Magnetic Fields

Lecture Contents

- Magnetic Fields and Forces.
- Magnetic Force Acting on a Current Carrying Conductor.

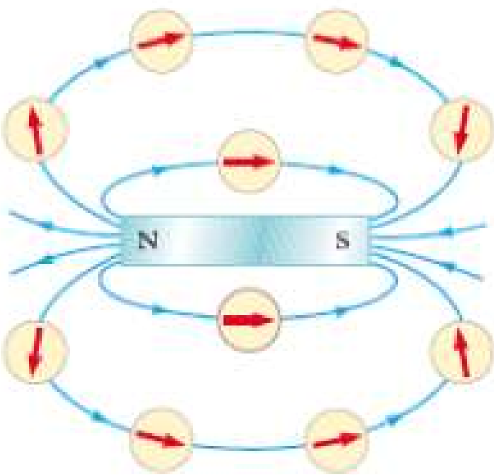
Magnetic Fields And Forces

•Electric Field is for any charged object.

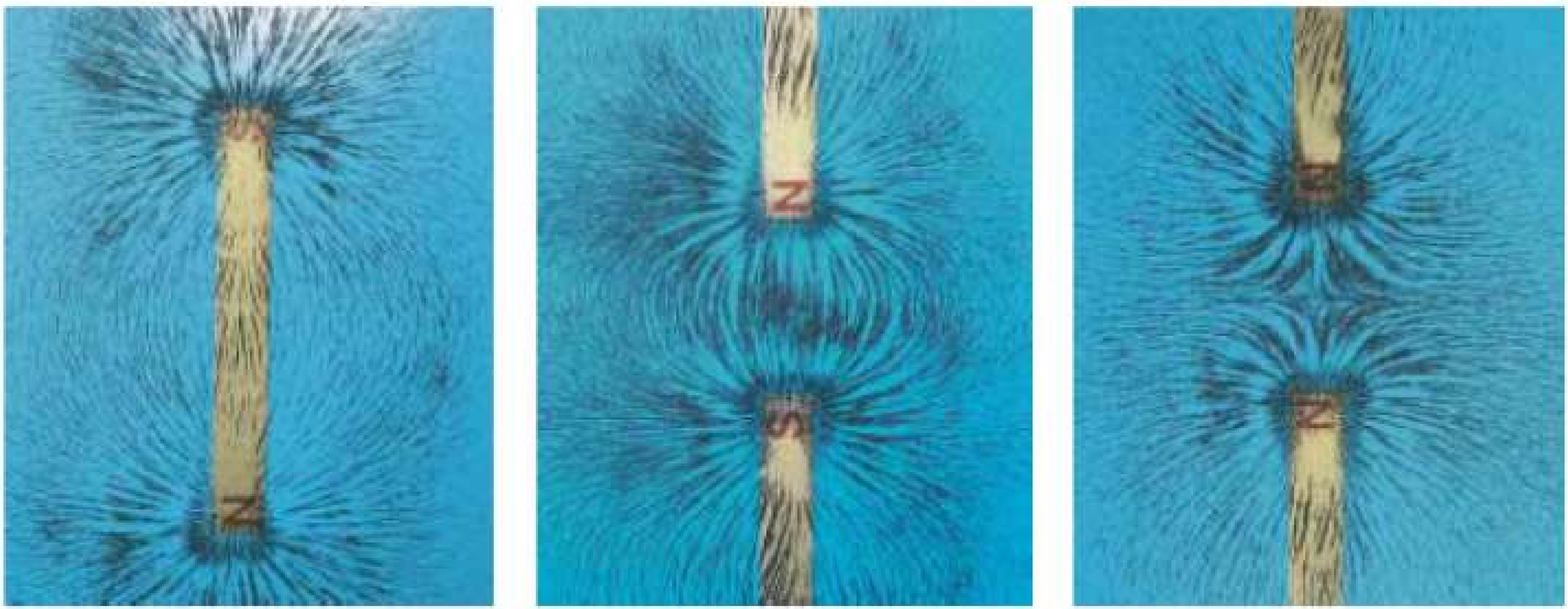
•Moving Charge creates magnetic field.

•Some materials are permanent magnet.

•The symbol of Magnetic Field is B.



Magnetic Fields And Forces



(a) (b) (c)

Magnetic Fields And Forces

- B can be defined in any point by terms of F_B (Magnetic force exerted by the field on a charged particle moving with a velocity of v).

The magnitude F_B of the magnetic force exerted on the particle is proportional to the charge q and to the speed v of the particle.

- The magnitude and direction of F_B depend on the velocity of the particle and on the magnitude and direction of the magnetic field B.

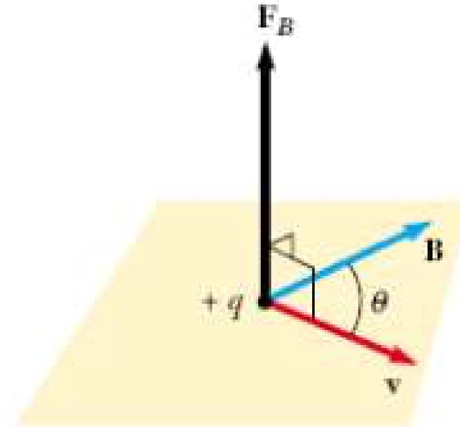
- When a charged particle moves parallel to the magnetic field vector, the magnetic force acting on the particle is zero.

Magnetic Fields And Forces

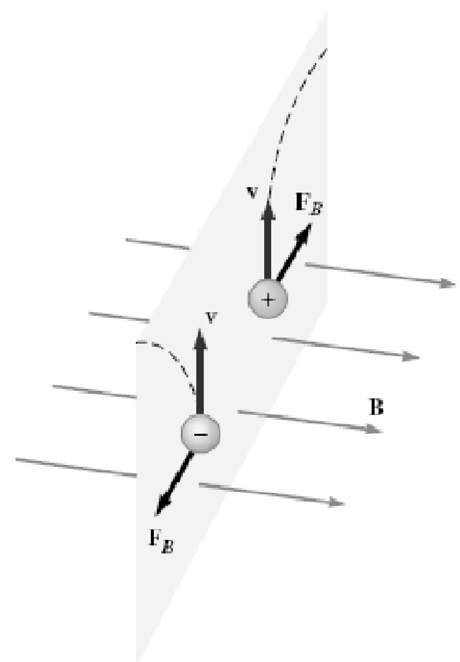
•When the particle's velocity vector makes any angle $\theta \neq 0$ with the magnetic field, the magnetic force acts in a direction perpendicular to both v and B; that is, F_B is perpendicular to the plane formed by v and B (Fig. a).

• The magnetic force exerted on a positive charge is in the direction opposite the direction of the magnetic force exerted on a negative charge moving in the same direction (Fig.b).

• The magnitude of the magnetic force exerted on the moving particle is proportional to sin !, where ! is the angle the particle's velocity vector makes with the direction of B.



(a)

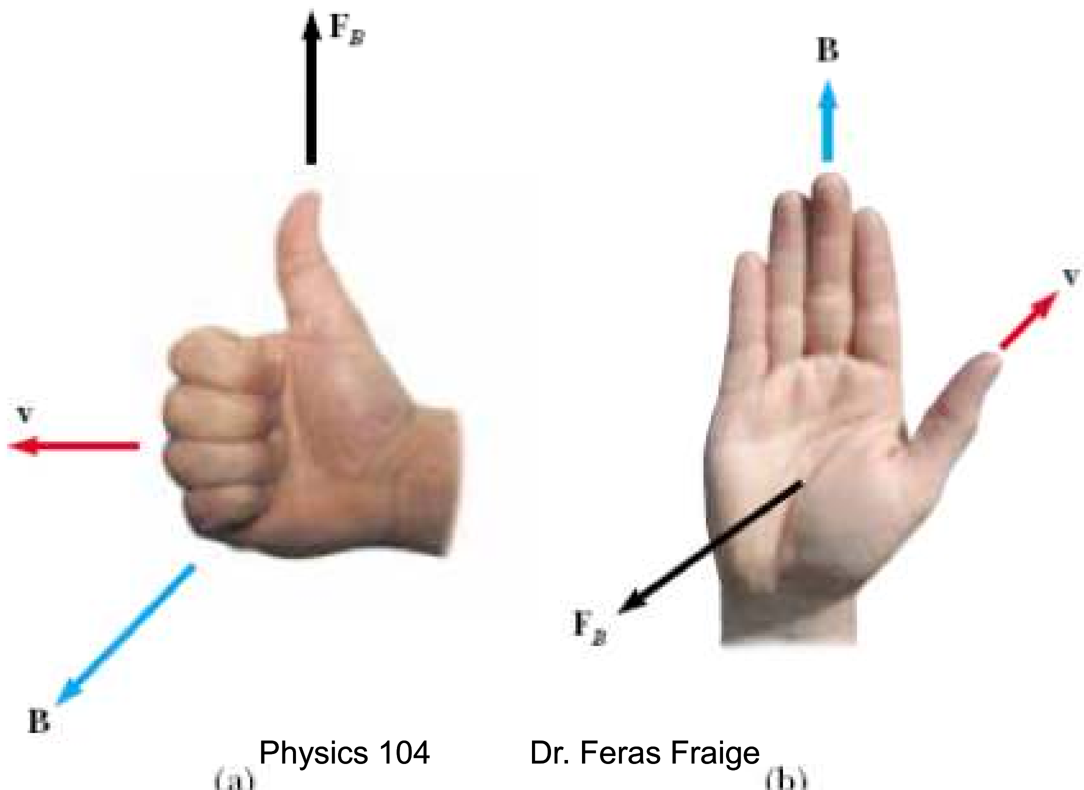


(b)

Magnetic Fields And Forces

- The magnetic Force can be defined as

$$\mathbf{F}_B = q\mathbf{v} \times \mathbf{B}$$



Magnetic Fields And Forces

•The magnitude of the magnetic Force is

$$\mathbf{F}_B = q\mathbf{v} \times \mathbf{B}$$

$$F_B = |q| vB \sin\theta$$

$$1\ \text{T} = 1 \frac{\text{N}}{\text{C} \cdot \text{m/s}}$$

$$1\ \text{T} = 10^4\ \text{G}.$$

• The electric force acts along the direction of the electric field, whereas the magnetic force acts perpendicular to the magnetic field.

• The electric force acts on a charged particle regardless of whether the particle is moving, whereas the magnetic force acts on a charged particle only when the particle is in motion.

•The electric force does work in displacing a charged particle, whereas the magnetic force associated with a steady magnetic field does no work when a particle is displaced because the force is perpendicular to the displacement.

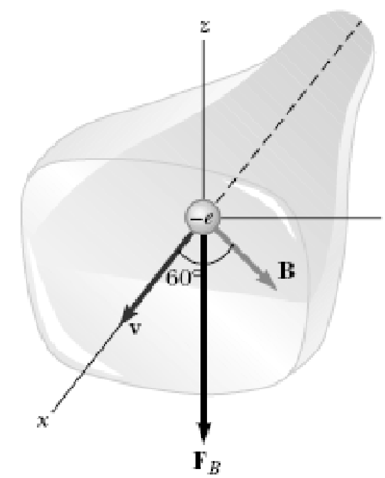
Typical Values of Magnetic Fields

Some Approximate Magnetic Field Magnitudes	
Source of Field	**Field Magnitude (T)**
Strong superconducting laboratory magnet	30
Strong conventional laboratory magnet	2
Medical MRI unit	1.5
Bar magnet	10^{-2}
Surface of the Sun	10^{-2}
Surface of the Earth	0.5×10^{-4}
Inside human brain (due to nerve impulses)	10^{-13}

Example 1

An electron in a television picture tube moves toward the front of the tube with a speed of 8.0×10^6 m/s along the x axis (Fig. 29.5). Surrounding the neck of the tube are coils of wire that create a magnetic field of magnitude 0.025 T, directed at an angle of 60° to the x axis and lying in the xy plane.

(A) Calculate the magnetic force on the electron using



$$\begin{aligned} F_B &= |q| vB \sin\theta \\ &= (1.6 \times 10^{-19}\ \text{C})(8.0 \times 10^6\ \text{m/s})(0.025\ \text{T})(\sin 60°) \\ &= \boxed{2.8 \times 10^{-14}\ \text{N}} \end{aligned}$$

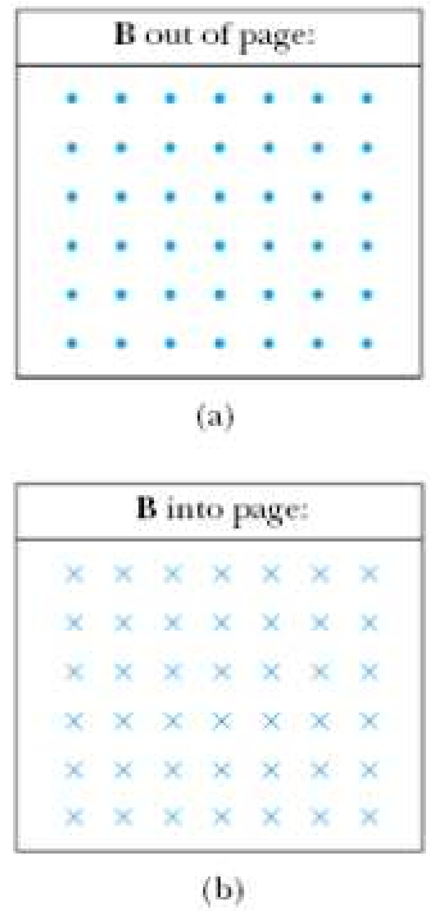
Magnetic Force acting on a Current-carrying conductor

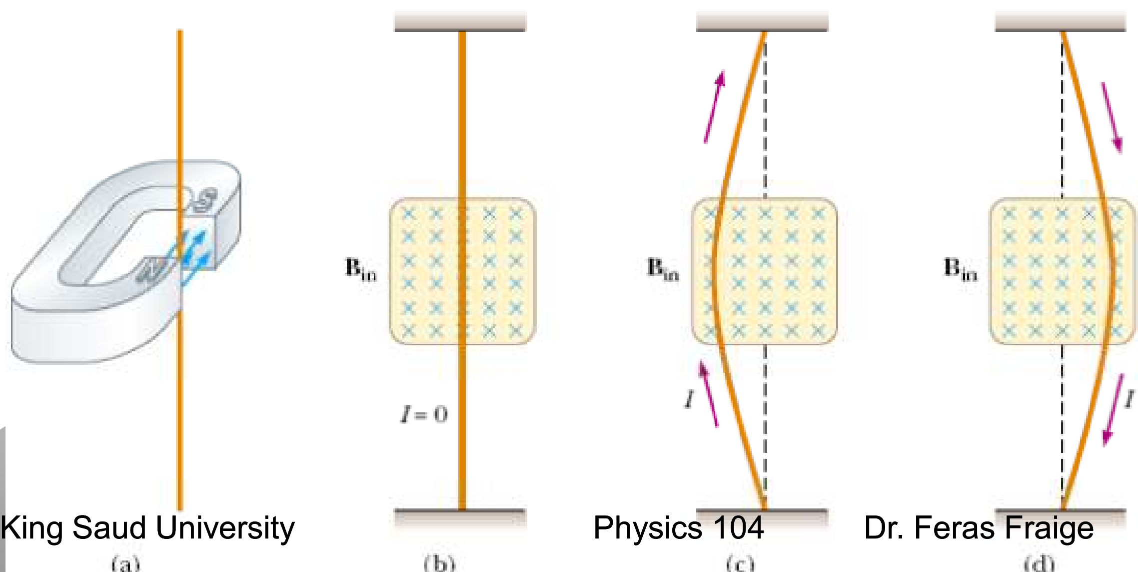
•Magnetic force exerted on a moving charge.

•The current is the time rate of moving charges.

B direction➔Dots: perpendicular out from the page and coming out toward you.

Crosses: perpendicular into the page and fired away from you.





Magnetic Force acting on a Current-carrying conductor

- Magnetic force exerted on a moving charge is

$$\mathbf{F}_B = (q\mathbf{v}_d \times \mathbf{B})$$

- In a wire total charge should accounted for:

$\mathbf{F}_B = (q\mathbf{v}_d \times \mathbf{B})nAL$ But $I = nqv_dA$

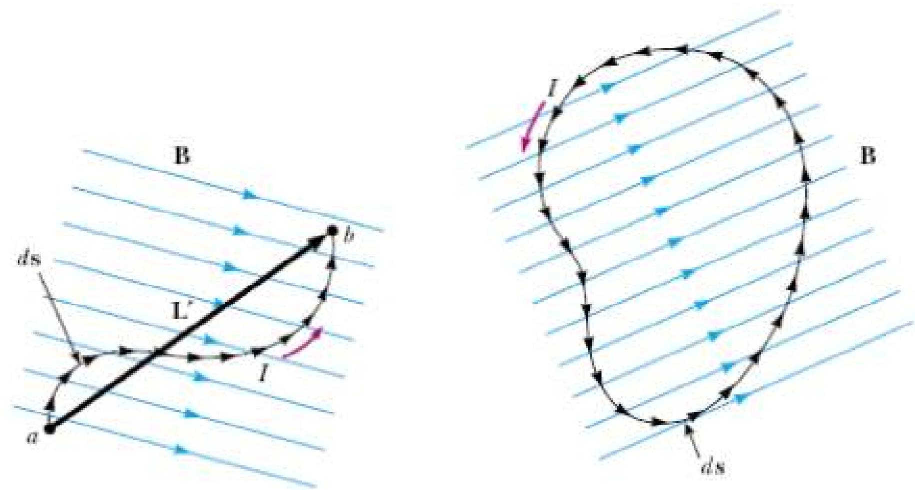
$$\mathbf{F}_B = I\mathbf{L} \times \mathbf{B}$$

- Applies to straight segment of wire at uniform magnetic field.
- What about a Curved wire?

Magnetic Force acting on a Current-carrying conductor

- The magnetic force on a curved wire is

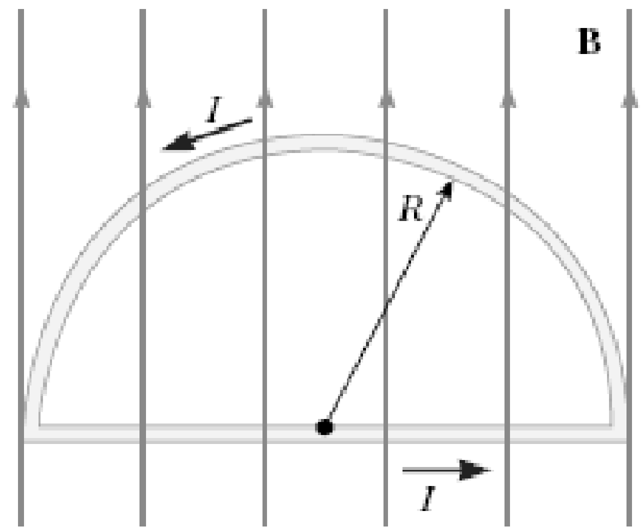
$$\mathbf{F}_B = I\,\mathbf{L}' \times \mathbf{B}$$



(a) (b)

Example 1

A wire bent into a semicircle of radius R forms a closed circuit and carries a current I. The wire lies in the xy plane, and a uniform magnetic field is directed along the positive y axis, as shown in Figure 29.12. Find the magnitude and direction of the magnetic force acting on the straight portion of the wire and on the curved portion.



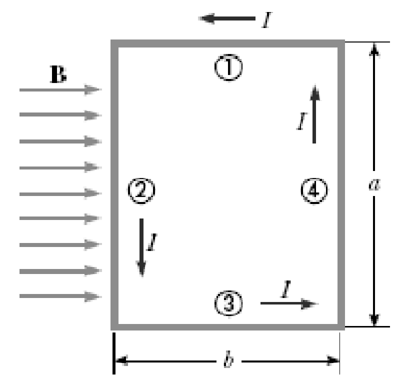
- *Straight segment:*

$\mathbf{F}_B = I\,\mathbf{L} \times \mathbf{B}$

- $F_1 = ILB = 2IRB$ *k*
- *For the curved wire is the same except the direction*
- *For the loop is the sum*

Torque on a Current loop in a Magnetic Field

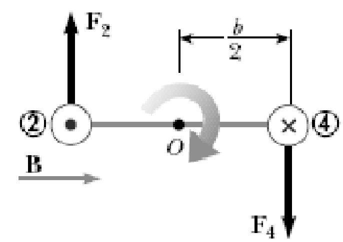
- Loop has a current *I*.
- No magnetic force acting on sections 1 and 3 (why?).
- The mag Magnetic force on section 2 and 4 = IaB.
- The max torque can be estimated by:



(a)

$$\tau_{\max} = F_2\frac{b}{2} + F_4\frac{b}{2} = (IaB)\frac{b}{2} + (IaB)\frac{b}{2} = IabB$$

$$\tau_{\max} = IAB$$

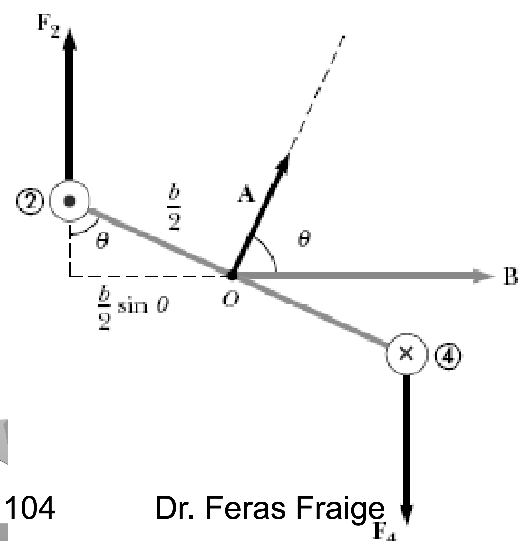


(b)

$$\tau = F_2\frac{b}{2}\sin\theta + F_4\frac{b}{2}\sin\theta$$

$$= IaB\left(\frac{b}{2}\sin\theta\right) + IaB\left(\frac{b}{2}\sin\theta\right) = IabB\sin\theta$$

$$= IAB\sin\theta$$



$$\tau = I\mathbf{A}\times\mathbf{B}$$

Torque on a Current loop in a Magnetic Field

- The product of I and A is termed magnetic dipole moment.

$$\boldsymbol{\mu} = I\mathbf{A}$$

- The torque is then

$$\boldsymbol{\tau} = \boldsymbol{\mu} \times \mathbf{B}$$

Example 2

- A rectangular coil of dimensions 5.40 cm × 8.50 cm consists of 25 turns of wire and carries a current of 15.0 mA. A 0.350-T magnetic field is applied parallel to the plane of the loop.

  (A) Calculate the magnitude of its magnetic dipole moment.

  (B) What is the magnitude of the torque acting on the loop?

$$\mu_{\text{coil}} = NIA = (25)(15.0 \times 10^{-3}\ \text{A})(0.054\,0\ \text{m})(0.085\,0\ \text{m})$$

$$= \boxed{1.72 \times 10^{-3}\ \text{A}\cdot\text{m}^2}$$

$$\tau = \mu_{\text{coil}} B = (1.72 \times 10^{-3}\ \text{A}\cdot\text{m}^2)(0.350\ \text{T})$$

$$= \boxed{6.02 \times 10^{-4}\ \text{N}\cdot\text{m}}$$

Example 3

- Many satellites use coils called *torquers* to adjust their orientation. These devices interact with the Earth's magnetic field to create a torque on the spacecraft in the x, y, or z direction. The major advantage of this type of attitude-control system is that it uses solar-generated electricity and so does not consume any thruster fuel.

  If a typical device has a magnetic dipole moment of $250\ \mathrm{A \cdot m^2}$, what is the maximum torque applied to a satellite when its torquer is turned on at an altitude where the magnitude of the Earth's magnetic field is 3.0×10^{-5} T?

$$\tau_{\max} = \mu B = (250\ \mathrm{A \cdot m^2})(3.0 \times 10^{-5}\ \mathrm{T})$$

$$= 7.5 \times 10^{-3}\ \mathrm{N \cdot m}$$