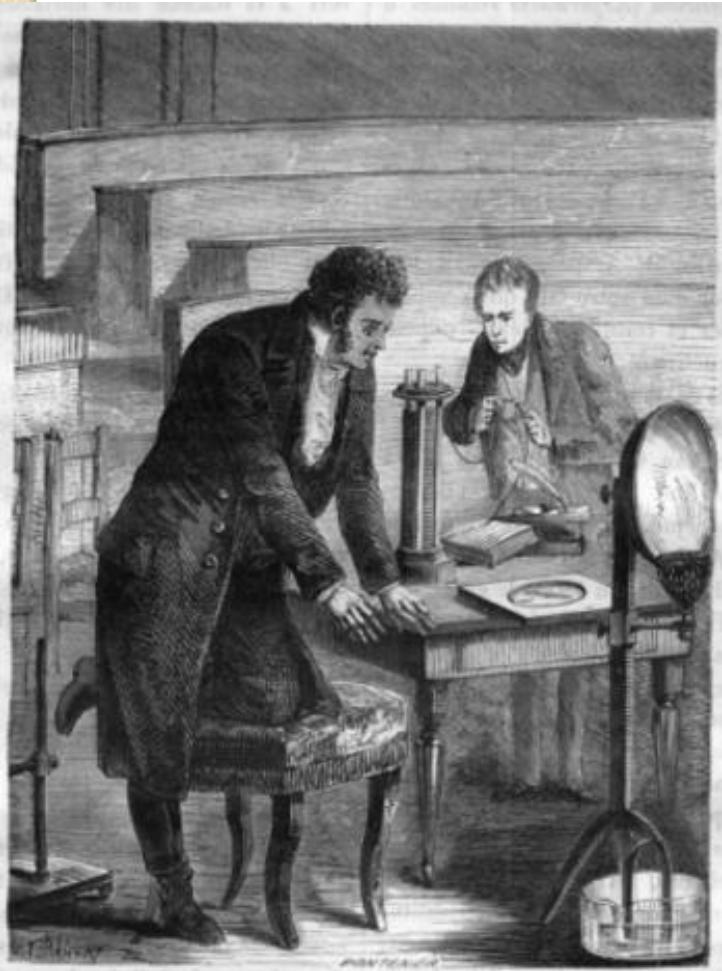


The Galvanometer



Oersted of Copenhagen

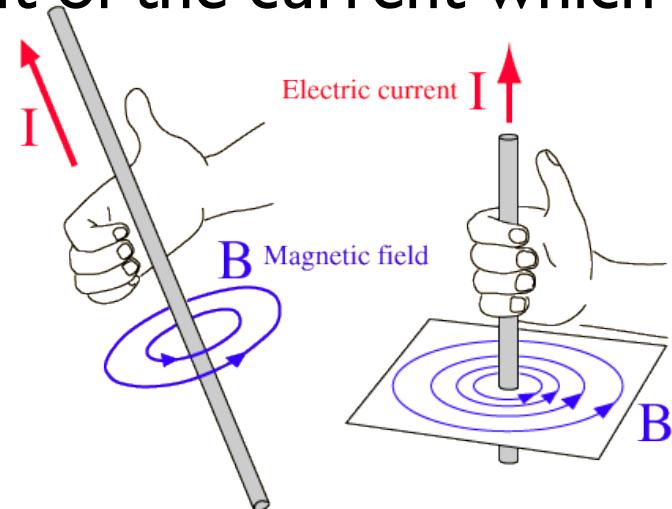


"Let the opposite poles of the galvanic apparatus be joined by a metallic wire...Let the rectilinear part of this wire be placed in a horizontal position over the magnetic needle duly suspended, and parallel to it...These things being thus arranged, the magnetic needle will be moved, and indeed, under that part of the joining wire which receives electricity most immediately from the negative end of the galvanic apparatus, will decline towards the west." -Oersted's pamphlet, "Experimenta circa efficaciam conflictus electrici in acum magneticam"

Ampere

“There was lacking an instrument which would enable us to recognize the presence of the electric current in a pile or a conductor and which would indicate the energy and the direction of it. This instrument now exists; all that is needed is that the pile, or any portion of the conductor, should be placed horizontally, approximately in the direction of the magnetic meridian, and that an apparatus similar to a compass, which, in fact, differs from it only in the use that is made of it, should be placed above the pile or either above or below a portion of the conductor. So long as the circuit is interrupted, the magnetic needle remains in its ordinary position, but it departs from this position as soon as the current is established, so much the more as the energy is greater...I think that to distinguish this instrument from the ordinary electrometer we should give it the name of galvanometer and that it should be used in all experiments on electric currents, as we habitually use an electrometer on electric machines, so as to see at every instant if a current exists and what is its energy.” - memoir, presented to the Academy of Sciences on October 2, 1820

“It determines the direction of the current from this general fact, that if one places oneself in thought in the direction of the current in such a way that it is directed from the feet to the head of the observer and that he has his face turned toward the needle; the action of the current will always throw toward the left that one of the ends of the needle which points toward the north and which I shall always call the austral pole of the magnetic needle, because it is the pole similar to the southern pole of the earth. I express this more briefly by saying, that the austral pole of the needle is carried to the left of the current which acts on the needle.”



Schweigger

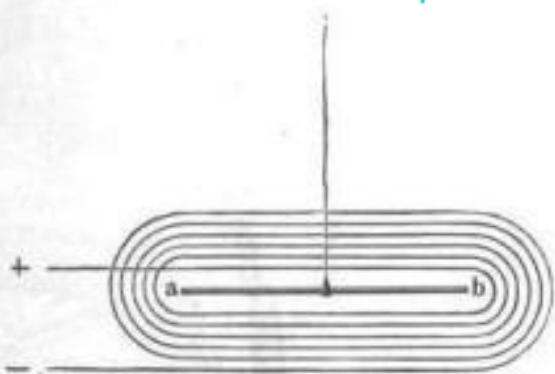
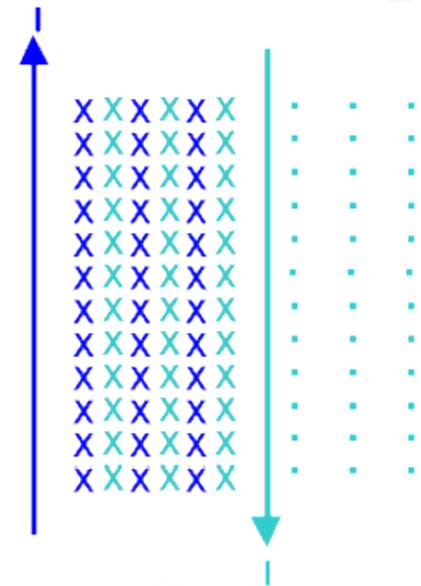
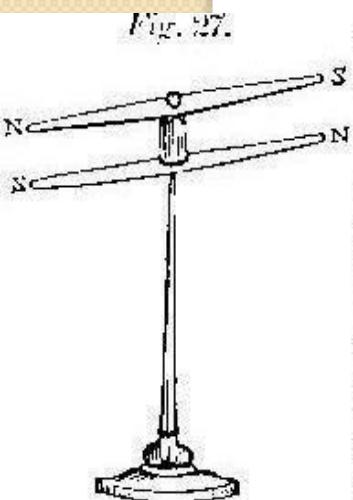
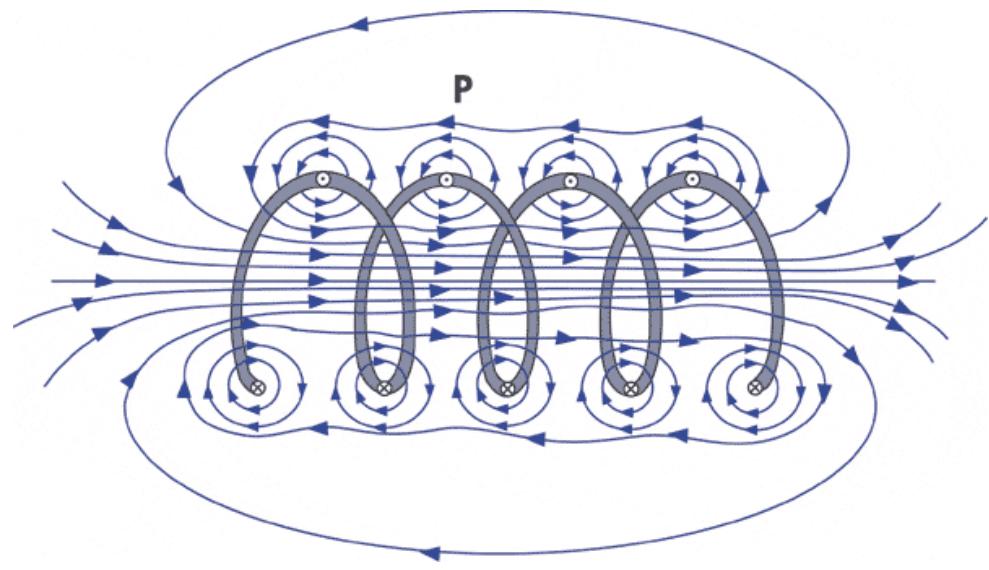
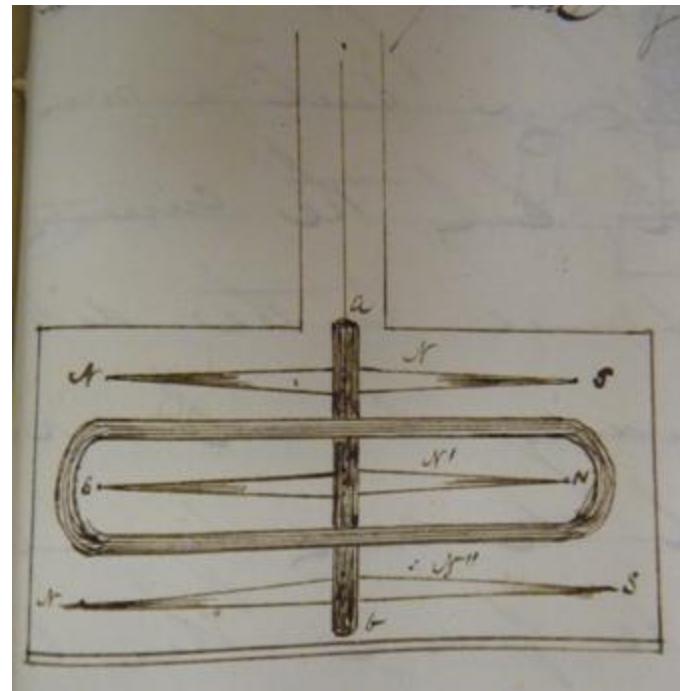
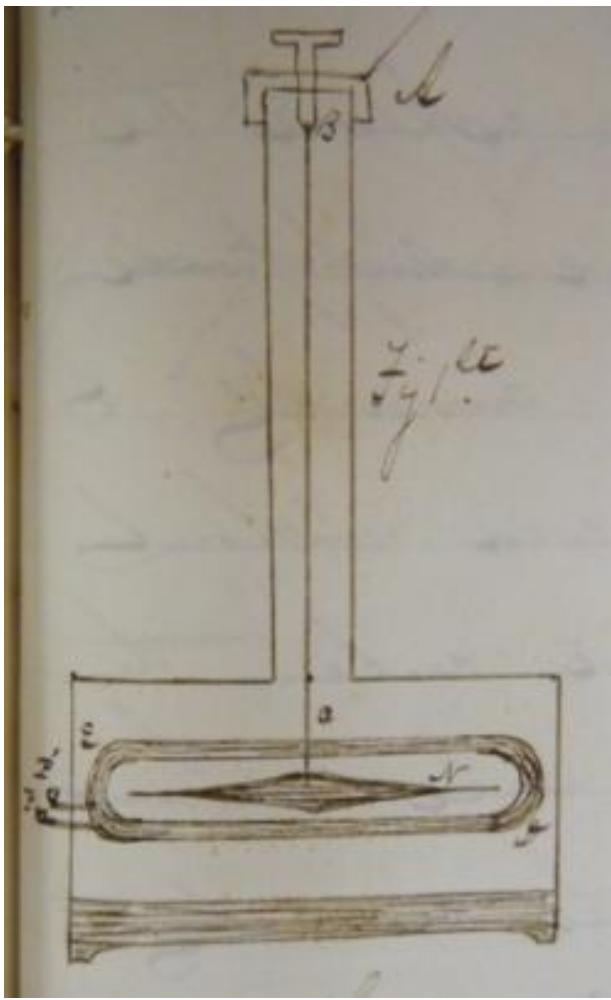


Fig. 62.



"We have noticed the fact that magnetism is much more powerful when acting through a coil of wire. Prof. Schweigger of Halle has taken advantage of this and invented an instrument called the galvanometer by which the smallest current of galvanism is readily detected. There are two forms of the instrument called the simple and compound. The first replicated in Fig 1st consists of [a] large coil of wire ED rolled upon itself and insulated with silk or wax, in this a needle N is suspended by a silk thread BC from a movable head A. The two ends of the copper wire coil terminate in two cups PP' containing a little mercury in order that they may be united with the poles of a battery when a current is required to be tested, and the whole is covered with a glass case. The compound galvanometer differs from the simple, only in having a greater number of needles. By this means we not only neutralize the magnetic influence of the earth, but also make the instrument more sensitive. These needles are suspended by a thread fastened to a straw ab or some other light substance into which the needles are placed." -Daniel Ayres Jr.'s Student Notebook, lecture notes from Joseph Henry's Natural Philosophy class, 1841





Quantity Versus ~~Quality~~

Intensity

"The galvanometers mentioned in this paper, and referred to in the last, are of two kinds; one, which is used with a helix, to indicate the action of an induced current of intensity, consists of about five hundred turns of fine copper wire, covered with cotton thread, and more effectually insulated by steeping the instrument in melted cement, which was drawn into the spaces between the spires by capillary attraction. The other galvanometer is formed of about forty turns of a shorter and thicker wire, and is always used to indicate an induced current, of considerable quantity, but of feeble intensity. The needle of both these instruments is suspended by a single fibre of raw silk." -Scientific Writings of Joseph Henry, Vol. I, p150

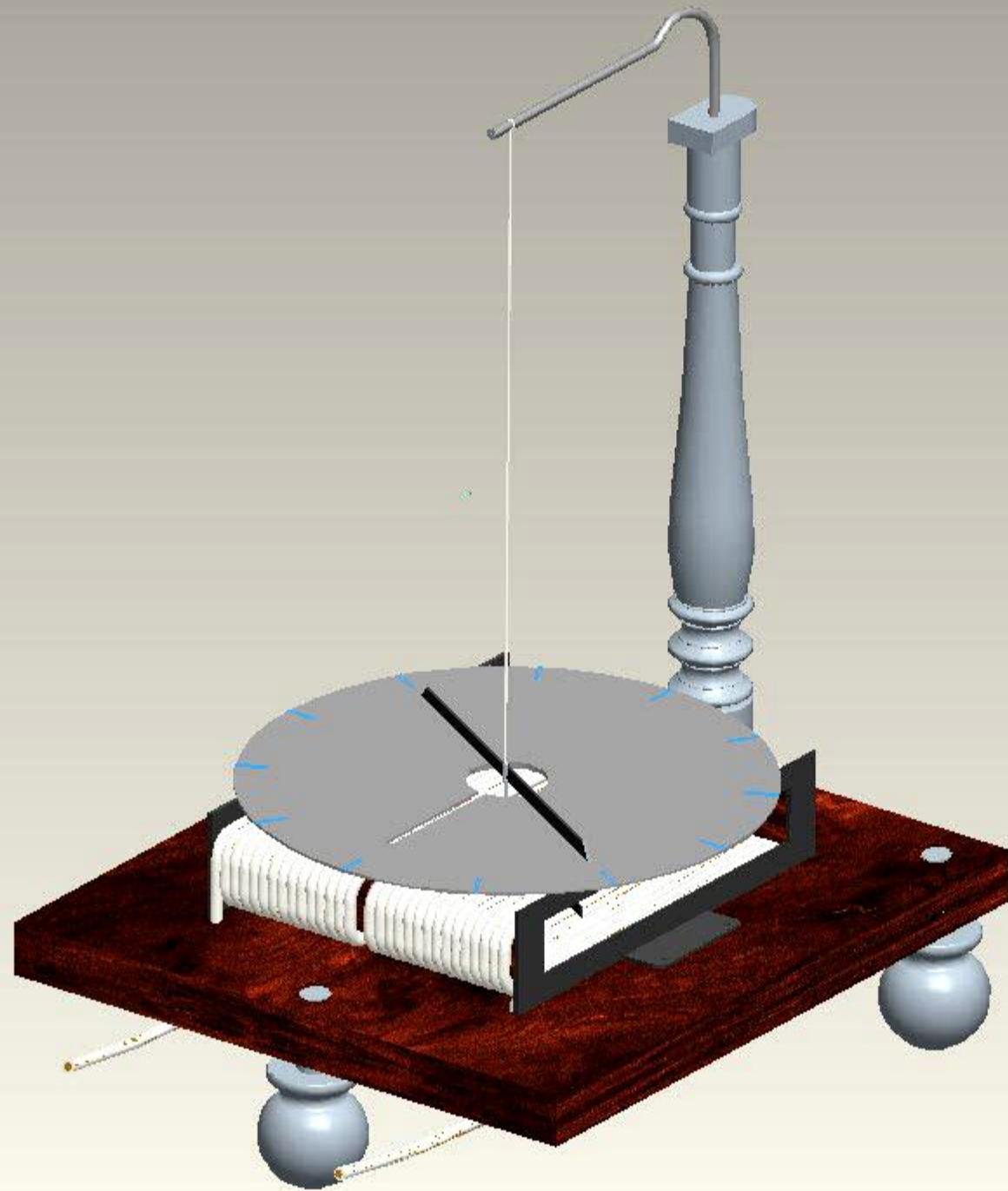


4 mm wire
30 turns
.04 Ohms



Versus

.50 mm wire
166 turns
6.55-6.75 Ohms





Understanding the Phenomenon

“To the effect which takes place in this conductor and in the surrounding space, we shall give the name of the conflict of electricity...The electric conflict acts only on the magnetic particles of matter. All non-magnetic bodies appear penetrable by the electric conflict, while magnetic bodies, or rather their magnetic particles, resist the passage of this conflict. Hence they can be moved by the impetus of the contending powers.

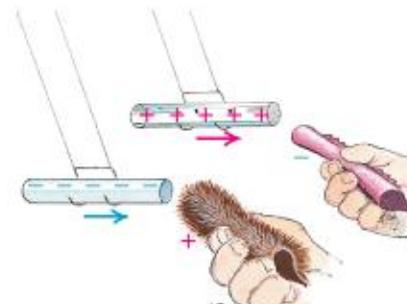
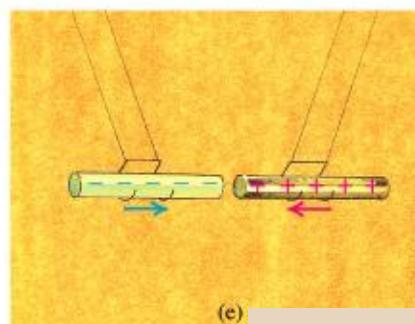
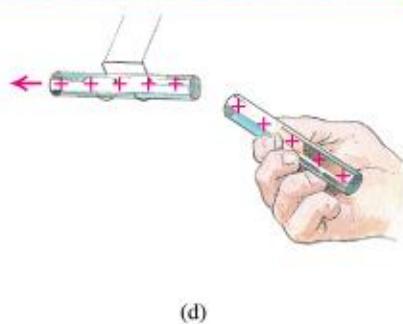
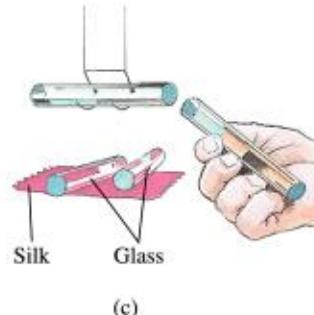
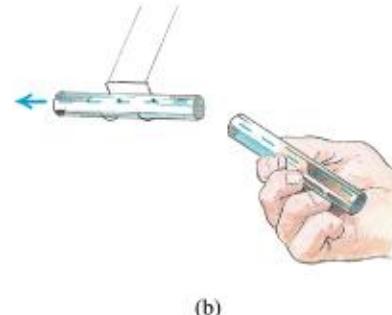
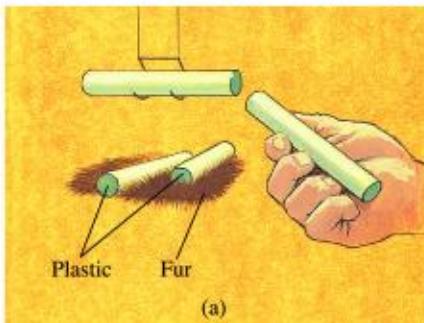
It is sufficiently evident from the preceding facts that the electric conflict is not confined to the conductor, but dispersed pretty widely in the circumjacent space.

From the preceding facts we may likewise infer that this conflict performs circles; for without this condition it seems impossible that the one part of the uniting wire, when placed below the magnetic pole, should drive it towards the east, and when placed above it towards the west; for it is the nature of a circle that the motions in opposite parts should have an opposite direction. Besides, a motion in circles, joined with a progressive motion, according to the length of the conductor, ought to form a conchoidal or spiral line; but this, unless I am mistaken, contributes nothing to explain the phenomena hitherto observed.

All the effects on the north pole above-mentioned are easily understood by supposing that negative electricity moves in a spiral line bent towards the right, and propels the north pole, but does not act on the south pole. The effects on the south pole are explained in a similar manner, if we ascribe to positive electricity a contrary motion and power of acting to the south pole, but not upon the north.” — “Experiments on the Effect of a Current of Electricity on the Magnetic Needle,” *Annals of Philosophy*, October 1820

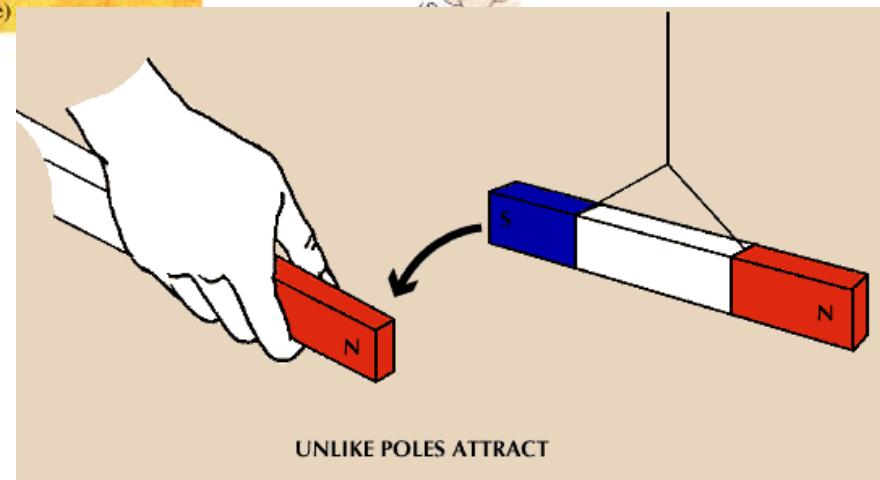
Fluid Theories

One-fluid
Franklin, Aepinus

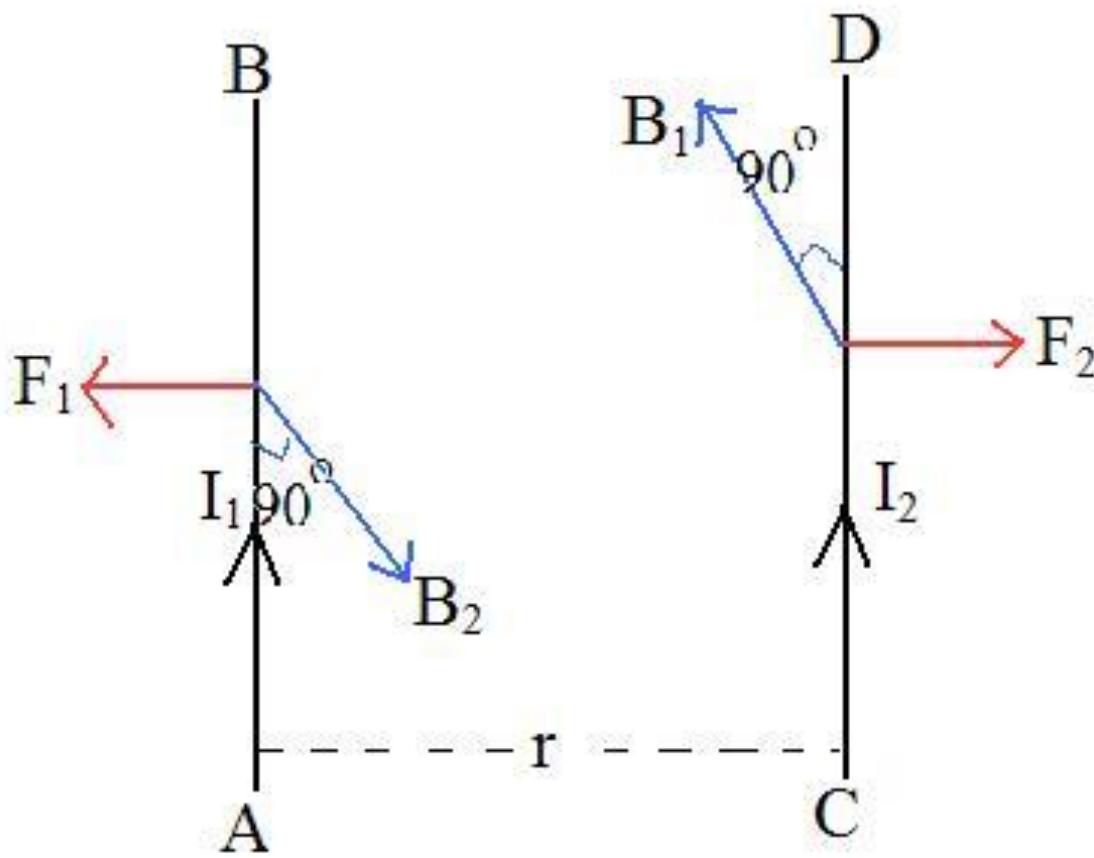


Copyright © Addison Wesley Longman, Inc.

Brugmans,
Wilcke-
Aural and boreal
fluids



du Fay-
vitreous and
resinous fluids
Supported by
Coulomb

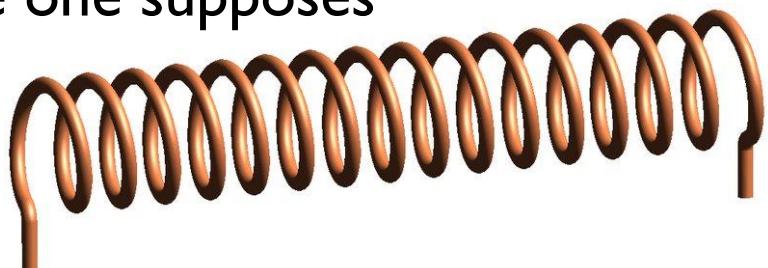


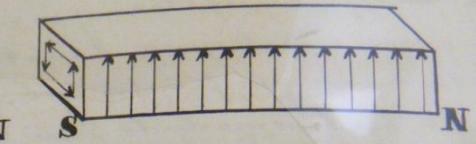
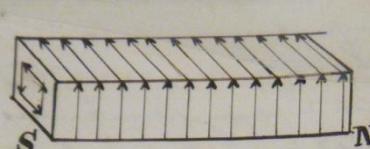
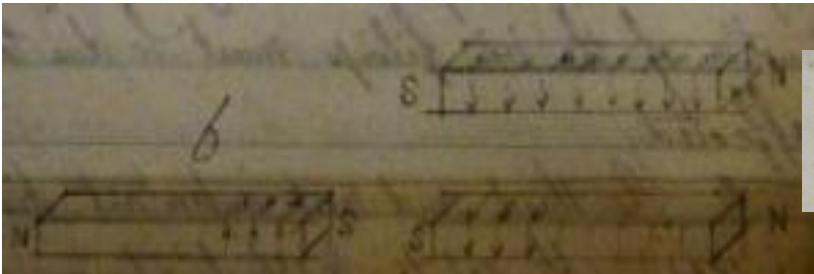
“We now turn to the examination of this last action and of the action of two magnets on each other and we shall see that they both come under the law of the mutual action of two electric currents, if we conceive one of these currents as set up at every point of a line drawn on the surface of a magnet from one pole to the other, in planes perpendicular to the axis of the magnet, so that from the simple comparison of facts it seems to me impossible to doubt that there are really such currents about the axis of a magnet, or rather that magnetization consists in a process by which we give to the particles of steel the property of producing, in the sense of the currents of which we have spoken, the same electromotive action as is shown by the voltaic pile... the current which is immediately established in this pile will act to direct it or to attract or repel it either by another electric current or by a magnet, which, as we shall see, is only an assemblage of electric currents.

It is thus that we come to this unexpected result, that the phenomena of the magnet are produced by electricity and that there is no other difference between the two poles of a magnet than their positions with respect to the currents of which the magnet is composed, so that the austral pole is that which is to the right of the currents and the boreal pole that which is to the left.” —memoir presented to the Academy, Oct 2. 1820

*-Theorie des
phenomenes
electrodynamique
uniquement
deduite de
l'experience*

“So long as one does not accept the explanation which I give of the action of magnets and so long as one attributes these two sorts of forces to molecules of an austral fluid and of a boreal fluid it is impossible to refer them to a single principle; but if one adopts my way of looking at the constitution of magnets, one sees by the preceding calculations that both these types of action and the values of the forces which result from them are deduced immediately from my formula, and that to find these values it is sufficient to substitute for the combination of two molecules, one of them of austral fluid, and the other of boreal fluid, a solenoid whose ends, which are the two definite points on which depend the forces with which we are dealing, are situated exactly at the points where one supposes the molecules of the two fluids to be situated.”





“Ampere’s theory which explains all these motions, rests as we have seen on the one fact. Currents in the same direction attract, in opposite directions repel, and the one hypothesis. Around every atom of the magnet currents of electricity are moving at right angles to the magnets length. The currents around the interior atoms (fig 5) neutralize each other’s effects, and those around the exterior atoms produce as their resultant the currents around the magnet. We say that these currents move around each atom of the magnet, because no matter into how many pieces we break a magnet, each portion still magnetic, ie. has these currents...

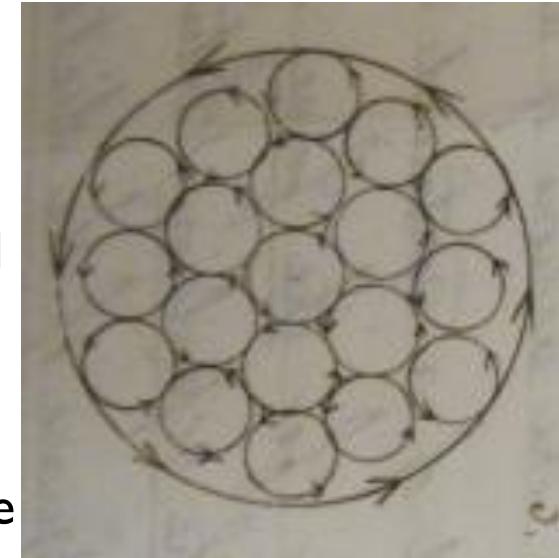
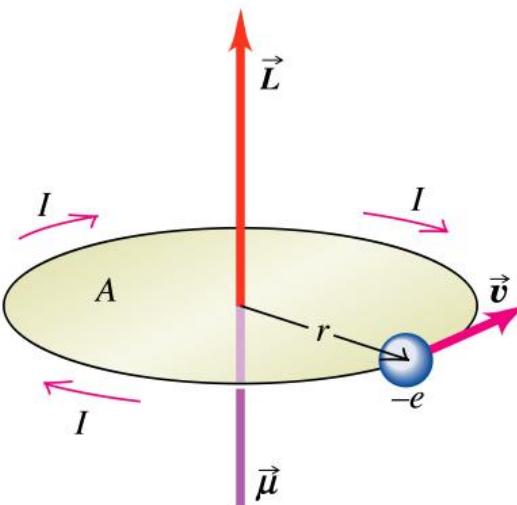


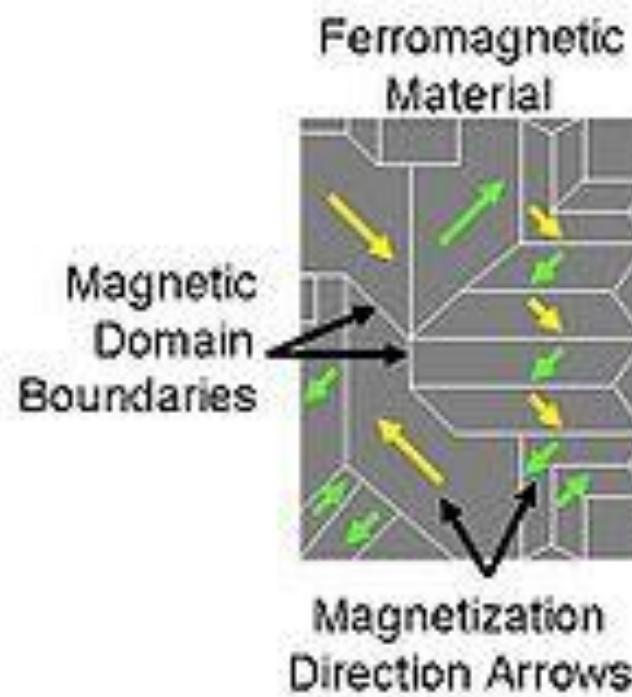
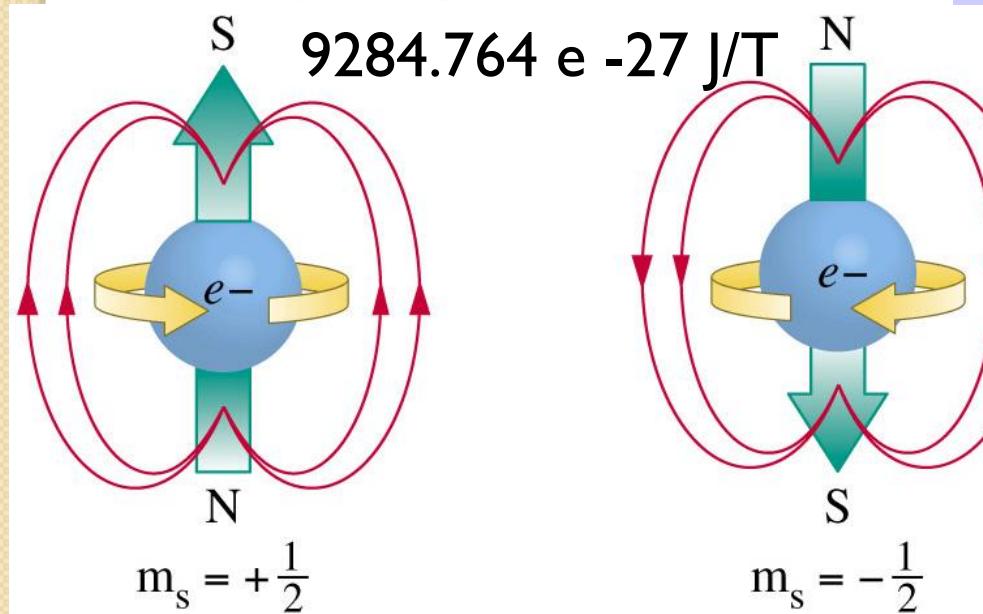
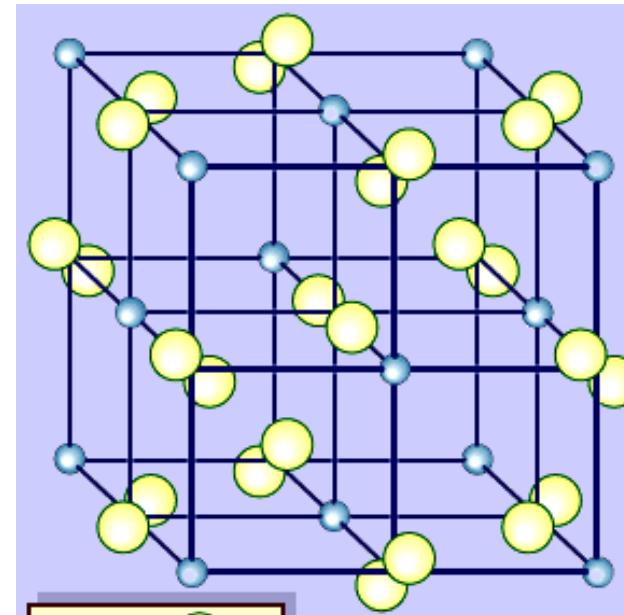
Figure 5

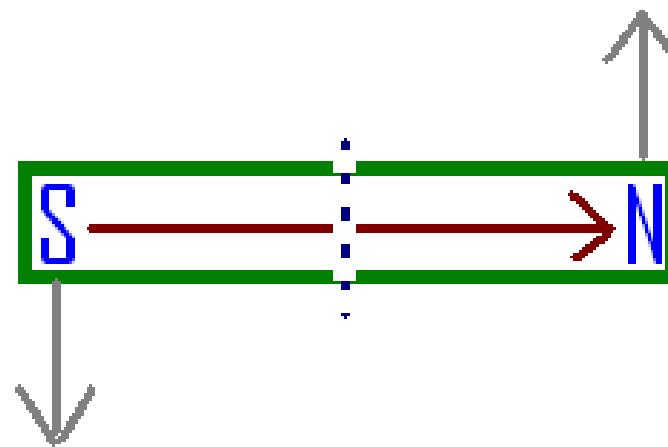
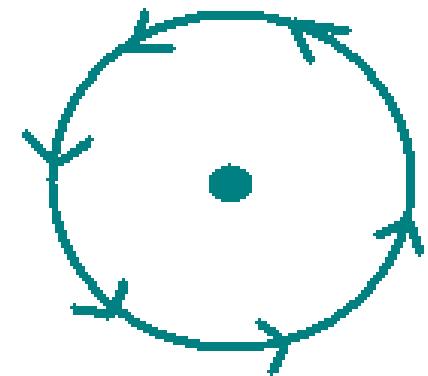
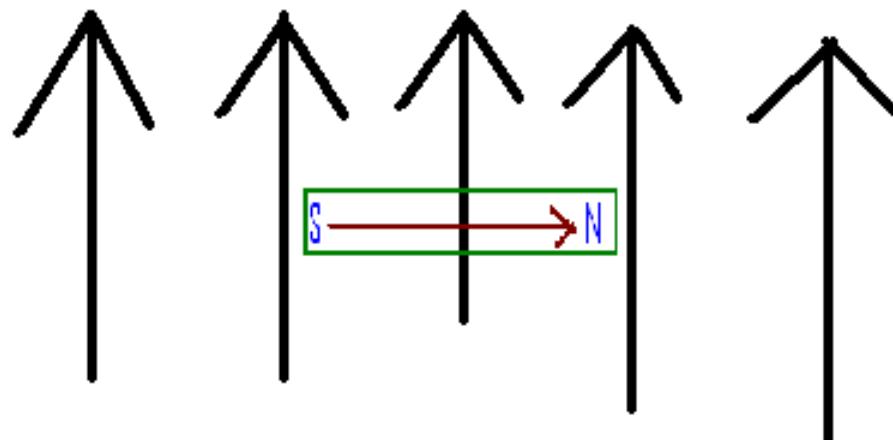
We can now explain Oersted’s experiment (p171).
The needle is turned at right angles to the connecting wire by the force which tends to bring the currents in the needle parallel, and in the same direction with that through the wire.”

-William J. Gibson’s
Notebook, 1842-3



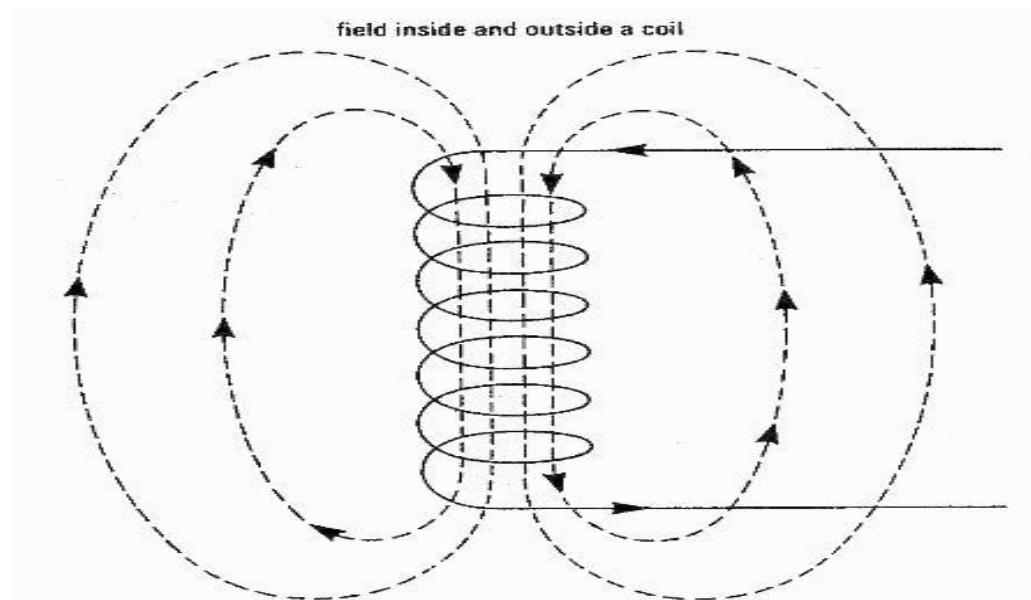
Copyright © Addison Wesley Longman, Inc.



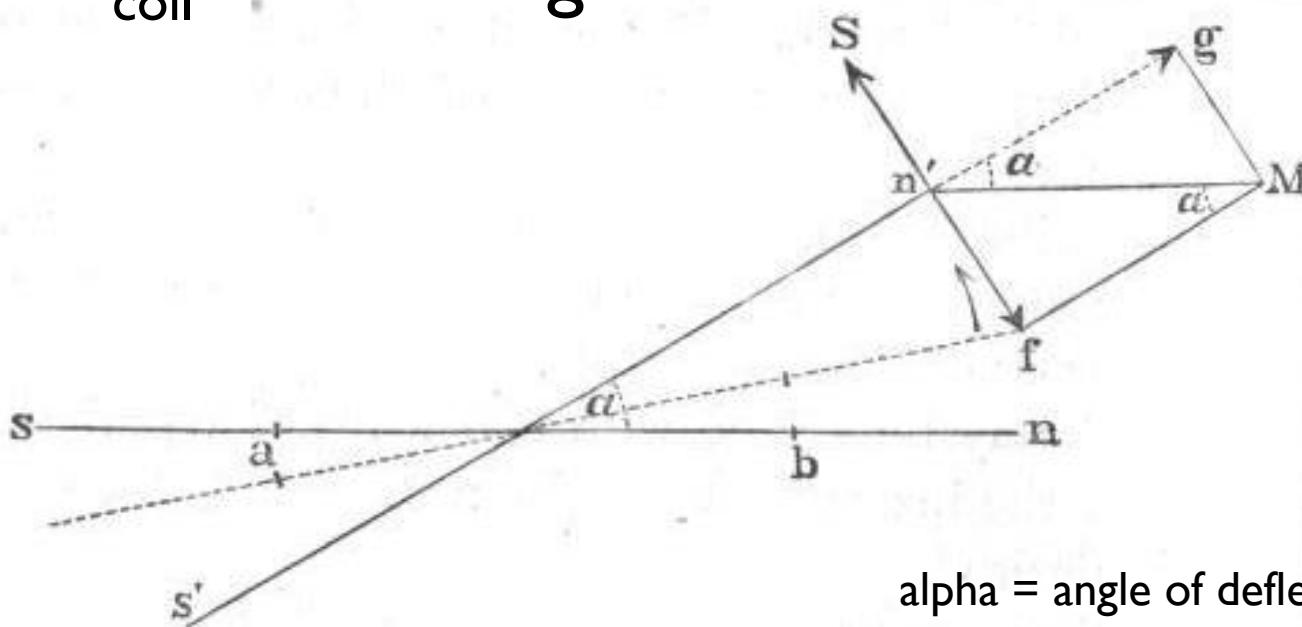


Problems

- Detection over quantitative measurement
- Needle moving out of plane of coil -> deflection not proportional
- Weak effect on needle above



- Magnetic torque from Earth's magnetic field = torque from coil's field
- $B_{\text{earth}} \sin(\alpha) = B_{\text{coil}}$
- $B_{\text{coil}} = \mu_{\text{naught}} * N * I / L$



α = angle of deflection
 $\mu_{\text{naught}} = 4 * \pi * 10^{-7}$
 N = # turns
 I = current
 L = length of coil
 B_{earth} at Princeton, NJ = 20,453.8 nT