Physics 1502Q:
8.2 Magnetic Force on Currents

Announcements & Reminders

- Complete prelab **before lab**
- Next Homework is due **Monday at 11:59pm**
- Next Reading Assignment is due **Sunday at 11:59pm**

Preview of this week and next two weeks

Su	M	T	W	Th	F	Sa
6 Reading Assignment Due 11:59 PM	7 HW Due 11:59 PM	8 Intro to Magnetism/ Magnetic Force I	9	10 Magnetic Force II	11 Lab 6: Kirchhoff's Laws Pre-lab 6 Due before lab	12
13	14	15 SPRING RECESS	16	17	18	19
20 Reading Assignment Due 11:59 PM	21 HW Due 11:59 PM	22 Magnetic Torque/Biot-Savart Law	23	24 Biot-Savart Law II + Exam 2 Review	25 MIDTERM EXAM #2 4 PM NO LAB/NO PRELAB	26

Forces and Torques on Currents

LEARNING GOALS

By the end of this unit, you should be able to:

- Model quantitatively how electric currents respond to magnetic fields
- Calculate the magnetic dipole moment of a current loop
- Model the torque on a current loop in a magnetic field
- Calculate the magnetic potential energy of a magnetic dipole

The Magnetic Force

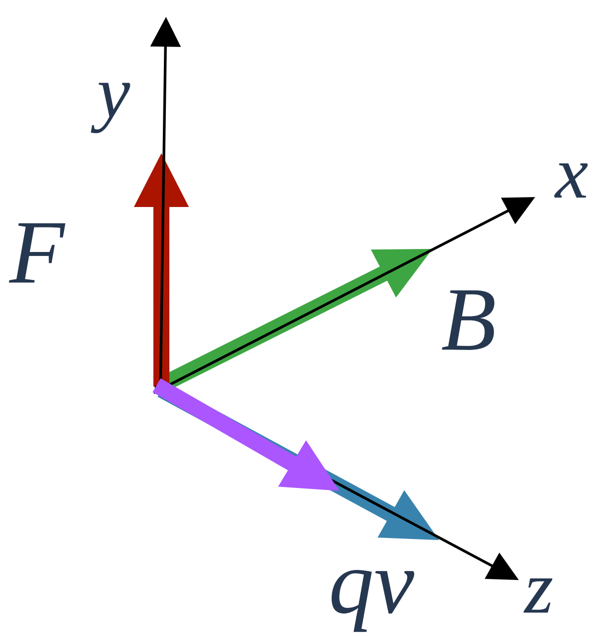
$$\boxed{\vec{F} = q\vec{v} \times \vec{B}}$$

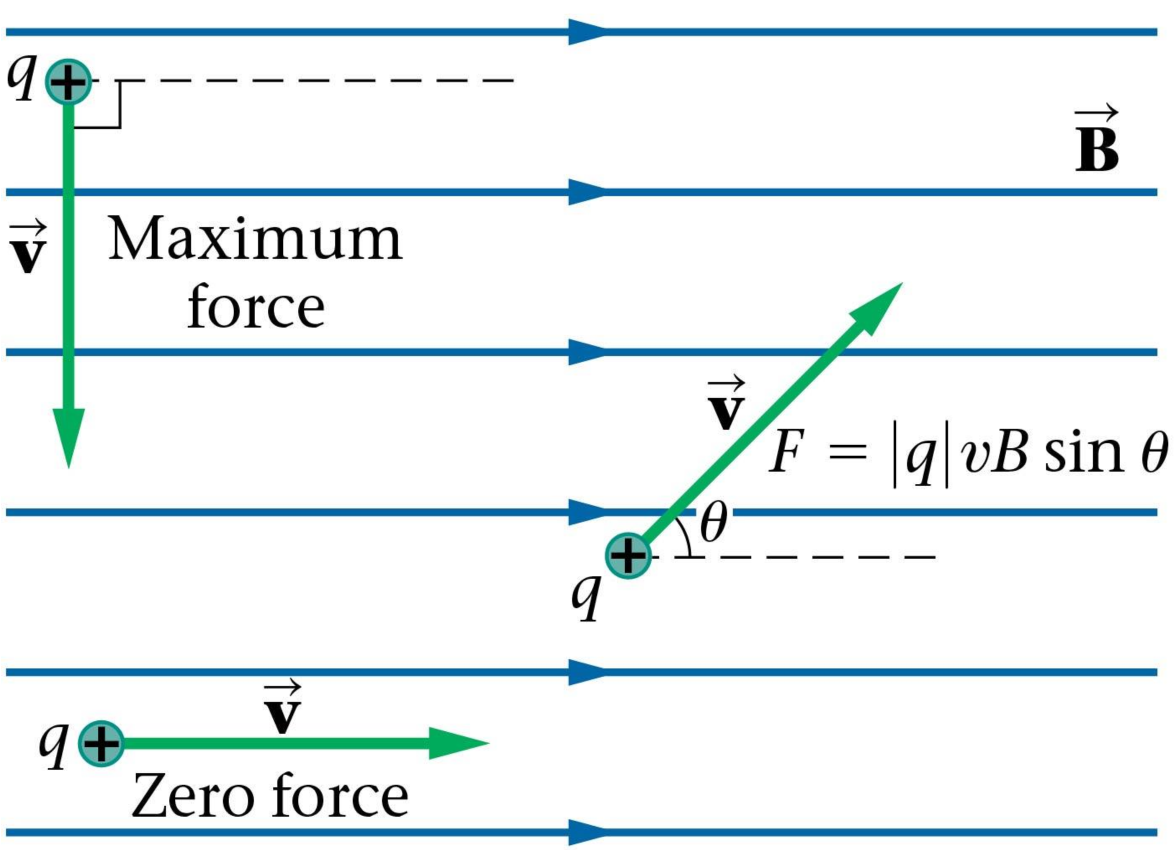
Magnetic Field

$$\boxed{F = qvB \sin \theta}$$

(for the magnitude)

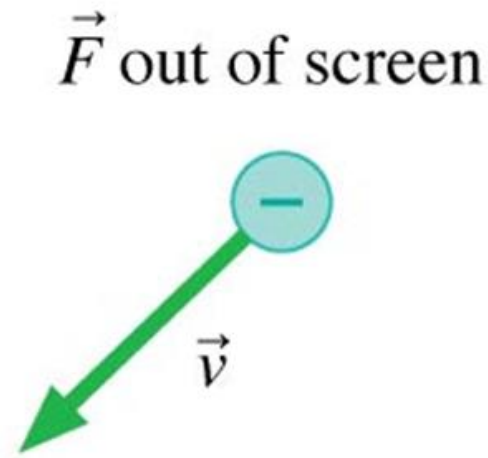
Direction given according to the cross product

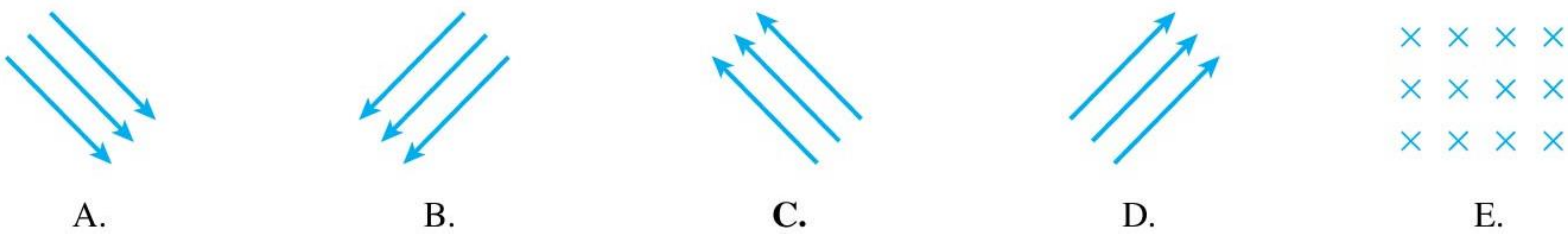




Question: Magnetic Field Acting on a Charged Particle

Which magnetic field causes the observed force?





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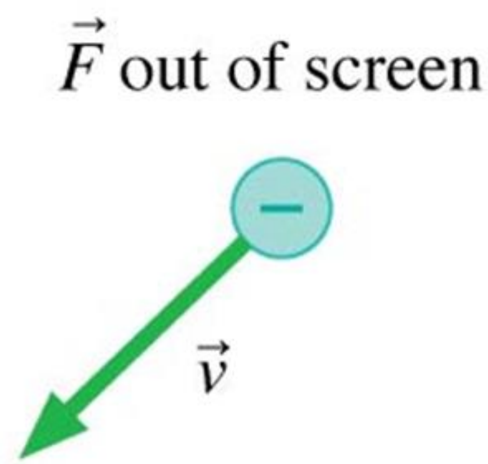
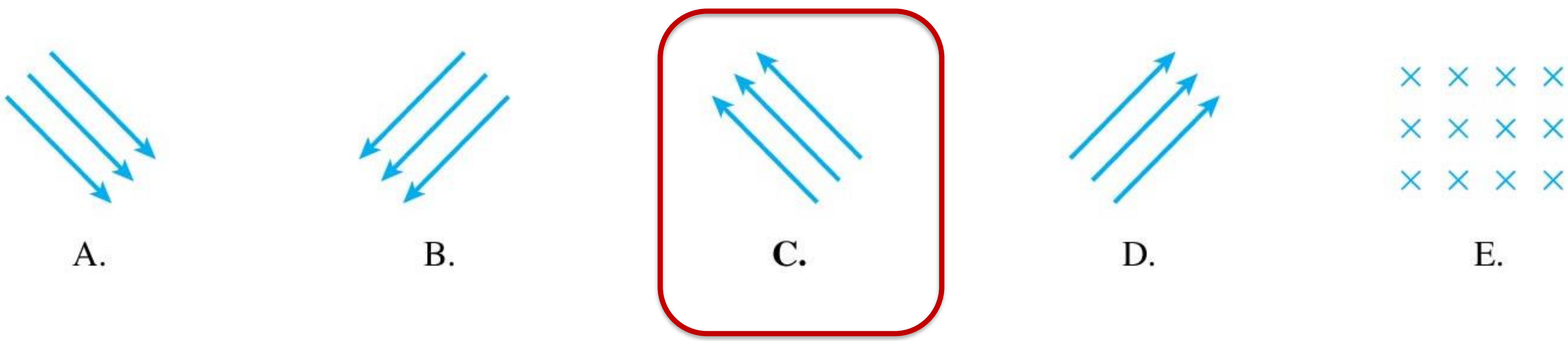




Magnetic Force on a Current

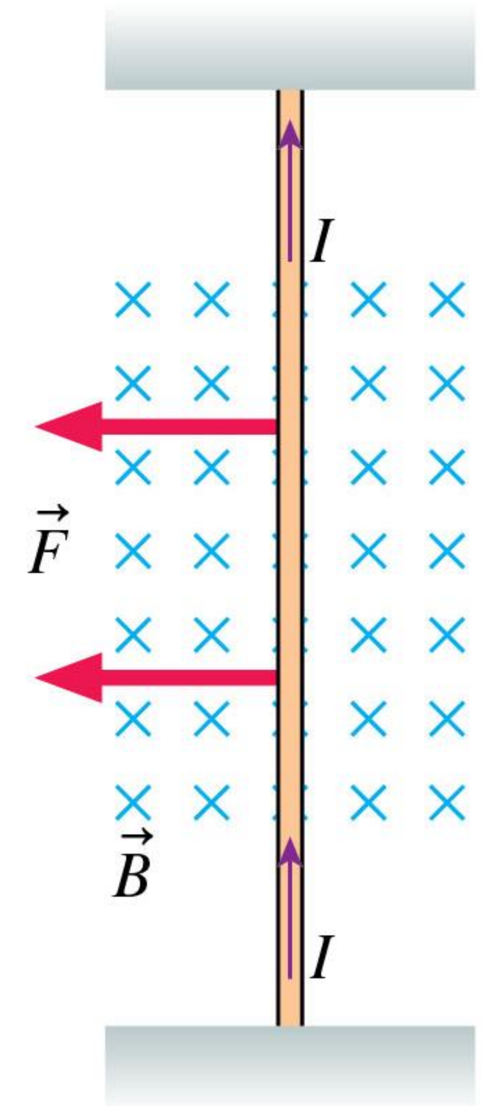
- Last class: $\vec{F} = q\vec{v} \times \vec{B}$ (force on a single charge)
- Today: We have a group of charges moving as an electric current

$$I = \frac{q}{\Delta t} \longrightarrow q = I\left(\frac{L}{v_d}\right)$$

$$v_{avg} = v_{drift} = v_d$$

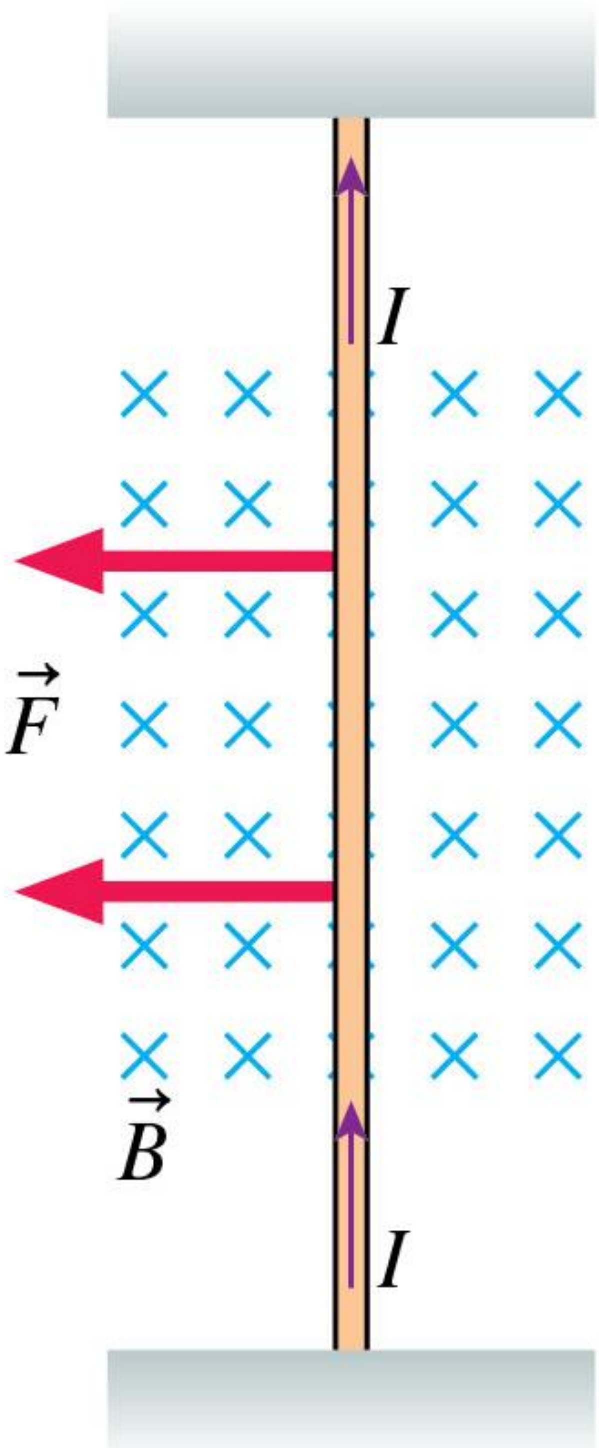
$$\vec{F} = q\vec{v_d} \times \vec{B} = I\left(\frac{L}{v_d}\right)\vec{v_d} \times \vec{B}$$

$$\boxed{\vec{F} = I\vec{L} \times \vec{B}}$$

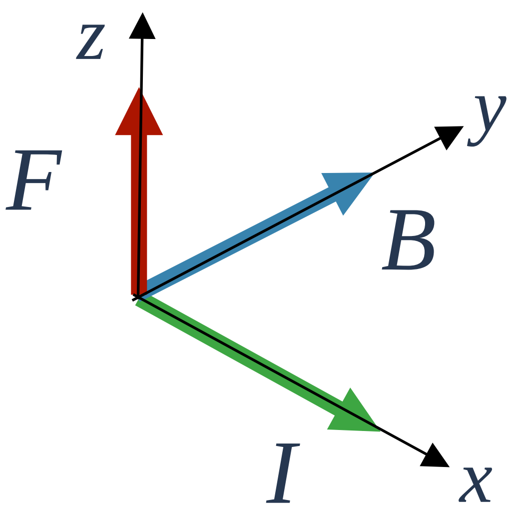


- Where L points in the direction of the current

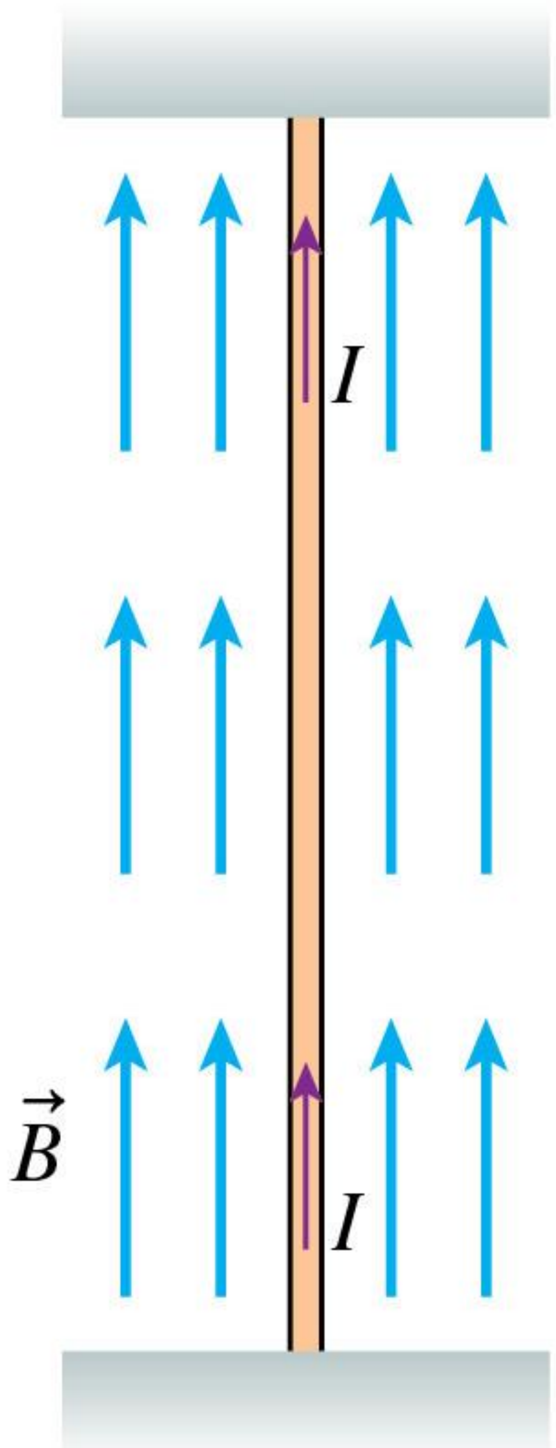
Direction of Magnetic Force on Current-Carrying Wire



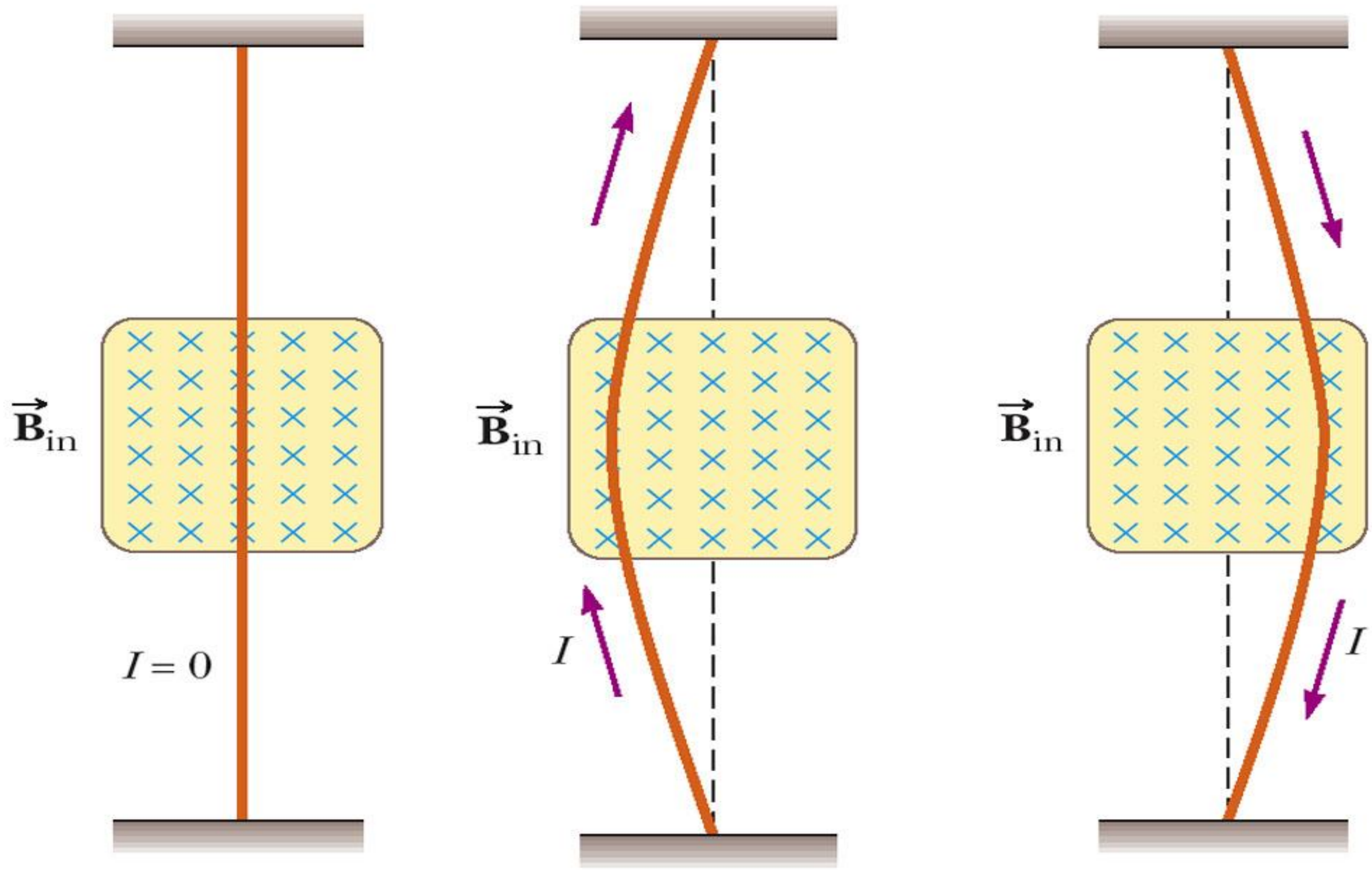
- Force in the direction of the right-hand rule.



- There's no force on a current-carrying wire parallel to a magnetic field.



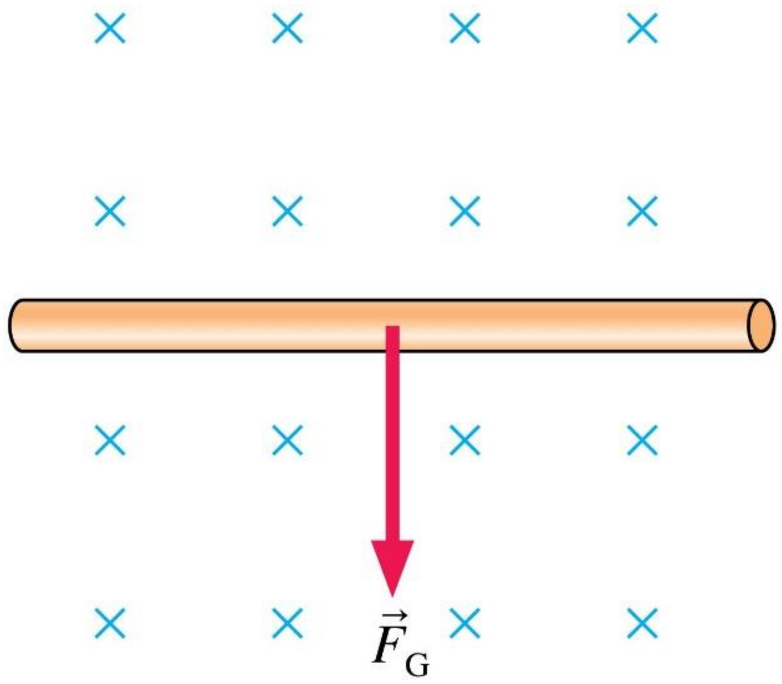
Force on a Current-Carrying Wire



Force on Wires Demo

Question: Magnetic Levitation

The horizontal wire can be levitated—held up against the force of gravity—if the current in the wire is:



A. Right to left.

B. Left to right.

C. It can't be done with this magnetic

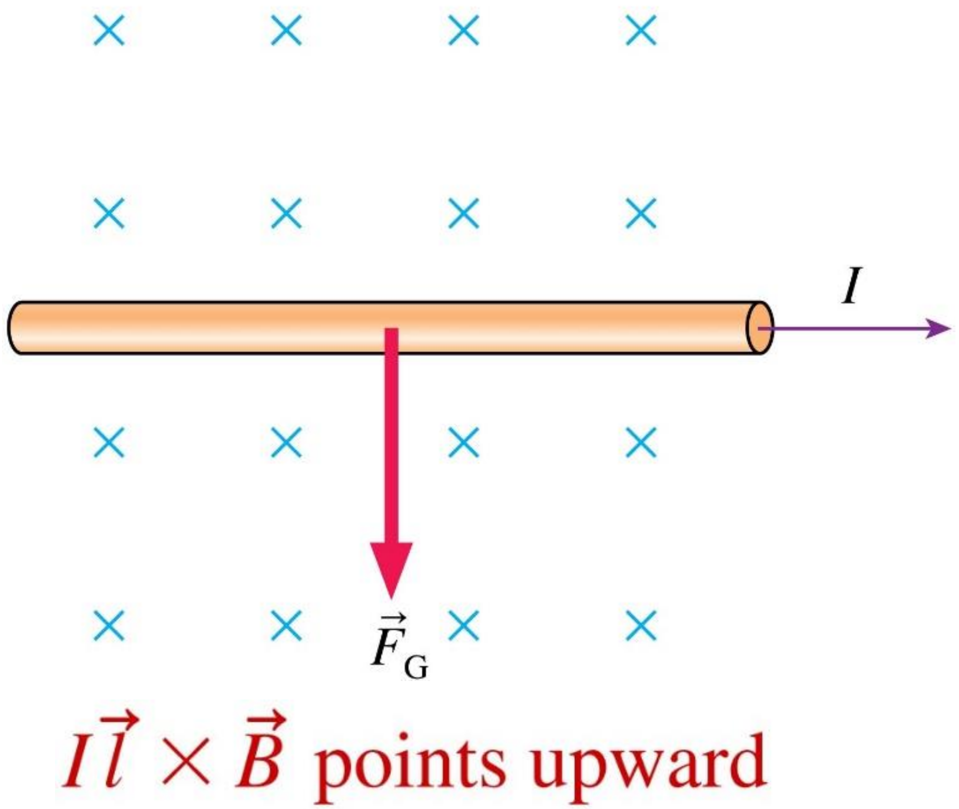
Question: Magnetic Levitation Answer

The horizontal wire can be levitated—held up against the force of gravity—if the current in the wire is:

A. Right to left.

B. Left to right.

C. It can't be done with this magnetic



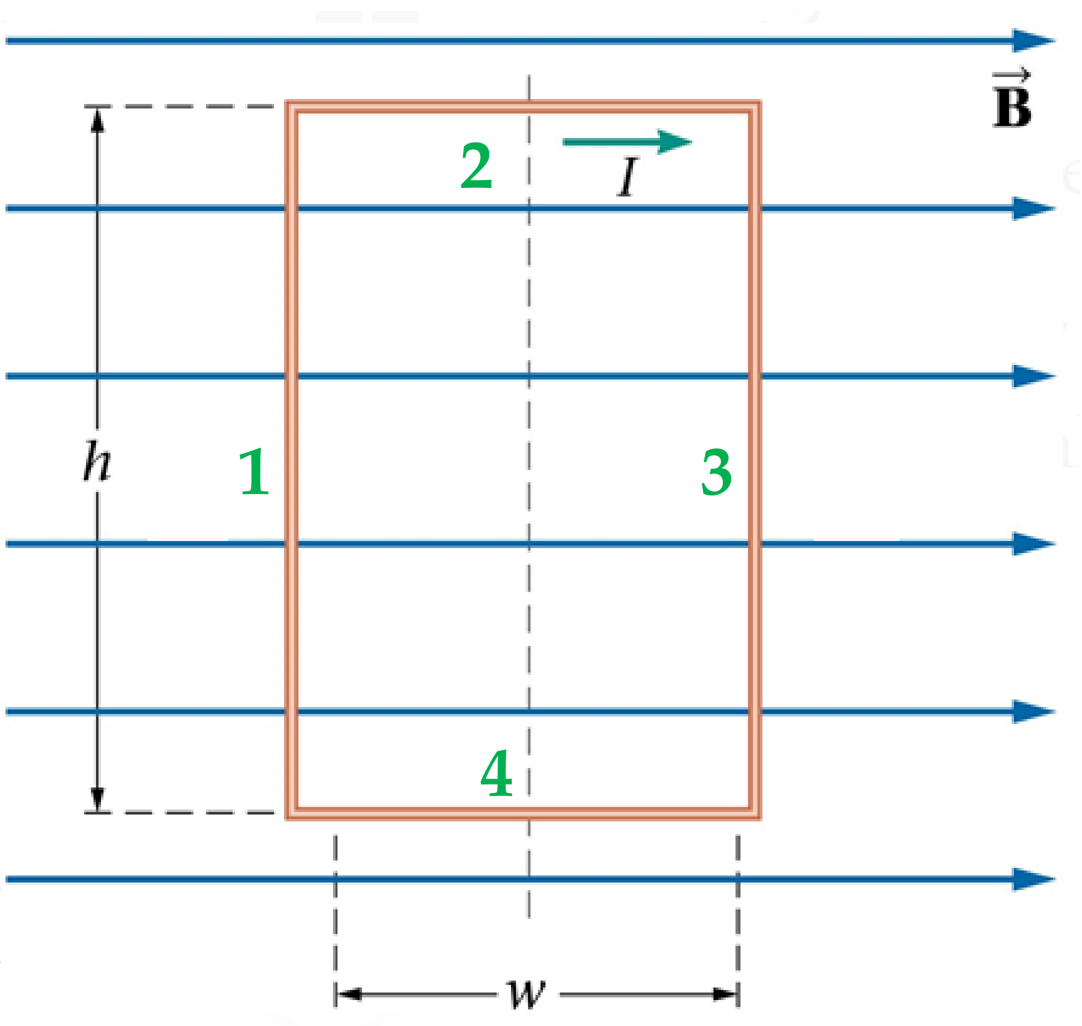
Loops of Current

A wire loop has a current of $I = 1.0\text{mA}$ and is held in a constant magnetic field of $B = 1.0\ \text{T}$. What is the net force on the wire loop?

- Conceptual Analysis

1. Look at the force on each wire separately

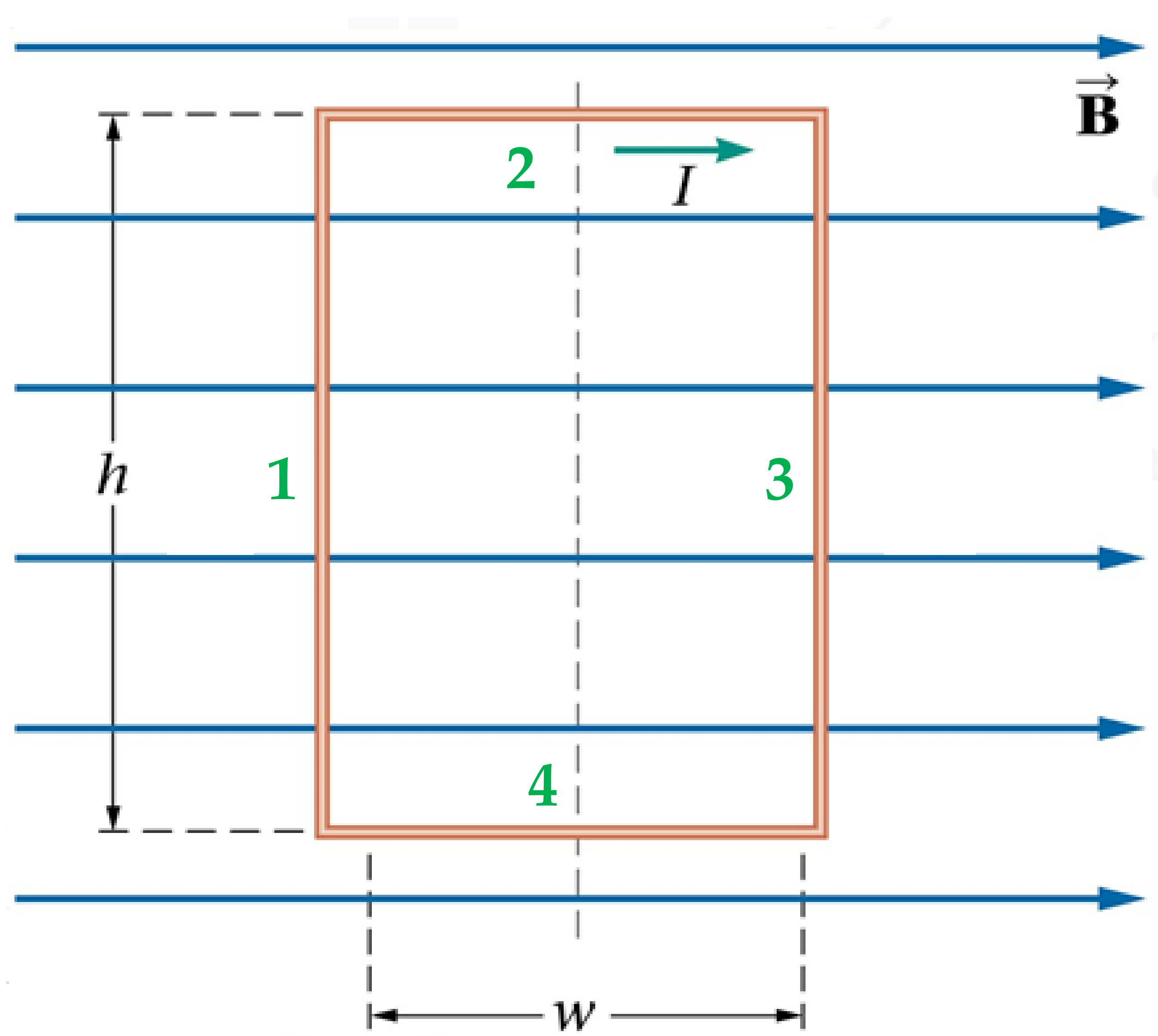
2. Then add up the forces.



Group Activity: Loops of Current

A wire loop has a current of $I = 1.0\text{mA}$ and is held in a constant magnetic field of $B = 1.0\text{ T}$. What is the net force on the wire loop?

Draw the direction of the force for each section. (If the force = 0, then write 0)



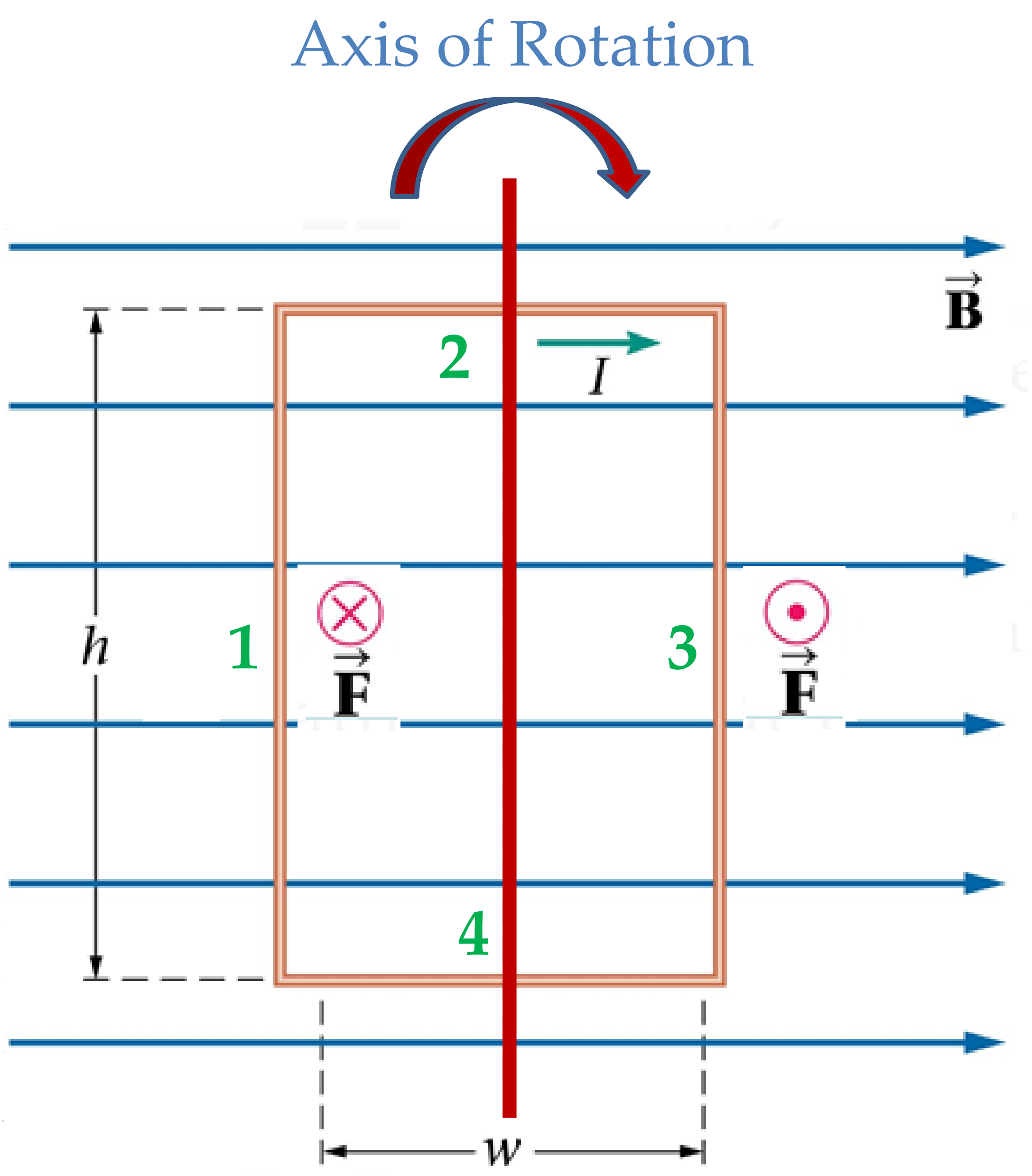
Loops of Current

A wire loop has a current of $I = 1.0 \text{mA}$ and is held in a constant magnetic field of $B = 1.0$ T. What is the net force on the wire loop?

The net force is 0, but the net torque is non-zero

Loop will tend to rotate in the magnetic field.

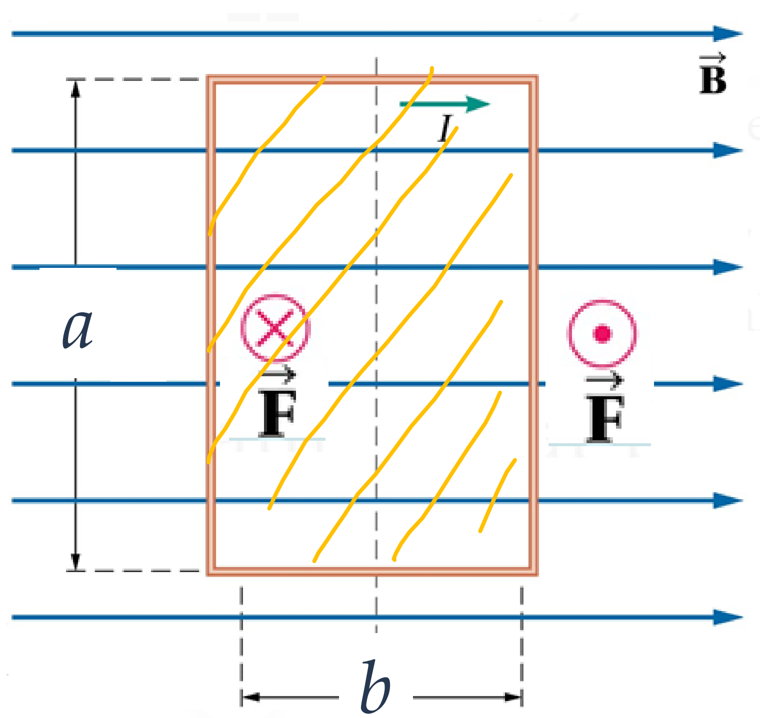
The magnetic field applies torque to the coil.



Torque on Wire Loops

$$\vec{\tau} = \vec{r} \times \vec{F}$$

Top View



Torque on one side

$$\tau = \frac{b}{2} F \sin\theta$$

$$F = ILB = IaB$$

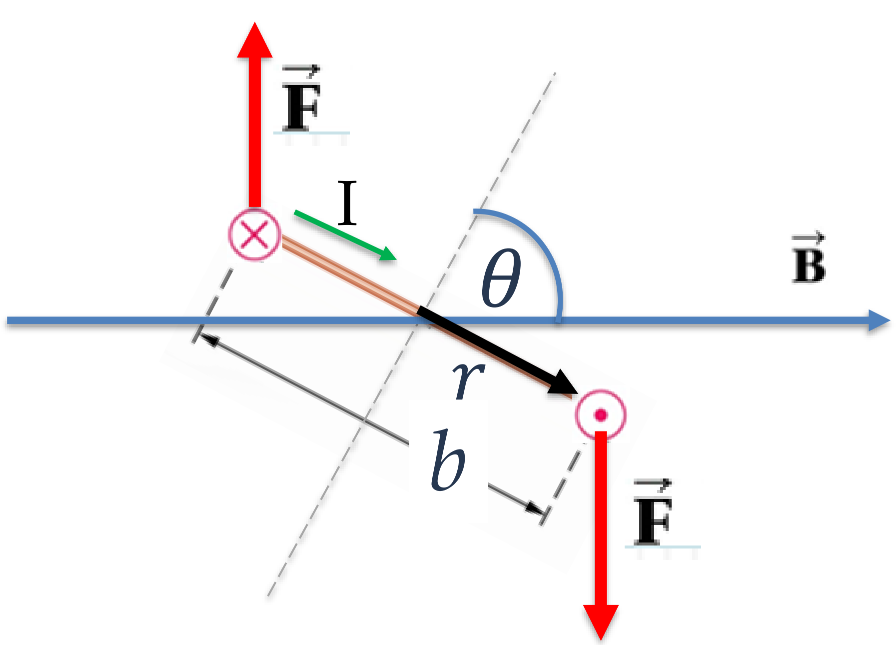
Torque on all sides

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

$$\tau = IAB\sin\theta$$

where $A = ab$ = area

Side View

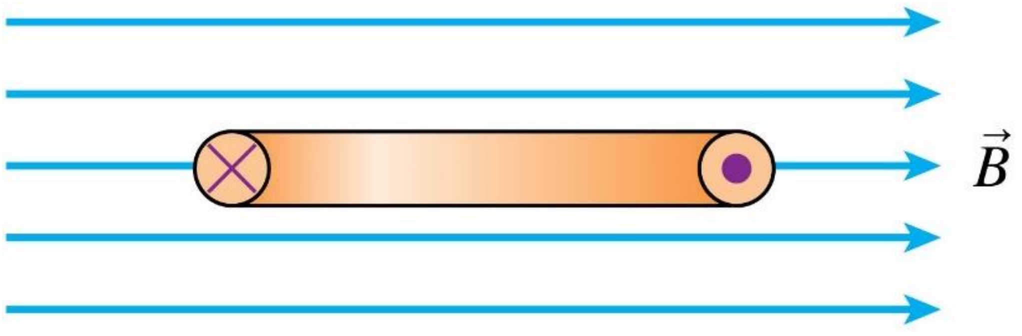


If there are N turns, then

$$\boxed{t = NIAB\sin q}$$

Question: Force on Wire Loops

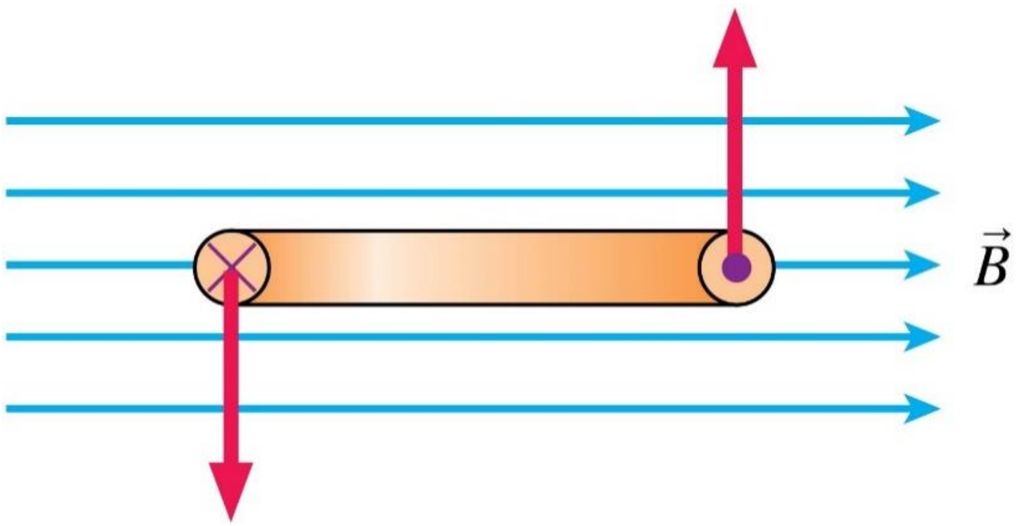
If released from rest, the current loop will:



A. Move upward.
B. Move downward.
C. Rotate clockwise.
D. Rotate counterclockwise.
E. Do something not listed here.

Question: Force on Wire Loops Answer

If released from rest, the current loop will:



A. Move upward.

B. Move downward.

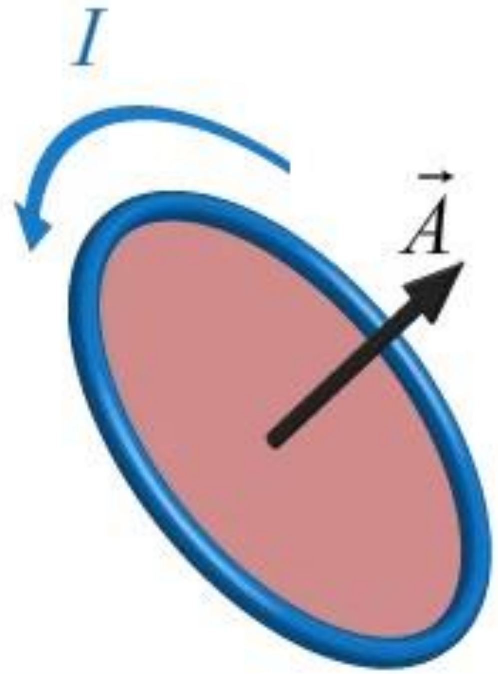
C. Rotate clockwise.

D. Rotate counterclockwise.

E. Do something not listed here.

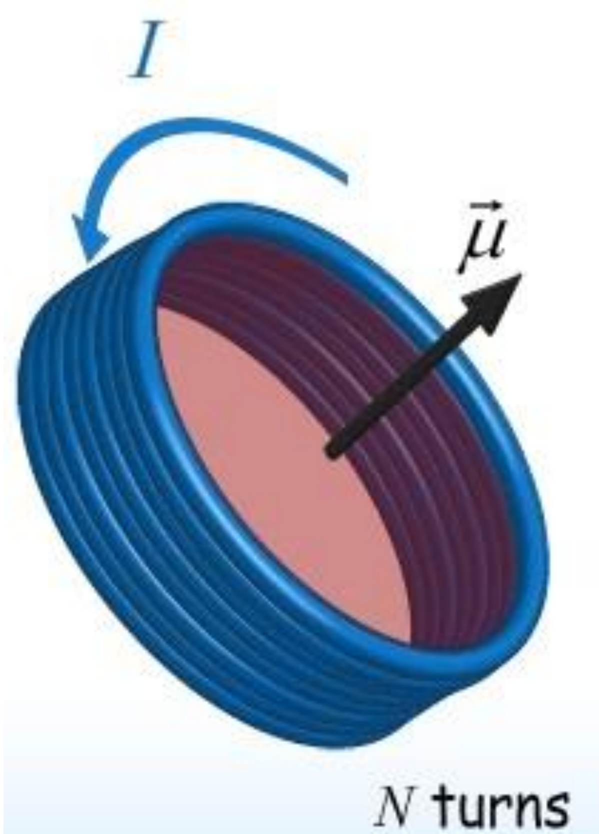
Net torque but no net force

Magnetic Dipole Moment: Multiple Loops



Magnetic Dipole Moment Vector:

$$\boxed{\vec{\mu} = NI\vec{A}}$$



SI unit: [A.m^2]

Area vector:
Magnitude = Area
Direction uses R.H.R.

Torque on Wire Loops

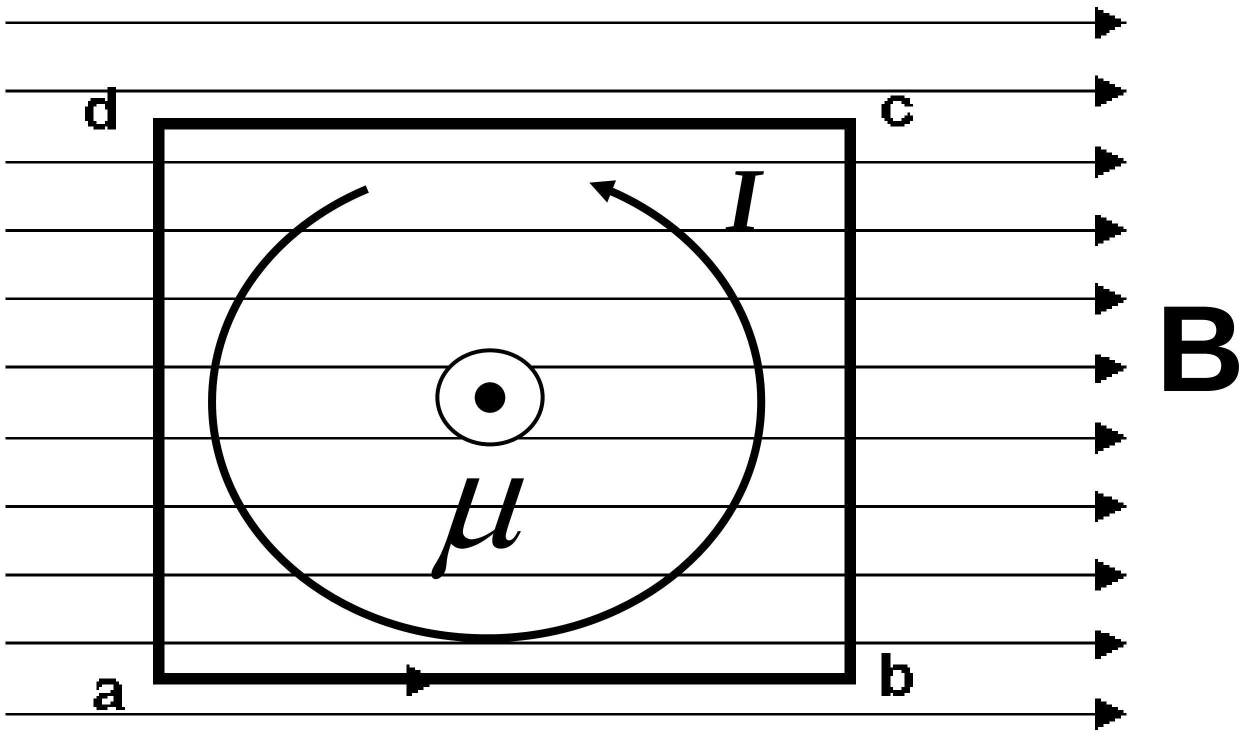
$$\vec{\mu} = NI\vec{A}$$

$$+$$

$$t = NIAB\sin q$$

$$\Downarrow$$

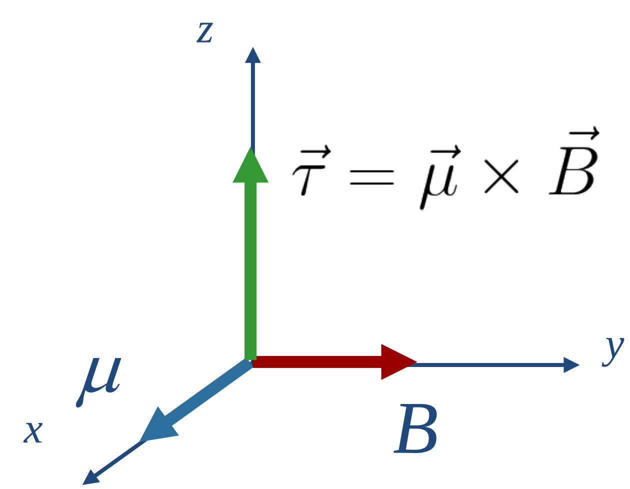
$$\tau = \mu B \sin\theta$$



In this case μ is out of the page (using right hand rule)

In general,

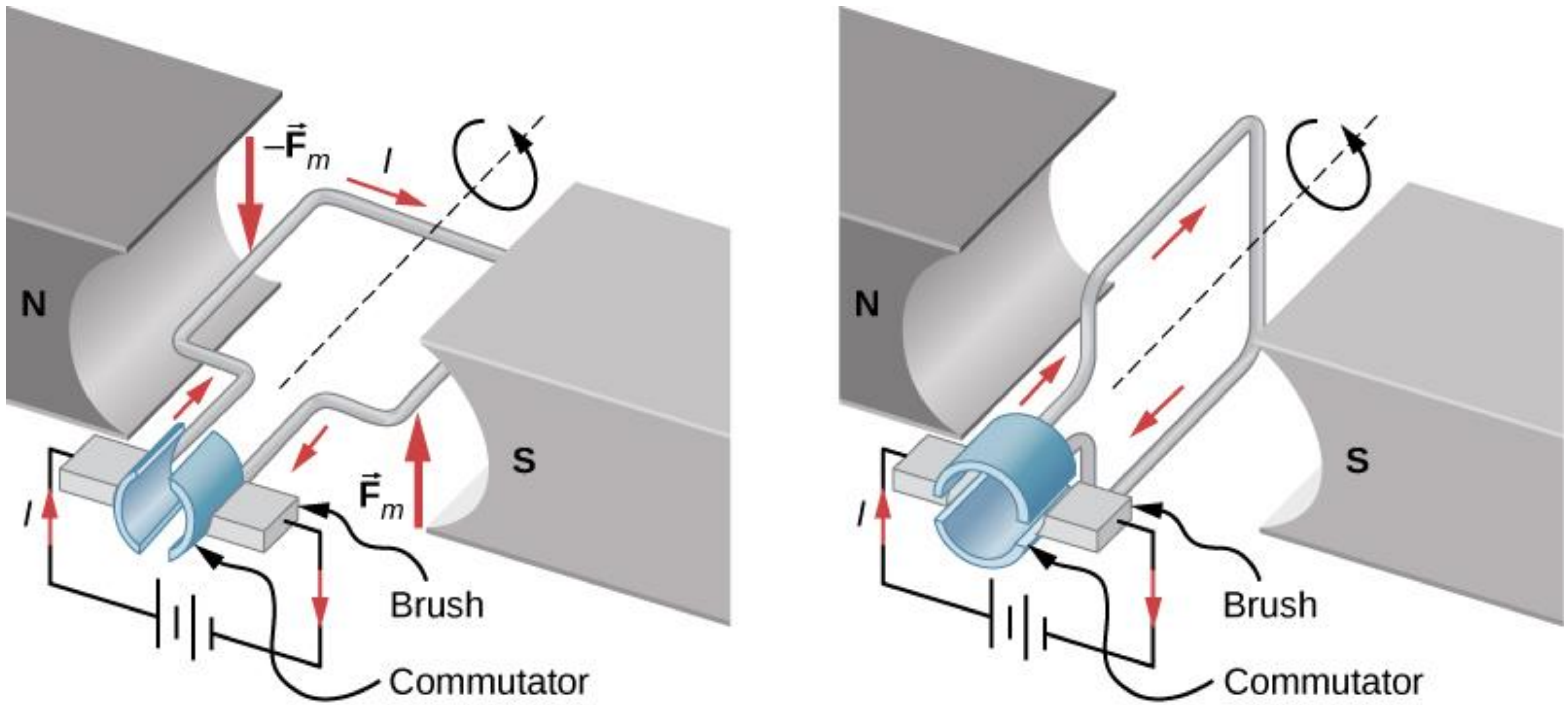
$$\boxed{\vec{\tau} = \vec{\mu} \times \vec{B}}$$



$\vec{\tau} = \vec{\mu} \times \vec{B}$ is up in this case

DC Motor Demo

DC Motors



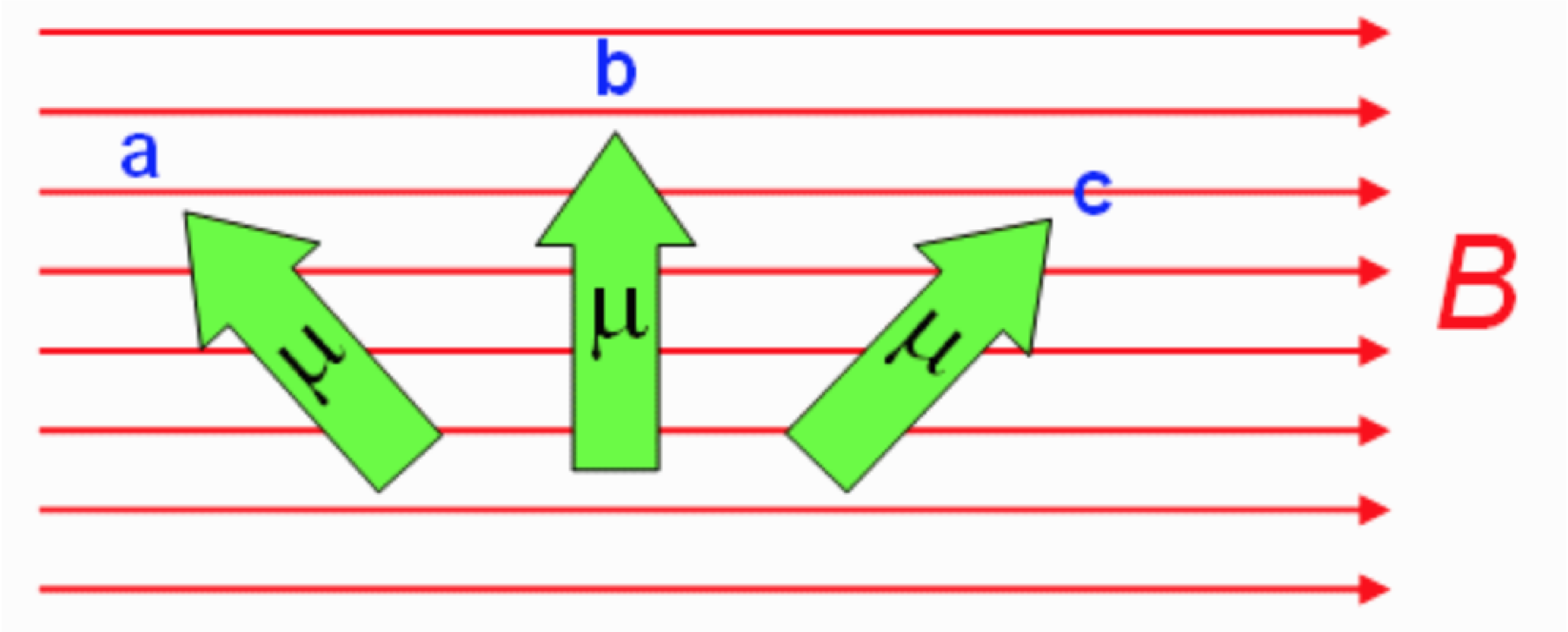
(a) (b)

- The commutator switches the direction of the current every half cycle.
- Torque always points the same direction.

Question: Magnetic Torque

Three different orientations of a magnetic dipole moment in a constant magnetic field are shown below.

Which orientation results in the largest magnetic torque on the dipole?



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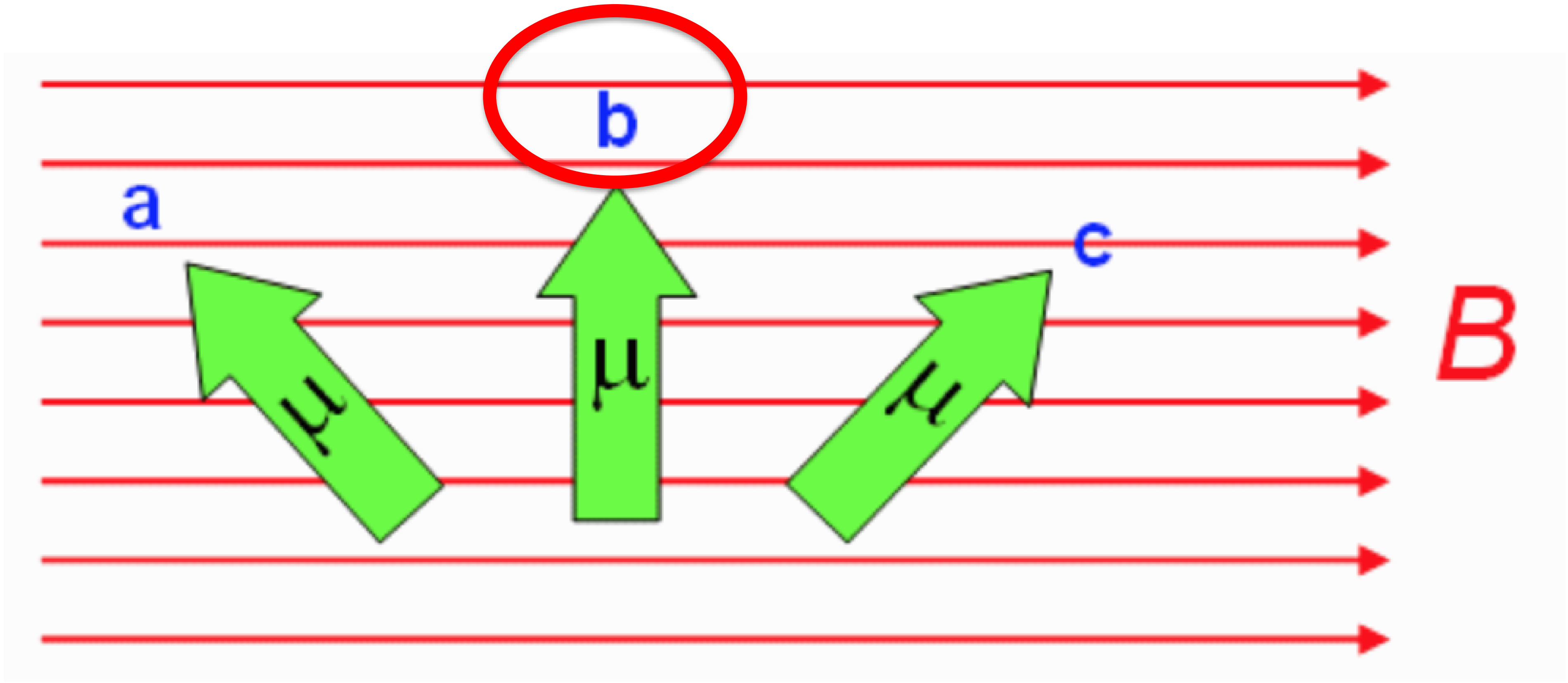

$$\tau = \mu B \sin\theta$$

The torque is maximum when the angle = 90^o ($\sin\theta=1$)