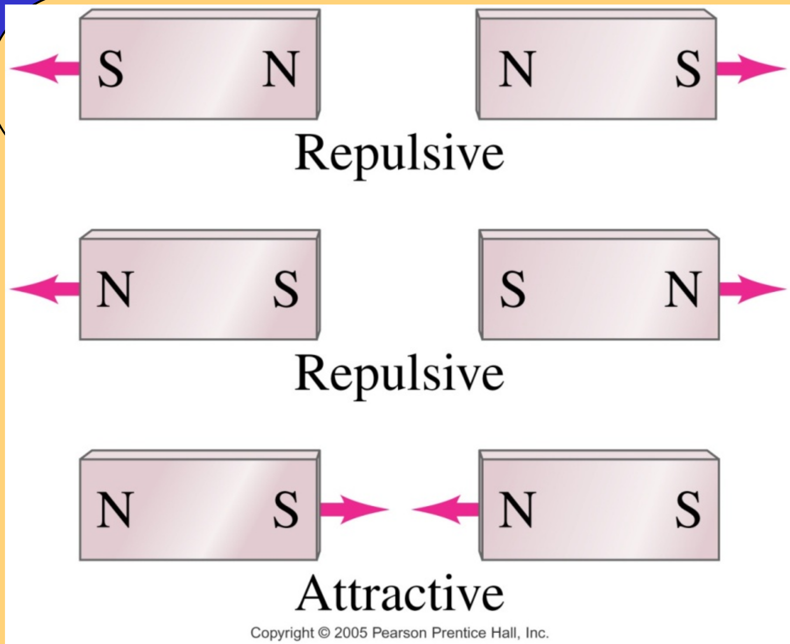
Chapter 20: Magnetism

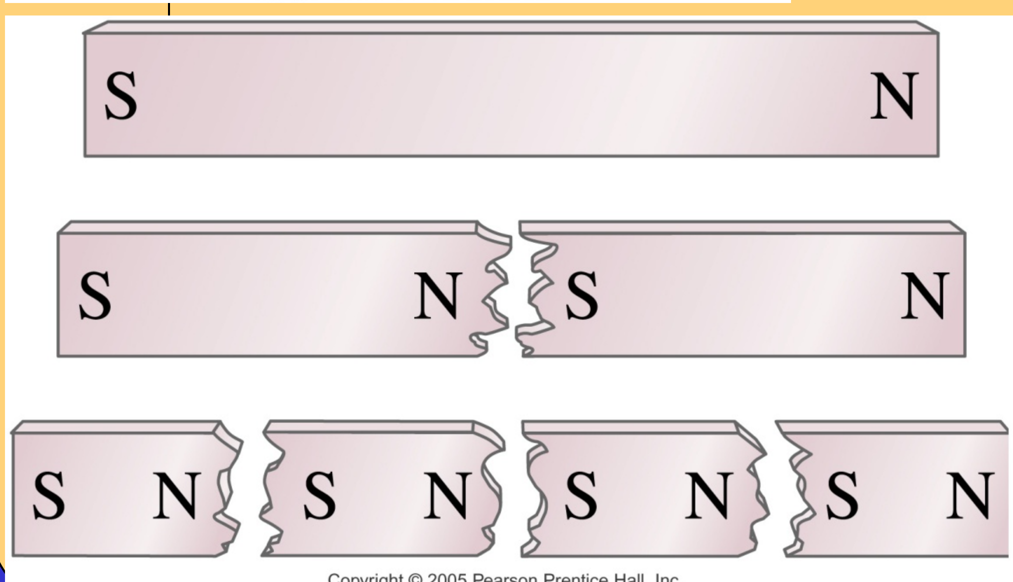


Magnets have two ends – **poles** – called north and south.
Like poles repel; unlike poles attract

BUT magnetic poles ARE DIFFERENT from charges.

Charges can be isolated, but magnetic poles CANNOT. You cut a magnet and get two smaller magnets. Magnetic monopoles DO NOT exist.

compass needle = bar magnet, points North.

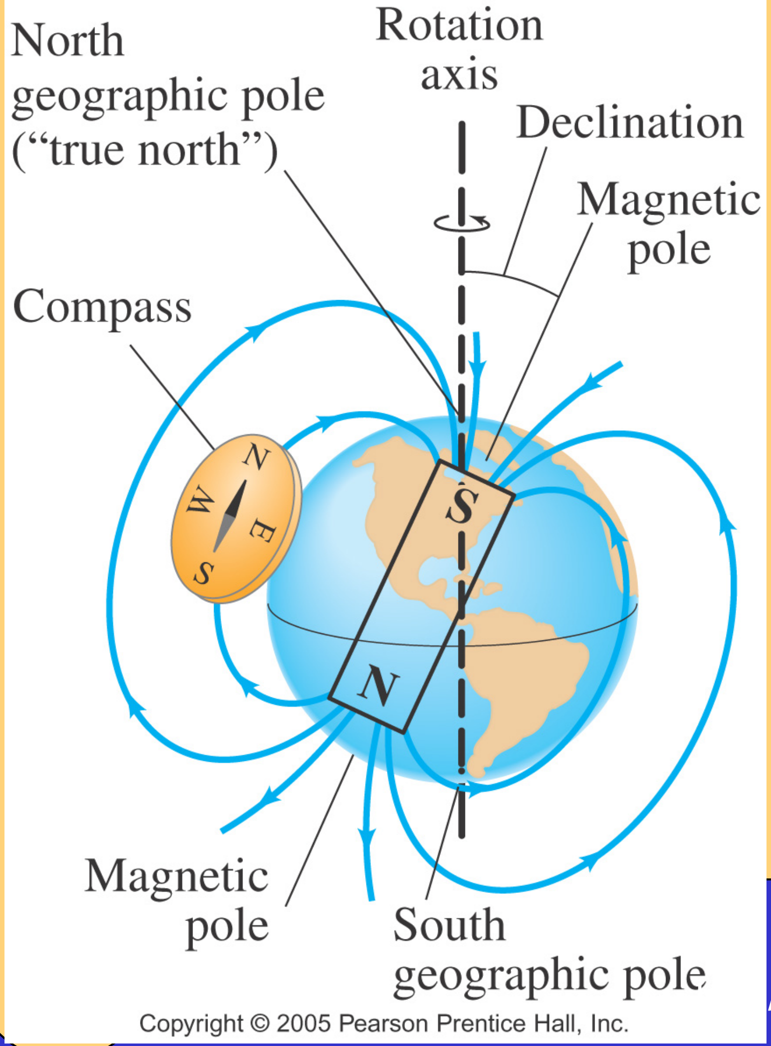


Iron and few other materials show strong magnetic effects. They are called **ferromagnetic** (Fe, Co, Ni)

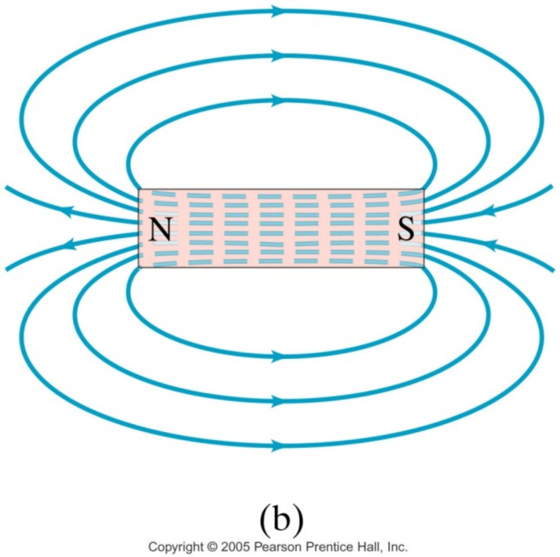
We can think of a **magnetic field** surrounding a magnet, just like an electric field surrounds an electric charge

Magnetic Fields

Magnetic fields can be visualized using magnetic field lines, which are always closed loops. Force = interaction between one magnet and magnetic field of the other.



Direction =direction that the north pole of compass points



The Earth's magnetic field is similar to that of a bar magnet.

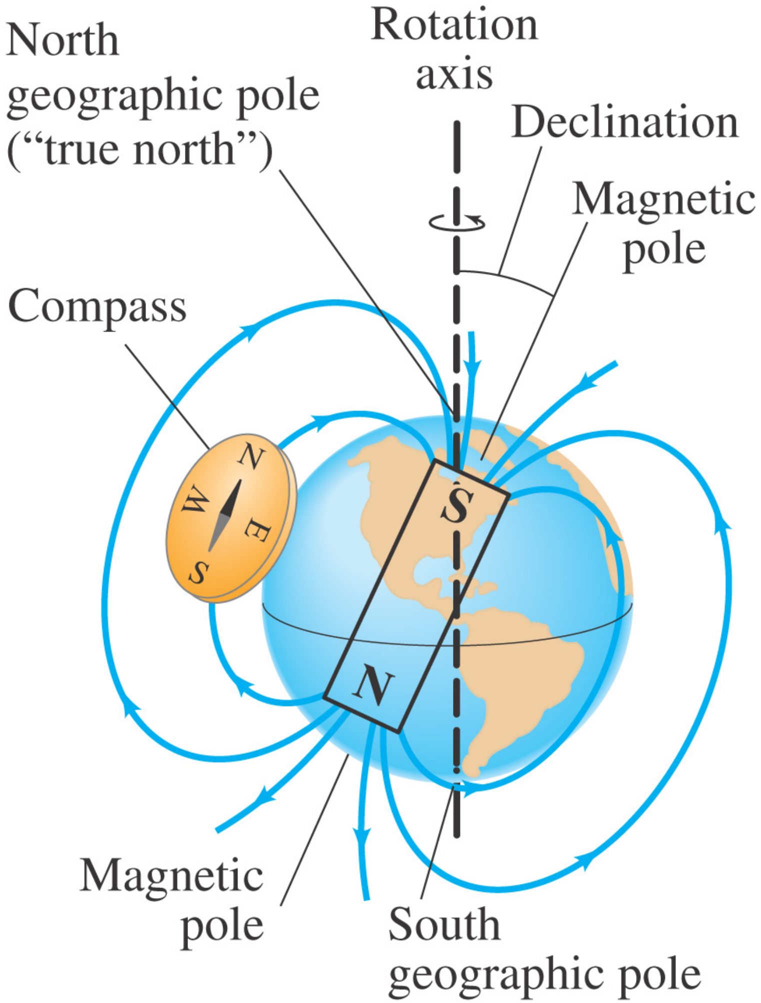
Note that the Earth's "North Pole" is really a south magnetic pole, as the north ends of the compass is attracted to it.

Earth's poles move in time and even reverse direction

https://www.youtube.com/watch?v=t2NqVJtNp6Y

//www.teachersdomain.org/resource/ess05.sci.ess.eiu.solarwind/

Earth Magnetic Field



Cause of Earth's magnetic field
https://www.youtube.com/watch?v=t2NqVJtNp6Y

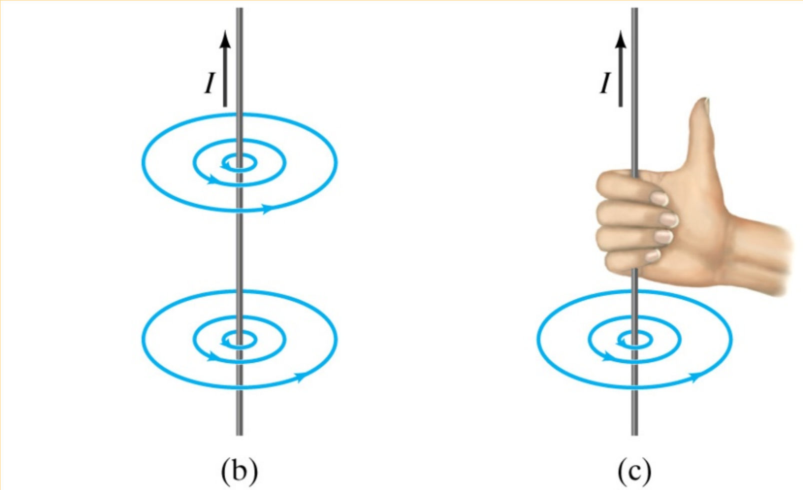
Auroras:
https://www.youtube.com/watch?v=nXxwZVbDt1c

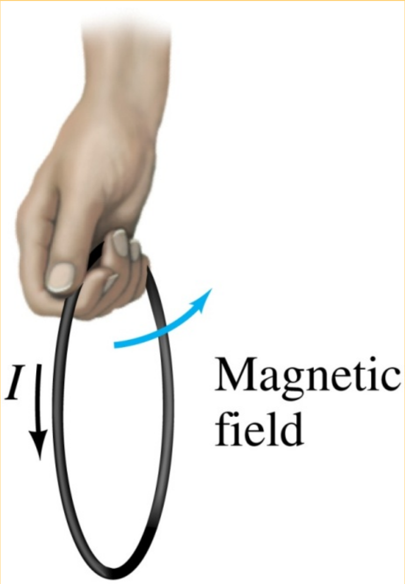
SOLAR WIND:
http://www.teachersdomain.org/resource/ess05.sci.ess.eiu.solarwind/

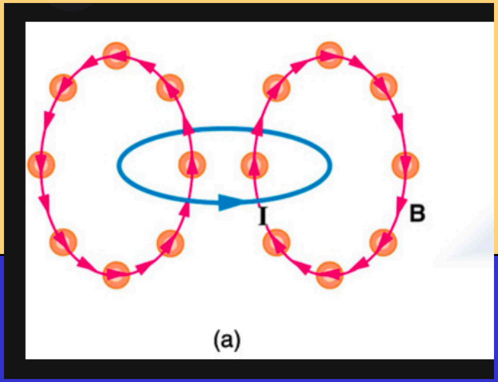
Electric Current-Magnetic Fields

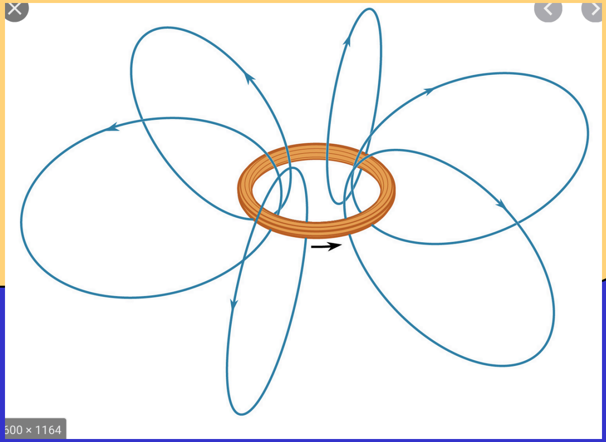
Experiment shows that, just like magnets, **electric current produces a magnetic field**

The direction of the field is given by a right-hand rule.





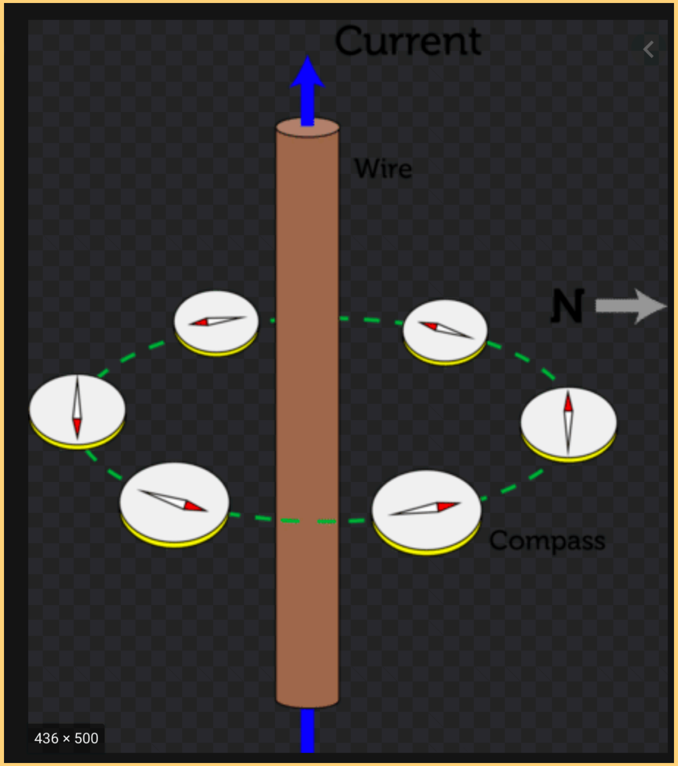




Electric Current-Magnetic Fields

Compass around wire.

Therefore electric current (by creating a magnetic field around it) exerts force on magnet.

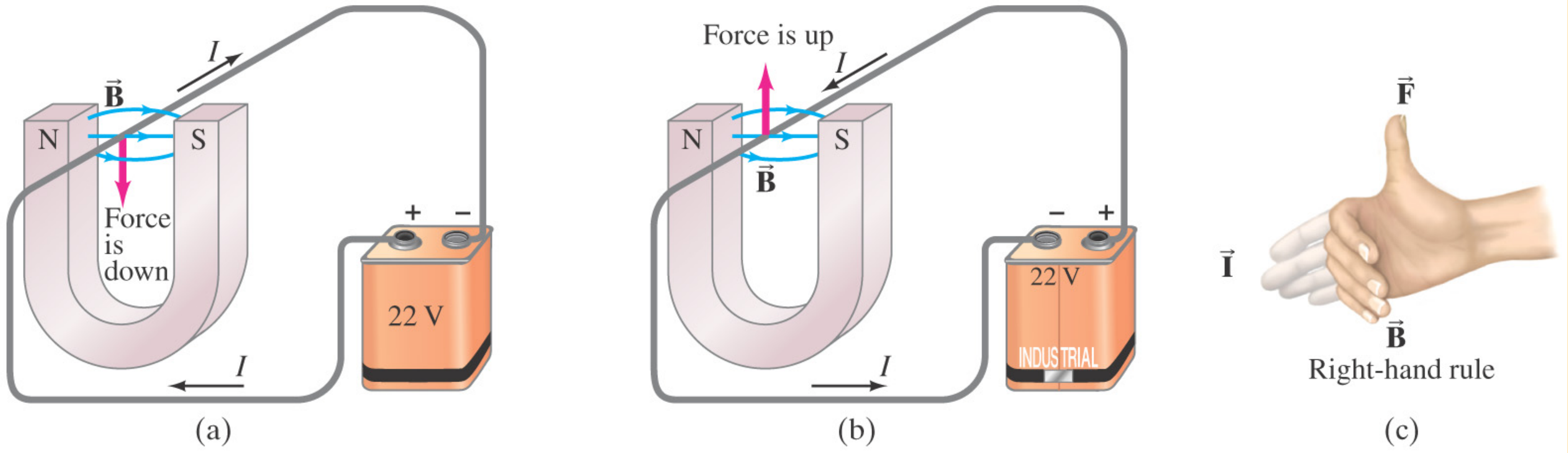


Electric Current-Magnetic Fields

If electric current exerts force on magnet.

From 3rd law: magnet must exert force on current

F is perpendicular to I,B



Right-hand Rule:
(Watch next video for more examples)

Force on Electric Current

The force on the wire depends on the current, the length of the wire, the magnetic field, and its orientation.

$$F = IlB \sin\theta$$

This equation defines the magnetic field B.

Maximum and minimum force depend on angle

Unit of B: the tesla, T. (SI)

1 T = 1 N/A·m.

the gauss (G). In CGS

1 G = 10^{-4} T.

Ex. 20-1 A wire carrying a 30-A current has length 12 cm between the pole faces of a magnet at an angle of 60°. The magnetic field is approximately uniform at 0.90 T. We ignore the field beyond the pole pieces. What is the magnitude of the force on the wire?

2.8N

Force on Electric Current

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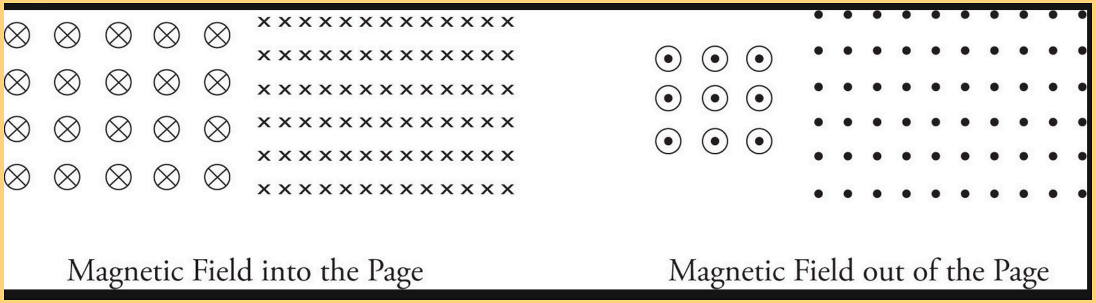
$$F = IlB \sin\theta$$

Unit of B: the tesla, T. (SI)

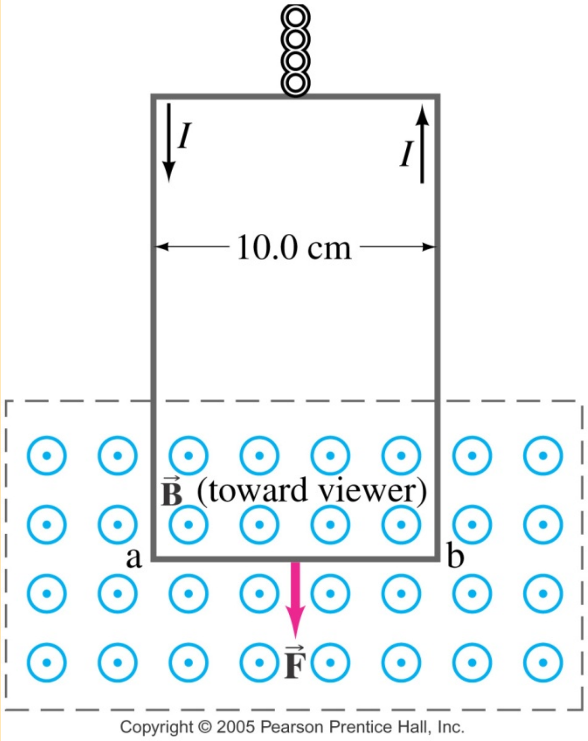
1 T = 1 N/A·m.

Convention for magnetic field pointing out of page and into the page.



Force on Electric Current

Ex. 20-2 A rectangular loop of wire hangs vertically as in the figure. A magnetic field is directed horizontally, perpendicular to the wire, and points out of the page at all points. The magnetic field is almost uniform. The top portion of the wire loop is free of the field. The loop hangs from a balance which measures a downward force (besides the gravitational force) of 3.48×10^{-2} N when the wire carries I=0.245 A. What is the magnitude of the magnetic field B?



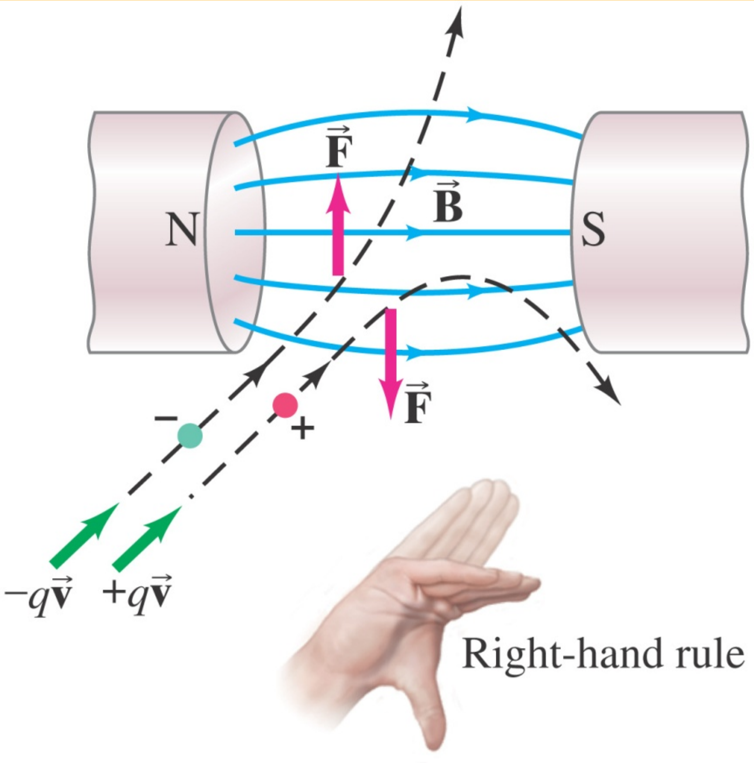
1.42 T

Force on Electric Charge

The force on a moving charge is related to the force on a current:

$$F = IlB\sin\theta = (Nq/t)lB\sin\theta = NqvB\sin\theta$$

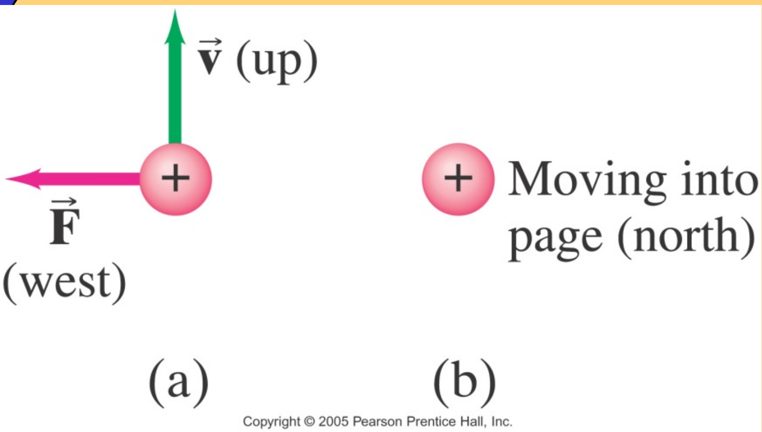
$$F = qvB\sin\theta$$



Once again, the direction is given by a right-hand rule.

NOTE: electron position is opposite to the current.

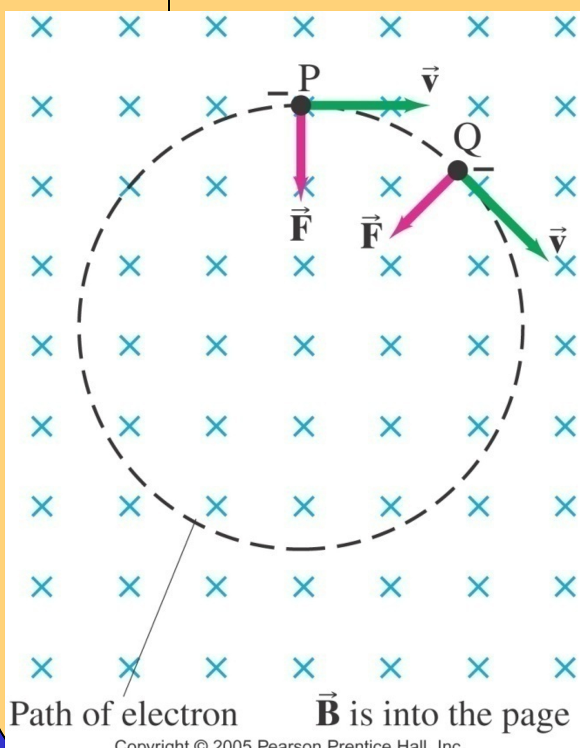
Force on Electric Charge



Ex. 20-4 A proton having a speed of $5.0x10^6$m/s in a magnetic field feels a force of $8.0x10^{-14}$ N toward the west when it moves vertically upward. When moving horizontally in a northerly direction, it feels zero force. Determine the magnitude and direction of the magnetic field in this region (q=+e=$1.6x10^{-19}$ C)

0.10 T

If a charged particle is moving perpendicular to a uniform magnetic field, its path will be a circle. ($a=v^2/r$)

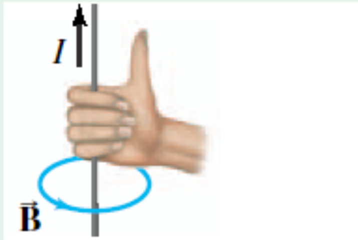
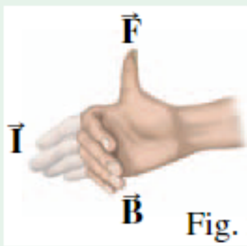
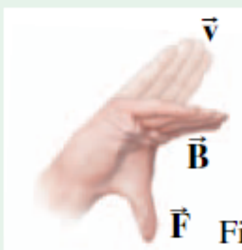


Ex. 20-5 an electron travels at 2.0x10^7 m/s in a plane perpendicular to a uniform 0.010-T magnetic field. What is the radius of the electron motion?
m= 9.1x10^(-31)kg

1.1 cm

Summary

TABLE 20–1 Summary of Right-hand Rules (= RHR)

Physical Situation	Example	How to Orient Right Hand	Result
1. Magnetic field produced by current (RHR-1)	 Fig. 20–8c	Wrap fingers around wire with thumb pointing in direction of current I	Fingers point in direction of $\vec{\mathbf{B}}$
2. Force on electric current I due to magnetic field (RHR-2)	 Fig. 20–11c	Fingers point straight along current I, then bent along magnetic field $\vec{\mathbf{B}}$	Thumb points in direction of force
3. Force on electric charge $+q$ due to magnetic field (RHR-3)	 Fig. 20–14	Fingers point along particle's velocity $\vec{\mathbf{v}}$, then along $\vec{\mathbf{B}}$	Thumb points in direction of force

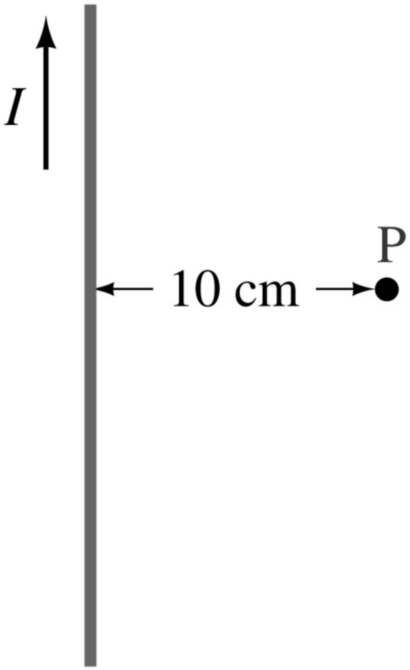
Magnetic Field due to long Wire

The field is inversely proportional to the distance from the wire:

$$B = \frac{\mu_0}{2\pi}\frac{I}{r}$$

The constant μ_0 is called the permeability of free space, and has the value:

$$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{T\cdot m/A}$$



Ex. 20-7 An electric wire in the wall of a building carries a dc current of 25 A vertically upward. What is the magnetic field due to this current at a point P 10 cm due north of the wire

B=5.0x10^(-5) T

Magnetic Field due to long Wire

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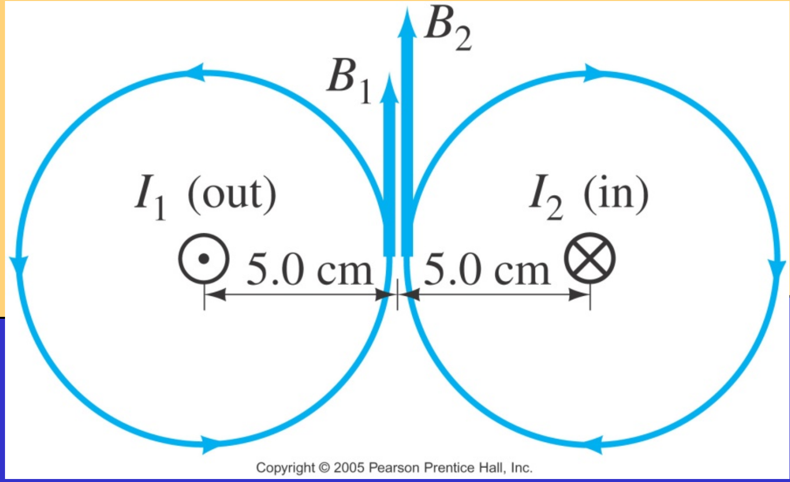
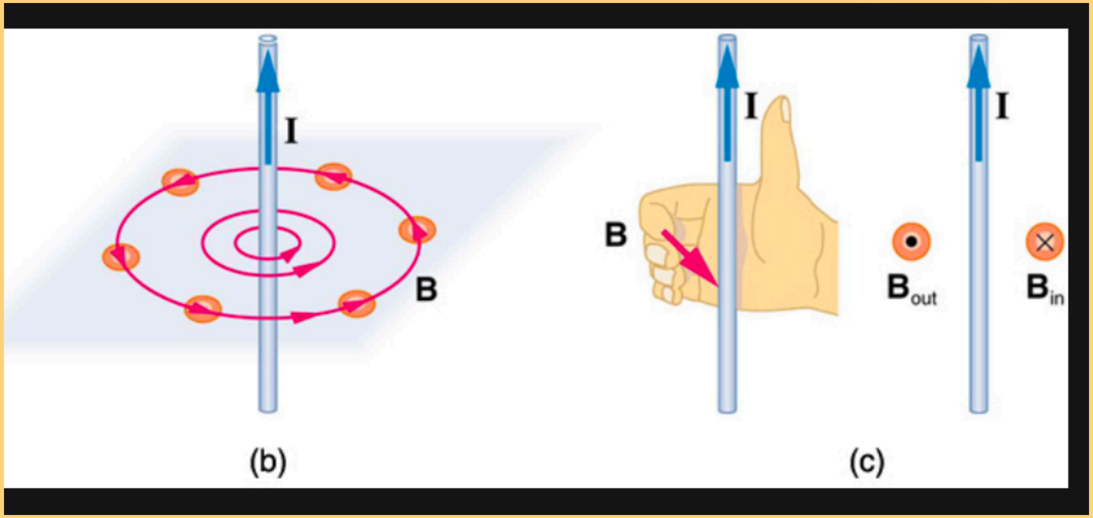
The constant μ_0 is called the permeability of free space, and has the value: $\mu_0 = 4\pi \times 10^{-7}\,\mathrm{T \cdot m/A}$

Ex. 20-8 Two parallel straight wires 10.0 cm apart carry currents in opposite directions. Current I1=5.0 A is out of the page and I2=7..0A is into the page. Determine the magnitude and direction of the magnetic field halfway between the two wires.

B=4.8x10^(-5) T
up



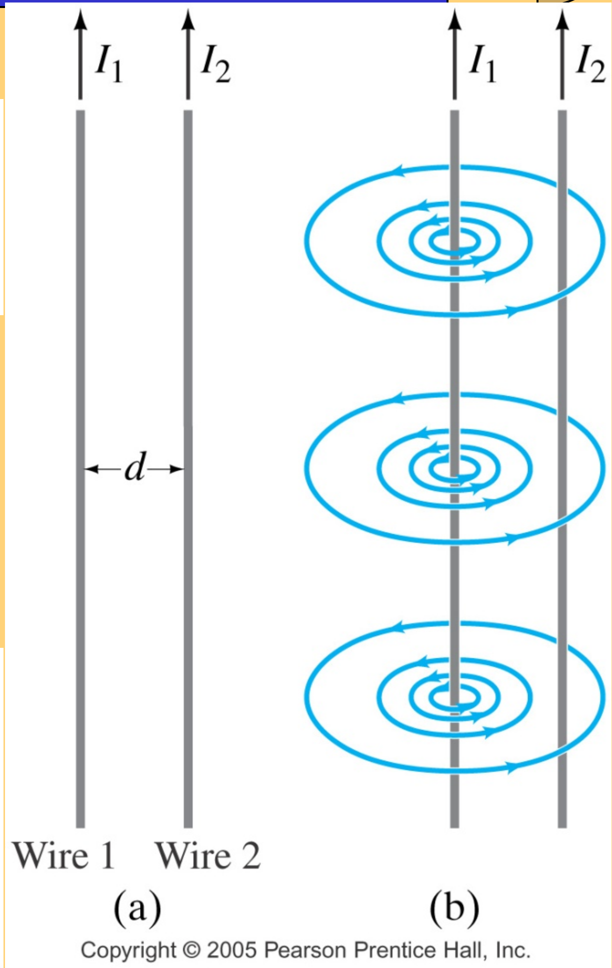
Force between two parallel wires



Force between two parallel wires

The magnetic field produced at the position of wire 2 due to the current in wire 1 is:

$$B_1 = \frac{\mu_0}{2\pi}\frac{I_1}{d}$$

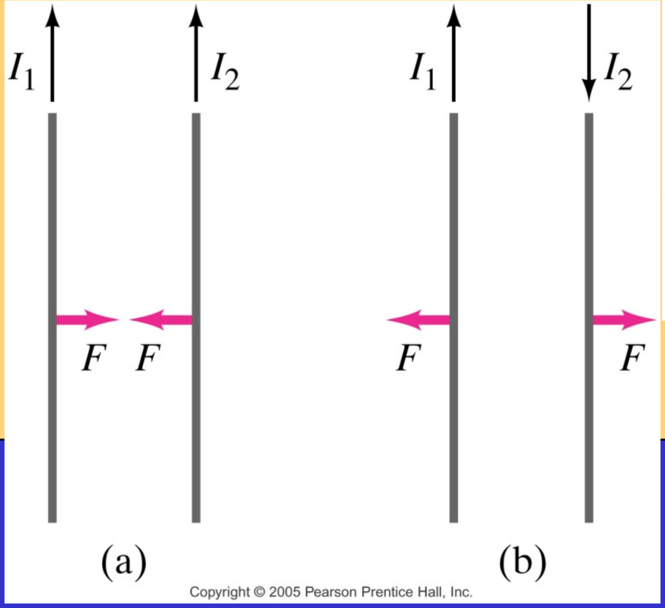


The force this field exerts on a length l_2 of wire 2 is:

$F_2 = B_1 I_2 l_2$

$$F_2 = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{d} l_2$$

Parallel currents attract; antiparallel currents repel.

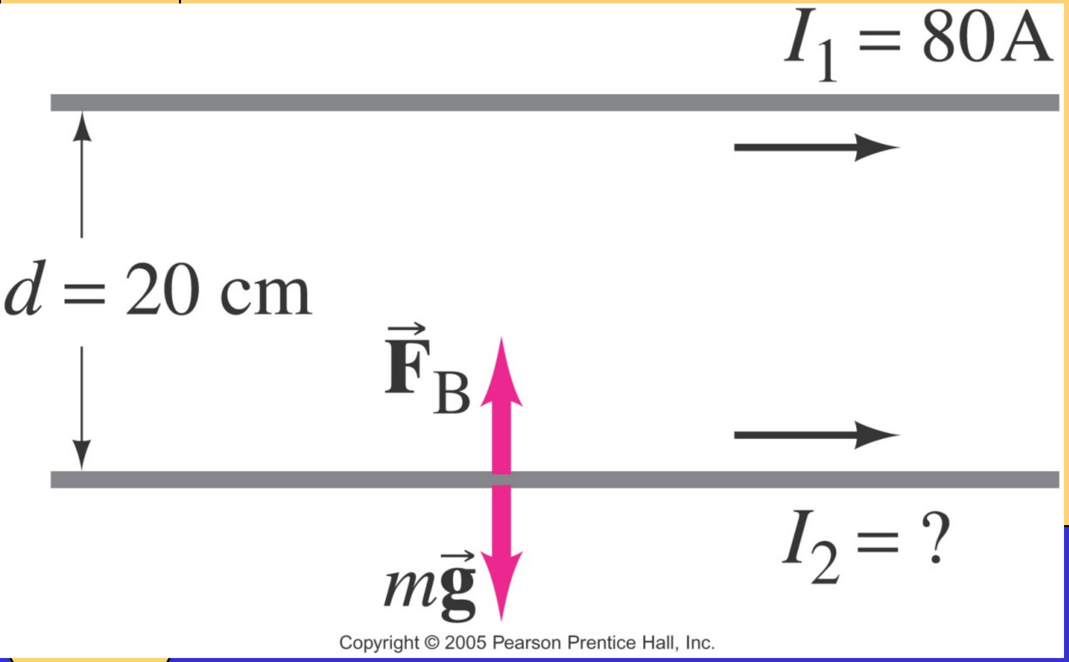


Force between parallel two wires

Ex. 20-10 The two wires of a 2.0-m –long appliance cord are 3.0 mm apart and carry a current of 8.0 A dc. Calculate the force one wire exerts on the other

F=8.5x10^(-3) N

Ex. 20-11 A horizontal wire carries a current I_1=80A dc. A second parallel wire 20 cm below it must carry how much current I_2 so that it does not fall due to gravity? The lower wire has mass of 0.12 g per meter of length



I_2=15A