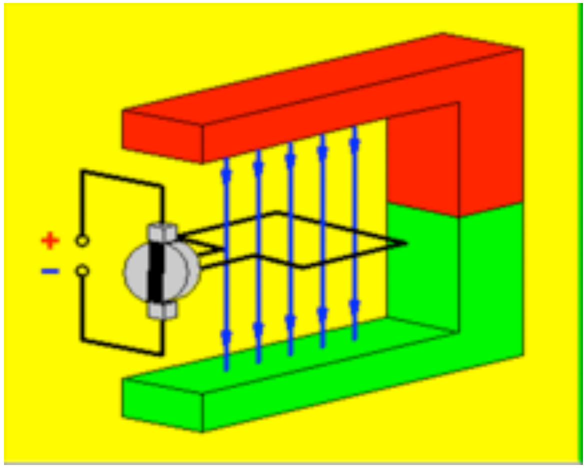
Electricity & Magnetism
Lecture 13

Today's Concept:

Torques



Physics @ SFU Surrey Open House

Thursday, March 1, 4 to 8 pm

(you don't have to be there all the time)

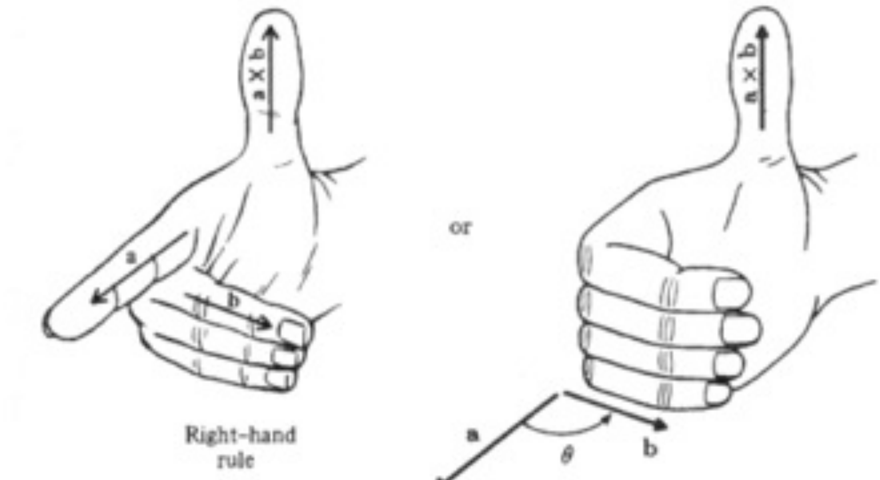
- Physics is going to set up a lot of interesting demos and displays.
- If you'd like to help out designing, setting up and and showing to visitors, please sign up on the white board by the door, or send me an email (exafs@sfu.ca).

Extra Deadlines

★Extra deadlines have been set up for Prelectures and Checkpoints that happened last week. Please do them if you haven't.

Last Time:

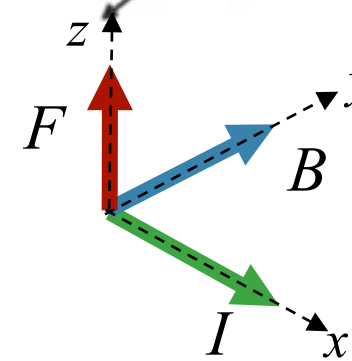
$$\vec{F} = q\vec{v} \times \vec{B}$$



This Time:

$$\vec{F} = q\sum_i \vec{v}_i \times \vec{B}$$

qv and IL have same Dimensions!



$$\vec{F} = qN\vec{v}_{avg} \times \vec{B}$$

$$N = nAL$$

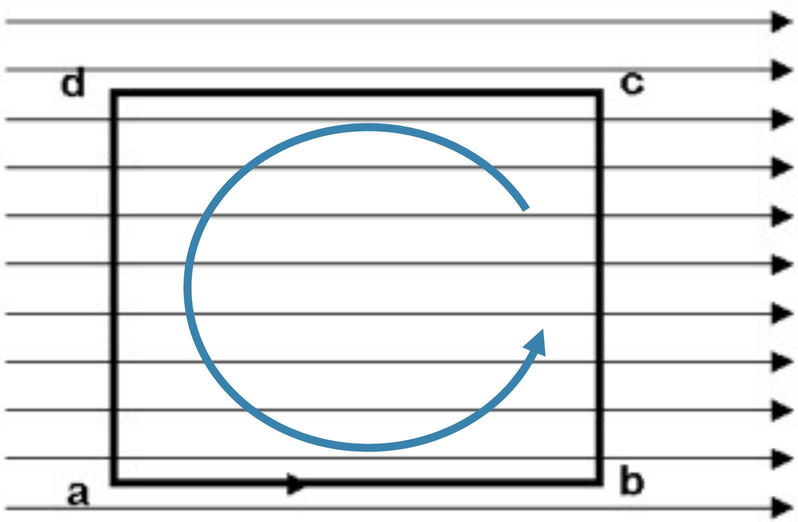
$$I = qnAv_{avg}$$

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

Clicker Question

2) A square loop of wire is carrying current in the counterclockwise direction. There is a horizontal uniform magnetic field pointing to the right.

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



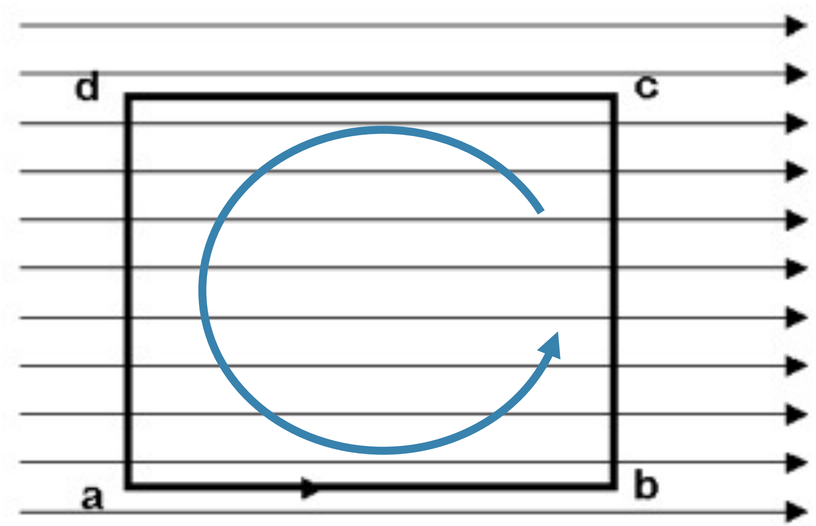
What is the force on section a-b on the loop?

A. Zero
B. Out of page
C. Into the Page

Clicker Question

2) A square loop of wire is carrying current in the counterclockwise direction. There is a horizontal uniform magnetic field pointing to the right.

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



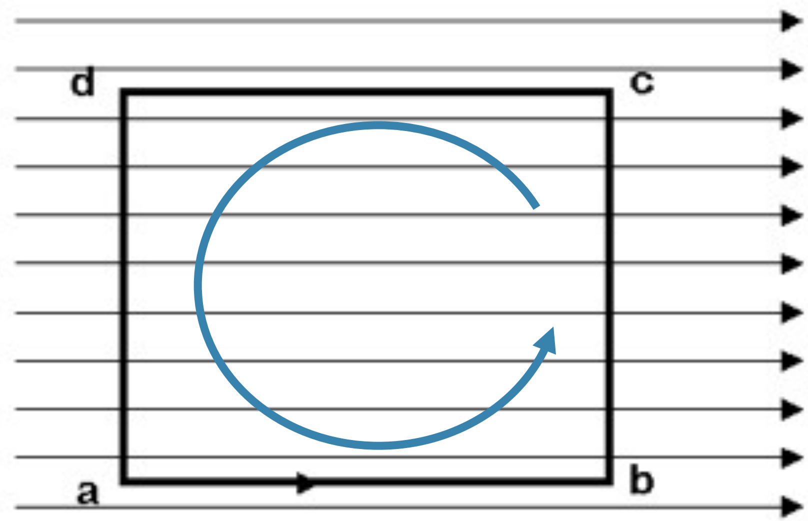
What is the force on section b-c on the loop?

A. **Zero**
B. **Out of page**
C. **Into the Page**

Clicker Question

2) A square loop of wire is carrying current in the counterclockwise direction. There is a horizontal uniform magnetic field pointing to the right.

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

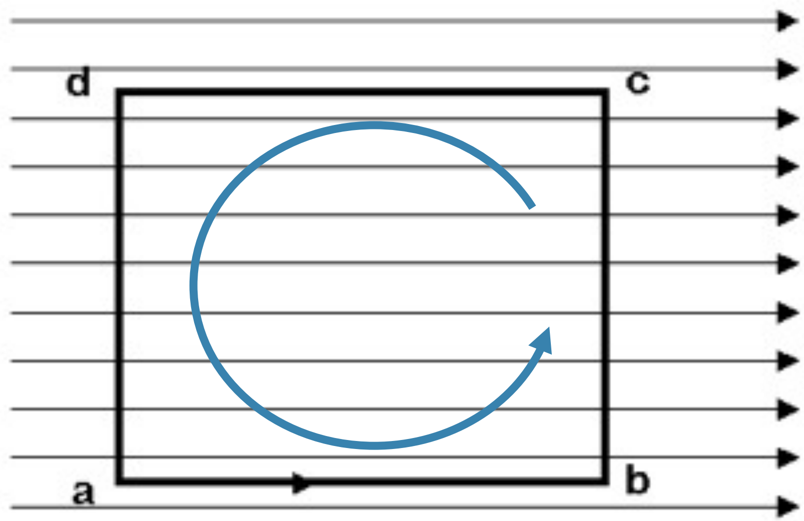


What is the force on section c-d on the loop?

A. **Zero**
B. **Out of page**
C. **Into the Page**

CheckPoint 2

2) A square loop of wire is carrying current in the counterclockwise direction. There is a horizontal uniform magnetic field pointing to the right.

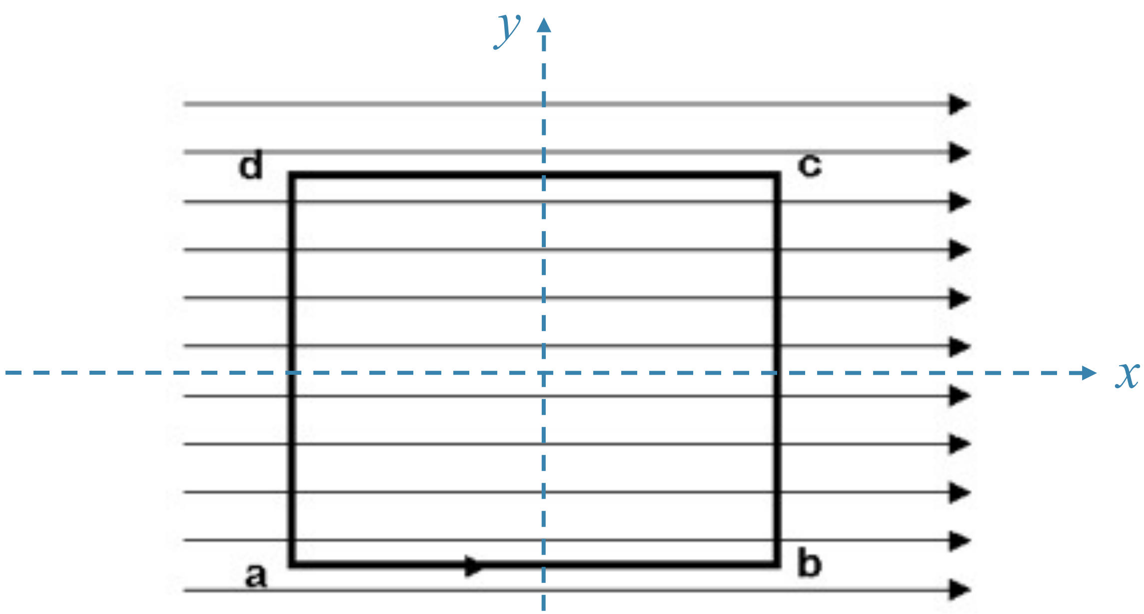


What is the direction of the net force on the loop?

A. Zero
B. Out of page
C. Into the Page

CheckPoint 4

A square loop of wire is carrying current in the counterclockwise direction. There is a horizontal uniform magnetic field pointing to the right.

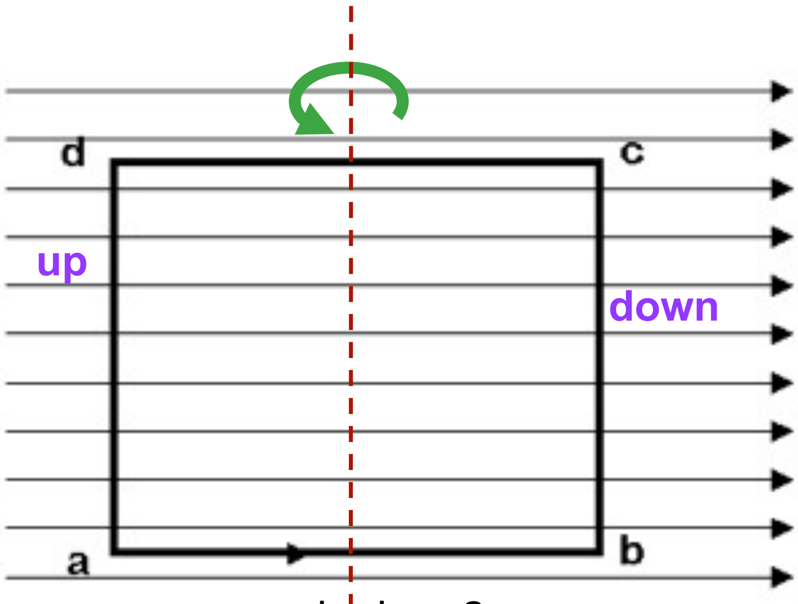


In which direction will the loop rotate?
(assume the z axis is out of the page)

A) Around the x axis
B) Around the y axis
C) Around the z axis
D) It will not rotate

CheckPoint 6

A square loop of wire is carrying current in the counterclockwise direction. There is a horizontal uniform magnetic field pointing to the right.

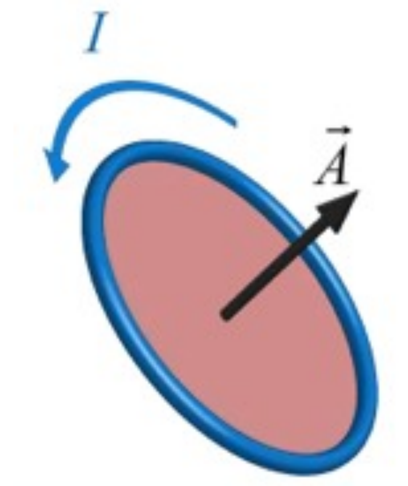


$$\vec{\tau} = \vec{R} \times \vec{F}$$

What is the direction of the **net torque** on the loop?

A) up
B) down
C) out of page
D) into page
E) net torque is zero

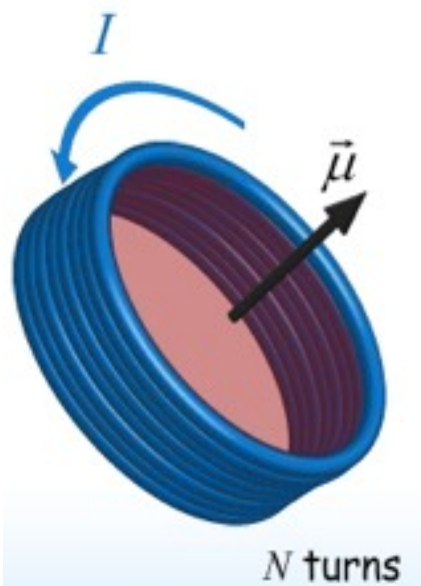
Magnetic Dipole Moment



Area vector

Magnitude = Area

Direction uses R.H.R.



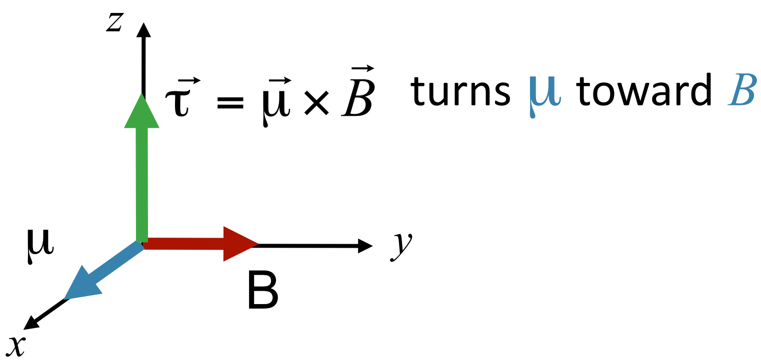
Magnetic Dipole moment

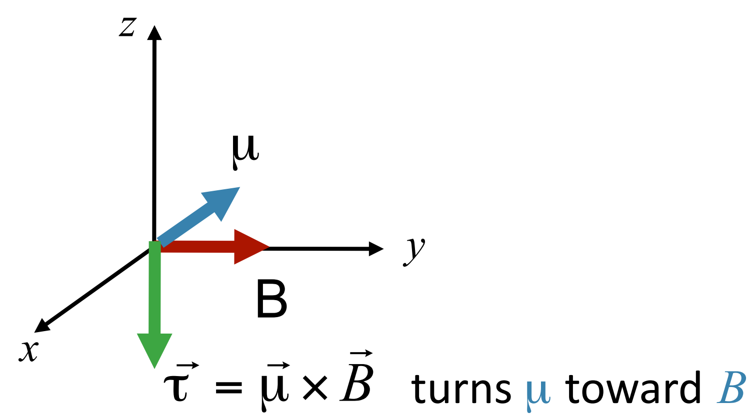
$$\vec{\mu} \equiv N I \vec{A}$$

μ Makes Torque Easy!

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

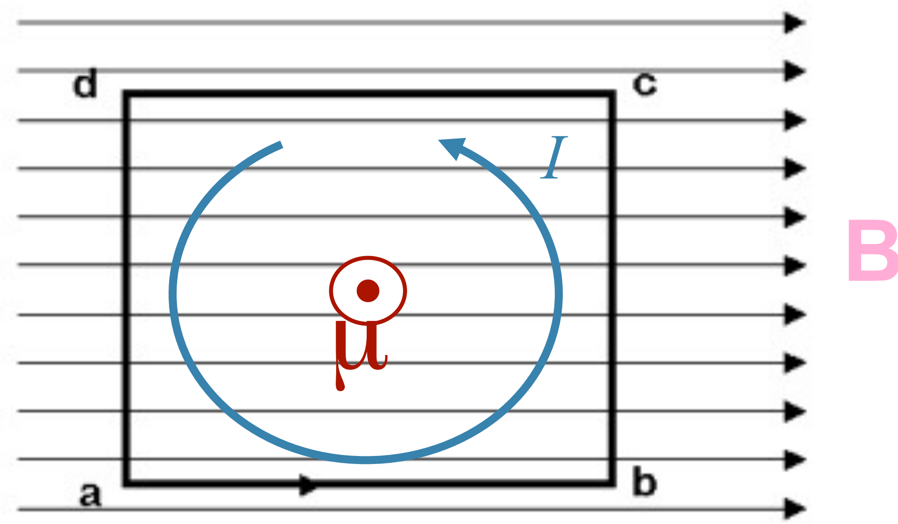
The torque always wants to line μ up with B!



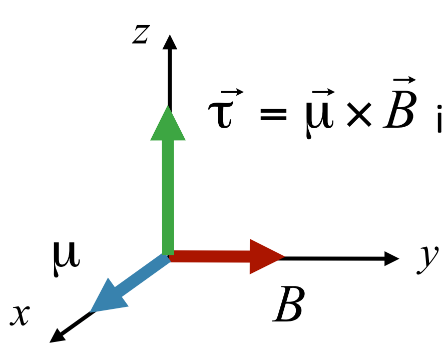


Practice with μ and τ

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



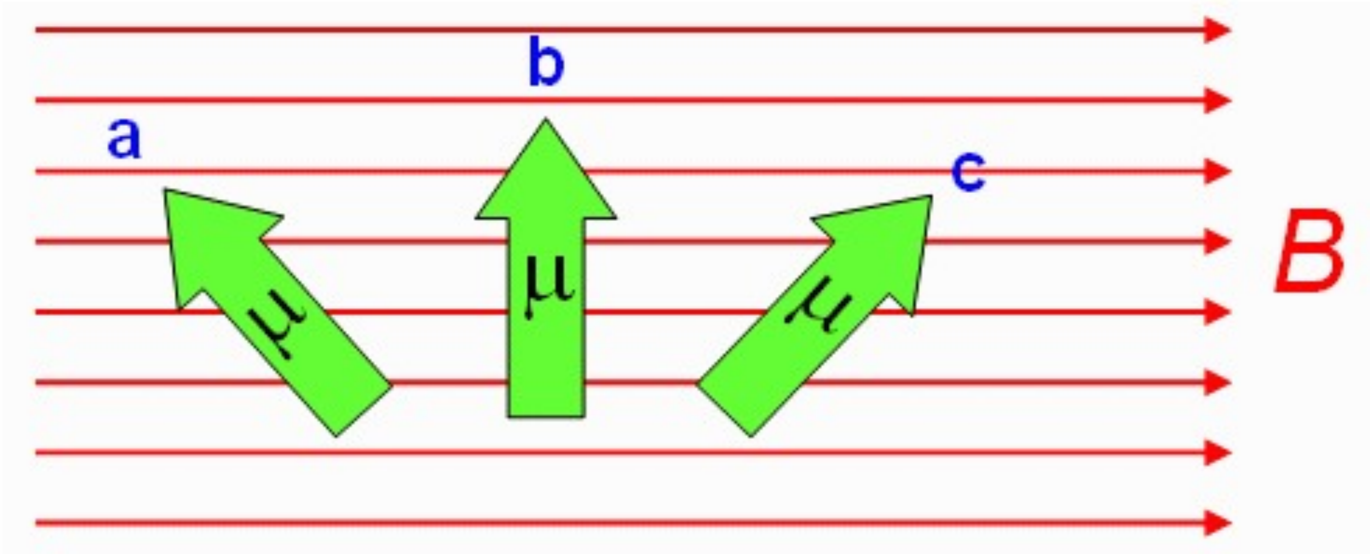
In this case μ is out of the page (using right hand rule)

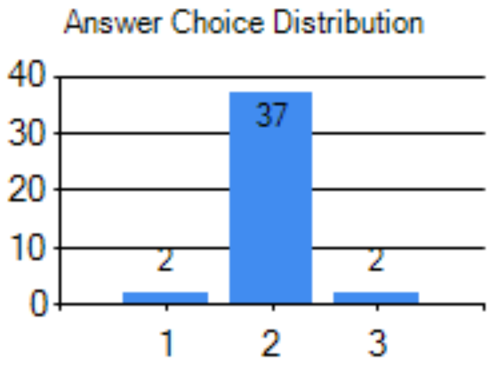


$\vec{\tau} = \vec{\mu} \times \vec{B}$ is up (turns μ toward B)

CheckPoint 8

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 ?





Magnetic Field does Work on Current-carrying wire

From Physics 140: $W = \int \tau \, d\theta$

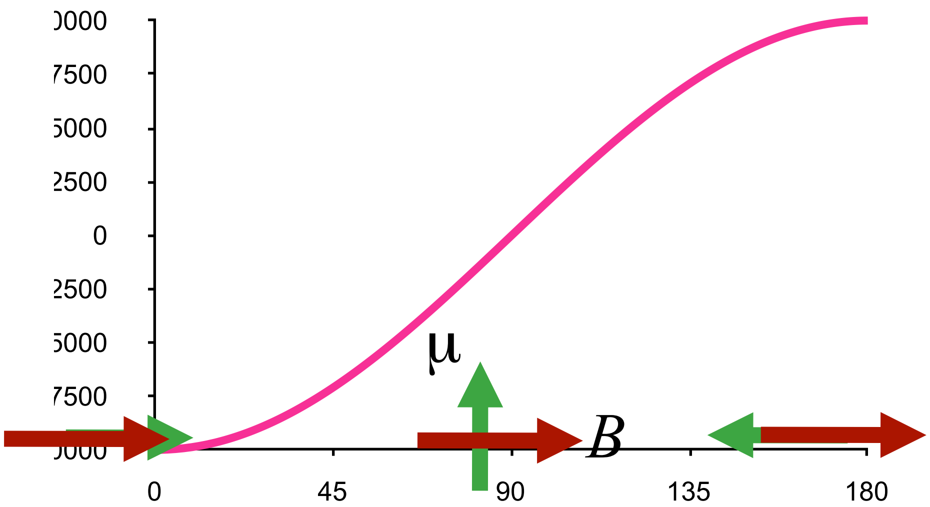
From Physics 141: $\vec{\tau} = \vec{\mu} \times \vec{B} = \mu B \sin(\theta)$

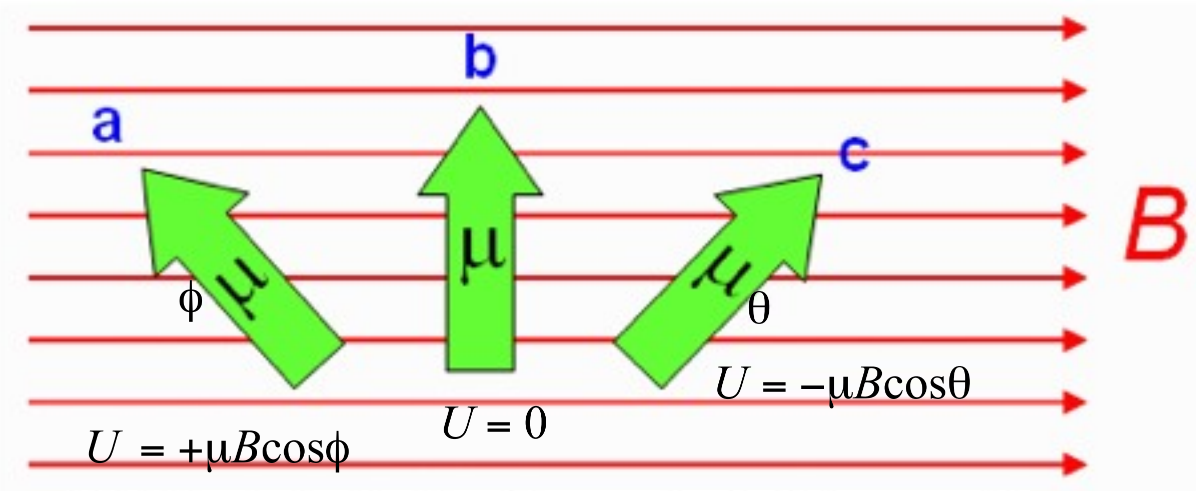
$$W = \int_{\theta}^{\pi/2} \mu B \sin\theta' \, d\theta' = \mu B \cos\theta = \vec{\mu} \cdot \vec{B}$$

$$\Delta U = -W$$

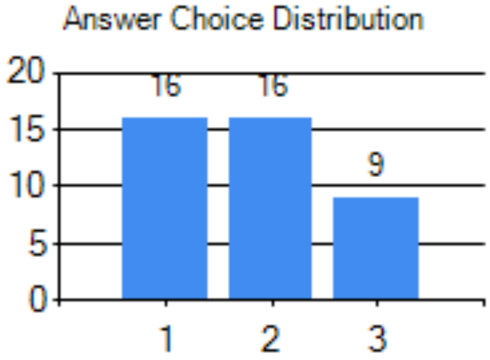
Define $U = 0$ at position of maximum torque

$$U = -\vec{\mu} \cdot \vec{B}$$



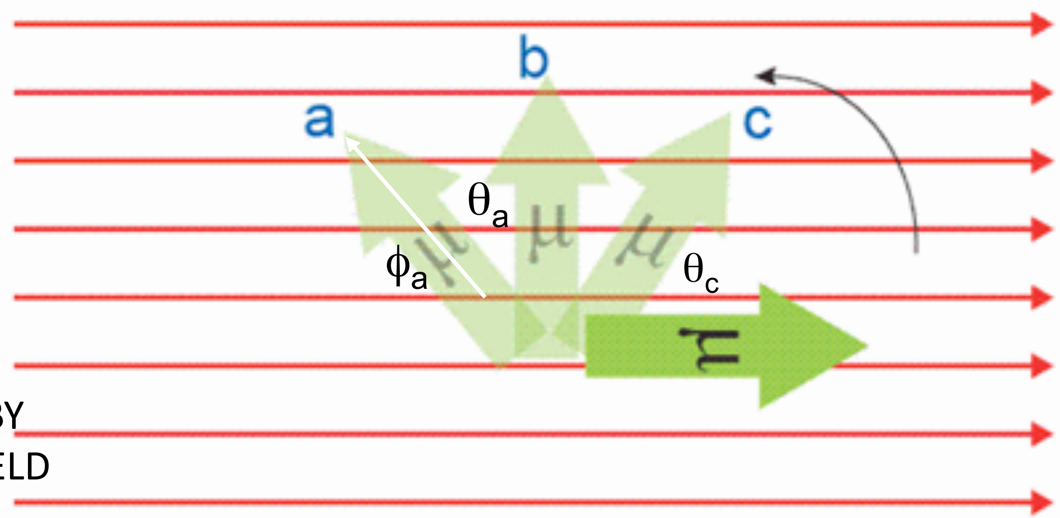


Which orientation has the most potential energy?



CheckPoint 12

12) In order to rotate an horizontal magnetic dipole to the three postions shown, which one requires the most work done?



BY YOU | BY FIELD

BY WHOM ?

○a ○b ○c

$$W_{by\ field} = -\Delta U = U_i - U_f$$

$$U = \vec{\mu} \cdot \vec{B}$$

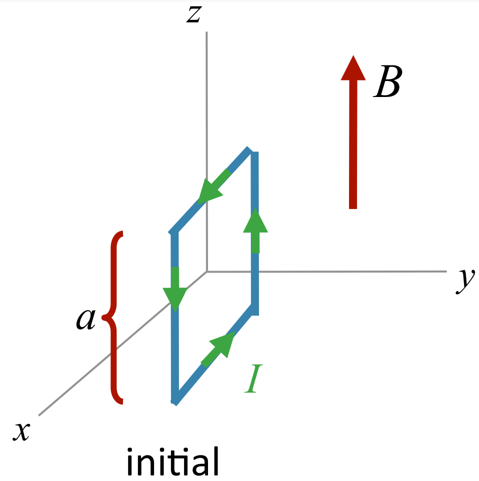
C): → $W_{by\_field} = -\mu B - (-\mu B \cos\theta_c) = -\mu B(1 - \cos\theta_c)$

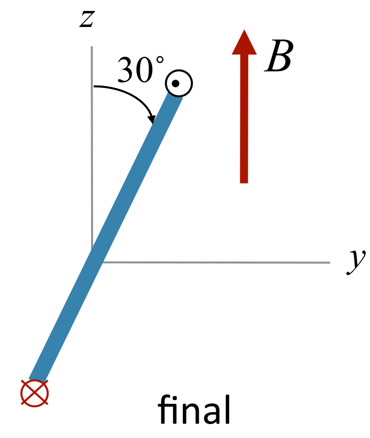
B): → $W_{by\_field} = -\mu B - 0 = -\mu B$

A): → $W_{by\_field} = -\mu B - (-\mu B \cos\theta_a) = -\mu B(1 + \cos\phi_a)$

Calculation

A square loop of side a lies in the x–z plane with current I as shown. The loop can rotate about x axis without friction. A uniform field B points along the $+z$ axis. Assume a, I, and B are known.





How much does the potential energy of the system change as the coil moves from its initial position to its final position.

Conceptual Analysis

A current loop may experience a torque in a constant magnetic field

$$\tau = \mu \times B$$

We can associate a potential energy with the orientation of loop

$$U = -\mu \cdot B$$

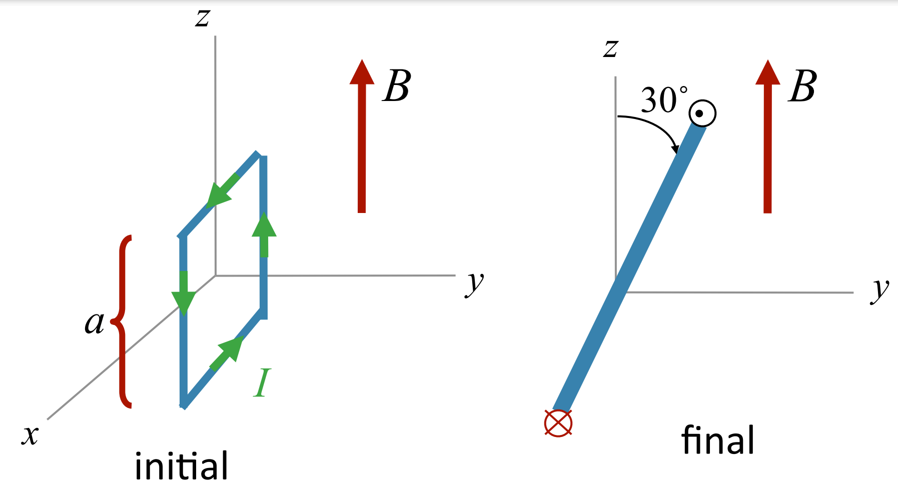
Strategic Analysis

Find μ

Calculate the change in potential energy from initial to final

Calculation

A square loop of side a lies in the x–z plane with current I as shown. The loop can rotate about x axis without friction. A uniform field B points along the $+z$ axis. Assume a, I, and B are known.



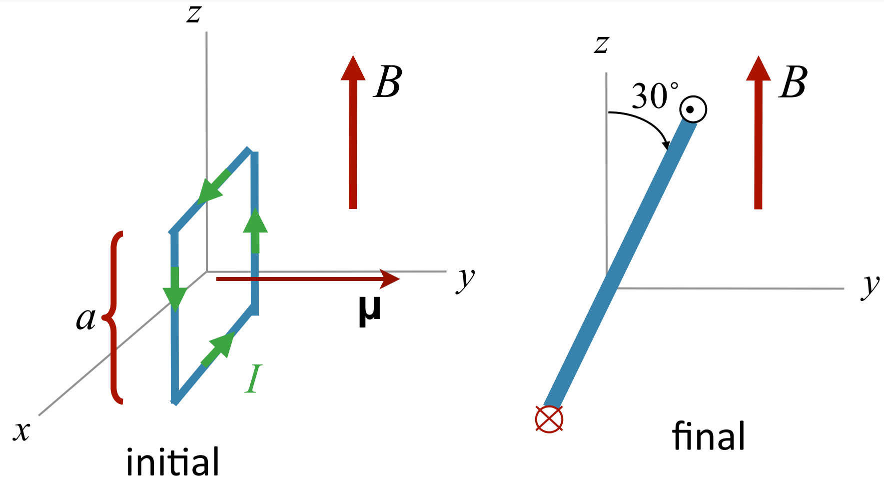
$\vec{\mu} = I\vec{A}$

What is the direction of the magnetic moment of this current loop in its initial position?

A) $+x$ B) $-x$ C) $+y$ D) $-y$

Calculation

A square loop of side a lies in the x–z plane with current I as shown. The loop can rotate about x axis without friction. A uniform field B points along the $+z$ axis. Assume a, I, and B are known.

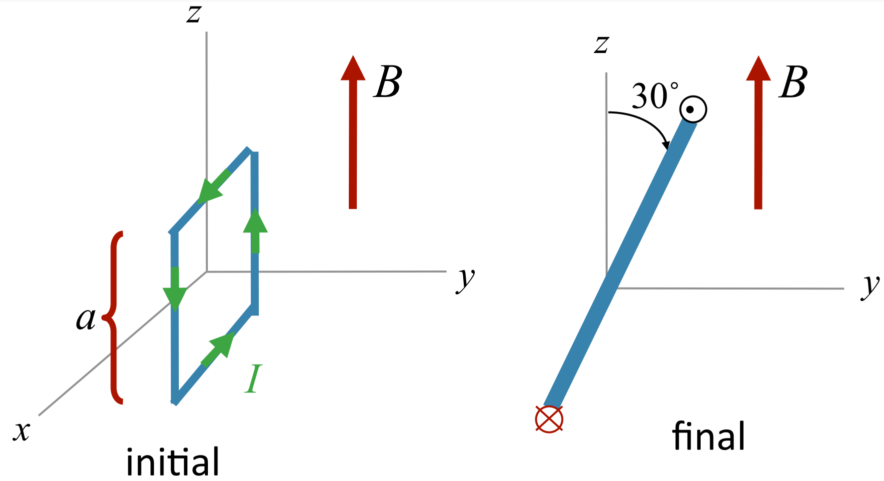


What is the direction of the torque on this current loop in the initial position?

A) $+x$ B) $-x$ C) $+y$ D) $-y$

Calculation

A square loop of side a lies in the x–z plane with current I as shown. The loop can rotate about x axis without friction. A uniform field B points along the $+z$ axis. Assume a, I, and B are known.



$$U = -\vec{\mu} \cdot \vec{B}$$

What is the potential energy of the initial state?

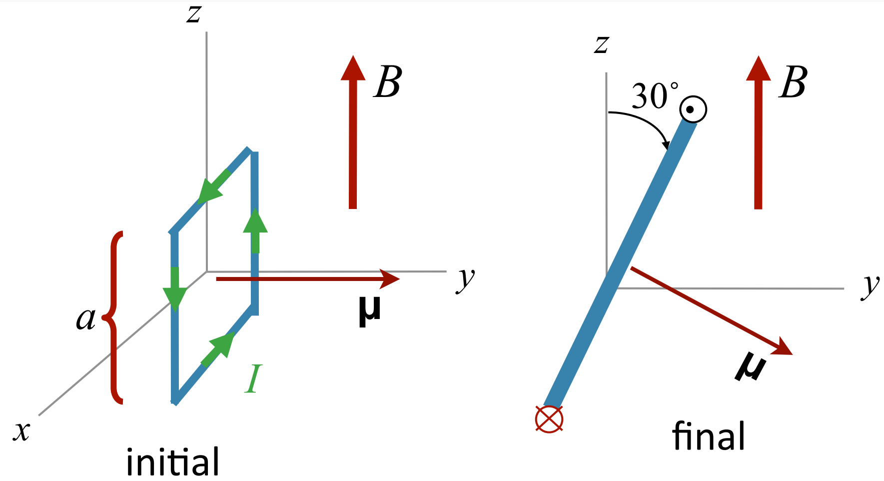
A) $U_{initial} < 0$

B) $U_{initial} = 0$

C) $U_{initial} > 0$

Calculation

A square loop of side a lies in the x–z plane with current I as shown. The loop can rotate about x axis without friction. A uniform field B points along the $+z$ axis. Assume a, I, and B are known.



$$U = -\vec{\mu} \cdot \vec{B}$$

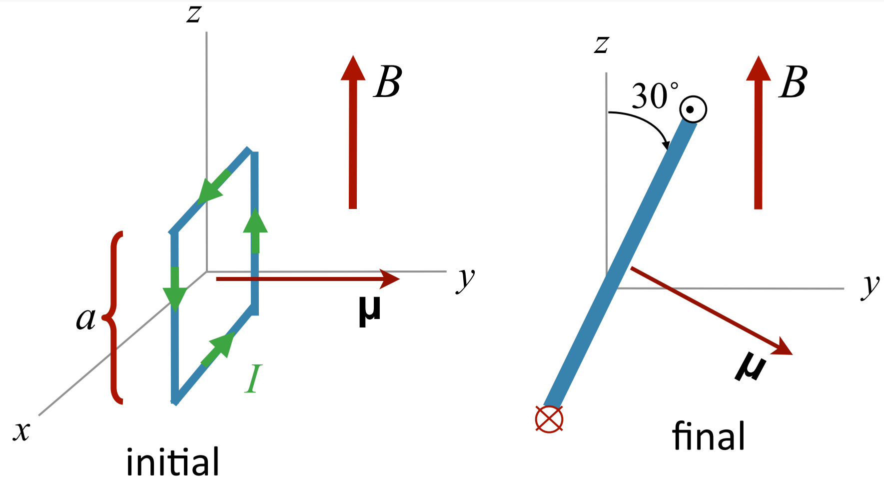
What is the potential energy of the final state?

A) $U_{final} < 0$ B) $U_{final} = 0$ C) $U_{final} > 0$

Calculation

A square loop of side *a* lies in the x–z plane with current I as shown. The loop can rotate about x axis without friction. A uniform field B points along the $+z$ axis. Assume a, I, and B are known.

$$U = -\vec{\mu} \cdot \vec{B}$$



What is the potential energy of the final state?

A) $U = Ia^2B$

B) $U = \frac{\sqrt{3}}{2} Ia^2B$

C) $U = \frac{1}{2} Ia^2B$