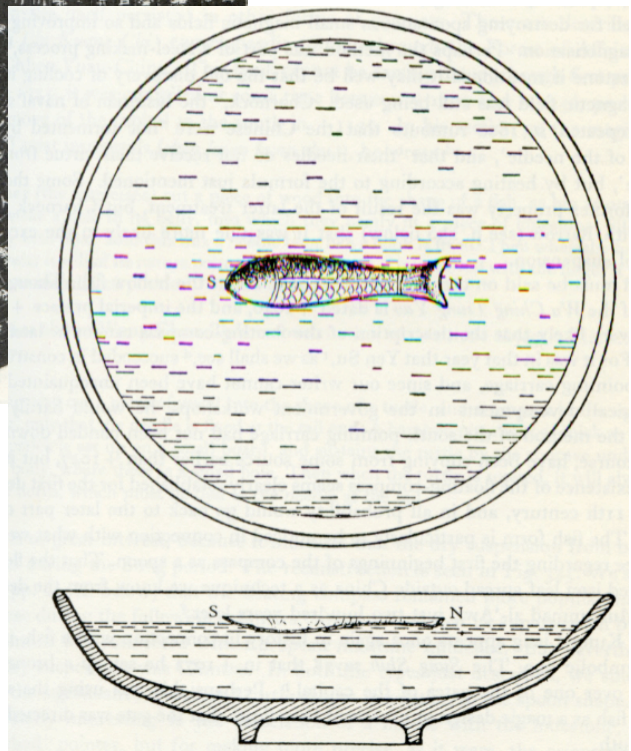
Geomancy

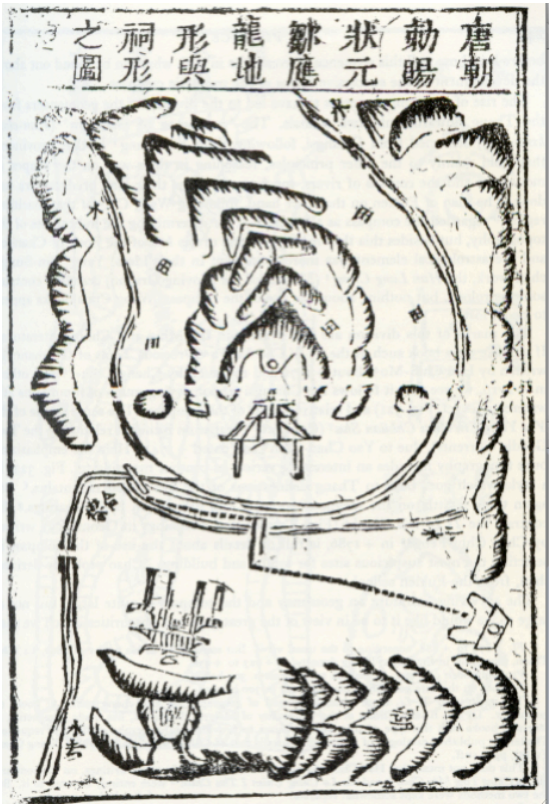
South pointer

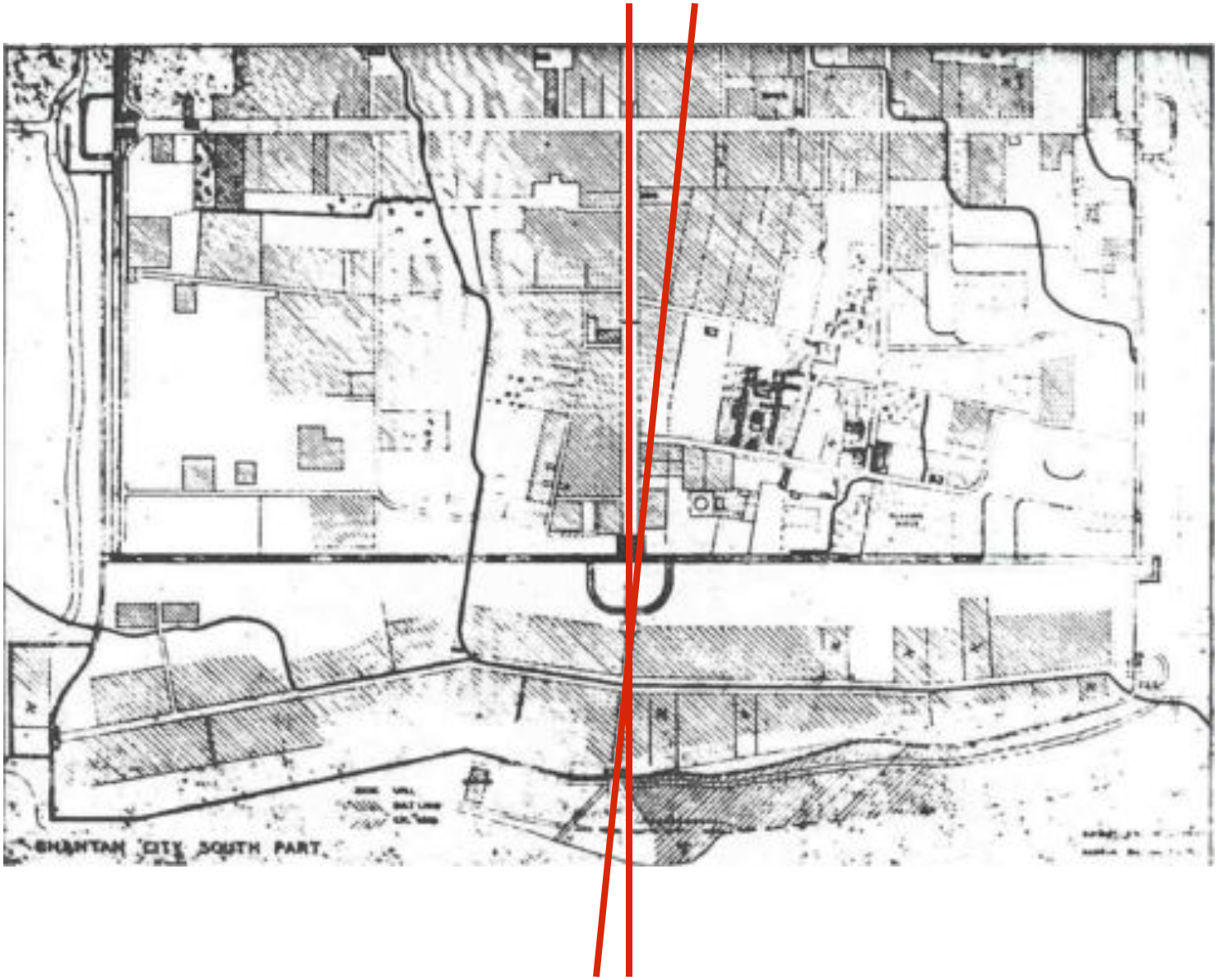


風水



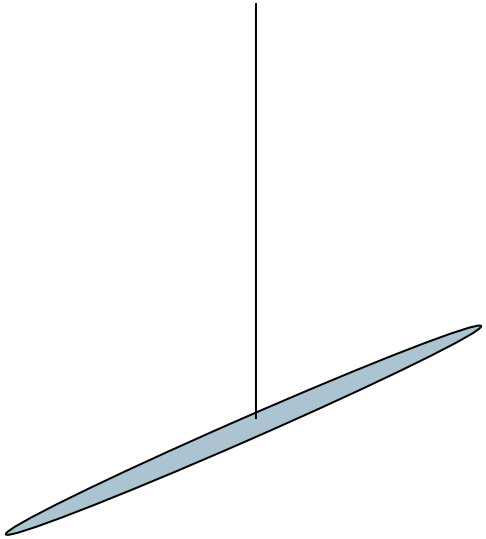

S
N
S
N


唐朝勅賜狀元鄒應龍地與形祠形之圖



Evidence of declination in the street plan of Shantan, Kansu.

Suspended compass



Floating compass

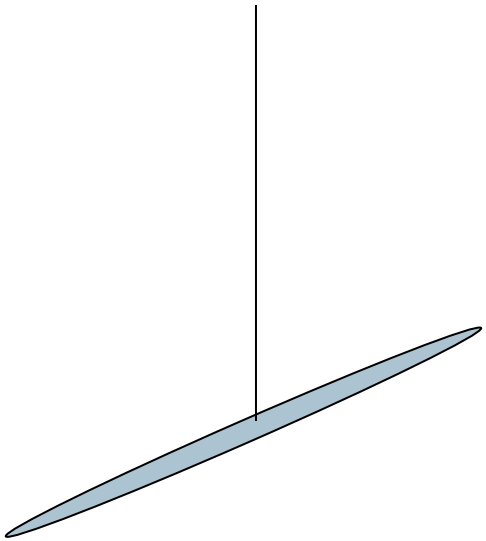
Shen Kua quote

Shen Kua (沈括) discovered how to make magnetized iron needles in 1060, and described the suspended needle compass in 1088. *Thermoremanence* and *induced magnetization* were discovered in China.

Suspended compass

Statue to the inventor

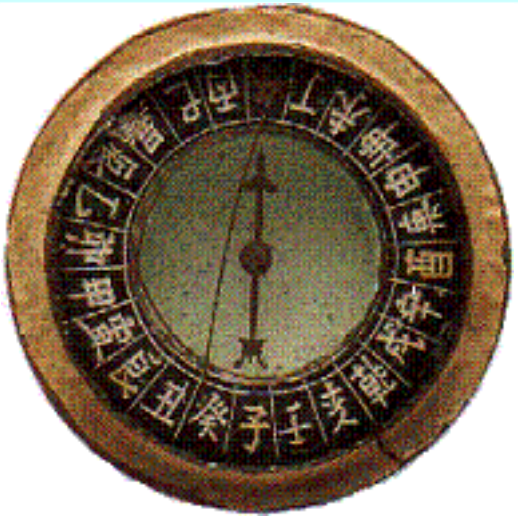
Bernal quote



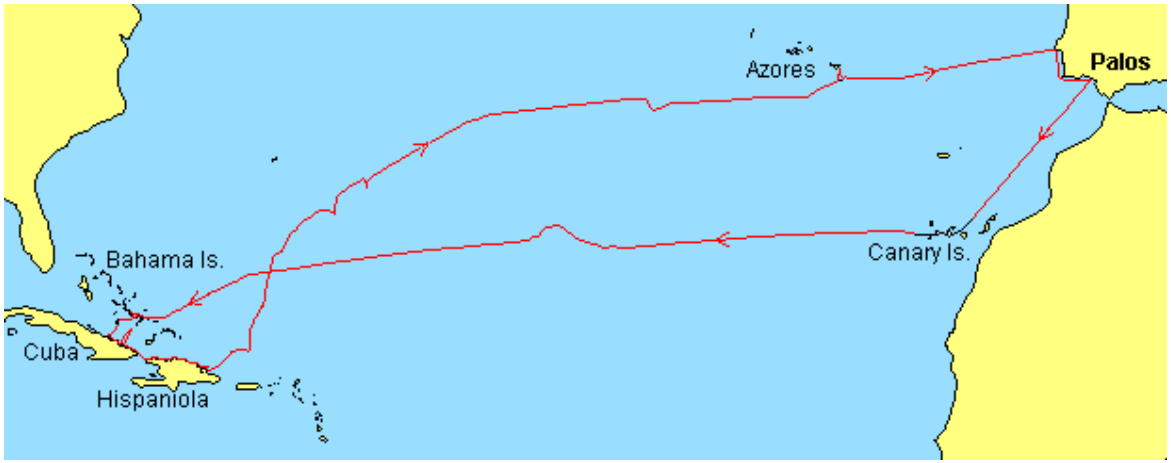
The English monk Alexander Neckham gives the first European description of the compass at the University of Paris in 1190.

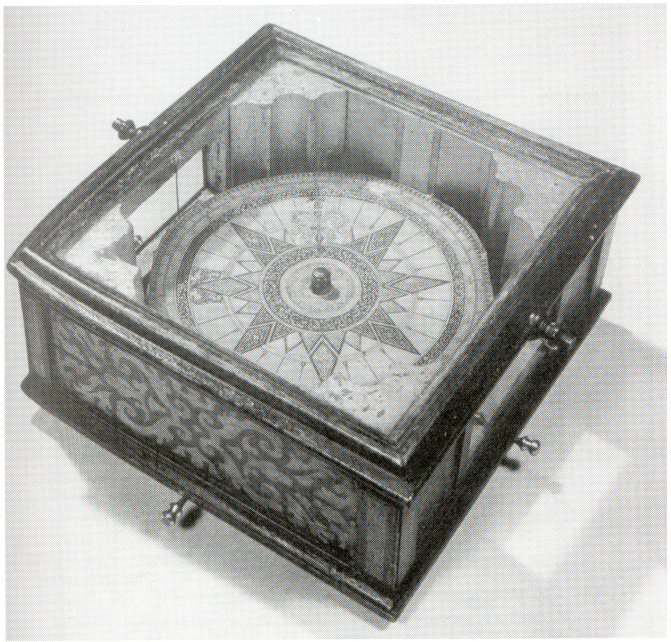
J D Bernal

Cheng Ho 1371-1428



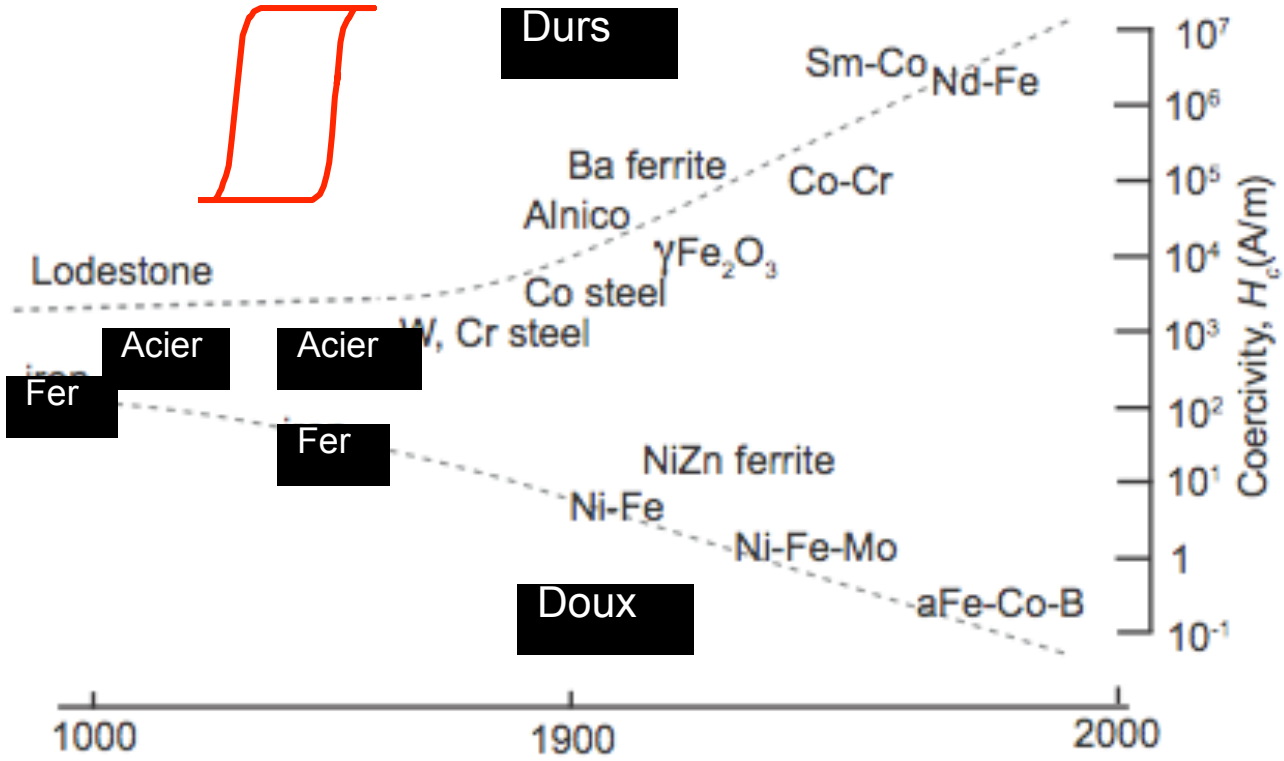
Christopher Columbus
1452 - 1506





Portuguese compass

Coercivité



L'histoire des matériaux magnétiques pendant le 20 ième siecle, c'est l'histoire de la maîtrise de la coercivité

1900: $10^{1} < H_c < 10^{4}$ A m^{-1} *2000*: $1 < H_c < 2\ 10^{7}$ A m^{-1}

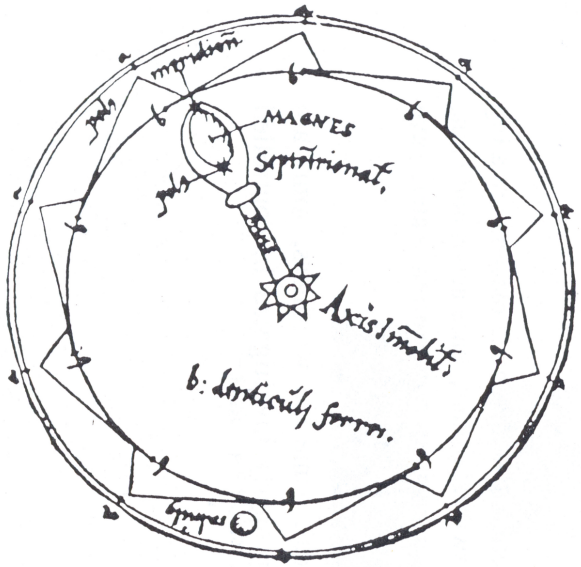
Dreams: magnetic levitation

The levitated island of Laputa from *Gulliver's Travels* by Johnathan Swift, 1727, was supposed to contain an enormous lodestone

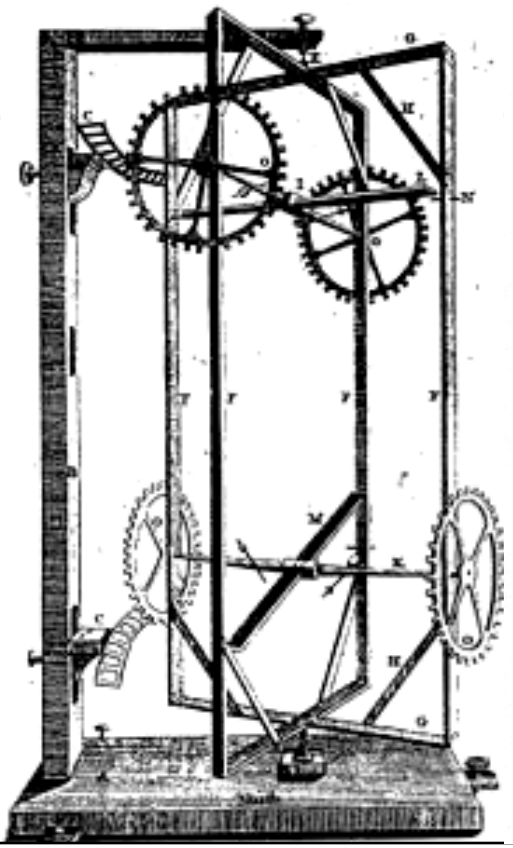
The fabulously-rich temple of Somnath in Gujerat was reputed to have a holy image magnetically-suspended in sanctuary. It was demolished by Muhmud of Ghazni in 1025.

Ghazni Quote

Dreams: perpetual motion



Petrus Peregrinus's perpetuum mobile from *Epistola de Magnete* (1269). Manuscript in TCD library



United States Patent [19]

Johnson

[54] PERMANENT MAGNET MOTOR

[76] Inventor: Howard R. Johnson, 3300 Mt. Hope Rd., Grass Lake, Mich. 49240

[21] Appl. No.: 422,306

[22] Filed: Dec. 6, 1973

[51] Int. Cl.² H02K 41/00; H02N 11/00

[52] U.S. Cl. 310/12; 310/152

[58] Field of Search ..... 24/DIG. 9; 415/DIG. 2; 46/236; 273/118 A, 119 A, 120 A, 121 A, 122 A, 123 A, 124, 125 A, 126 A, 130 A, 131 A, 131 AD, 134 A, 135 A, 136 B, 137 AE, 138 A

[56] References Cited

U.S. PATENT DOCUMENTS

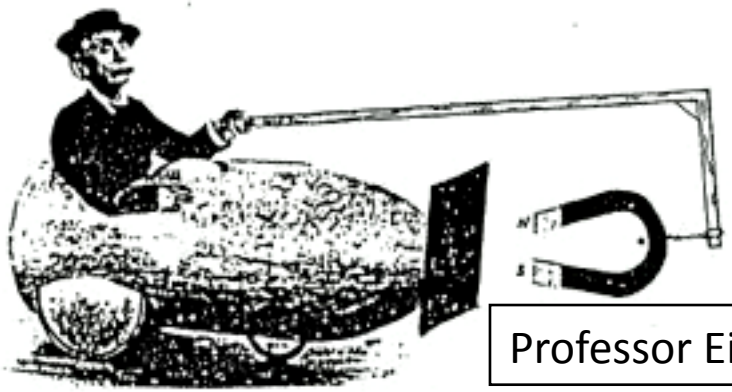
4,074,153 2/1978 Baker et al. 310/12

Primary Examiner—Donovan F. Duggan
Attorney, Agent, or Firm—Beaman & Beaman

[57] ABSTRACT

The invention is directed to the method of utilizing the unpaired electron spins in ferro magnetic and other materials as a source of magnetic fields for producing power without any electron flow as occurs in normal conductors, and to permanent magnet motors for utilizing this method to produce a power source. In the practice of the invention the unpaired electron spins occurring within permanent magnets are utilized to produce a motive power source solely through the superconducting characteristics of a permanent magnet and the magnetic flux created by the magnets are controlled and concentrated to orient the magnetic forces generated in such a manner to do useful continuous work, such as the displacement of a rotor with respect to a stator. The timing and orientation of magnetic forces at the rotor and stator components produced by permanent magnets to produce a motor is accomplished with the proper geometrical relationship of these components.

Croker's magnetic perpetual motion machine (1790) was only supposed to work in Barbados!



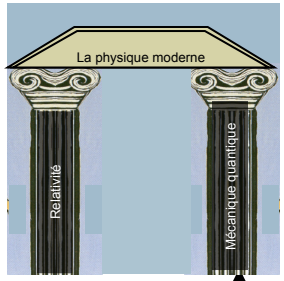
Professor Einstein's Magnetic Autocar, Berlin postcard, 1924.

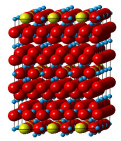
Thèse Marine LEPM CEN-G ILL Prix Nobel

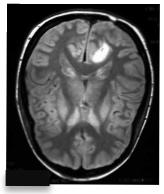
jeunesse | Ens | S'bourg | Grenoble | retraite

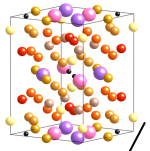
1900 1920 1940 1960 1980 2000

"Je ne désirais pas rester à Grenoble pour en faire le marche pied d'une carrière parisienne, mais bien avec l'intention de créer un centre de recherche suffisament important pour en retenir les cadres..."





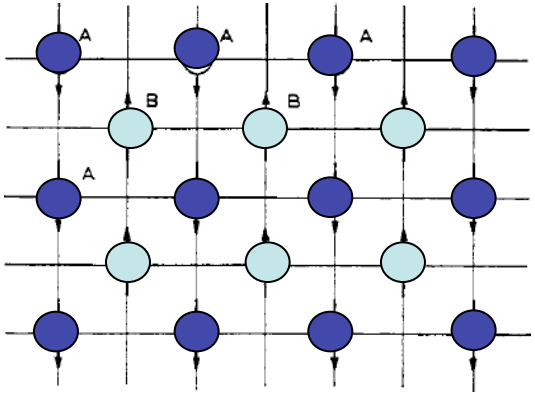


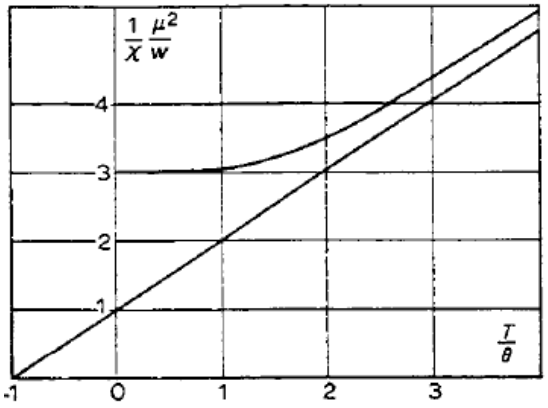


-e $E=mc^2$ $H_i=nM$ s ψ $\mathcal{H}=-JS_1.S_2$ rpe $BaFe_{12}O_{19}$ IRM pc $Nd_2Fe_{14}B$ gmr

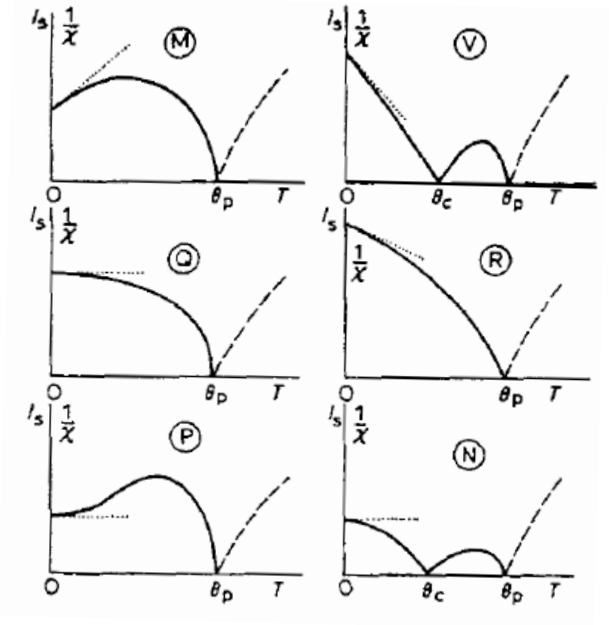
1900 1920 1940 1960 1980 2000

Antiferromagnétisme (paramagnetisme constante) 1936



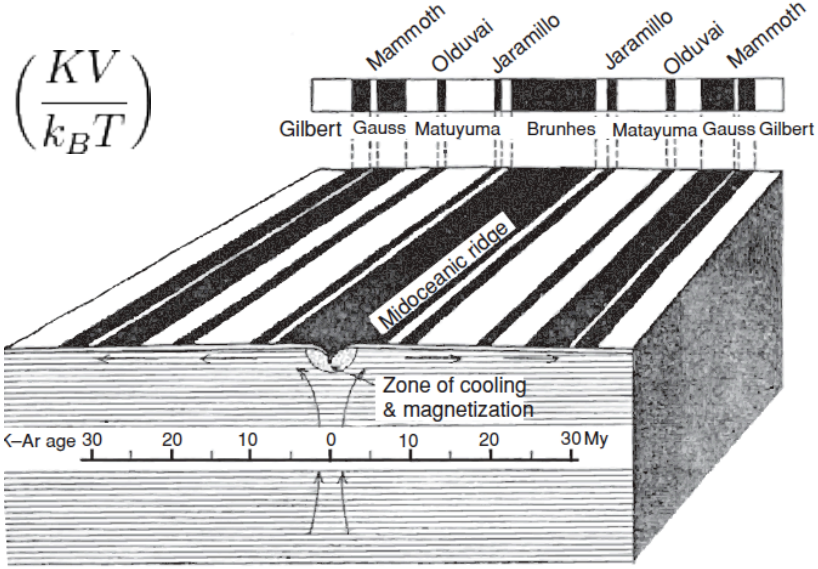


Ferrimagnétisme 1948



Superparamagnétisme (larves et terres cuites) 1949

$$\tau_N = \tau_0 \exp\left(\frac{KV}{k_B T}\right)$$

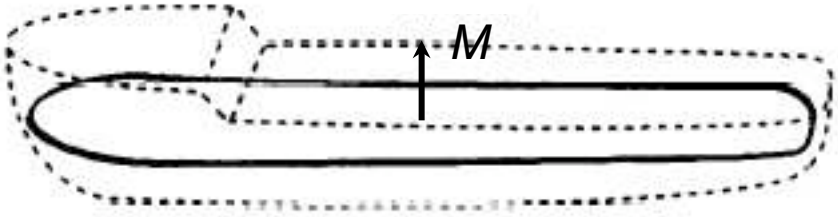


Prix Nobel 1970

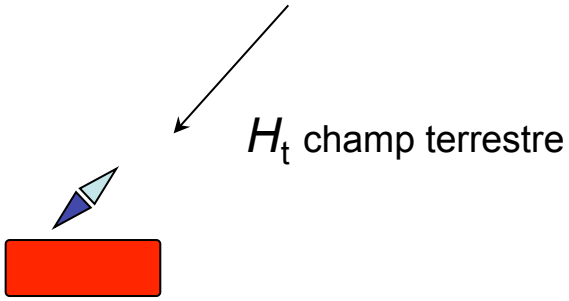
Louis Eugène Félix Néel

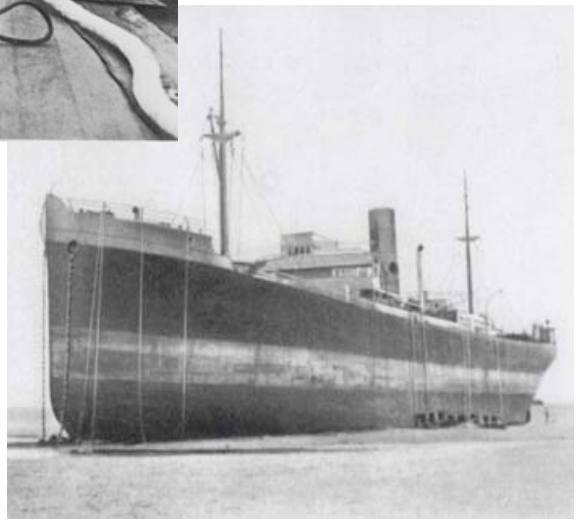
"For fundamental work and discoveries concerning antiferromagnetism and ferrimagnetism which have led to important applications in solid state physics"

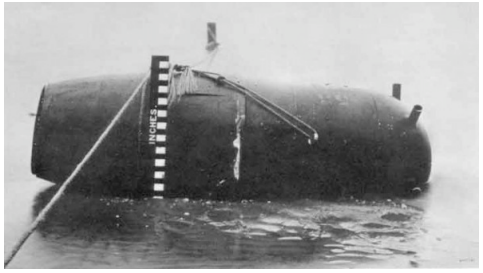
La désaimantation des navires. 1940



$M = aH + bH^2$







Septembre 1939; La guerre commence

Novembre 1939; Première mine magnétique allemande repêchée par les anglais

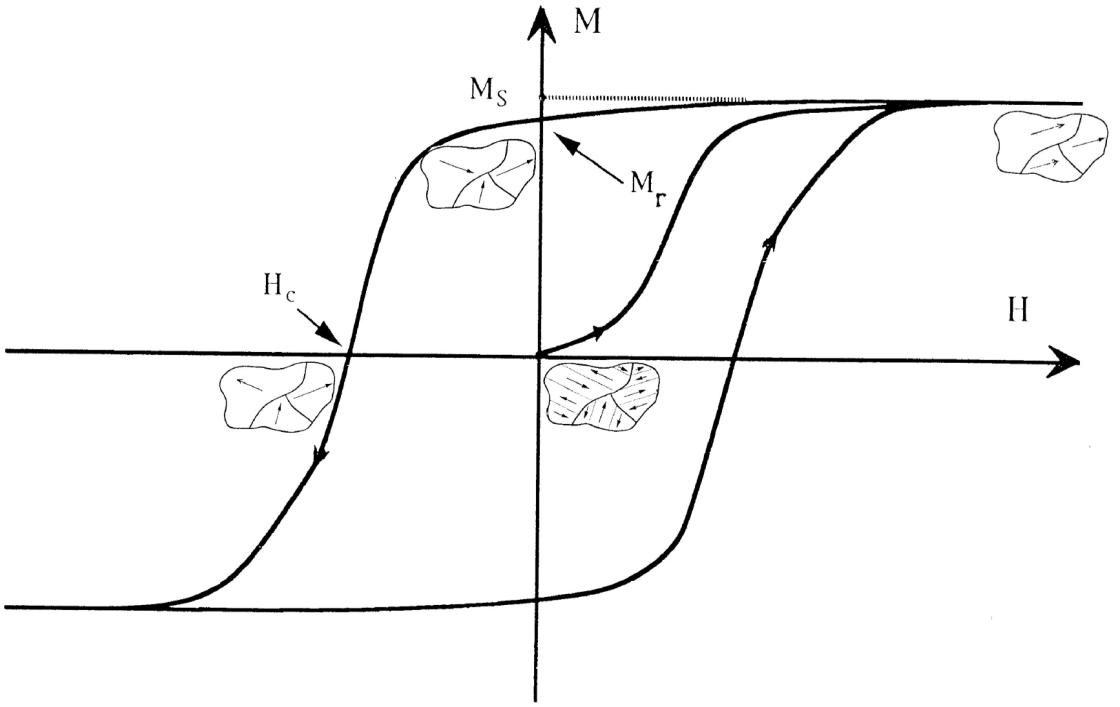
Janvier 1940; Première essai a désaimantation à Toulon

Avril 1940; Mission à Londres

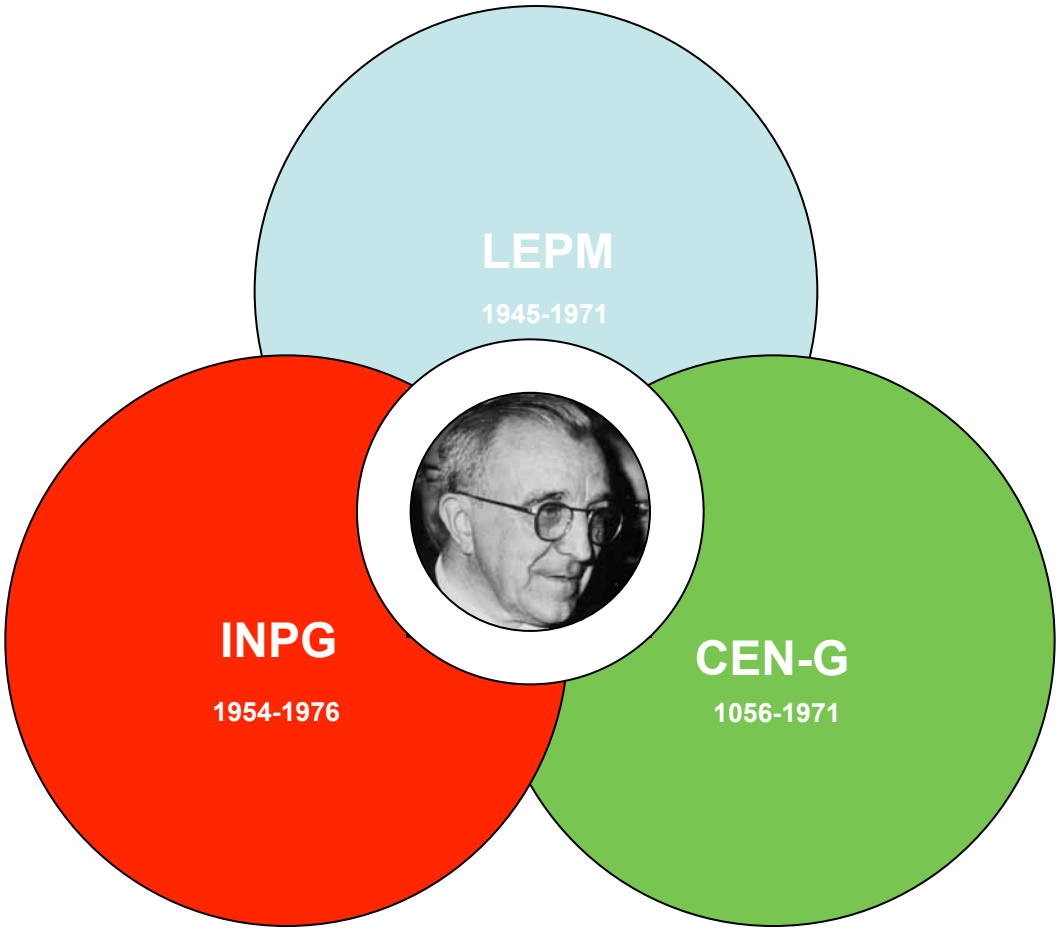
Mai 1940 Dunquerque

Juin 1940; Armistice. 520 navires désaimantes (6 par jour a Toulon et Cherbourg)

Juillet 1940; Déstruction de la flotte francaise à Mers el Kabir


M
M_S
M_r
H_c
H

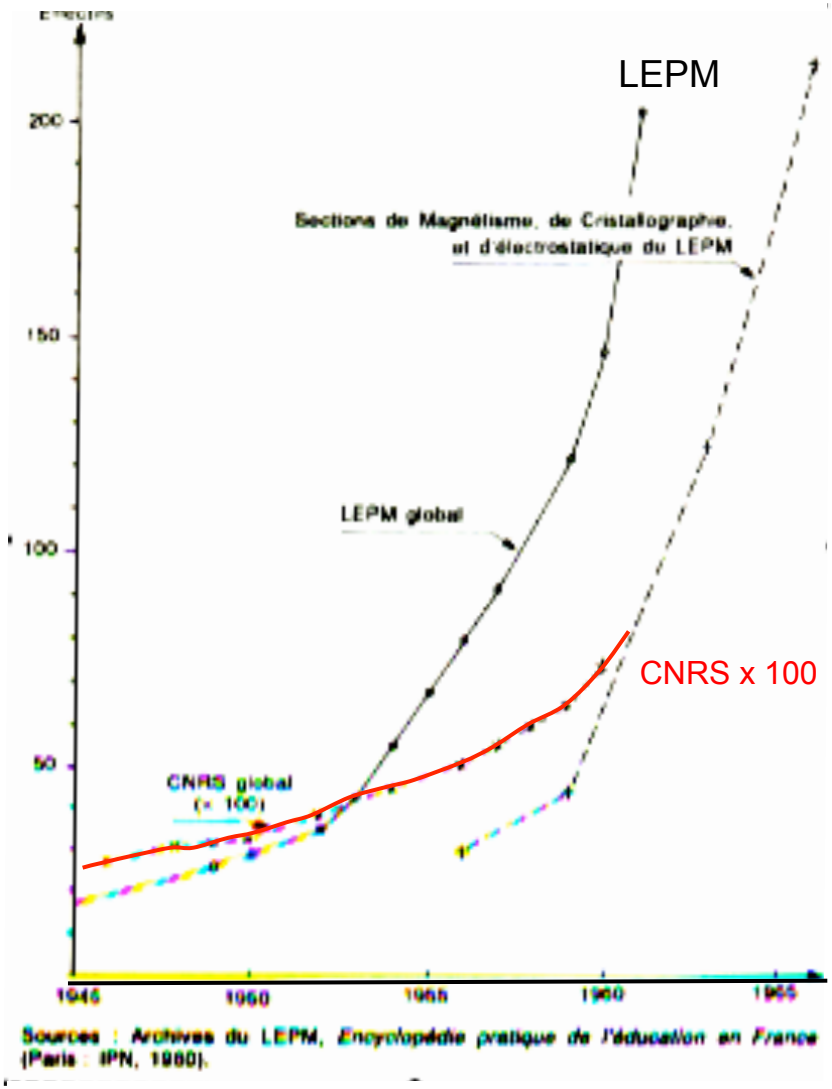
Cumul des mandats



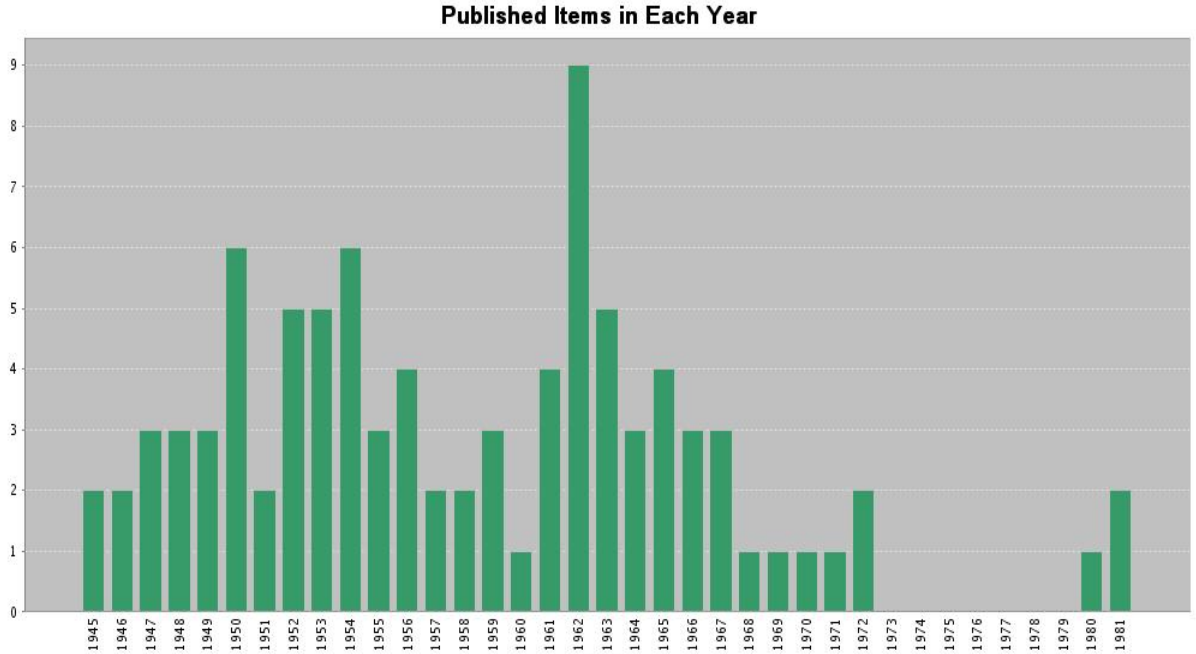
La construction du CEN-G


Grenoble
L'ancien polygone d'artillerie
Emplacement du Synchrotron Européen
Emplacement du futur ILL
Agrandissements du CEN-G
Labos. du LETI
Bâtiment administratif
CEN-G
Laboratoire d'Electrostatique et de Physique du Métal
Silos

Le Laboratoire d'Electrostatique et de Physique du Métal - CNRS



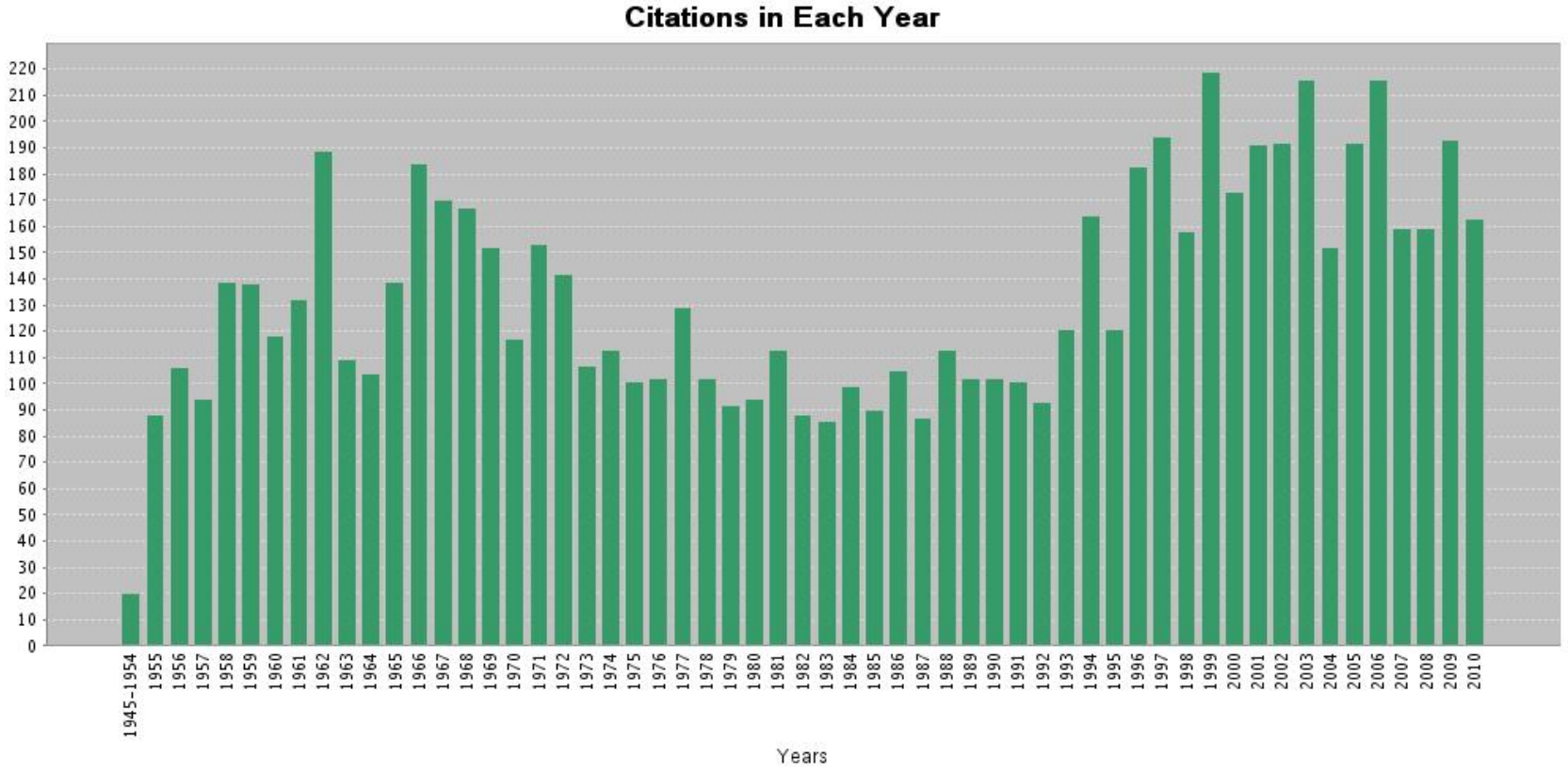
Institut Néel



Citations 7996

h 38

Citations/article 86

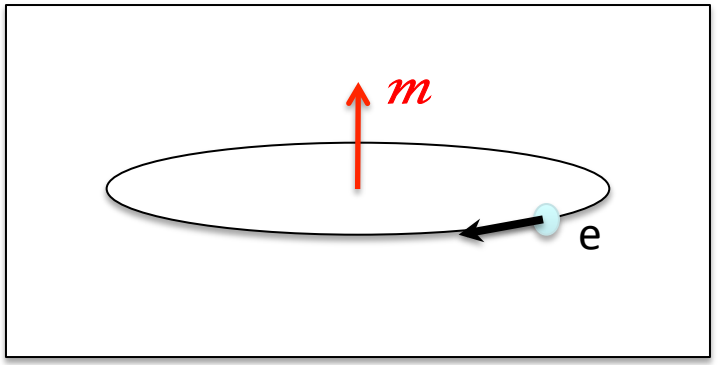


La plus importante est ce que j’avais fait à Grenoble. Pour le magnétisme, quelqu’un d’autre l’aurait découvert.

What of the dreams?

Perpetual motion.

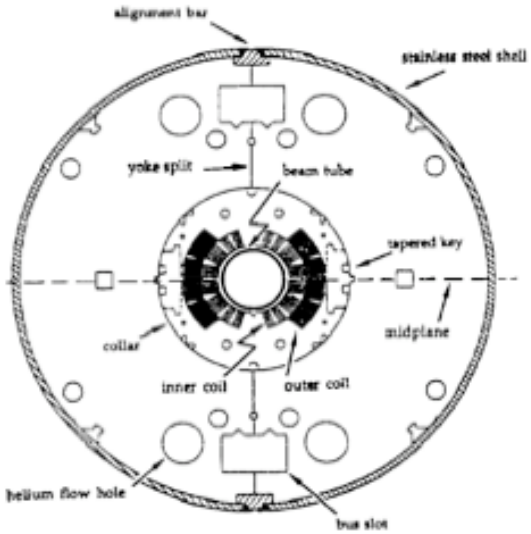
It exists somehow in the quantized angular momentum of the electron — but energy conservation is inviolate. The electronic *perpetuum mobile* can do no work



Levitation.

It *is* possible to have purely static levitation at room temperature using diamagnetic material, but the forces are very weak.

A thin sheet of graphite levitates above four permanent magnets



Superconducting magnets at the LHC, CERN produce a field of 6.7 T

A sumo wrestler standing on a magnetic plate levitated above a large disc of diamagnetic cuprate superconductor