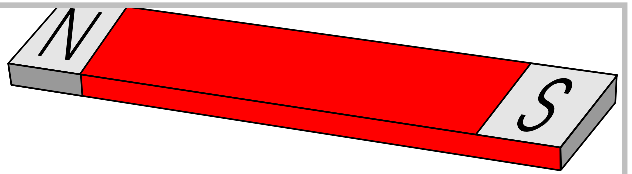
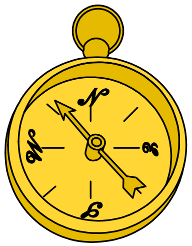
Magnetism



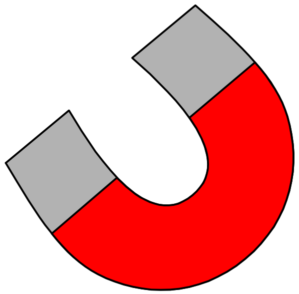
The ancient Greeks, originally those near the city of Magnesia, and also the early Chinese knew about strange and rare stones (possibly chunks of iron ore struck by lightning) with the power to attract iron. A steel needle stroked with such a "lodestone" became "magnetic" as well, and around 1000 the Chinese found that such a needle, when freely suspended, pointed north-south.

The magnetic compass soon spread to Europe. Columbus used it when he crossed the Atlantic ocean, noting not only that the needle deviated slightly from exact north (as indicated by the stars) but also that the deviation changed during the voyage. Around 1600 William Gilbert, physician to Queen Elizabeth I of England, proposed an explanation: the Earth itself was a giant magnet, with its magnetic poles some distance away from its geographic ones (i.e. near the points defining the axis around which the Earth turns).

http://www.phy6.org/earthmag/demagint.htm



William Gilbert



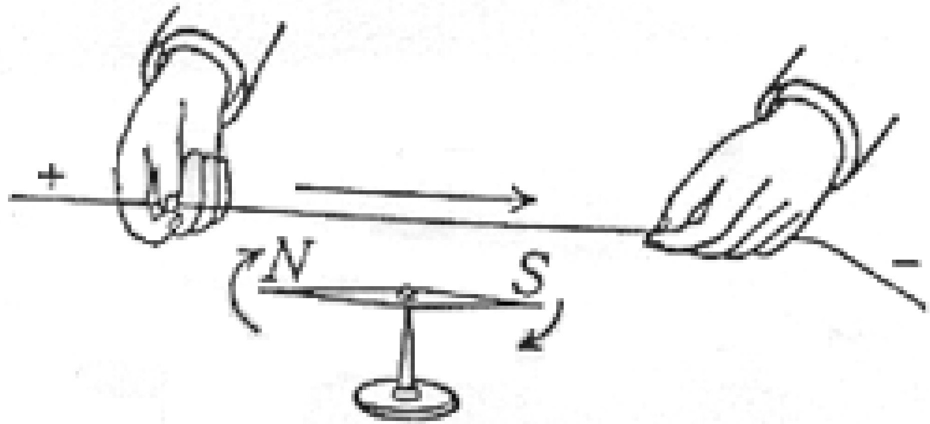
http://www-istp.gsfc.nasa.gov/Education/Intro.html

Edmond Halley

It was believed that the inside of the Earth was magnetized in the same fashion, and scientists were greatly puzzled when they found that the direction of the compass needle at any place slowly shifted, decade by decade, suggesting a slow variation of the Earth's magnetic field.

How can an iron magnet produce such changes? **Edmond Halley** (of comet fame) ingeniously proposed that the Earth contained a number of spherical shells, one inside the other, each magnetized differently, each slowly rotating in relation to the others.

Hans Christian Oersted was a professor of science at Copenhagen University. In 1820 he arranged in his home a science demonstration to friends and students. He planned to demonstrate the heating of a wire by an electric current, and also to carry out demonstrations of magnetism, for which he provided a compass needle mounted on a wooden stand.



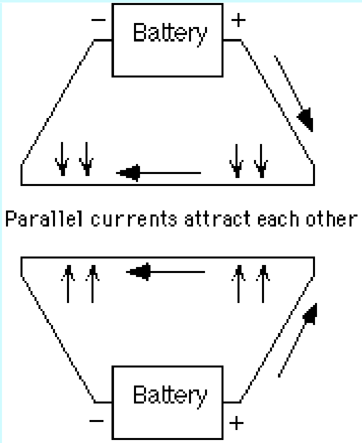
You will need:

- A pocket compass.
- A one-foot (30 cm) length of fairly thick wire, insulated or bare.
- A 1.5 volt electric cell ("battery") of size "D" or "C". The voltage is too low to cause any risk.

1. Lay the compass on a table, face upwards. Wait until it points north.
2. Lay the middle of the wire above the compass needle, also in the north-south direction *(compare to the above image "What Oersted Saw")*. Bend the ends of the wire so that they are close to each other.
3. Grab **one end** of the wire in **one hand** and press against one end of the battery.
4. Grab **the other end** with your **other hand**, and press momentarily against the other terminal of the battery. The needle will swing strongly by 90 degrees.

   Quickly disconnect (it is not good for the battery to draw such a large current). The needle will swing back to the north-south direction. Note that **no iron is involved** in producing the magnetic effect!

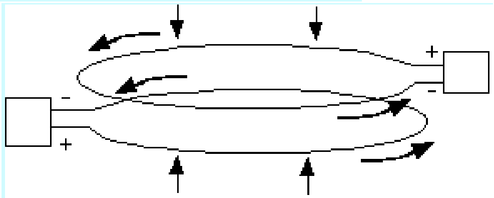
André-Marie Ampére in France felt that if a current in a wire exerted a magnetic force on a compass needle, two such wires also should interact magnetically. In a series of ingenious experiments he showed that this interaction was simple and fundamental--parallel (straight) currents attract, anti-parallel currents repel. The force between two long straight parallel currents was **inversely proportional to the distance** between them and proportional to the intensity of the current flowing in each.



Parallel currents attract each other

*--Two parallel currents in the **same** direction **attract** each other.*

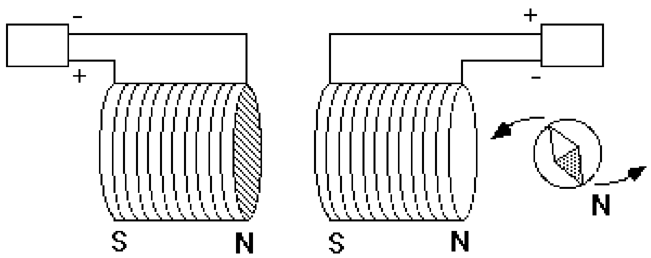
*--Two parallel currents in **opposite** direction **repel** each other.*



Parallel currents in two loops also attract

*--Two circular currents in the **same** direction **attract** each other.*

*--Two circular currents in **opposite** directions **repel** each other.*



Two coils of many parallel loops, with currents in the same direction, attract each other and act like magnets

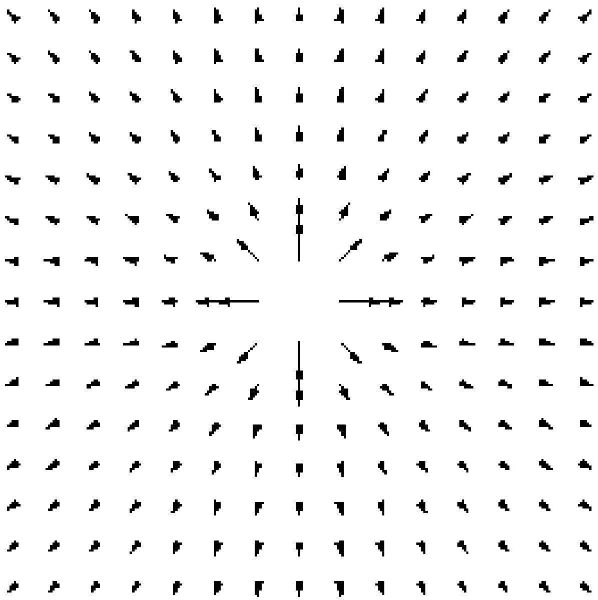


Figure 7.2: Electric Field of a Positive Point Charge

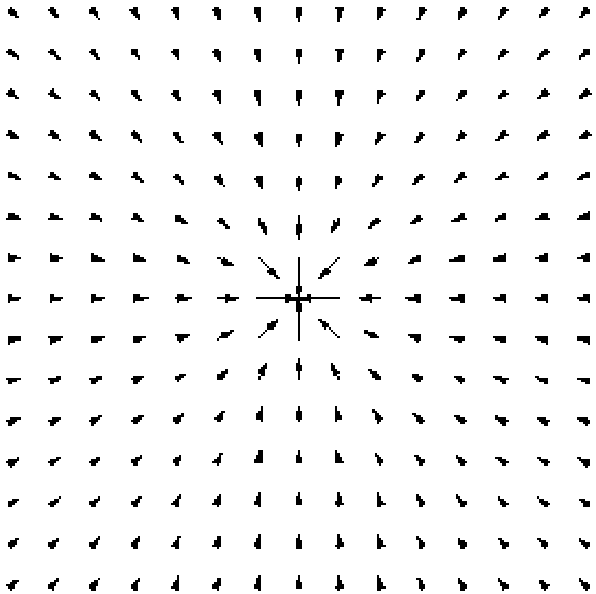


Figure 7.3: Electric Field of a Negative Point Charge

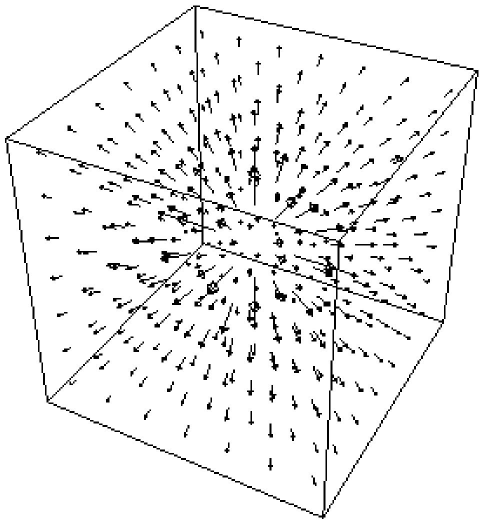


Figure 7.6: Electric Field due to Positive Charge

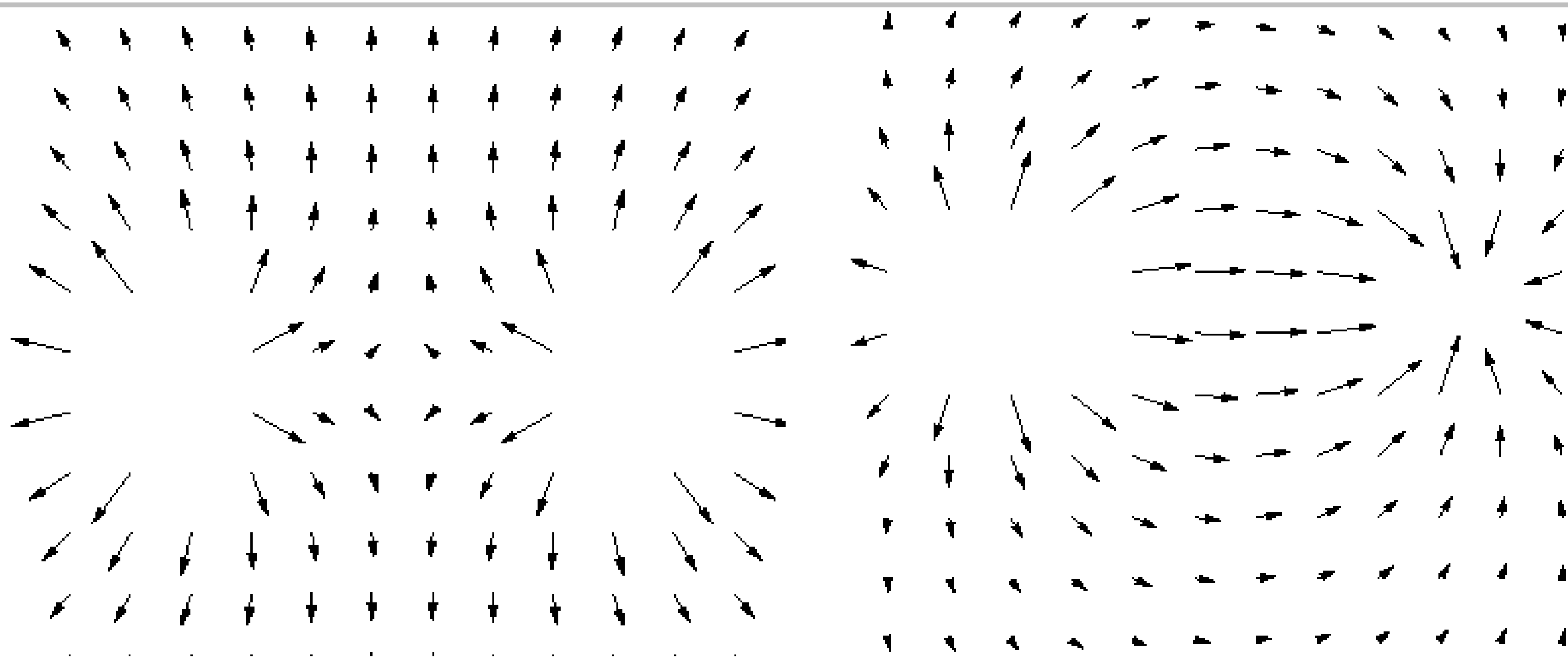
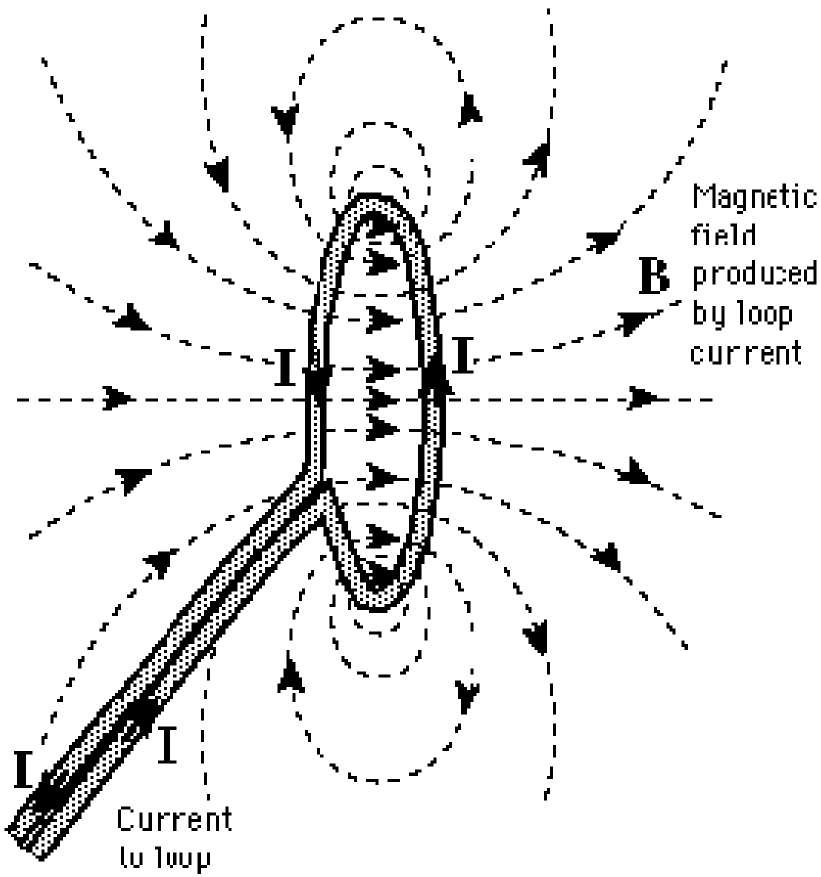
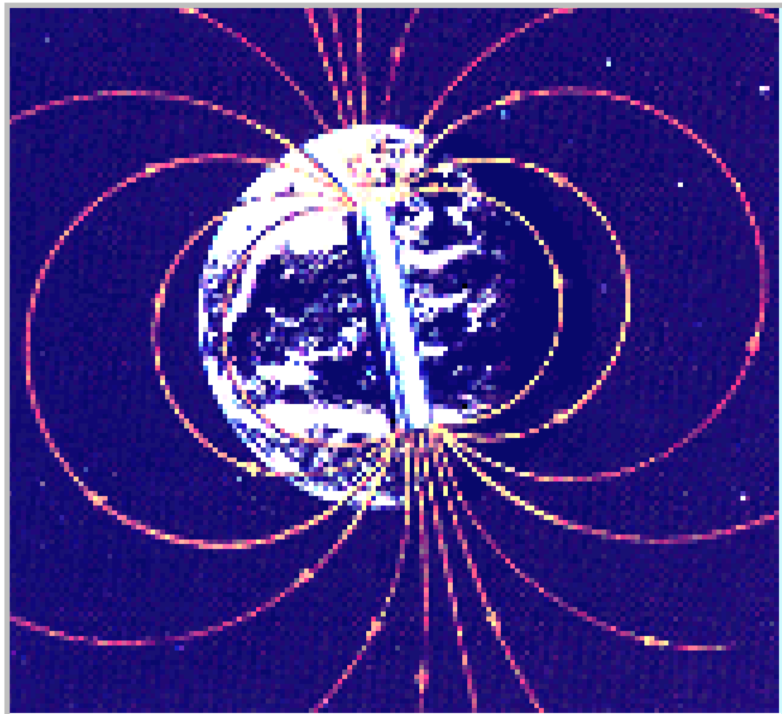


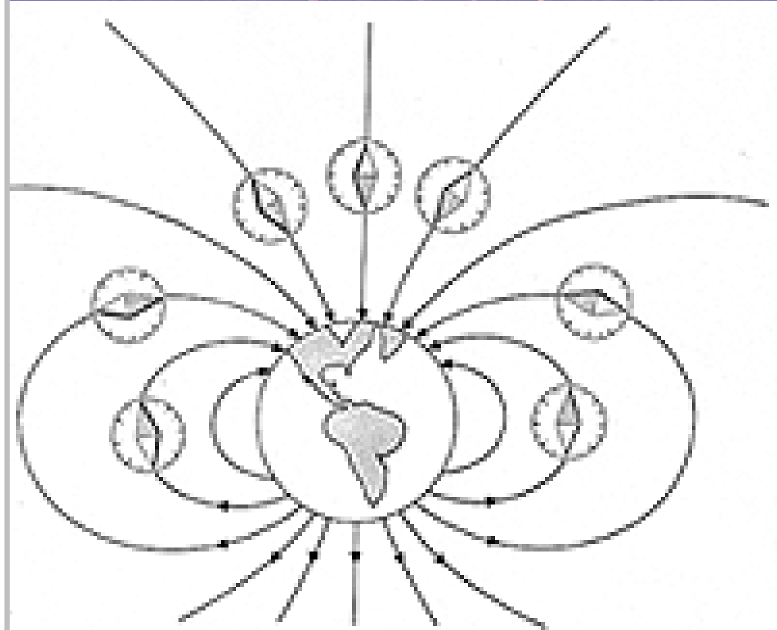
Figure 7.5: Electric Fields for Opposite Charges


Magnetic
field
B produced
by loop
current
I
I
I
I
Current
to loop

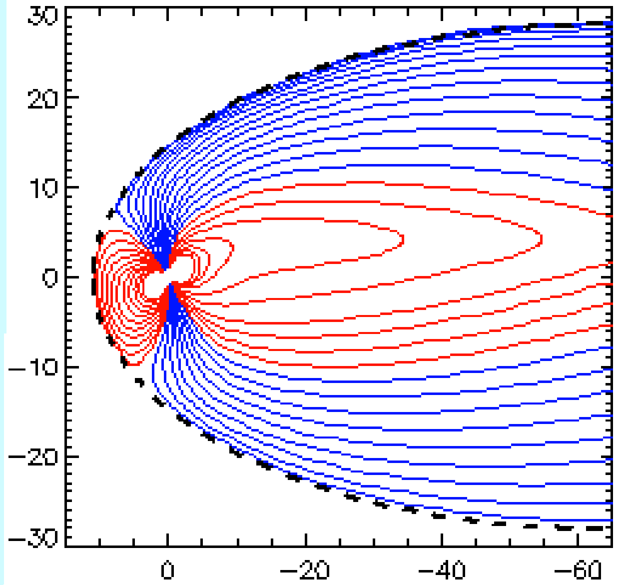
Maxwell

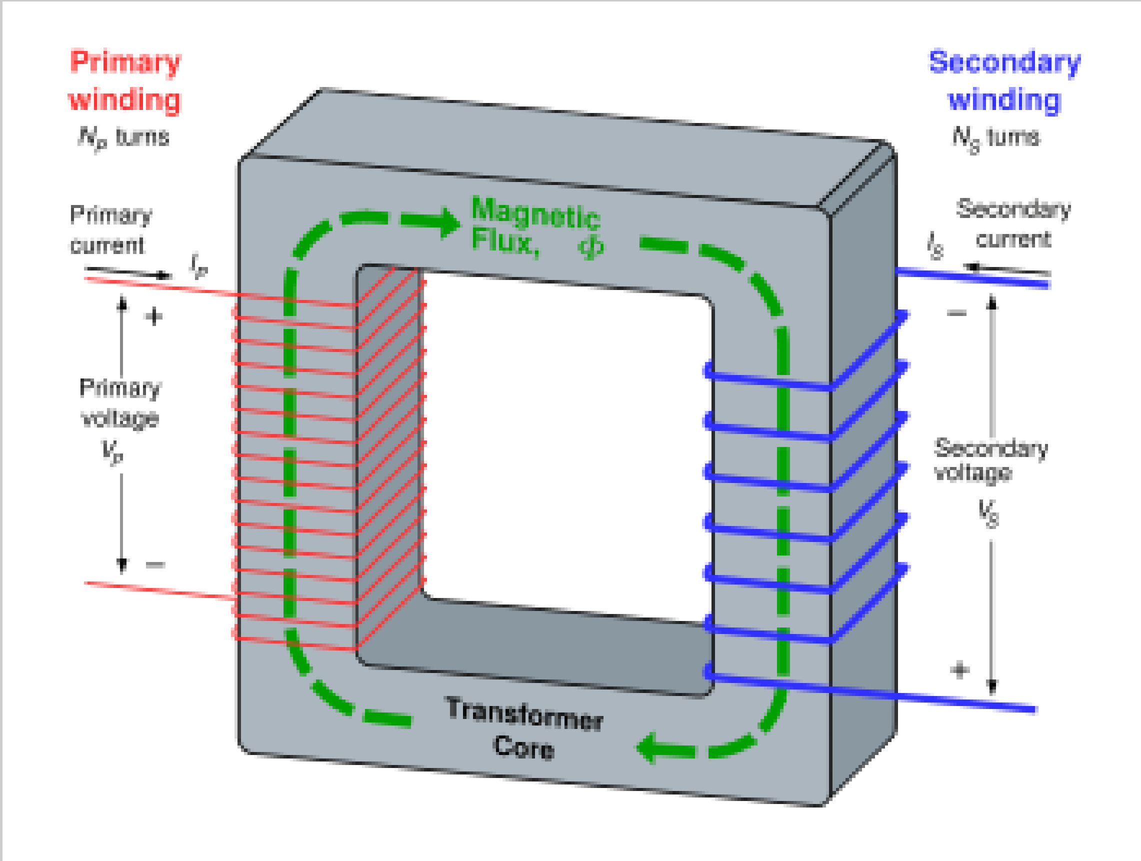
There thus existed **two kinds of forces** associated with electricity--electric and magnetic. In 1864 **James Clerk Maxwell** demonstrated a subtle connection between the two types of force, unexpectedly involving the velocity of light. From this connection sprang the idea that light was an electric phenomenon, the discovery of radio waves, the theory of relativity and a great deal of present-day physics.





Magnetospere





A practical step-down transformer showing magnetising flux in the core

Simplified

$$EPIP = ESIS$$