MF01 MAGNETISM

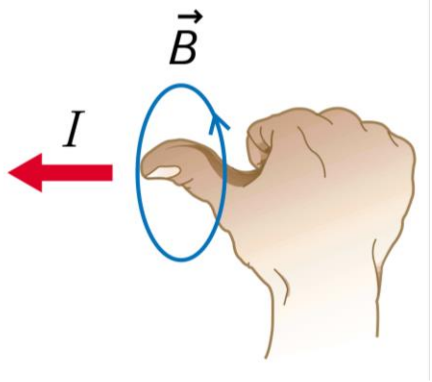
SPH4U

CH 8 (KEY IDEAS)

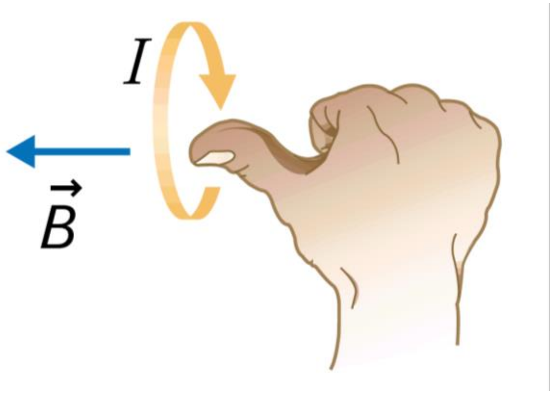
- define and describe concepts related to magnetic fields
- compare and contrast the properties of electric, gravitational, and magnetic fields
- predict the forces on moving charges and on a current-carrying conductor in a uniform magnetic field
- perform and analyze experiments and activities on objects or charged particles moving in magnetic fields
- analyze and explain the magnetic fields around coaxial cables
- describe how advances in technology have changed scientific theories
- evaluate the impact of new technologies on society

RIGHT-HAND RULES

- Straight Conductor

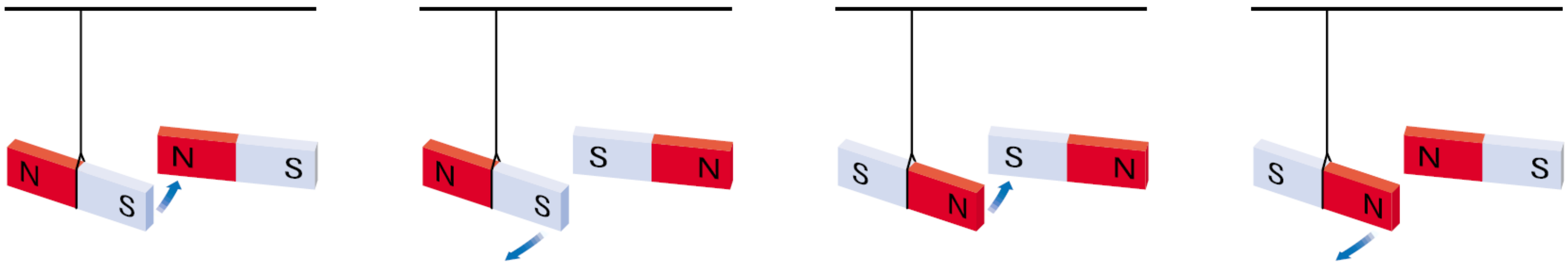


- Solenoid



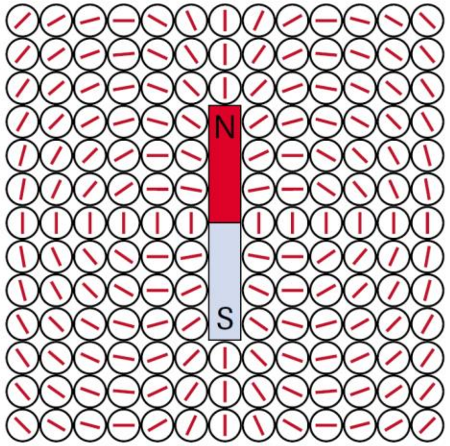
MAGNETS

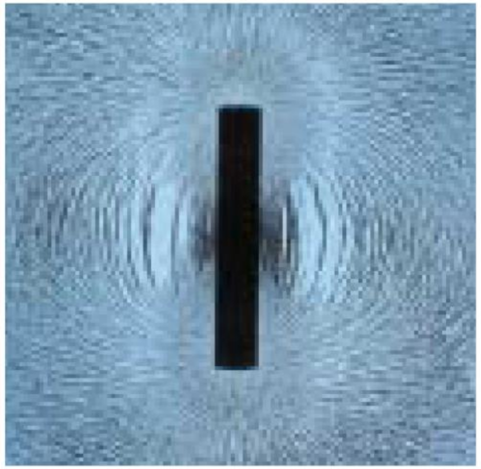
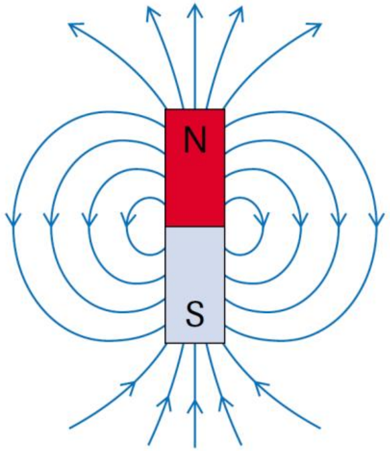
- **Poles:** the regions at the end of a magnetized body at which magnetic attraction is strongest; designated north and south
- **Law of Magnetic Poles:** Opposite magnetic poles attract. Similar magnetic poles repel.



MAGNETIC FIELDS

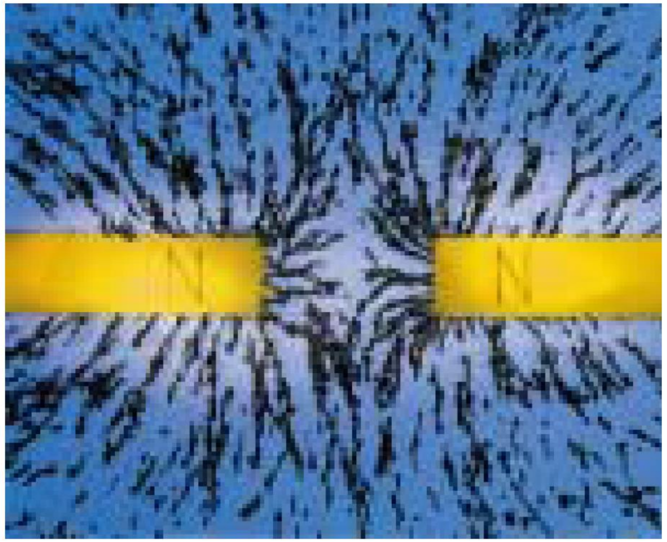
- **Magnetic Force Field ($\vec{B}$):** the area around a magnet in which magnetic forces are exerted
  - Note: we will explore the units later
- Below, we see the field by looking a a series of compasses, iron filings, or represented by field lines

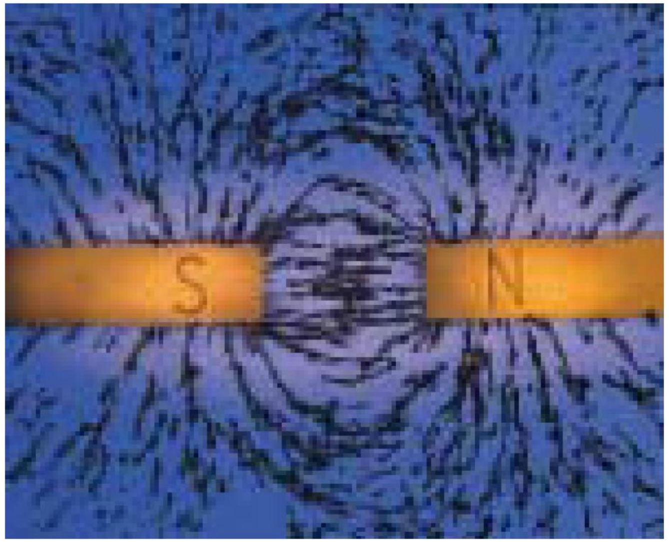


MAGNETIC FIELDS – CONT.

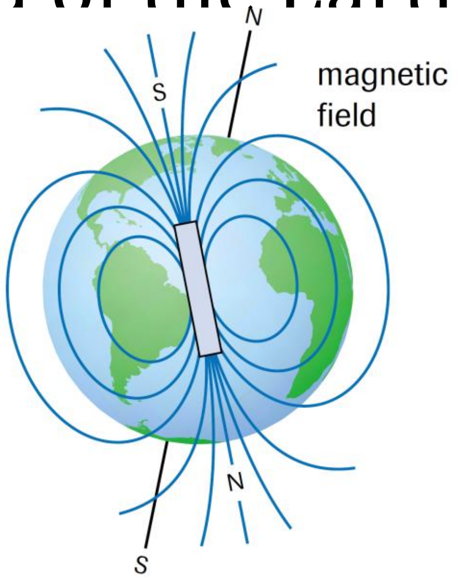
- Note: iron filings only show the pattern of the field, not the direction, as they have no N or S pole

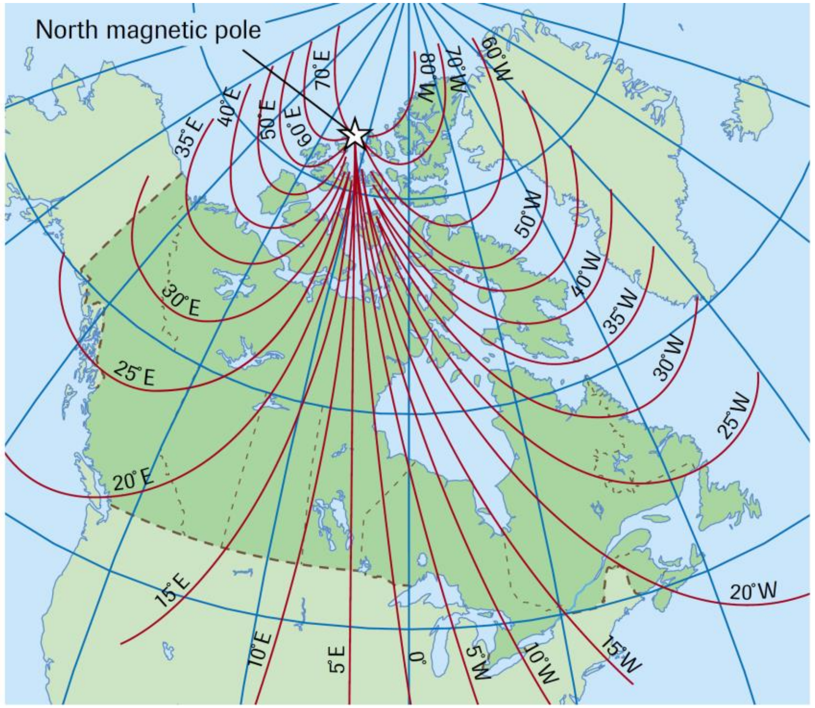




EARTH'S MAGNETIC FIELD

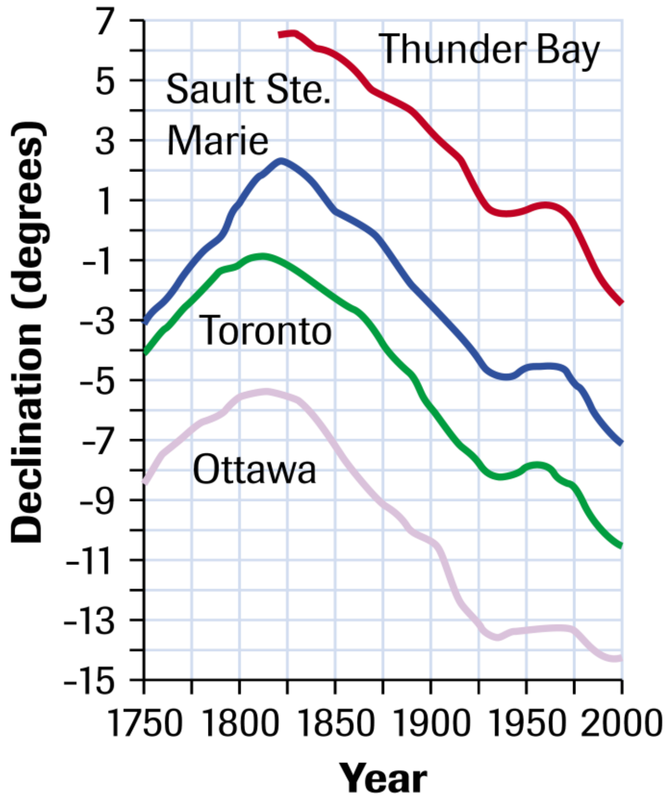
- Sir William Gilbert theorized there was a massive bar magnetic through the planet, as this fit the pattern of magnetic field of the Earth





EARTH'S MAGNETIC FIELD – CONT.

- Earth's magnetic N-pole (where a compass points) is not the same as the geographic north pole (north end of the axis of rotation)
- **Magnetic Declination:** the angle of difference between the magnetic N-pole and geographic N-pole
  - Different depending on location on Earth
  - Needs to be taken into account when using a compass to find true north

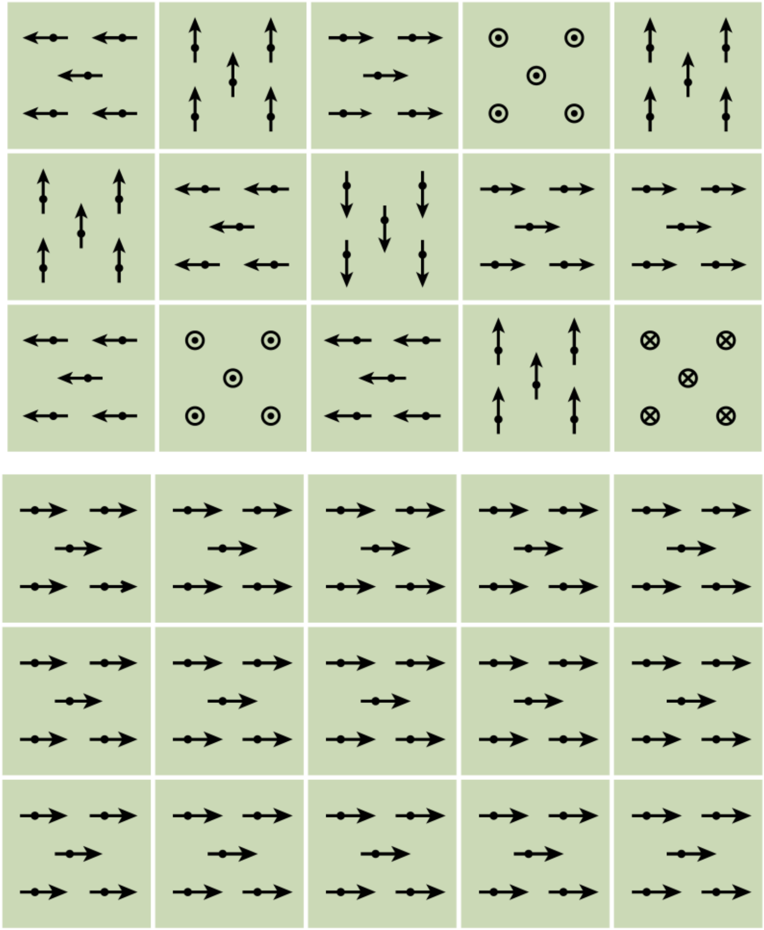


THE DOMAIN THEORY OF MAGNETISM

- **Domain Theory of Magnetism:** theory that describes, in terms of tiny magnetically homogeneous regions ("domains"), how a material can become magnetized: each domain acts like a bar magnet
- **Ferromagnetic Substance:** composed of a large number of tiny regions called <u>magnetic domains</u>
- **Magnetic Domain:** behave like a tiny bar magnet, with its own N- and S-poles

THE DOMAIN THEORY OF MAGNETISM

- **Unmagnetized:** all magnetic domains of a ferromagnetic substance are oriented at random
- **Magnetized:** a ferromagnetic substance is brought into a strong enough magnetic field to align its domains with the field; <u>induced magnet</u>
  - Some domains rotate into alignment
  - Some domains are enveloped by already-aligned domains growing in size
- Note: once the field is removed, the duration of the magnetism is dependent on the substance, and can last a long time or disappear immediately



PROPERTIES OF INDUCED MAGNETS

1. A needle is magnetized by rubbing it in one direction with a strong permanent magnet. This aligns the domains with the field of the permanent magnet.
2. When a bar magnet is broken in two, two smaller magnets result, each with its own N- and S-poles. It is impossible to produce an isolated N- or S-pole by breaking a bar magnet.
3. Induced magnets made of “soft” iron demagnetize as soon as the external field is removed. Examples include temporary magnets such as lifting electromagnets. In contrast, hard steel or alloys remain magnetized indefinitely. These include permanent magnets such as magnetic door catches. Impurities in the alloys seem to “lock” the aligned domains in place and prevent them from relaxing to their random orientation.

PROPERTIES OF INDUCED MAGNETS – CONT.

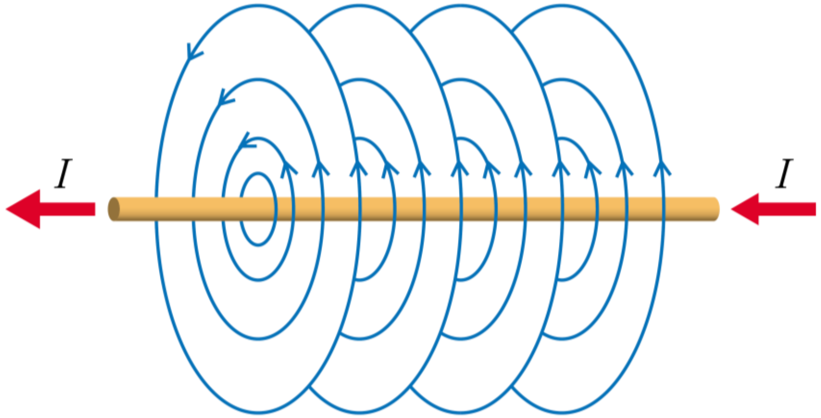
4. Heating or dropping a magnet can cause it to lose its magnetization, jostling the domains sufficiently to allow them to move and resume their random orientation. Each ferromagnetic material has a critical temperature above which it becomes demagnetized and remains demagnetized even upon cooling.
5. A strong external magnetic field can reverse the magnetism in a bar magnet, causing the former south-seeking pole to become north-seeking. This occurs when the domains reverse their direction of orientation by 180° due to the influence of the strong external field in the opposite direction.
6. Ships' hulls, columns and beams in buildings, and many other steel structures are often found to be magnetized by the combined effects of Earth's magnetic field and the vibrations imposed during construction. The effect is similar to stroking a needle with a strong magnet, in that the domains within the metals are caused to line up with Earth's magnetic field. Vibrations during construction aid in the realignment of the domains.

ELECTROMAGNETISM

- **Principle of Electromagnetism:** Moving electric charges produce a magnetic field.
- Historically, electricity and magnetism were considered discrete
- Discovered by Hans Christian Oersted (1777-1851), when he observed a magnetic compass needle being deflected by an electric current flowing through a nearby wire

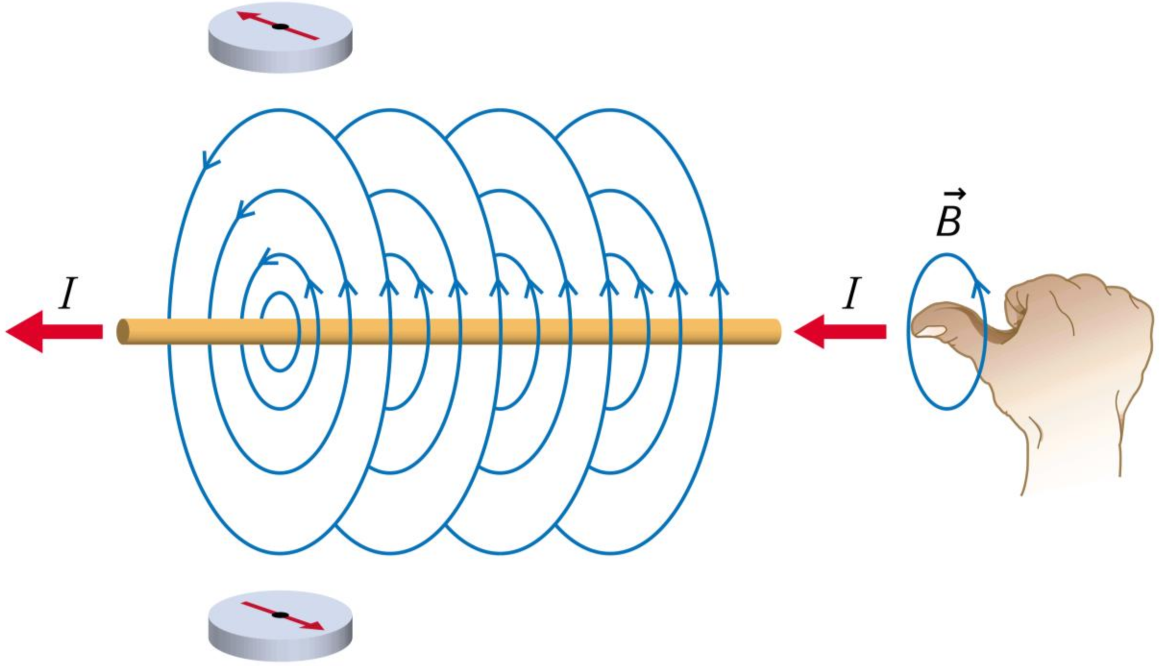
MAGNETIC FIELD OF A STRAIGHT CONDUCTOR

- An electric current passing through a straight wire will result in a magnetic field
- This magnetic field is represented by field lines forming concentric circles around the wire.
- When looking in the direction of the current flow, these circles move in a clockwise direction



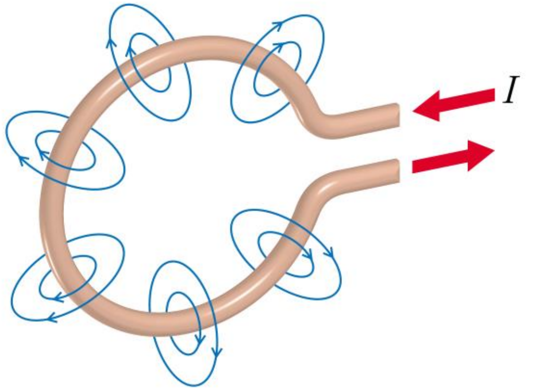
RIGHT-HAND RULE – STRAIGHT CONDUCTOR

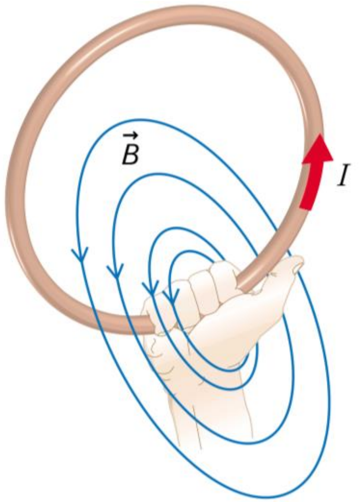
- **Right-Hand Rule for a Straight Conductor:** If a conductor is grasped in the right hand, with the thumb pointing in the direction of the current, the curled fingers point in the direction of the magnetic field lines.

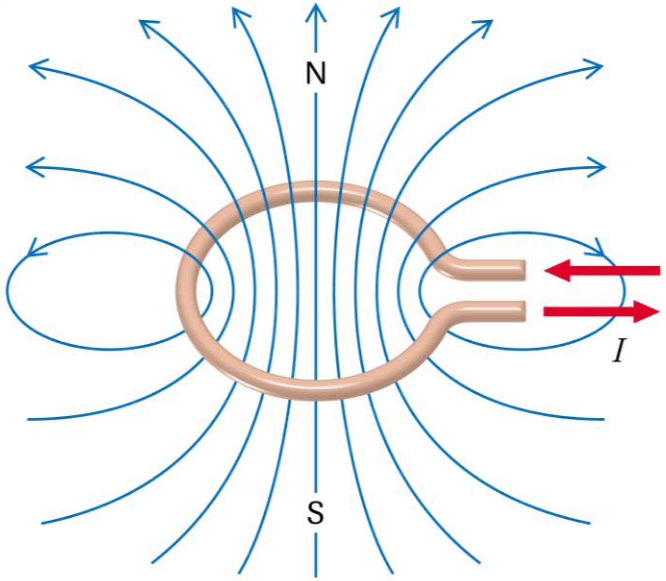


MAGNETIC FIELD OF A CURRENT LOOP

- Bending a wire into a loop, we compress the field lines inside the loop and expand the lines outside.
- The field strength is therefore stronger inside the loop than outside

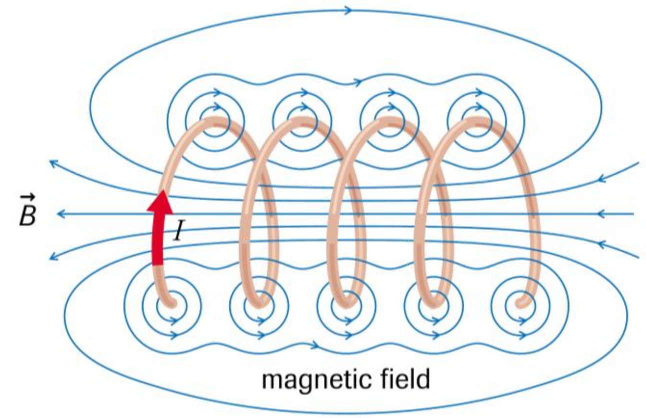


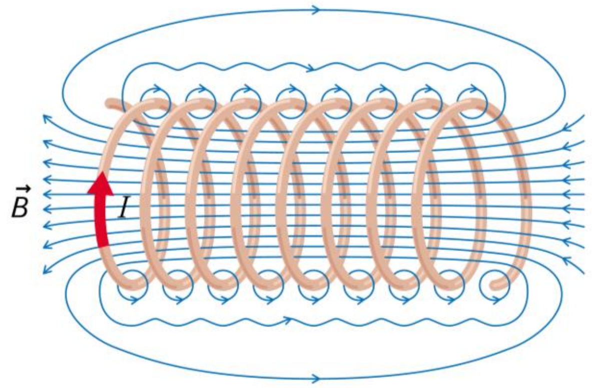




MAGNETIC FIELD OF A COIL OR SOLENOID

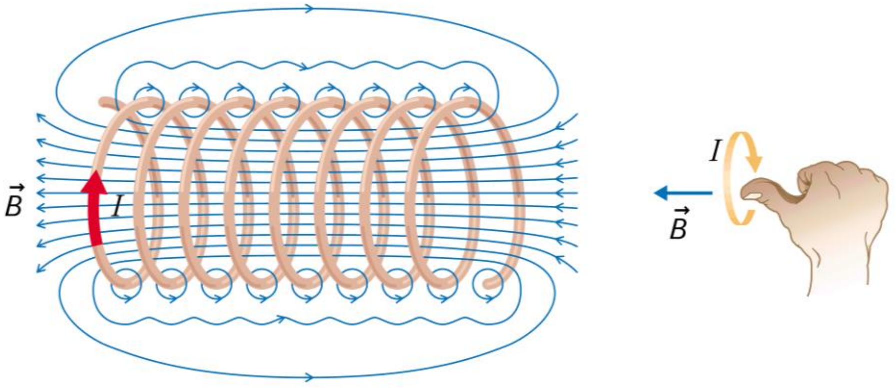
- **Solenoid:** a coiled conductor used to produce a magnetic field; when a current is passed through the wire, a magnetic field is produced inside the coil
  - Magnetic field is the sum of the magnetic field of its loops, and can be very strong
- Tightly coiled solenoids have nearly straight field lines that are very close together





RIGHT-HAND RULE – SOLENOID

- **Right-Hand Rule for a Solenoid:** If a solenoid is grasped in the right hand, with the fingers curled in the direction of the electric current, the thumb points in the direction of the magnetic field lines in its core.
- Note: this is consistent with our rule for the straight conductor



USING ELECTROMAGNETS AND SOLENOIDS

- Placing a ferromagnetic material in the core of a solenoid can greatly increase the magnetic field
- The total magnetic field is the sum of the field generated by the solenoid and the field generated by the induced magnet

$$\vec{B}_T = \vec{B}_S + \vec{B}_M$$

- Recall: “soft” iron loses its magnetism very quickly, and is usually preferred in applications where electromagnets are turned on and off

RELATIVE PERMEABILITY

- **Relative Magnetic Permeability:** the ratio of magnetic field strength using a particular core material relative to the magnetic field strength in the absence of the material
  - **high permeability:** the magnitude of the magnetic field will be high when using that material
  - **low permeability:** (close to 1) the magnitude of the magnetic field will be close to that of a vacuum; almost negligible effects

RELATIVE PERMEABILITY – CONT.

Material	Relative Magnetic Permeability
copper	0.999 99
water	0.999 999
vacuum	1.000 000
oxygen	1.000 002
aluminum	1.000 02
cobalt	170
nickel	1 000
steel	2 000
iron	6 100
permalloy	100 000

SUMMARY – NATURAL MAGNETISM AND ELECTROMAGNETISM

- The law of magnetic poles states that opposite magnetic poles attract, and similar magnetic poles repel.
- A magnet is surrounded by a magnetic force field.
- The domain theory states that ferromagnetic substances are composed of a large number of tiny regions called magnetic domains, with each domain acting like a tiny bar magnet. These domains can be aligned by an external magnetic field.
- The principle of electromagnetism states that moving electric charges produce a magnetic field.

PRACTICE

Readings

- Section 8.1 (pg 384)

Questions

- pg 391 #1,4,5,7