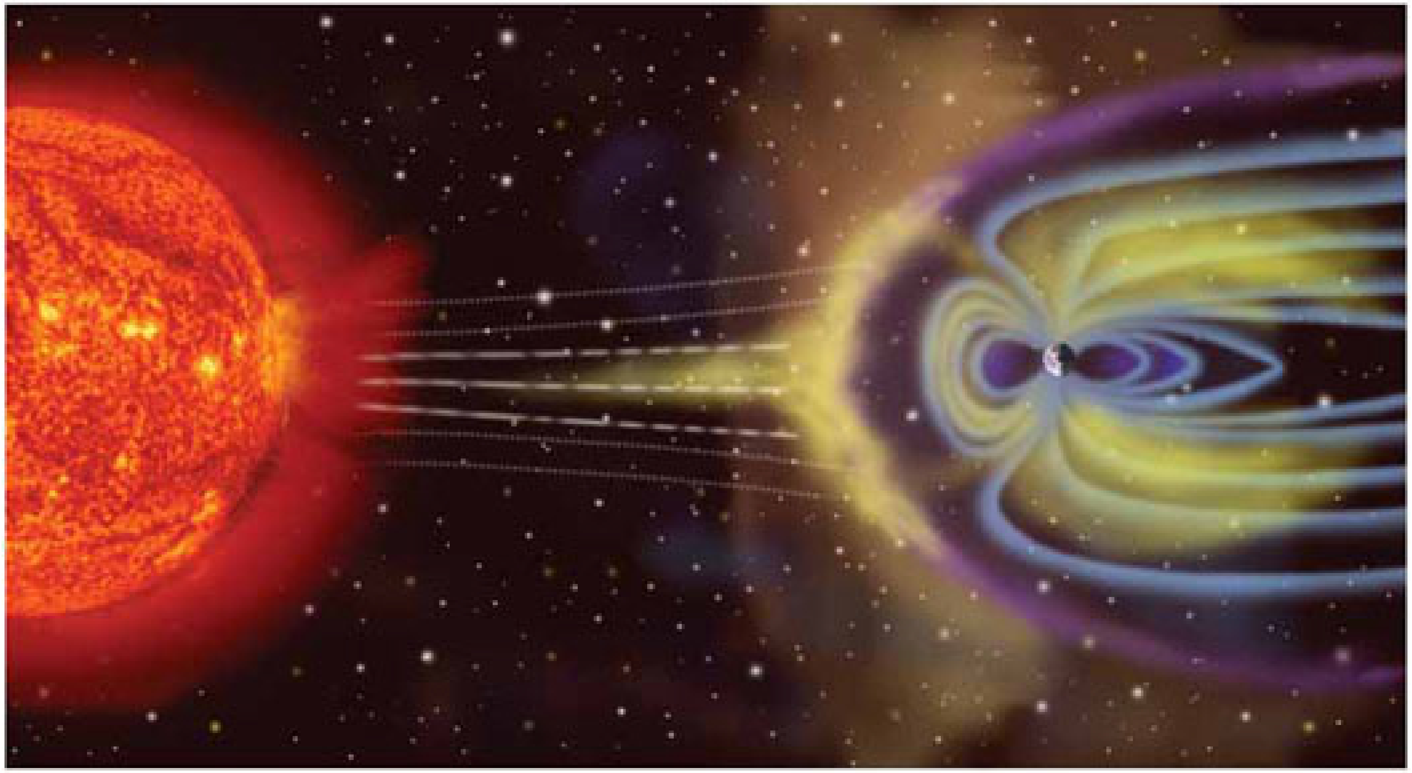
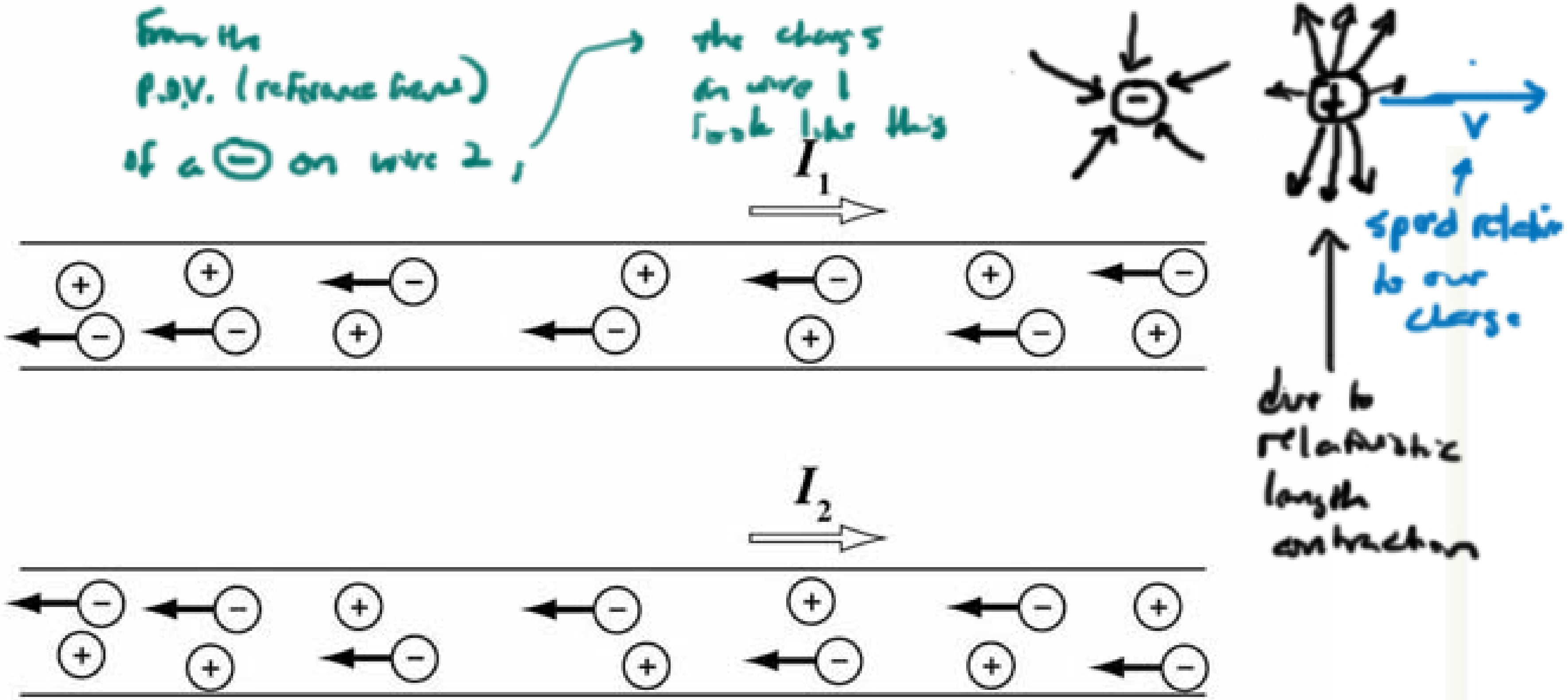
Module 11

Magnetism

Session Slides with Notes

Magnetism



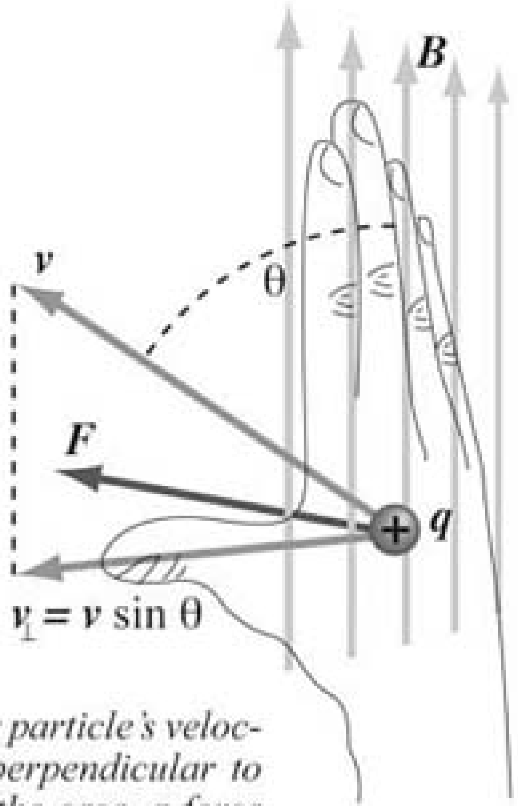


supplemental

Magnetic Force on a Moving Charge

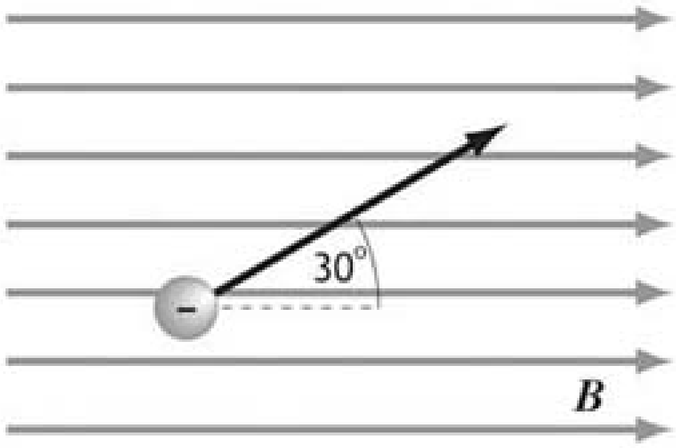
$$F = qB\,v\sin\theta$$

F	=	magnetic force
q	=	particle charge
B	=	magnetic field strength
v	=	particle speed
θ	=	angle between particle velocity and the magnetic field



To produce a magnetic force, a particle's velocity must have a component perpendicular to the magnetic field. If that is the case, a force is produced perpendicular to both the field and the particle's velocity.

A beta (β^-) particle (charge -1.6×10^{-19} C) moves at a speed of 1×10^5 m/s at an angle of 30° to a uniform 20T magnetic field in the plane of the image at right. What is the magnetic force on the particle?



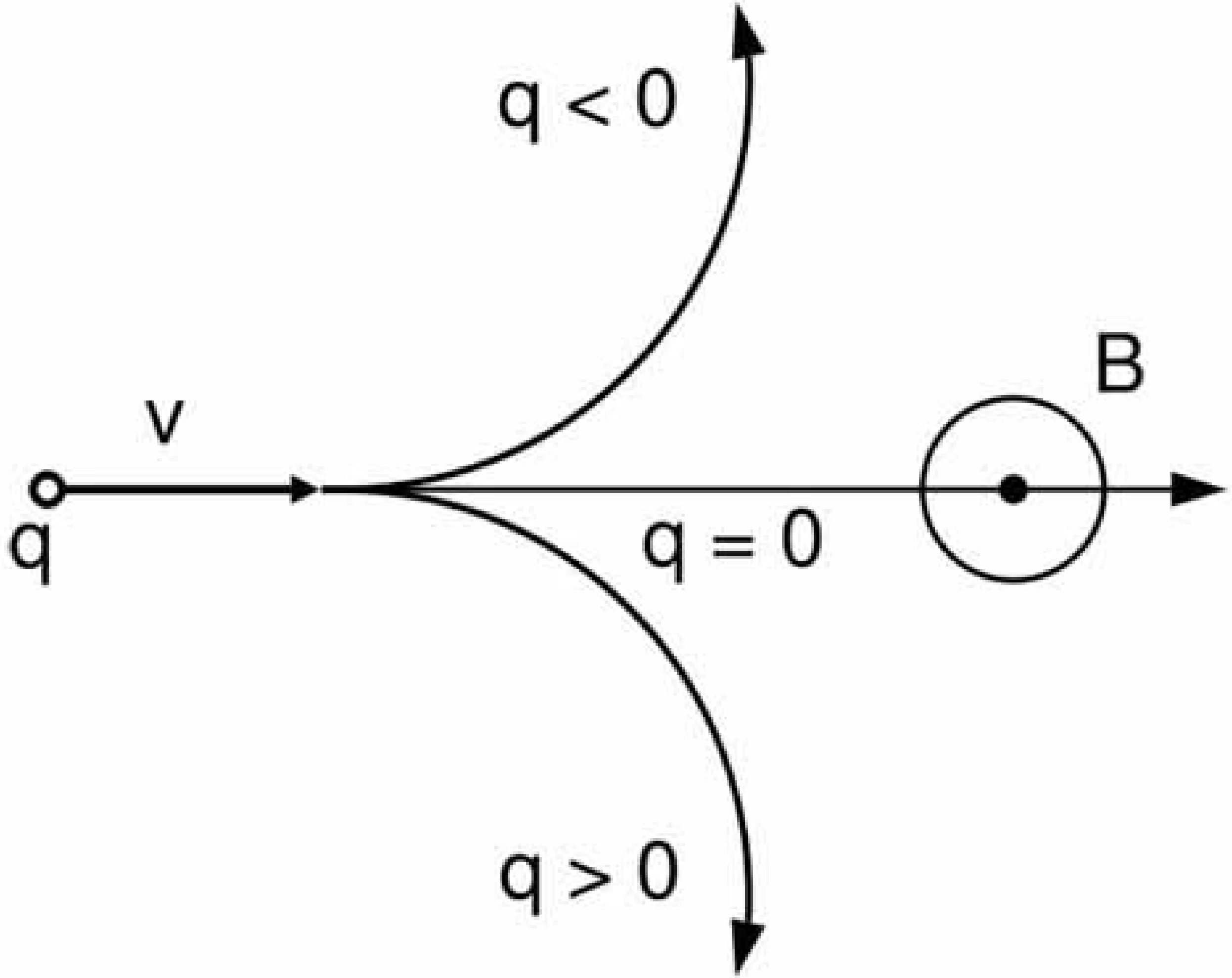
a. 1.6×10^{-13} N directed out of the plane

b. 1.6×10^{-13} N directed into the plane

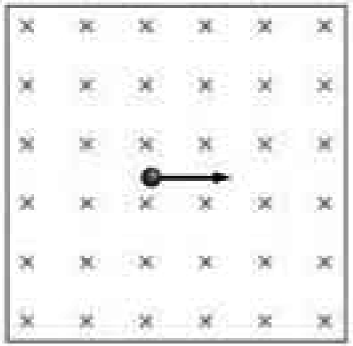
c. $\sqrt{3} \times 10^{-13}$ N directed out of the plane

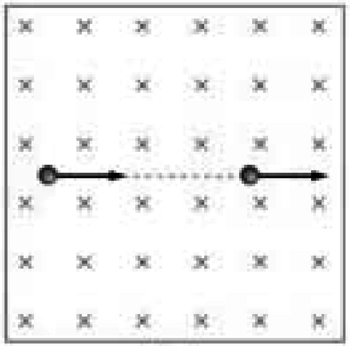
d. there is no magnetic force on the particle

$F = qBv_{\perp}$

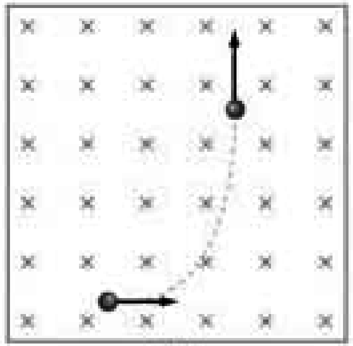

q < 0
B
v
q
q = 0
q > 0

The figure at right shows the instantaneous velocity of a positively charged particle within a uniform magnetic field. Particle velocity is perpendicular to the magnetic field (directed into the plane). Which of the following images best represents possible subsequent motion of the particle?

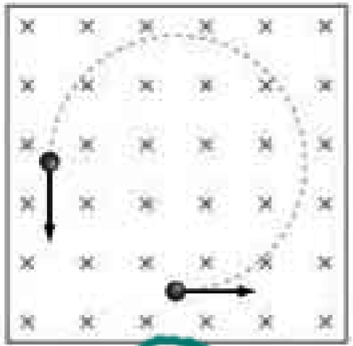




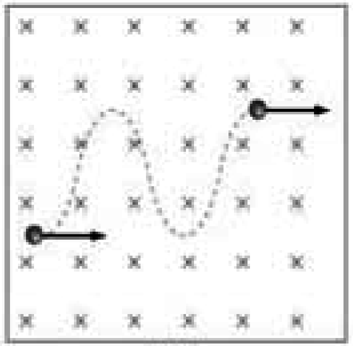
(a)



(b)

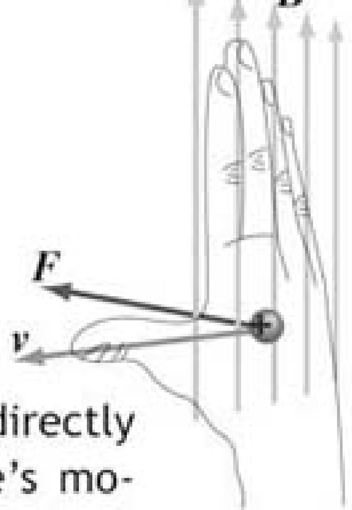


(c)



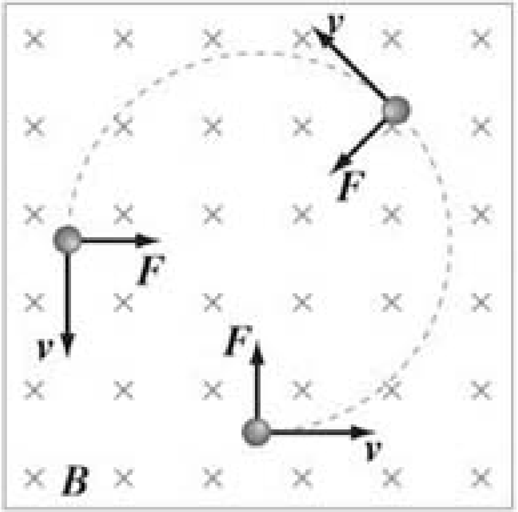
(d)

The answer is (c)



The magnetic force is perpendicular both to the particle velocity and to the magnetic field. The particle moves in a circle. The magnetic force is a *centripetal force*.

$$F = qvB = \frac{mv^2}{r}$$



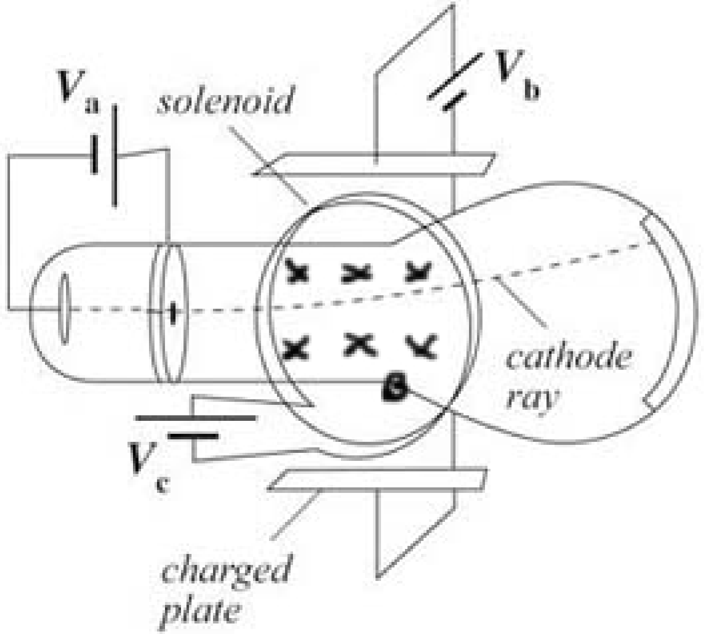
The radius of the circle is directly proportional to the particle's momentum, and inversely proportional to the charge and magnetic field strength.

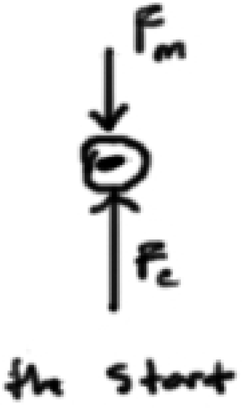
$$r = \frac{mv}{qB}$$

The angular frequency of a particle trapped in circular motion within a uniform magnetic field is called the *cyclotron frequency*.

NOTE THAT THE MAGNETIC FORCE IS PERPENDICULAR TO VELOCITY (AND INSTANTANEOUS DISPLACEMENT), SO A STEADY MAGNETIC FIELD DOES NO WORK ON A CHARGED PARTICLE. ITS DIRECTION CHANGES, BUT WITH NO DISSIPATION, KINETIC ENERGY IS CONSTANT.

The magnetic force produced by the solenoid current upon the cathode ray at right opposes the electrostatic force produced by the charged plates. Which of the following by itself could straighten the beam so that it strikes the center of the phosphorescent screen?





I. Increasing V_a

II. Decreasing V_a

III. Increasing V_b

IV. Increasing V_c

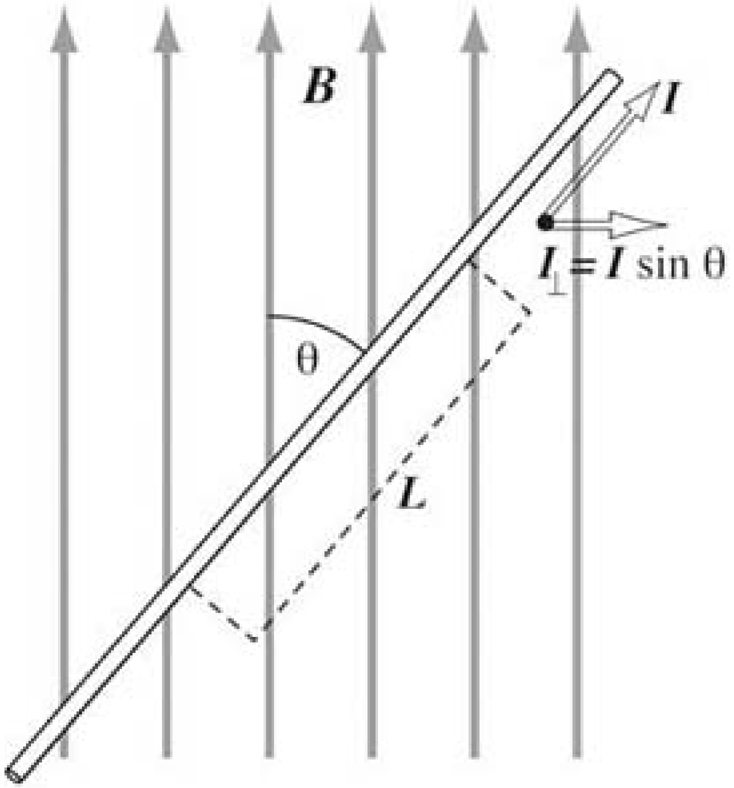
a. II only   b. IV only   c. I or IV   d. I, II or III

Magnetic Force on a Segment of Current Carrying Wire

$$F = LBI\sin\theta$$

Supplemental

F	=	magnetic force on wire segment
L	=	segment length
B	=	magnetic field strength
I	=	current
θ	=	angle between the current and the magnetic field

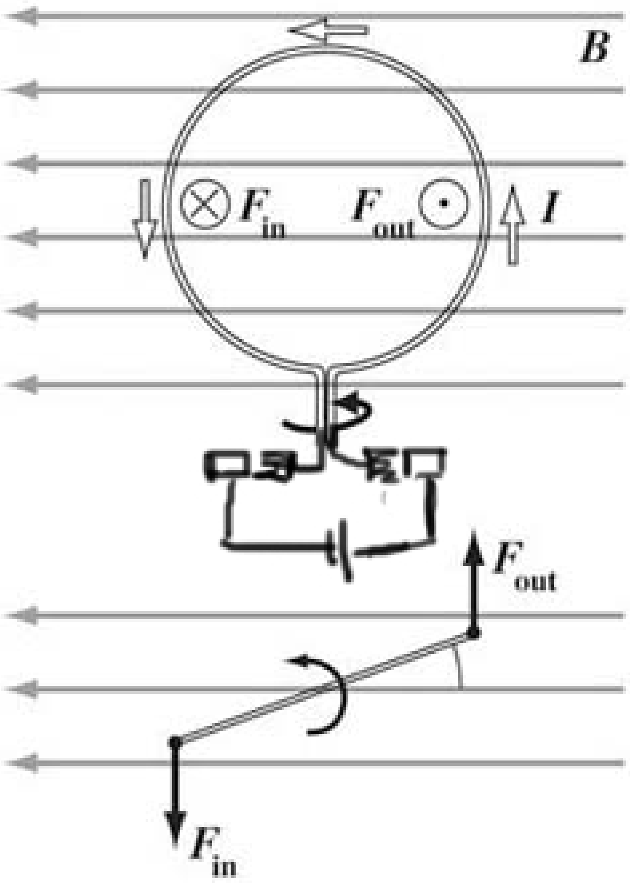


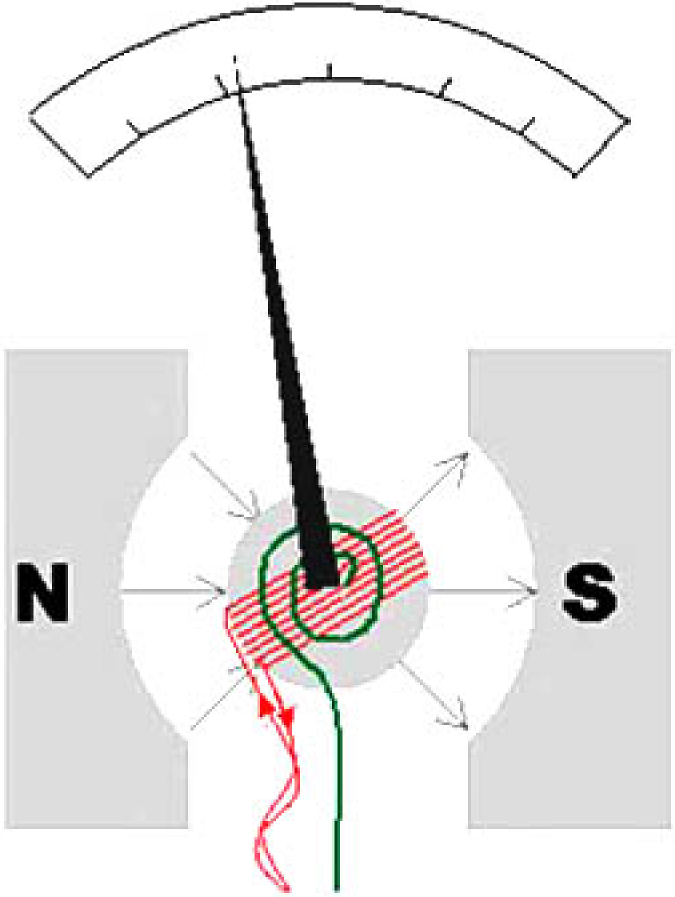
Magnetic force is directed out of the plane of the image.

Torque on a Current Loop within a Uniform Magnetic Field

$$\tau = IAB \cos \phi$$

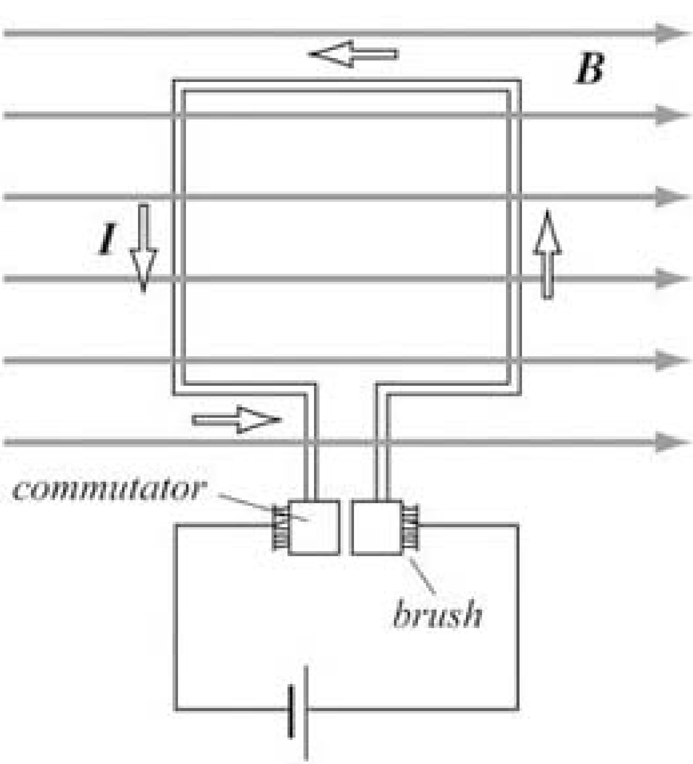
τ = torque on current loop
I = current
A = area of loop
B = magnetic field strength
ϕ = angle between the loop plane and the magnetic field





galvanometer to measure current

From the point of view depicted in the figure at right, which of the following occurs when current is supplied to the loop at right?



a. the loop rotates clockwise

b. the loop rotates counter-clockwise

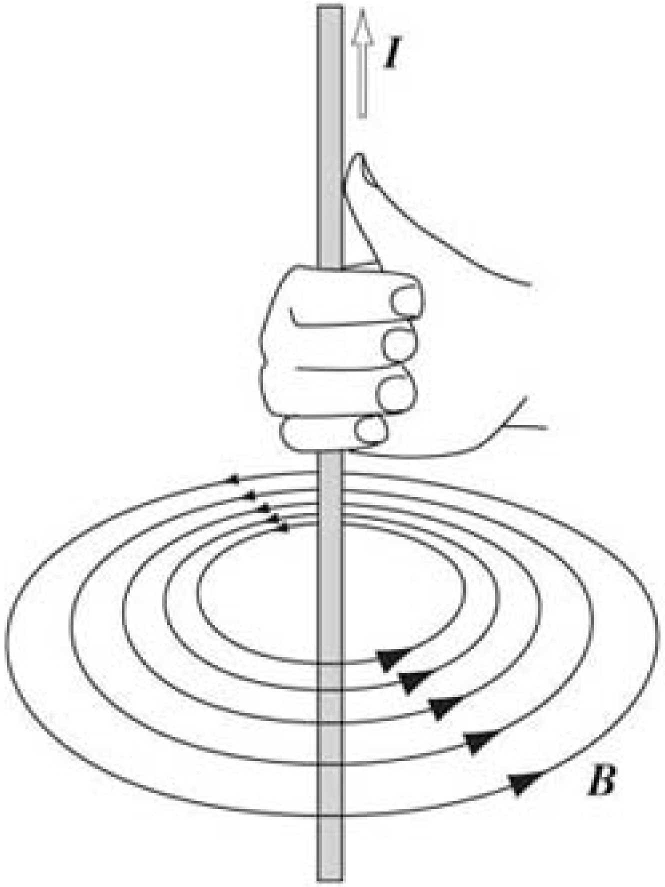
c. the loop is compressed

d. there is no net torque on the loop

Magnetic Field of a Straight Current Carrying Wire

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

B	=	magnetic field strength at distance d
I	=	current
μ_0	=	pemeability of free space ($4\pi \times 10^{-7}$ T m/A)
d	=	distance from the wire



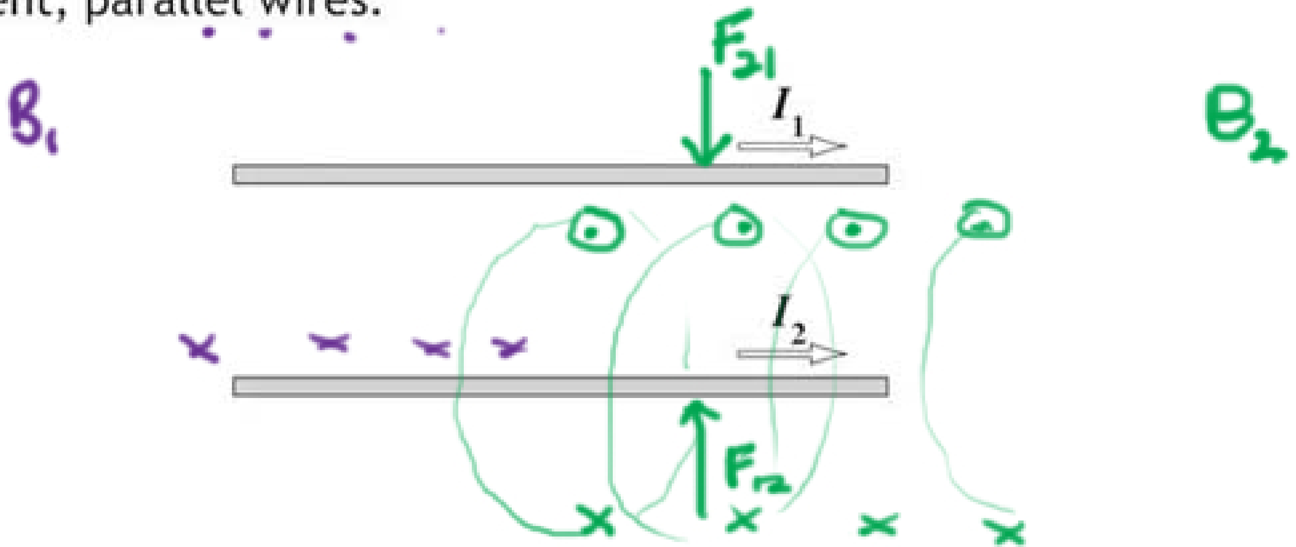
2nd right hand rule

to determine the magnetic field of a current.

Ampere's Law

For any closed loop path, the sum of the products of the length elements and the magnetic field in the direction of the length elements is proportional to the electric current enclosed in the loop (magnetic permeability, μ_0, is the constant of proportionality).

When electric current is flowing in the same direction through two, adjacent, parallel wires:



a. The wires attract each other

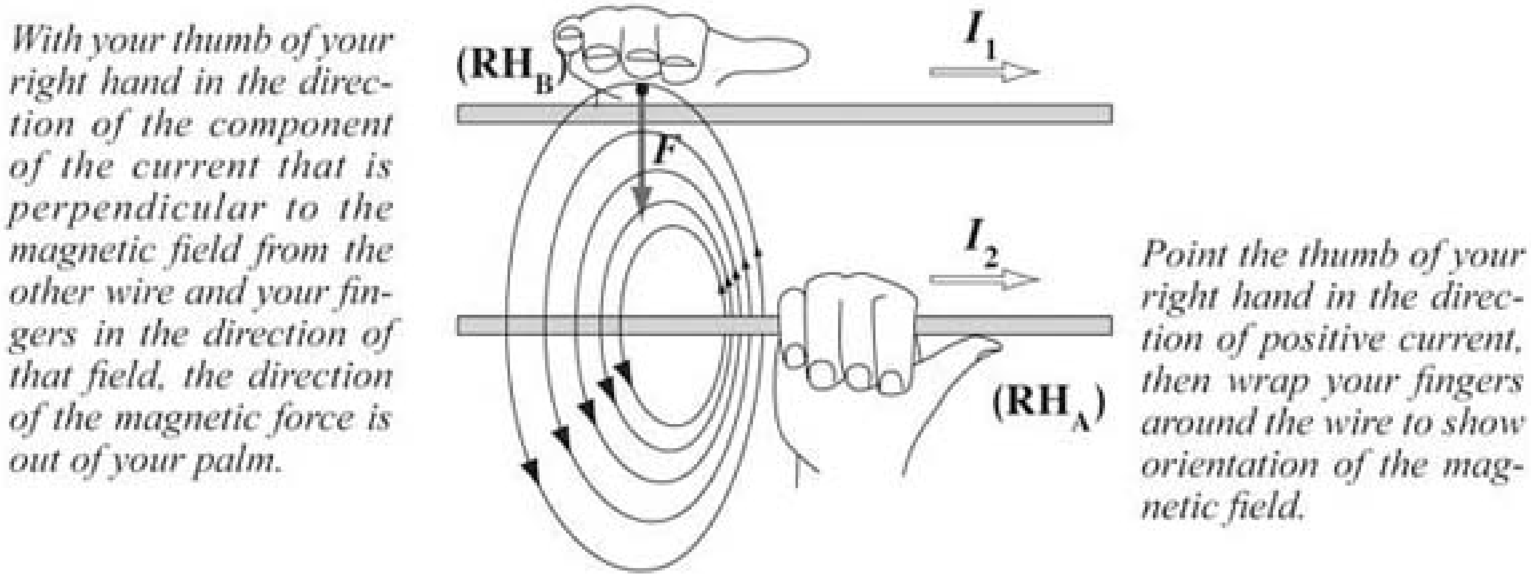
b. The wires repel each other

c. The wires do not interact

d. The wires generate an alternating current

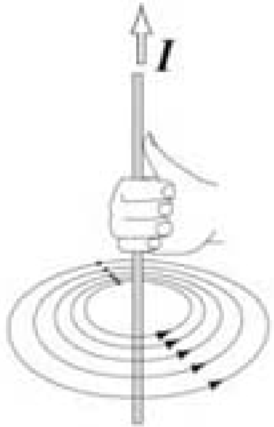
The answer is (a)

Use both right hand rules: Use the first rule, ($\mathbf{RH_A}$), to predict the orientation of a field produced by the current of one of the wires. The second rule, ($\mathbf{RH_B}$), predicts the orientation of the magnetic force (of course, each wire feels an equal and opposite attractive force).



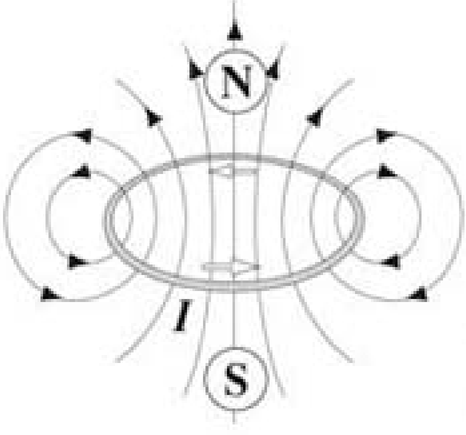
PARALLEL WIRES WITH CURRENT IN THE SAME DIRECTION ATTRACT EACH OTHER. PARALLEL WIRES WITH CURRENT IN THE OPPOSITE DIRECTION REPEL EACH OTHER. PERPENDICULAR WIRES DO NOT INTERACT.

Magnetic Fields Produced by Various Current Geometries



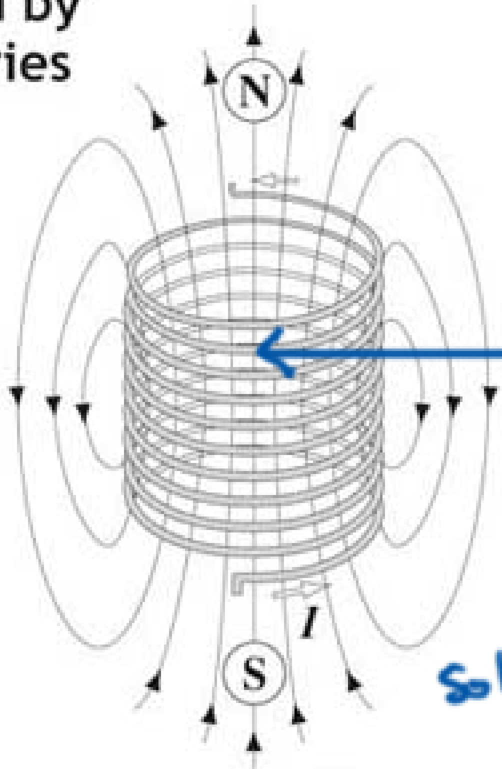
$$B = \frac{\mu_0 I}{2\pi d}$$

- B = magnetic field strength
- I = current
- μ_0 = pemeability of free space ($4\pi \times 10^{-7}$ T m/A)
- d = distance from the wire



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

- B = magnetic field strength at loop center
- r = radius



inside is a uniform magnetic field

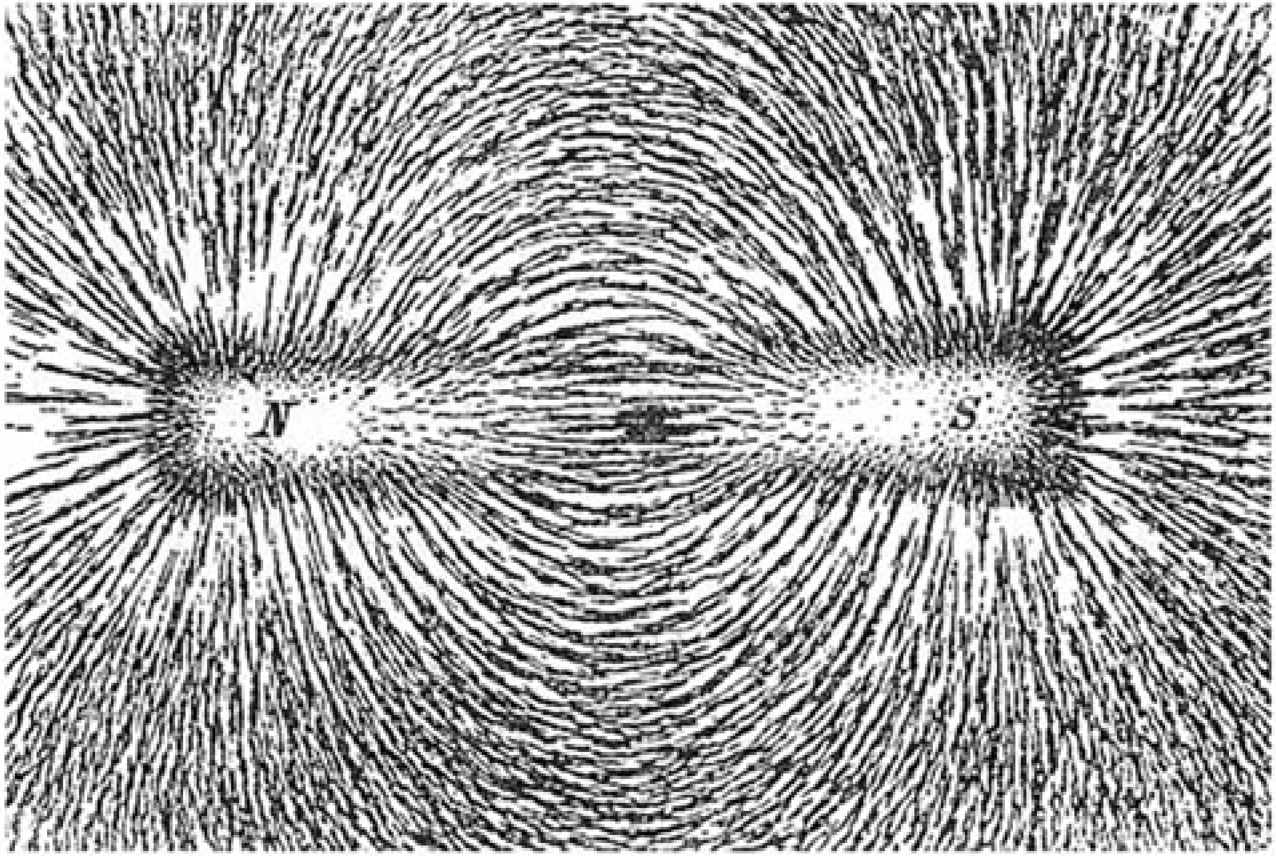
solenoid

$$B = n \mu_0 I$$

- B = magnetic field strength within the solenoid
- n = turns per unit length

formulas are supplementary

Magnetism in matter



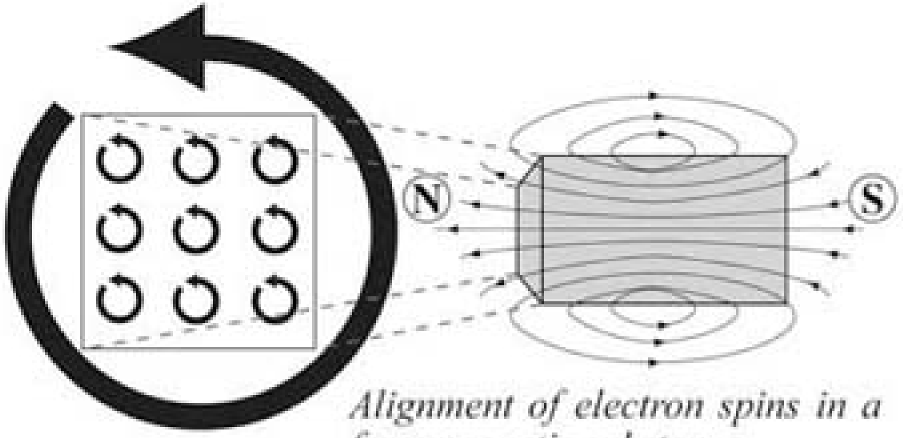
Magnetism in Matter

Paramagnetism

Paramagnetic substances contain electrons within atomic or molecular orbitals that are unpaired, producing net electron spin. Paramagnetic substances are weakly attracted by magnetic fields.

Ferromagnetism

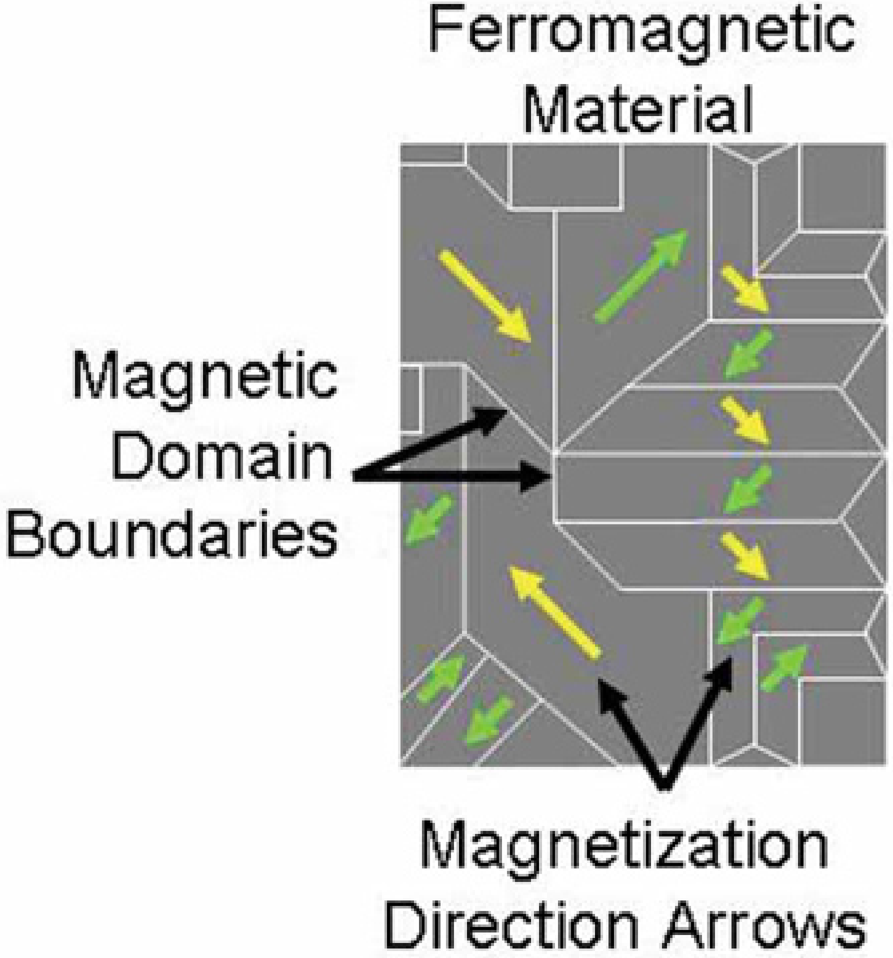
Ferromagnetic substances can be permanently magnetized as randomly oriented electron spins align cooperatively in domains. Ferromagnetism is much stronger than paramagnetism.

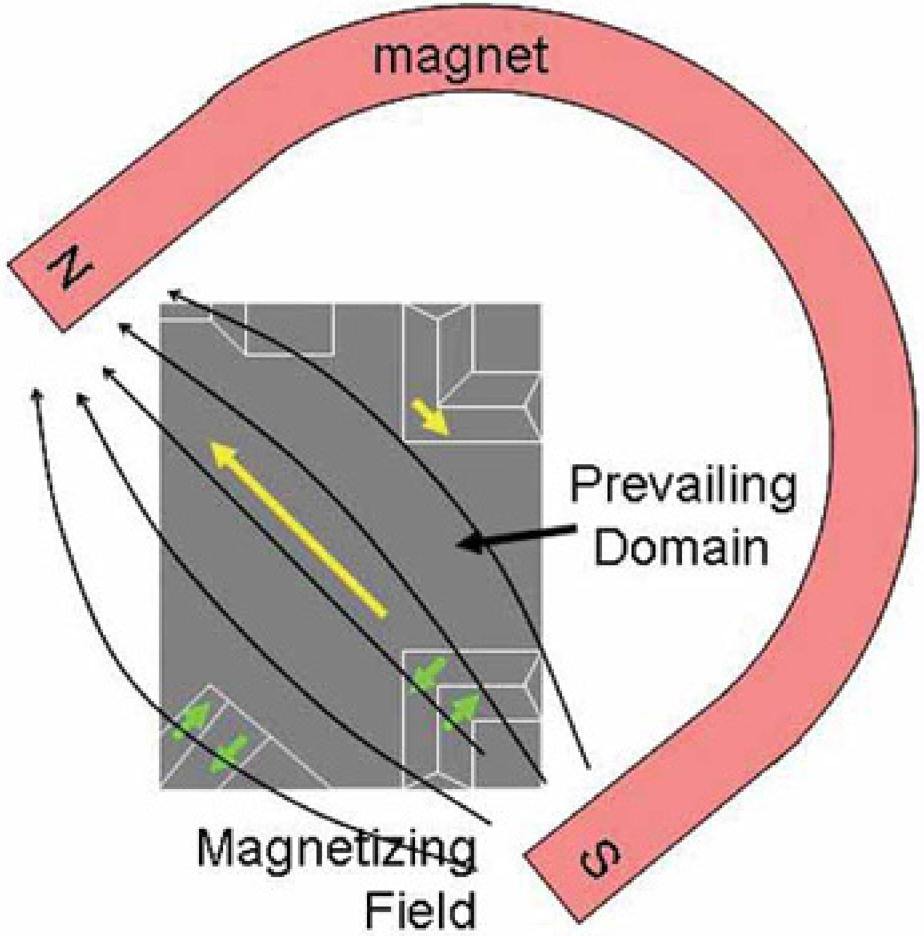


Alignment of electron spins in a ferromagnetic substance.

Diamagnetism

In diamagnetic substances all electrons are paired. Diamagnetic substances are very, very weakly repelled by magnetic fields, a much weaker interaction than either paramagnetism or ferromagnetism.


Ferromagnetic Material
Magnetic Domain Boundaries
Magnetization Direction Arrows


magnet
N
S
Prevailing Domain
Magnetizing Field