DRAWING #1: MAGNETISM

MAGNETISM

AS ELECTRICITY BECAME STUDIED IN THE 18th CENTURY, THERE WAS SPECULATION THAT THERE MAY BE A CONNECTION BETWEEN ELECTRICITY AND MAGNETISM...

... WHICH WAS FOUND IN 1819.

NOTE: SOME OF THE CONCEPTS FROM ELECTROSTATICS CAME AFTER THIS (e.g., GAUSS'S LAW WAS FORMULATED IN 1835, BUT NOT PUBLISHED UNTIL 1867).

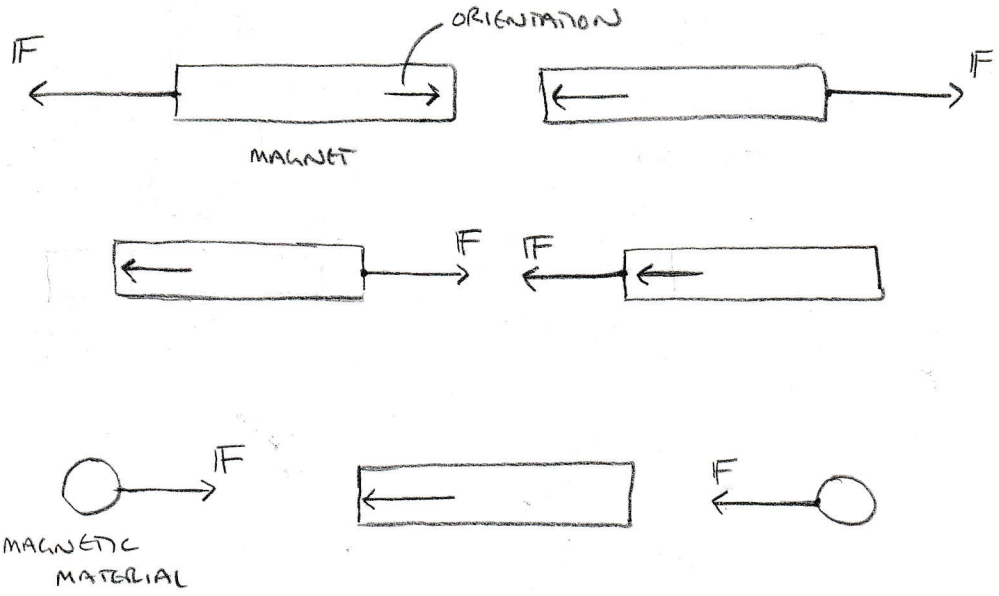
AN UNDERSTANDING OF MAGNETISM, AND ITS CONNECTION TO ELECTRICITY, BEGINS WITH MAGNETS...

DRAWING #2: MAGNETS AND MAGNETIC MATERIALS

A MAGNET IS A MATERIAL OR OBJECT THAT EXERTS AN ATTRACTIVE FORCE ON CERTAIN MATERIALS, AND ATTRACTS OR REPELS OTHER MAGNETS, DEPENDING ON THEIR RELATIVE ORIENTATION.

THE MAGNETIC FORCE

THESE ARE CALLED MAGNETIC MATERIALS.



NOTE: WHILE CERTAIN OBJECTS CAN BE MAGNETIZED, THEY DO NOT TEND TO STAY MAGNETIZED; PERMANENT MAGNETS ARE PERSISTENTLY MAGNETIZED.

A NUMBER OF FEATURES ANALOGOUS TO ELECTROSTATICS CAN BE OBSERVED.

DRAWING #3: BAR MAGNET (MAGNETIC POLES) MODEL

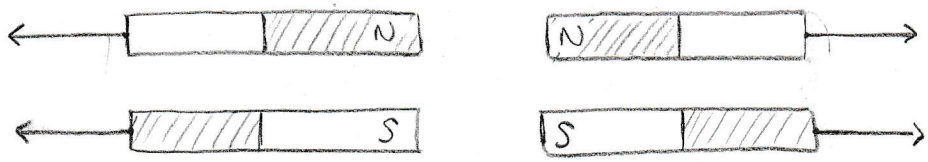
IT IS USEFUL TO DEVELOP A MODEL TO DESCRIBE THE PROPERTIES OF MAGNETS. ONE SUCH MODEL IS THAT OF MAGNETIC POLES:

CONSIDER A BAR MAGNET; A BAR WITH NORTH (N) AND SOUTH (S) MAGNETIC POLES:

NOTE: THE CONCEPT OF POLES (AND NORTH/SOUTH) SHOULD NOT BE TAKEN LITERALLY; THIS IS SIMPLY A WAY OF DESCRIBING THE TWO ENDS OF A MAGNET.

WITH THIS MODEL, WE CAN DESCRIBE THE DIRECTION OF THE FORCE BETWEEN MAGNETS:

LIKE POLES REPEL



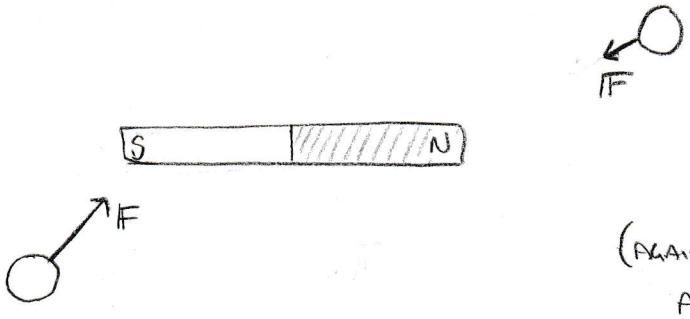
UNLIKE POLES ATTRACT

THE BEHAVIOR OF MAGNETIC POLES IS ANALOGOUS TO THAT OF ELECTRIC CHARGE (LIKE CHARGES REPEL; UNLIKE CHARGES ATTRACT)...

(WE WILL COME BACK TO "ANALOGOUS")

DRAWING #4: BAR MAGNETS AND MAGNETIC MATERIALS

WE CAN ALSO DESCRIBE THE INTERACTION BETWEEN A BAR MAGNET AND MAGNETIC MATERIALS:



(AGAIN, THE FORCE IS EVERYWHERE ATTRACTIVE)

THIS BEHAVIOR IS ANALOGOUS TO THAT IN ELECTROSTATICS, WHERE NEUTRAL OBJECTS ARE ATTRACTED TO CHARGED OBJECTS, IRRESPECTIVE OF THE SIGN OF THE CHARGE (DUE TO POLARIZATION).

(WE WILL COME BACK TO "ANALOGOUS")

NOTE: THIS IS THE EXTENT TO WHICH WE'LL CONSIDER MAGNETIC MATERIALS

DRAWING #5: THE MAGNETIC FIELD I

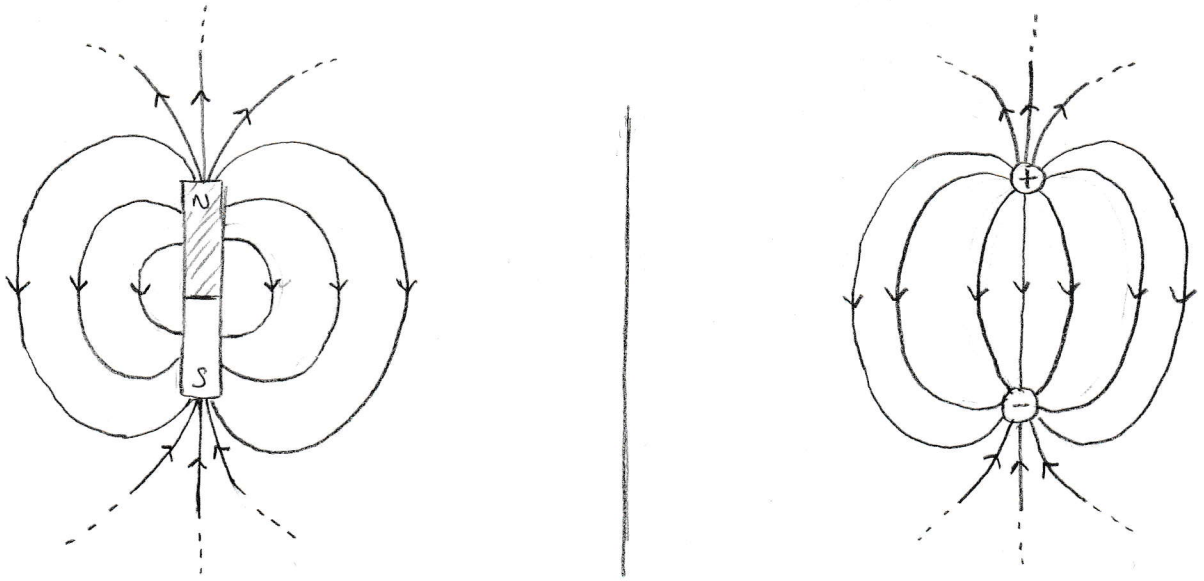
THE PRIOR EXAMPLES SHOW THAT THE MAGNETIC FORCE IS A LONG-RANGE FORCE (ACTION AT A DISTANCE).

WE ENCOUNTERED ACTION AT A DISTANCE IN ELECTROSTATICS, WHERE THE MATHEMATICAL CONCEPT OF A FIELD WAS INTRODUCED AS A WAY TO DESCRIBE THE LONG-RANGE ELECTRICAL FORCE.

THIS SUGGESTS THAT WE CAN DEFINE AN ANALOGOUS MAGNETIC FIELD ($\vec{B}$) AROUND OUR MAGNETS.

NOTE: IN ELECTROSTATICS WE DEFINED THE ELECTRIC FIELD AS THE FORCE THAT A CHARGE WOULD EXPERIENCE AT ANY POINT IN SPACE; HERE WE HAVE NOT YET MADE ANY PRECISE SPECIFICATION.

A COMPARISON OF WHAT THE ELECTRIC AND MAGNETIC FIELDS MIGHT LOOK LIKE:



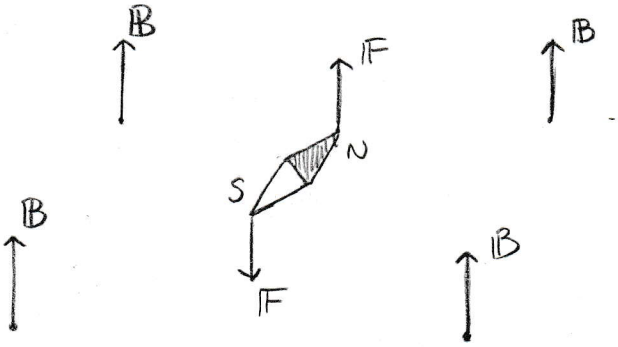
NOTE: THESE FIELDS ARE DRAWN USING FIELD LINES.

DRAWING #6 : THE MAGNETIC FIELD 2

IN ANALOGY WITH THE ELECTRIC FIELD, THE MAGNETIC FIELD ($\mathbb{B}$) EXERTS A FORCE ON MAGNETIC POLES.

NOTE: BY CONVENTION, THE FORCE ON A NORTH POLE IS PARALLEL TO $\mathbb{B}$; THAT ON A SOUTH POLE IS OPPOSITE TO $\mathbb{B}$.

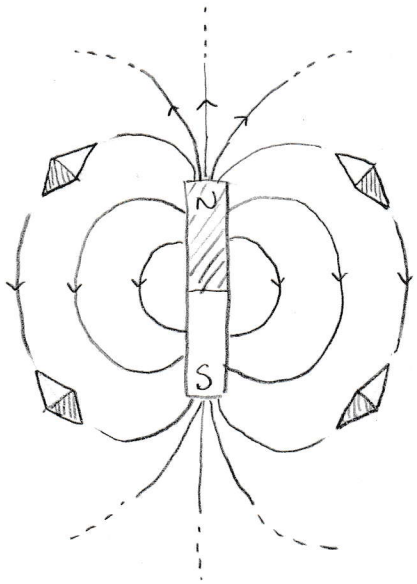
EXAMPLE:



NOTE: THE BAR MAGNET HAS BEEN DRAWN IN THE SHAPE OF A COMPASS NEEDLE.

THEREFORE, A SMALL MAGNET CAN BE USED TO "MAP OUT" THE MAGNETIC FIELD OF ANOTHER MAGNET (THIS IDEA IS SIMILAR TO THAT OF A TEST CHARGE IN ELECTROSTATICS).

EXAMPLE:



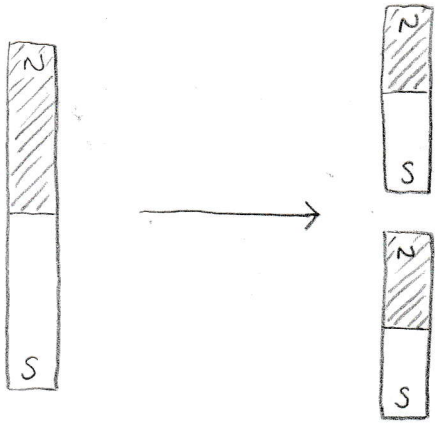
DRAWING #7: MAGNETIC CHARGE (MONOPOLE)

THEREFORE, THERE ARE A NUMBER OF SIMILARITIES BETWEEN MAGNETIC POLES AND ELECTRIC CHARGES (FORCES, THE CONCEPT OF A FIELD, ETC.) ...

... HOWEVER, THERE IS NO EXPERIMENTAL EVIDENCE THAT AN ANALOGOUS MAGNETIC CHARGE (OR MONOPOLE) EXISTS.

IT IS IMPOSSIBLE TO MAKE A MAGNETIC MONOPOLE FROM A BAR MAGNET BY CUTTING IT IN HALF...

... IF A BAR MAGNET IS CUT IN HALF, EACH PIECE ENDS UP WITH ITS OWN NORTH AND SOUTH POLES!



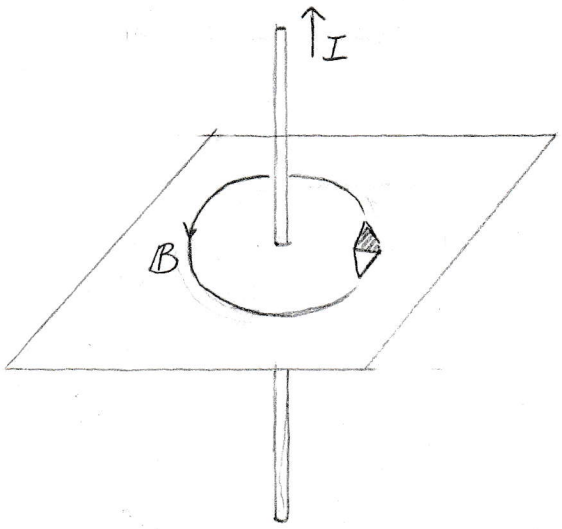
THEREFORE, UNLIKE IN ELECTROSTATICS (WHERE THE ELECTRICAL FORCE ACTS BETWEEN CHARGES AND/OR CHARGE DISTRIBUTIONS), THE MAGNETIC FORCE DOES NOT ARISE FROM A MAGNETIC CHARGE (MONOPOLE).

ALSO UNLIKE IN ELECTROSTATICS, WHERE ALL NEUTRAL OBJECTS ARE ATTRACTED TO CHARGED OBJECTS, ONLY MAGNETIC MATERIALS ARE ATTRACTED TO A MAGNET.

DRAWING #8: THE CONNECTION BETWEEN ELECTRICITY AND MAGNETISM

THE CONNECTION BETWEEN ELECTRICITY AND MAGNETISM CAME IN 1819 BY HANS CHRISTIAN ØRSTED:

MAGNETISM IS CAUSED BY AN ELECTRIC CURRENT (I) (THE TOTAL CHARGE PASSING THROUGH ANY SURFACE)



NOTE THE CIRCULATION OF B AROUND I.

NOTE FURTHER THE STRANGE DIRECTIONAL CHARACTER OF THE MAGNETIC FIELD: THE DIRECTION OF B IS GIVEN BY THE RIGHT-HAND RULE, GIVEN THAT THE CURRENT FLOWS IN THE DIRECTION OF THE THUMB.

IN OTHER WORDS:

MOVING CHARGES ARE THE SOURCE OF THE MAGNETIC FIELD