Your Comments

why is the direction of torque in such a weird direction?

I'm not as scared about torque this time around...at least for now. Also, I'm going to office hours tomorrow (Sun) as a new approach to how I spend my time on HW. What do you recommend for me to work on so I can have other questions for the TAs when I go? (I know Tipler problems are available, I'm just not relishing the thought of doing them.).

How do we get the direction of L for F=IL x B? Is it just the same direction as I? If so why is the formula not F=LI x B? The direction of L just feels as though it should be arbitrary but we need it to determine the direction of force.

I love solving for the MAGNETude. Ha! Haha! ha...

This is all extremely confusing. Please be sure to go over important concepts in lecture. It's always easier to understand when you say it than when the prelecture says it.

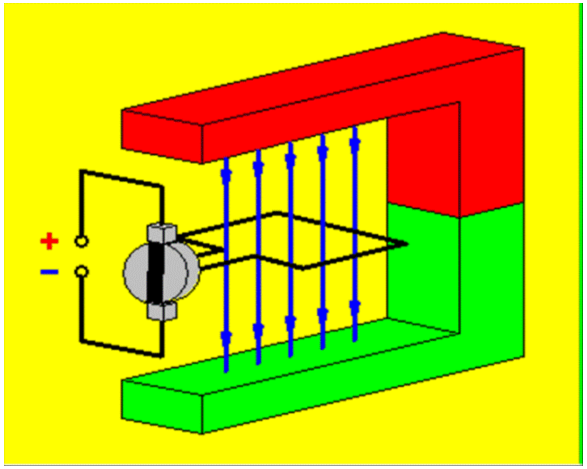
其实第一次听说要做prelecture我是拒绝的,因为，你不能让我做，我就马上去做。第一我要试一下，因为我不愿意做完了以后再加一些特技上去，答案“duang”一下，全是绿色的进度条，这样观众出来一定会骂我，根本没有这样的prelecture，就证明上面那个是假的

The checkpoints really got me confused about the direction of the magnetic moment and it's relation to the direction of the magnetic field.

Physics 212
Lecture 13

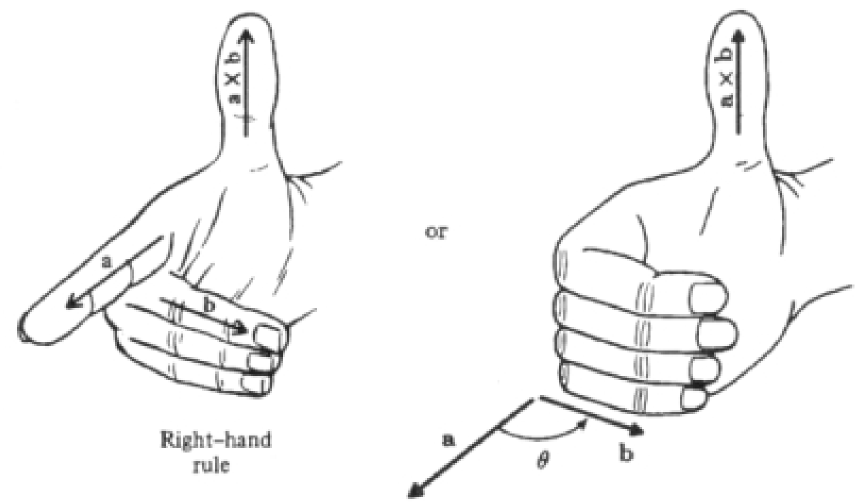
Today's Concept:

Torques



Last Time:

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



This Time:

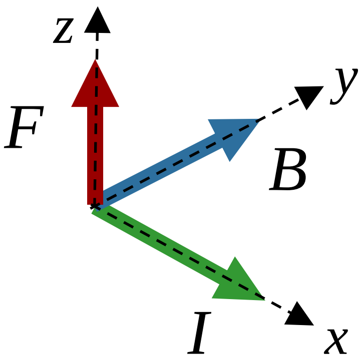
$$\vec{F} = q\sum_i \vec{v}_i \times \vec{B}$$

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

$$N = nAL$$

$$I = qnAv_{avg}$$

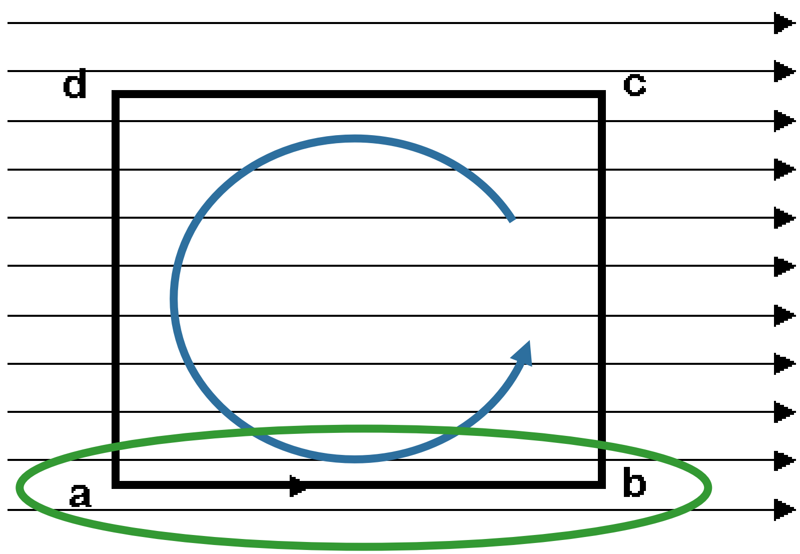
$$\vec{F} = I\vec{L} \times \vec{B}$$



Clicker Question

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

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



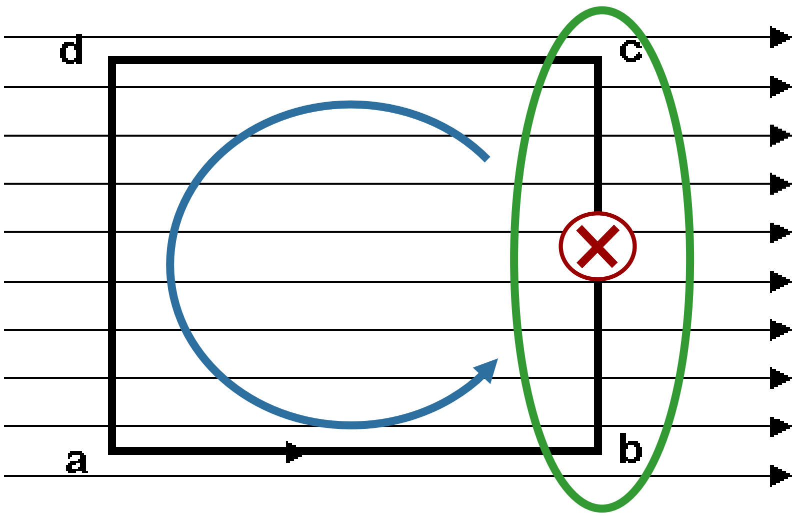
What is the force on section a-b of the loop?

- **A.** zero
- **B.** out of the page
- **C.** into the page

Clicker Question

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 of the loop?

A. zero

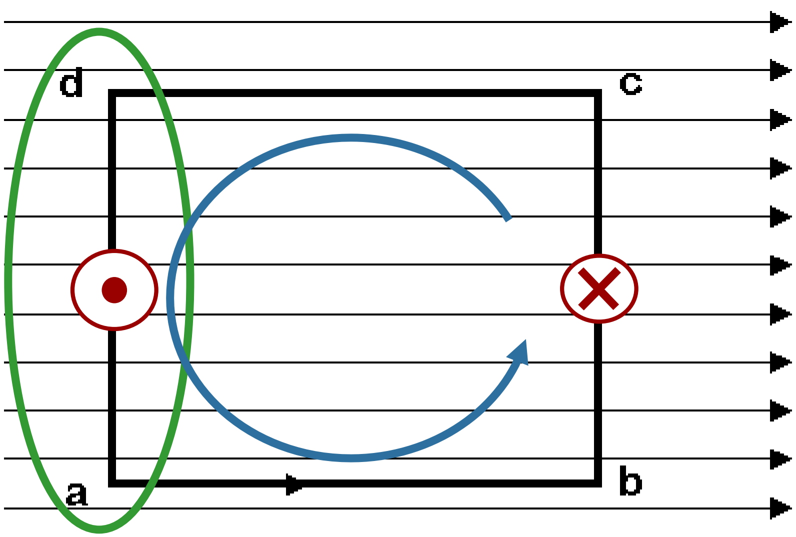
B. out of the page

C. $\boxed{\text{into the page}}$

Clicker Question

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 d-a of the loop?

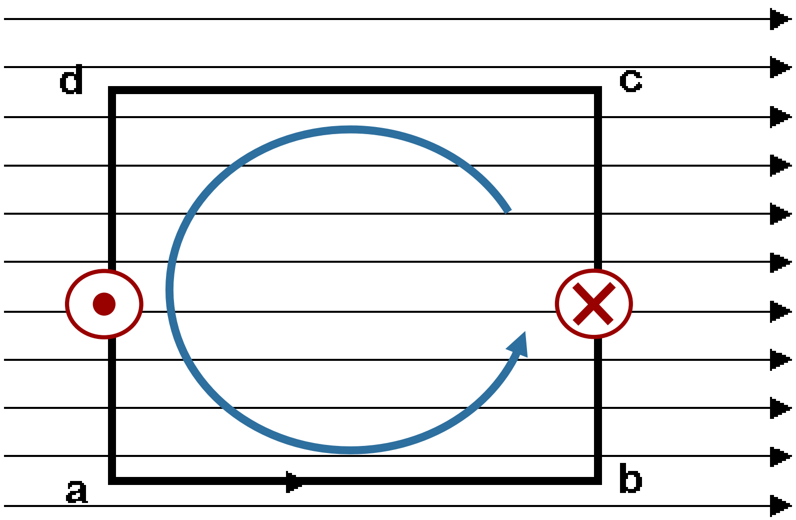
A) Zero

B) $\boxed{\text{Out of the page}}$

C) Into the page

CheckPoint 1a

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

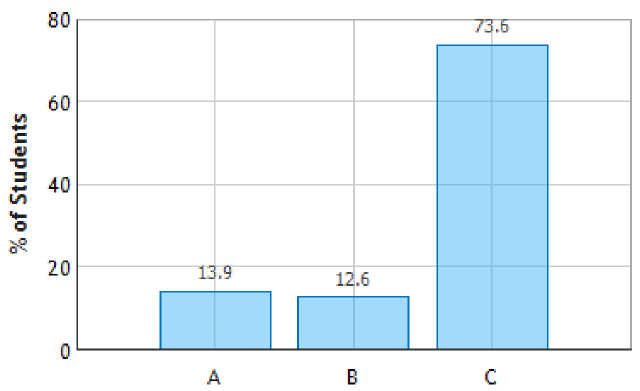


What is the direction of the net force on the loop?

A. Out of the page ***B.*** Into of the page

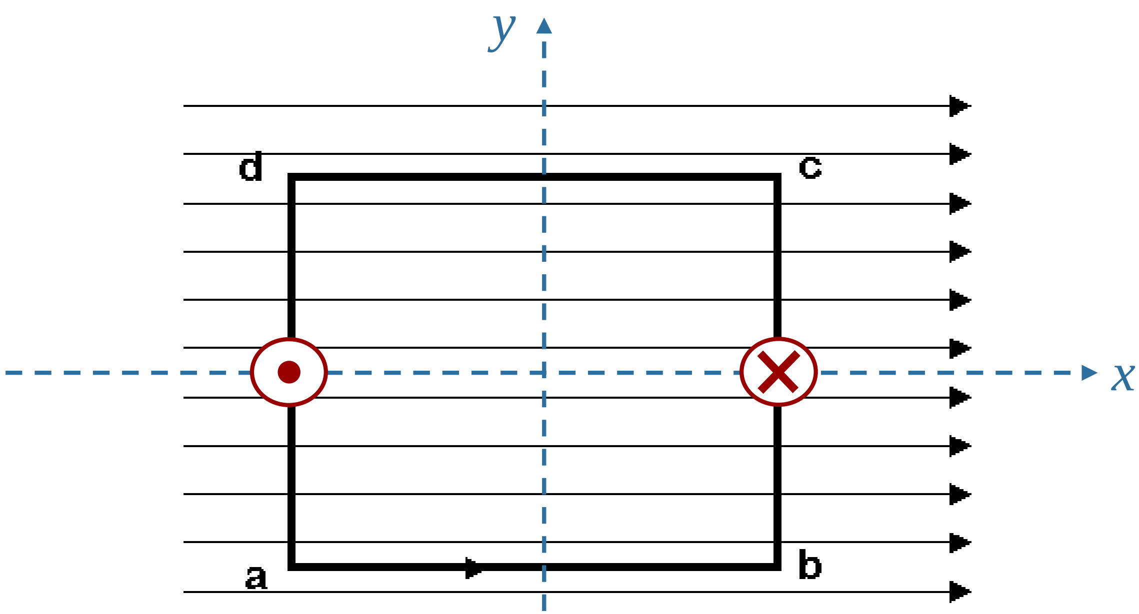
C. The net force on the loop is zero

"In a closed loop the length between the start point and the end point is zero so the cross product is zero and the force is zero!



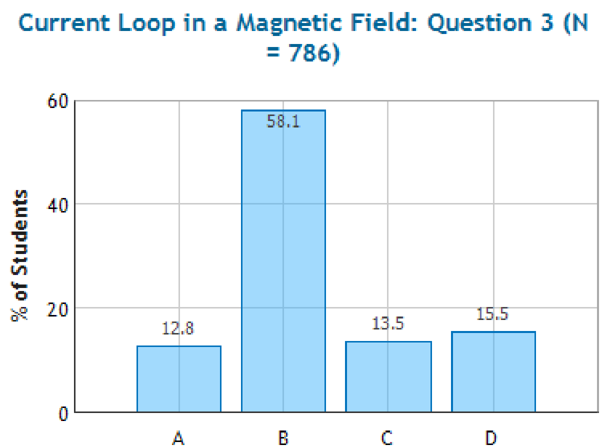
CheckPoint 1b

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



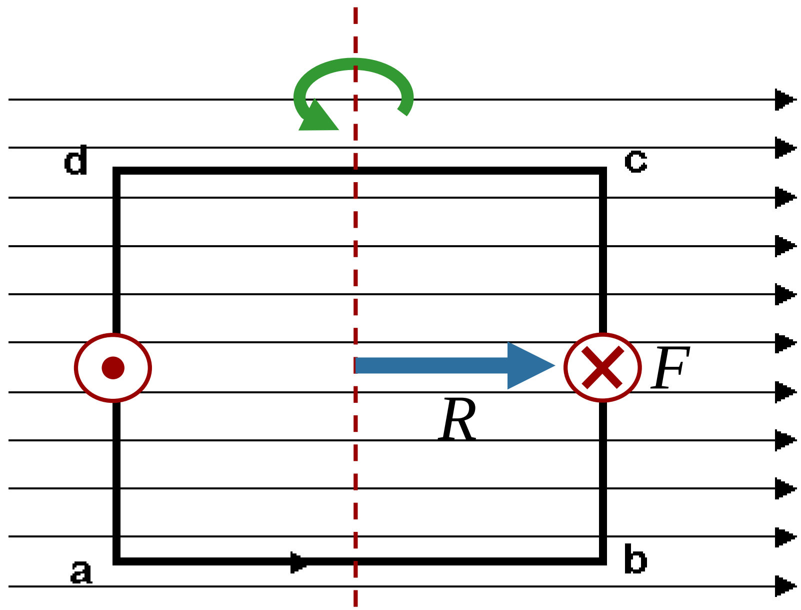
In which direction will the loop rotate?
(assume the z axis is out of the page)

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



CheckPoint 1c

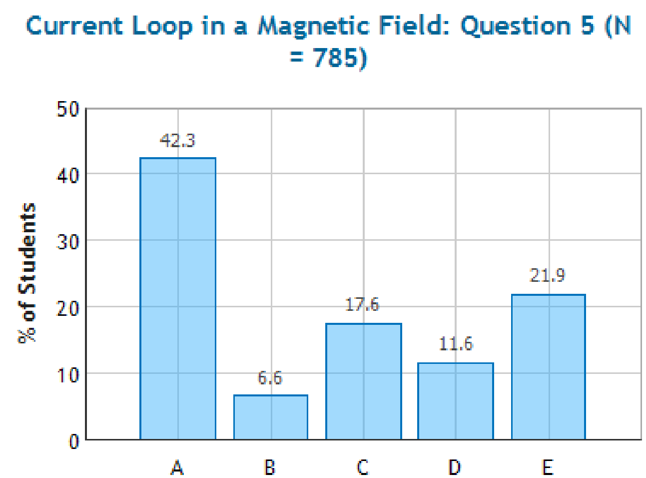
A square loop of wire is carrying current in the counterclockwise direction. There is a horizontal uniform magnetic field pointing to the right.



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

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

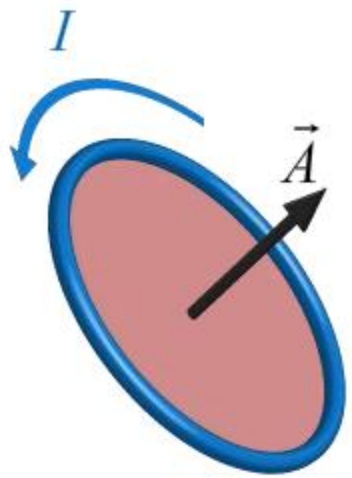
A. Up
B. Down
C. Out of the page
D. Into the page
E. The net torque is zero



r x f = torque

Magnetic Dipole Moment

EXPLAIN THE MAGNETIC DIPOLE... What IS IT?!?!?!?!!?!?!

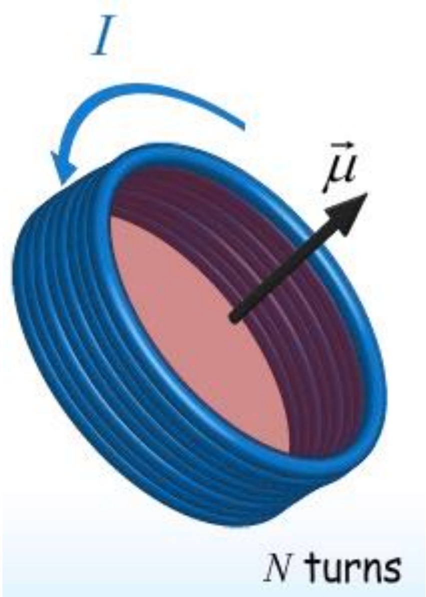


Area vector

Magnitude = Area

Direction uses R.H.R.

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



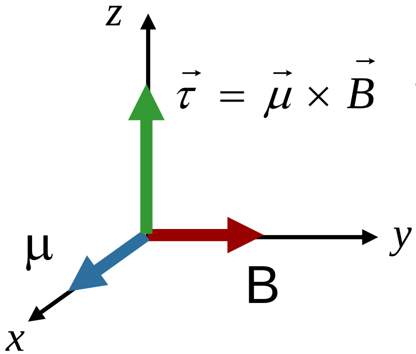
Magnetic Dipole moment

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

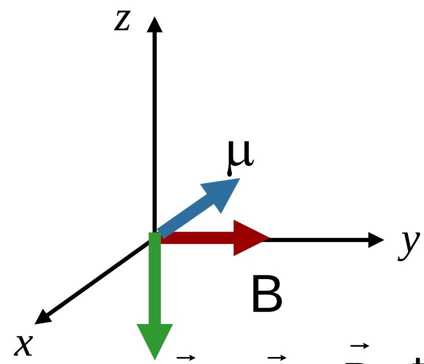
μ Makes Torque Easy!

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

The torque always wants to line μ up with B!



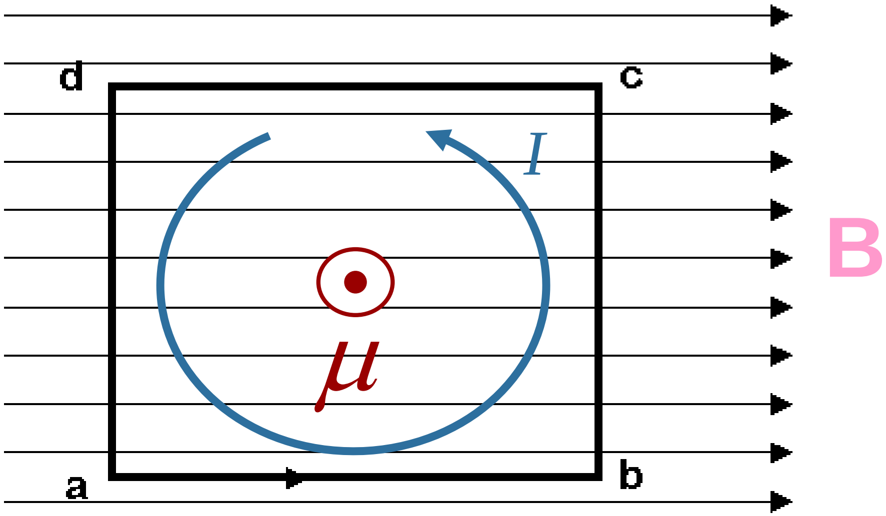
$\vec{\tau} = \vec{\mu} \times \vec{B}$ turns μ toward B



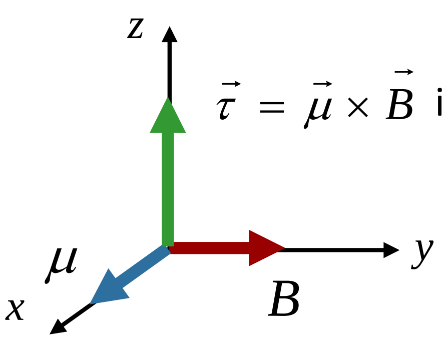
$\vec{\tau} = \vec{\mu} \times \vec{B}$ turns μ toward B

Practice with μ and τ

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



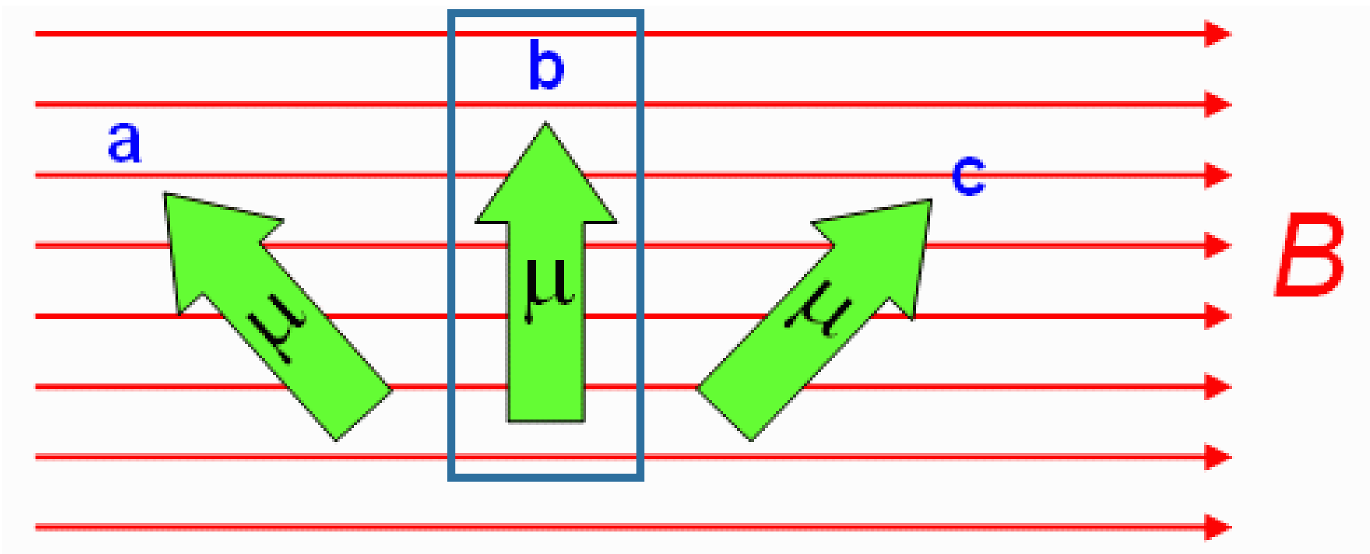
In this case μ is out of the page (using right hand rule)



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

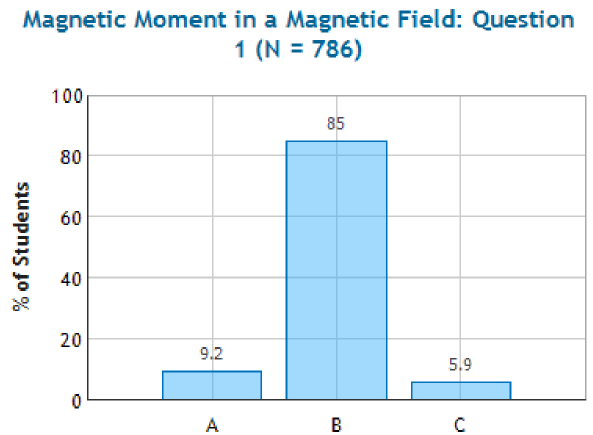
CheckPoint 2a

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?



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

Biggest when $\vec{\mu} \perp \vec{B}$



Magnetic Field can do Work on $\vec{\mu}$

From Physics 211: $$W = \int \tau \, d\theta$$

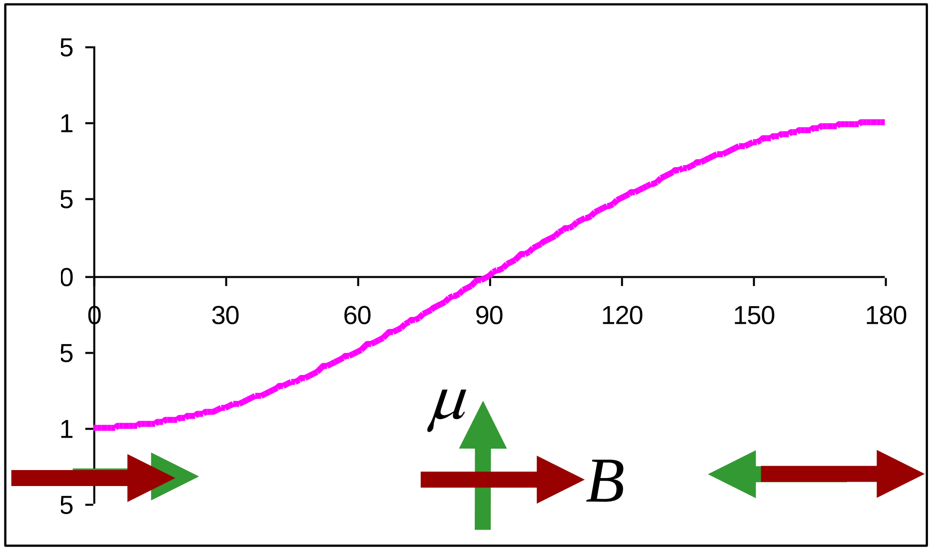
From Physics 212: $$\vec{\tau} = \vec{\mu} \times \vec{B} = \mu B \sin(\theta)$$

$$W = \int \mu B \sin(\theta) \, d\theta = \mu B \cos(\theta) = \vec{\mu} \cdot \vec{B}$$

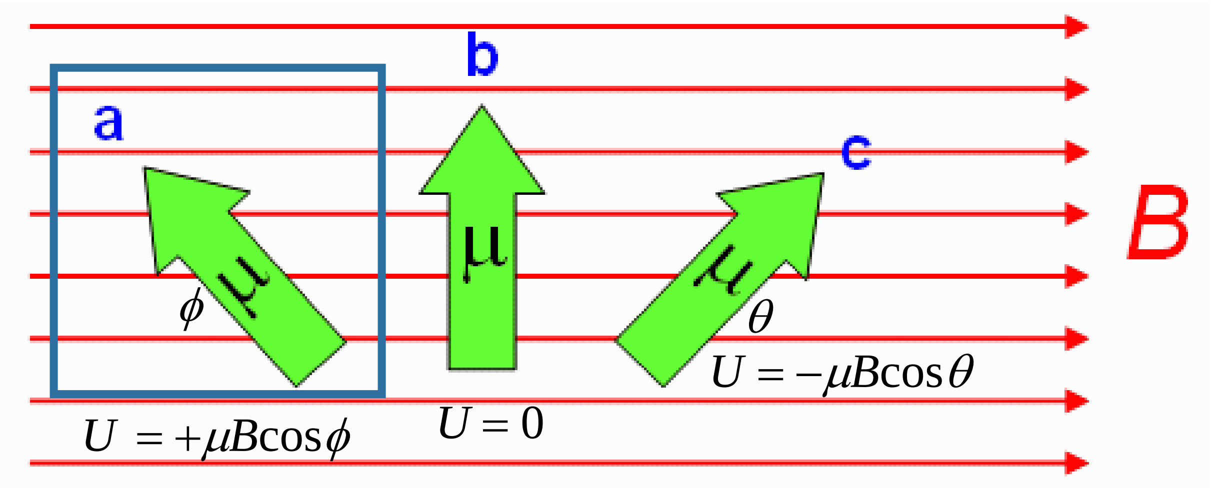
$$\Delta U = -W$$

Define $U = 0$ at position of maximum torque

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

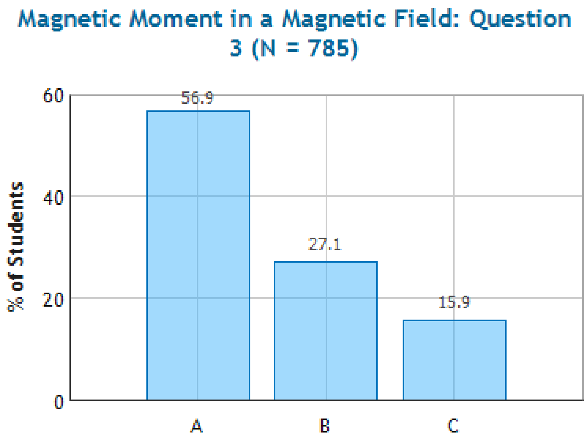


CheckPoint 2b



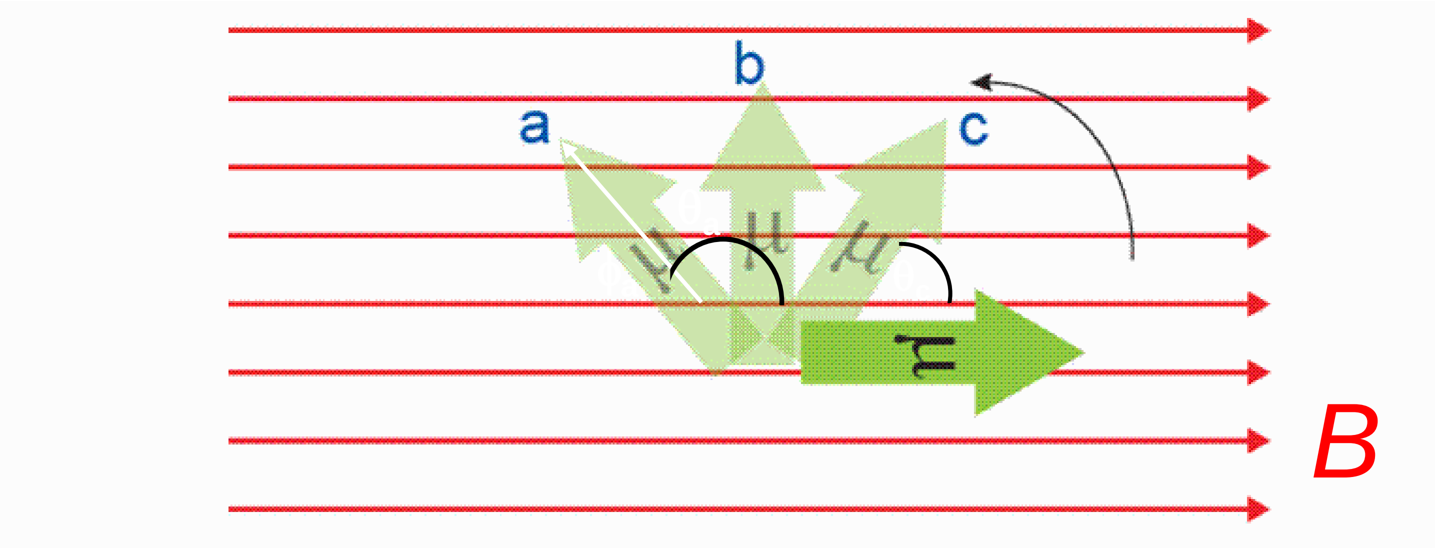
Which orientation has the most potential energy?

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



ACT

Three different orientations of a magnetic dipole moment in a constant magnetic field are shown below. We want to rotate the dipole in the CCW direction.



First, consider rotating to position c. What are the signs of the work done by you and the work done by the field?

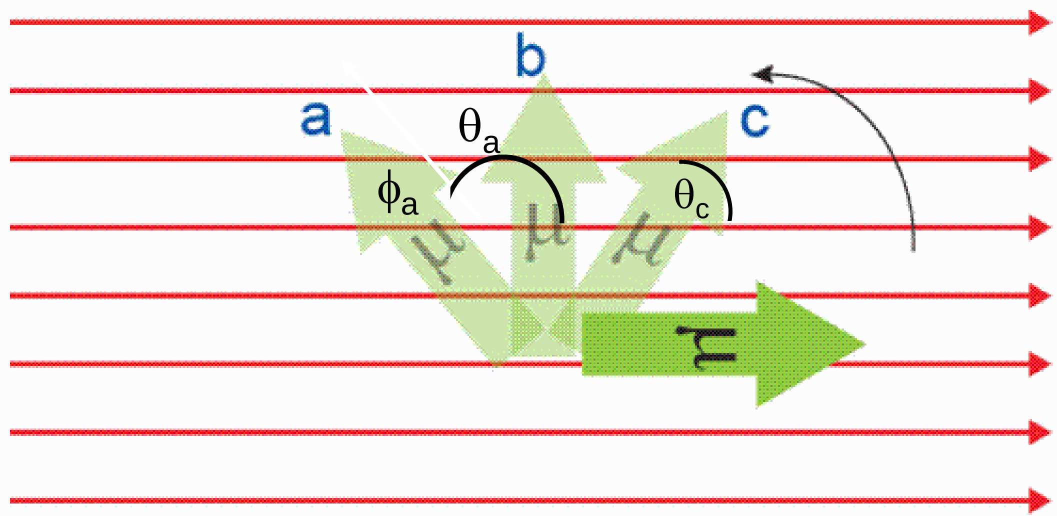
$$W_{field} = -\Delta U$$

A) $W_{you} > 0$, $W_{field} > 0$
B) $W_{you} > 0$, $W_{field} < 0$
C) $W_{you} < 0$, $W_{field} > 0$
D) $W_{you} < 0$, $W_{field} < 0$

- **$\Delta U > 0$, so $W_{field} < 0$. W_{you} must be opposite W_{field}**
- **Also, torque and displacement in opposite directions → $W_{field} < 0$**

CheckPoint 2c

Three different orientations of a magnetic dipole moment in a constant magnetic field are shown below. In order to rotate a horizontal magnetic dipole to the three positions shown, which one requires the most work done by the magnetic field?



○a ○b ○c

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

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

BY FIELD

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

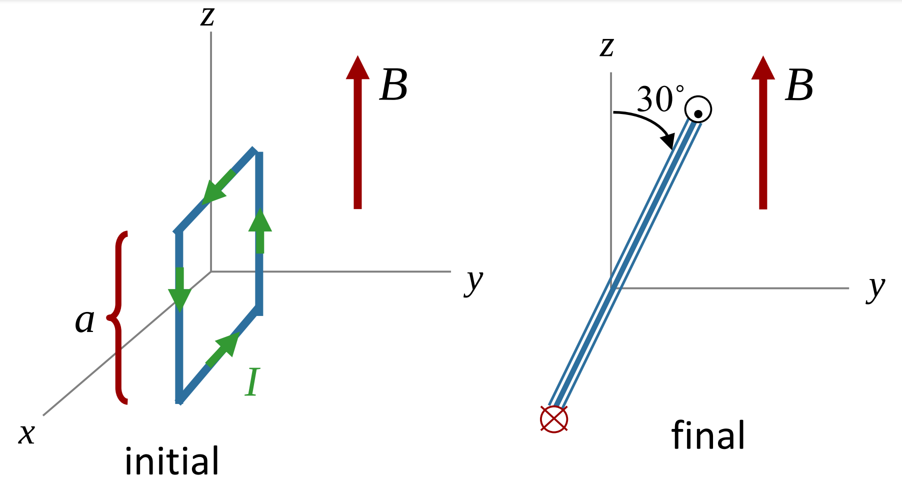
B): $W_{by\_field} = -\mu B - 0 = -\mu B$

BY YOU

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

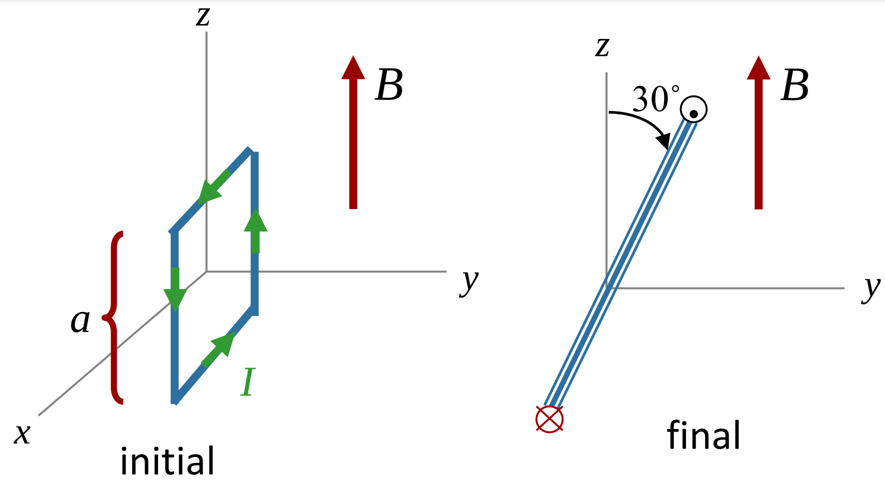
$$U = -\mu \cdot B$$

Strategic Analysis

Find μ

Calculate the change in potential energy from initial to final

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.



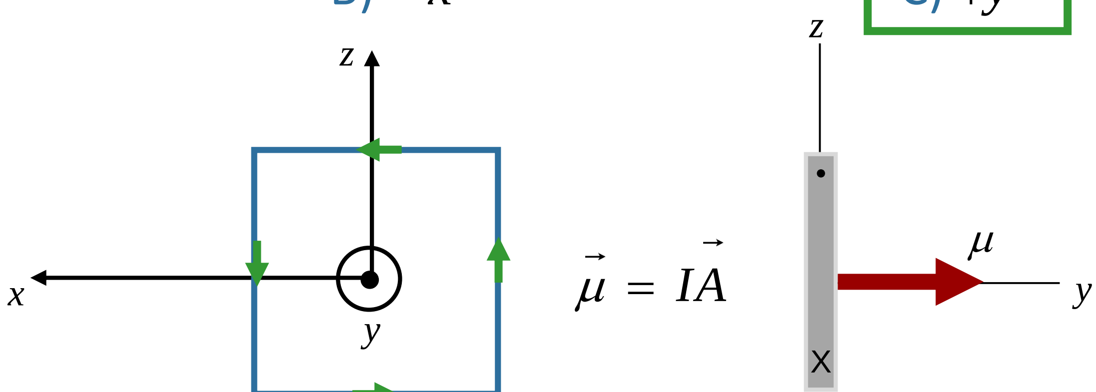
What is the direction of the magnetic moment of this current loop in its initial position?

A) $+x$

B) $-x$

C) $+y$

D) $-y$

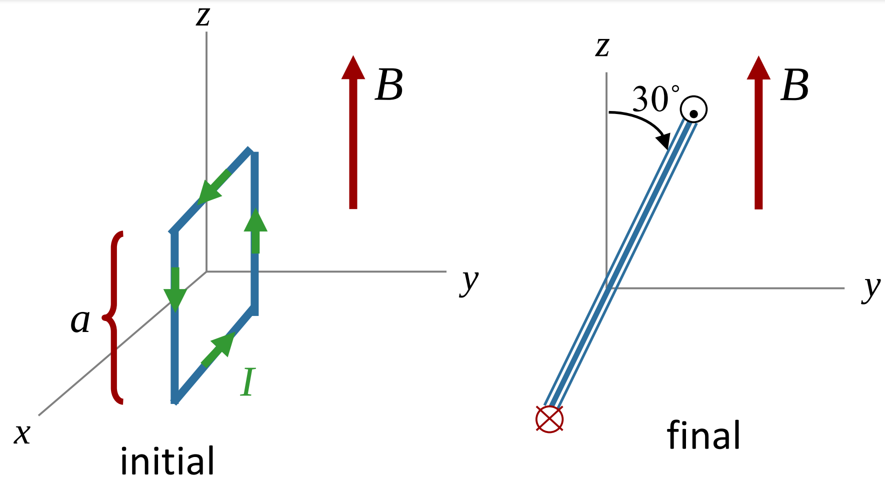


$$\vec{\mu} = I\vec{A}$$

Right Hand Rule

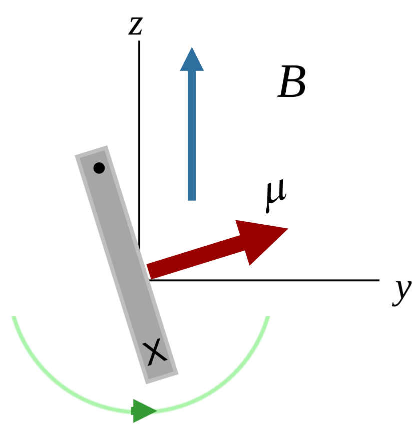
Calculation

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?

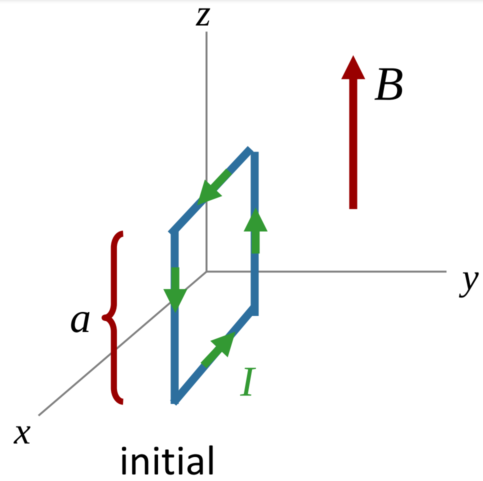
$\boxed{\text{A)}\ +x}$ B) $-x$ C) $+y$ D) $-y$

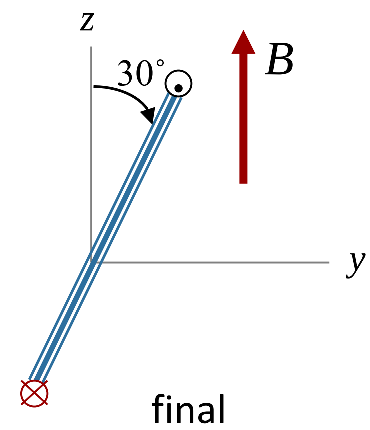


Calculation

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.

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



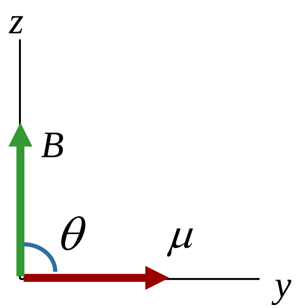


What is the potential energy of the initial state?

A) $U_{initial} < 0$

B) $\boxed{U_{initial} = 0}$

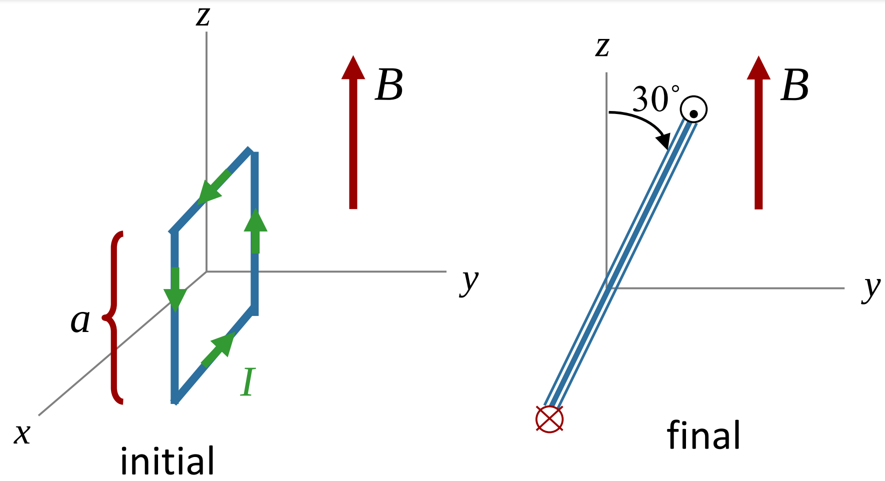
C) $U_{initial} > 0$



$$\theta = 90^0 \Rightarrow \vec{\mu} \bullet \vec{B} = 0$$

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.



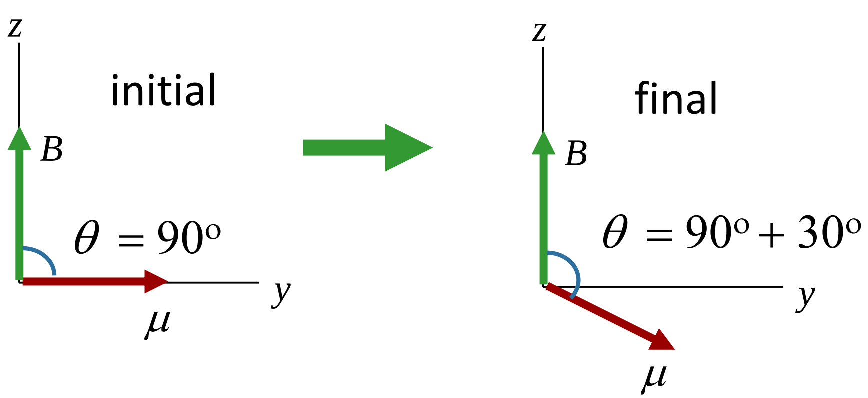
$$U = -\vec{\mu} \cdot \vec{B}$$

What is the potential energy of the final state?

A) $U_{final} < 0$

B) $U_{final} = 0$

C) $\boxed{U_{final} > 0}$



$\theta = 120^0$

$\vec{\mu} \bullet \vec{B} < 0$

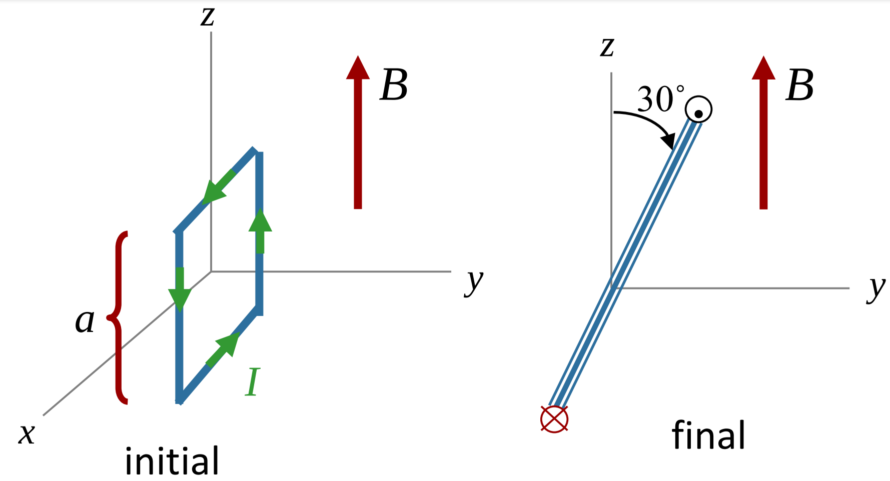
$U = -\vec{\mu} \cdot \vec{B} > 0$

Check: μ moves away from B

Energy must increase !

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.



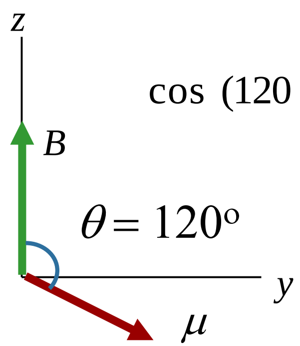
$$\boxed{U = -\vec{\mu} \cdot \vec{B}}$$

What is the potential energy of the final state?

A) $U = Ia^2 B$

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

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



$$\cos(120^\circ) = -\frac{1}{2}$$

$$U = -\vec{\mu} \cdot \vec{B} = -\mu B \cos(120^o) = \frac{1}{2}\mu B$$

$$\mu = Ia^2$$

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