

Your Comments

Well I know I can't say the concepts were easy. In addition I am not sure they are difficult. Therefore, I assume that I found the concepts difficult. I would like to be sure that we discuss everything there is to discuss.

I often accidentally use my left hand to figure out the direction of a cross product because it's hard to move my right hand into those crazy vector positions.

Please go over the concept of the dipole and its potential energy

Torque and potential energy were confusing to understand conceptually. .

Torque was always confusing to me! Even in 211!

I'm pretty intimidated by this topic.

I know we haven't found any yet, but with future advances in physics, do you believe we will ever find a monopole?

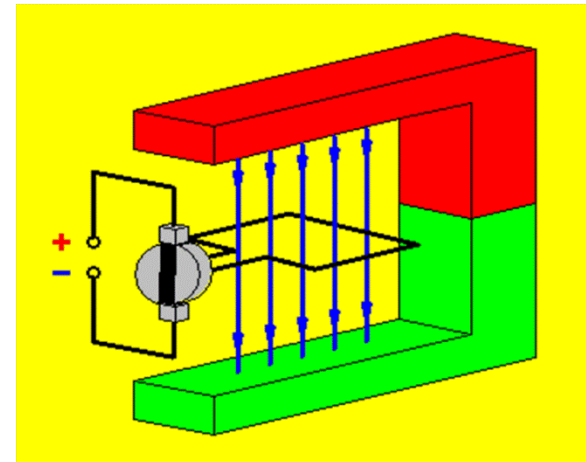
Woah give me a **MOMENT** to process this because my head's spinning because torque and oh look there's a cat MEWing

Physics 212

Lecture 13

Today's Concept:

Torques



Last Time:

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

This Time:

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



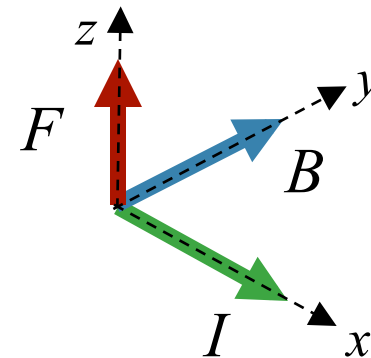
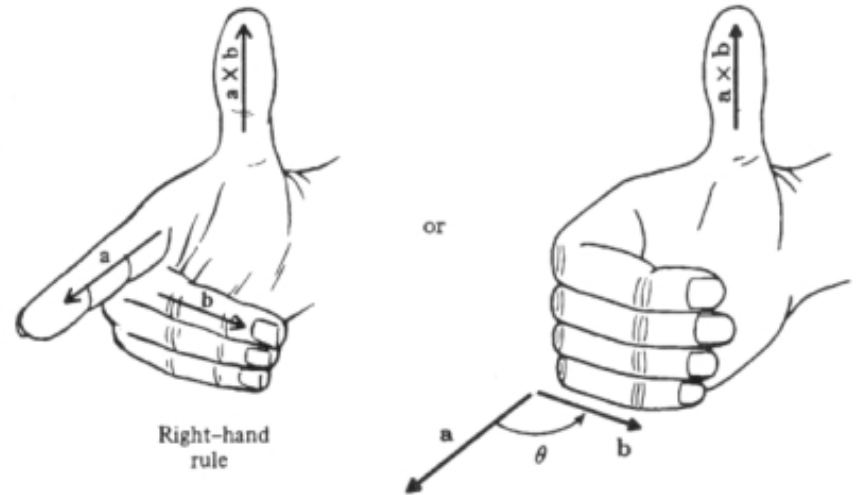
$$\vec{F} = qN\vec{v}_{avg} \times \vec{B}$$

$N = nAL$

$$I = qnAv_{avg}$$



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

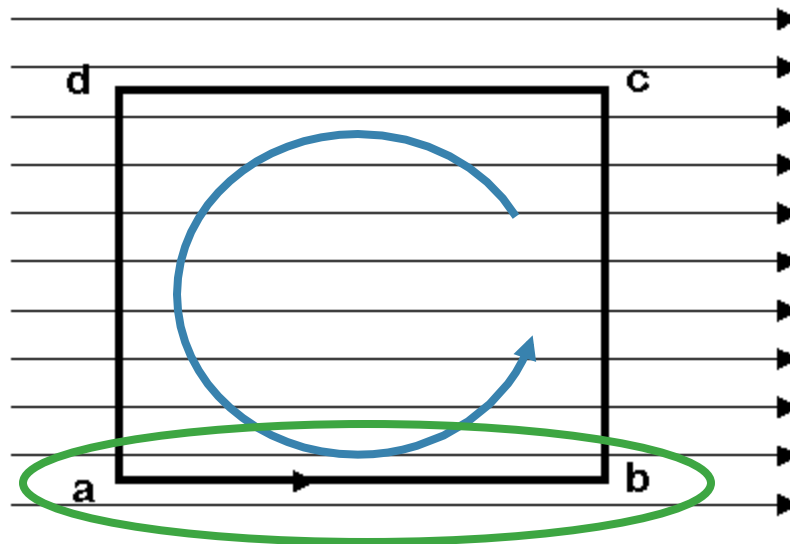


Clicker Question



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

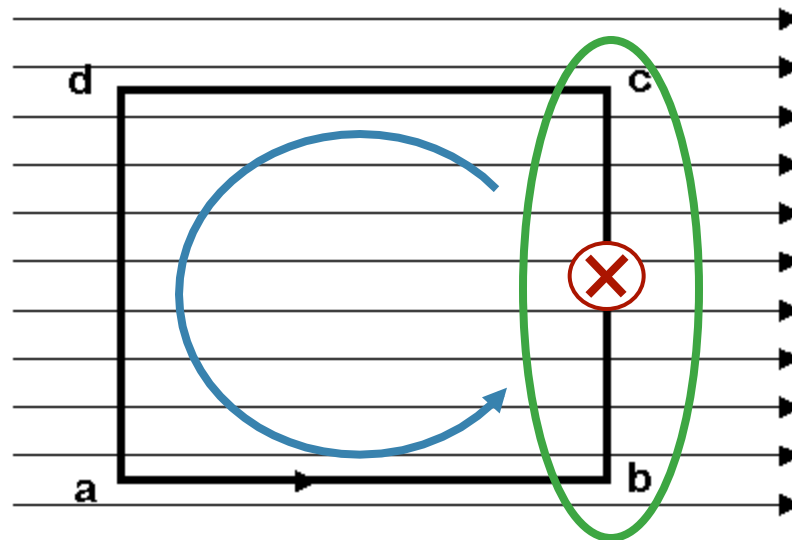
C. into the page

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

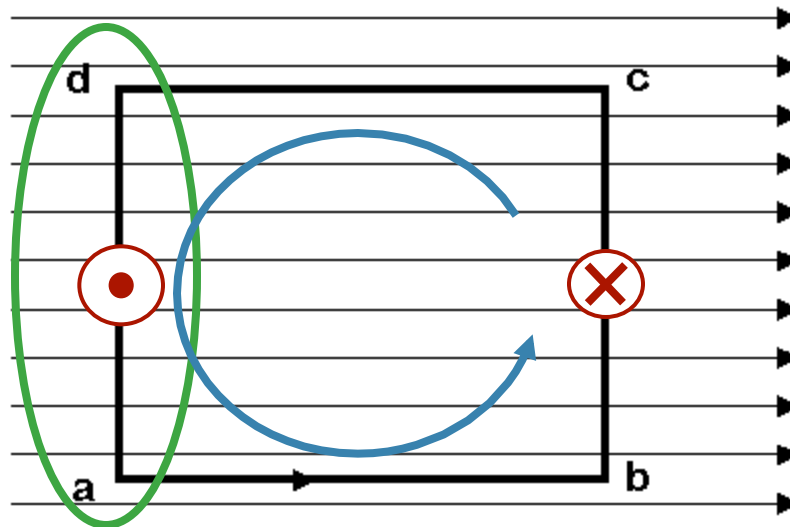
C. into the page

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.

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

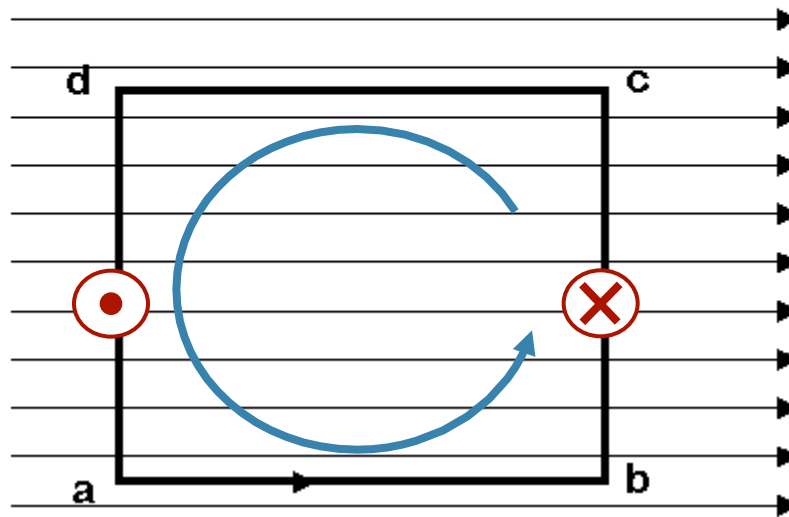


What is the force on section d-a of the loop?

- A) Zero
- B) Out of the page
- C) Into the page

Checkpoint 1a

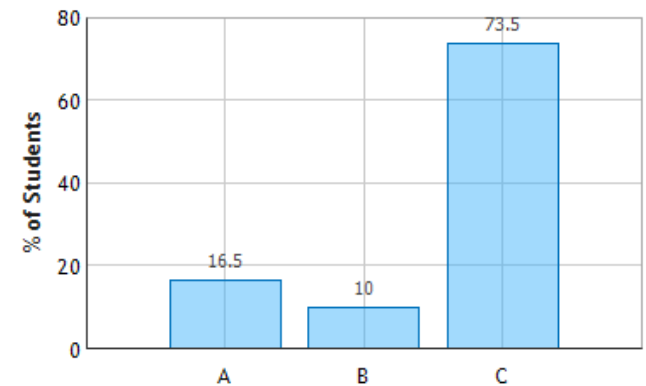
A square loop of wire is carrying current in the counterclockwise direction. There is a horizontal uniform magnetic field pointing to the right.



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

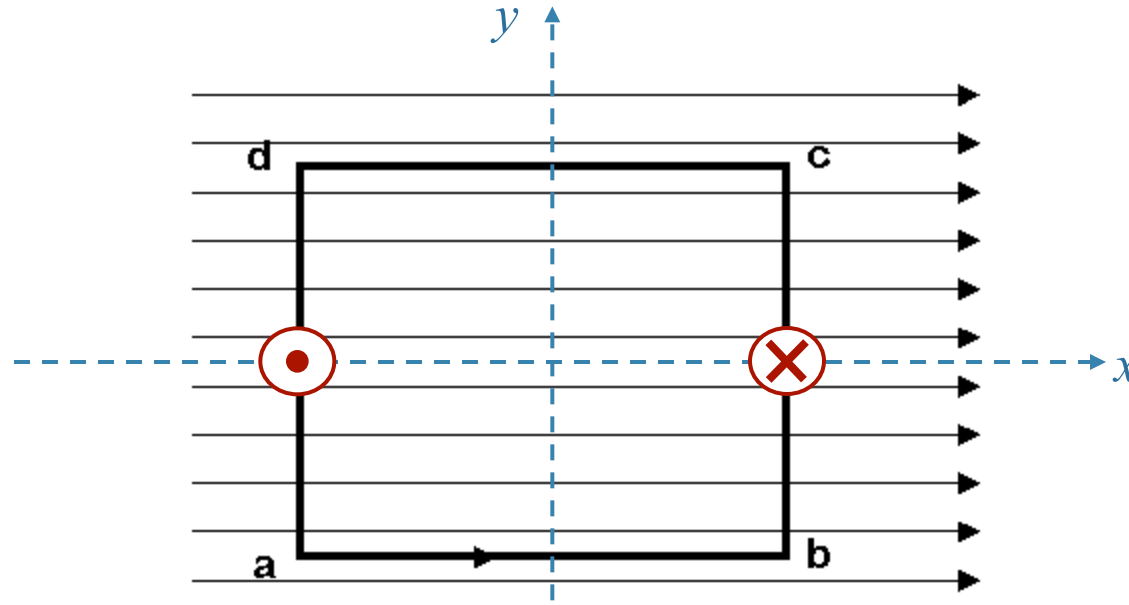
- A.** Out of the page **B.** Into of the page
C. The net force on the loop is zero

“it is a closed loop (length vector is 0) so the net force is 0 $F = IL \times B = 0$ ”



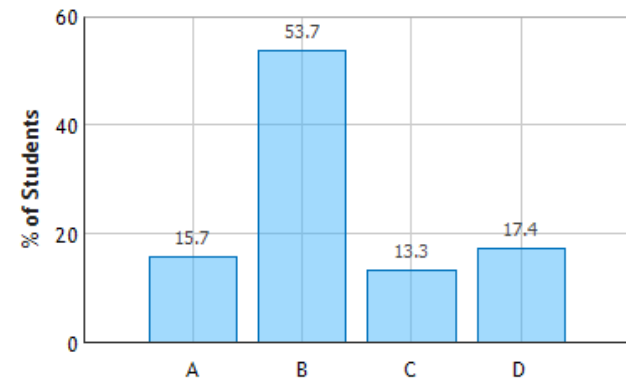
CheckPoint 1b

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



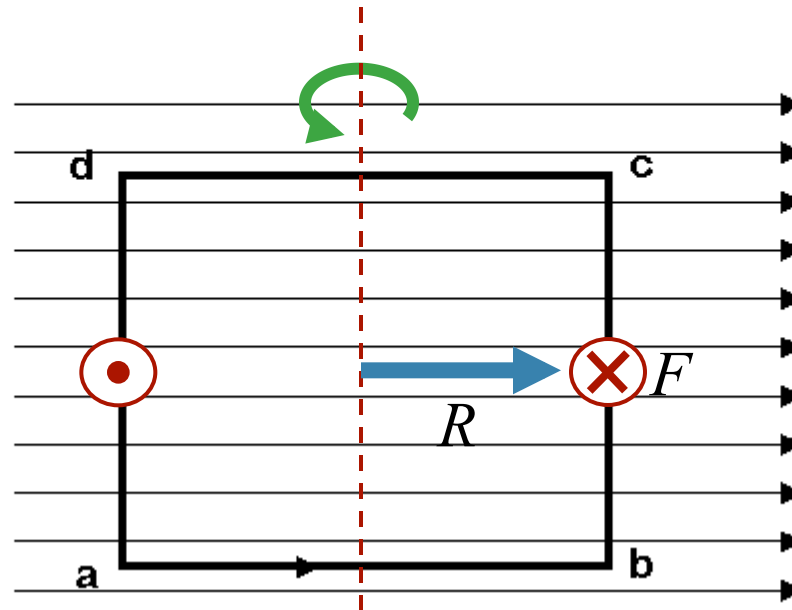
In which direction will the loop rotate?
(assume the z axis is out of the page)

- 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?

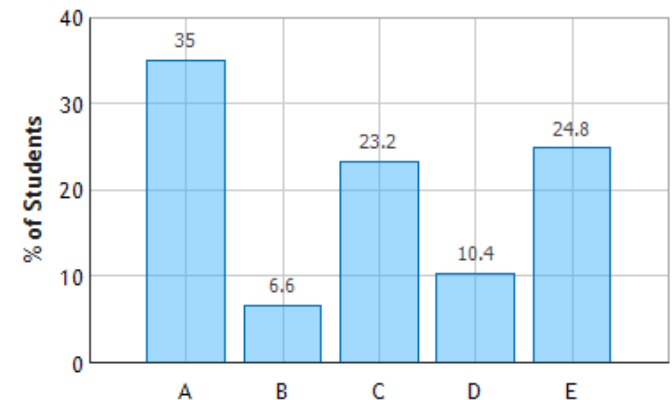
A. Up

B. Down

C. Out of the page

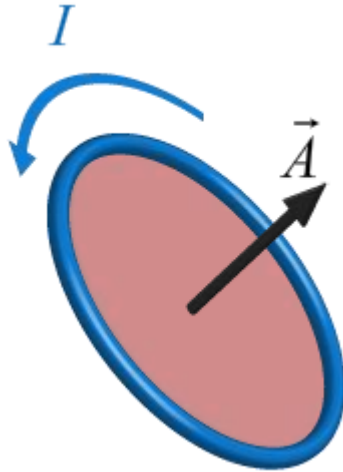
D. Into the page

E. The net torque is zero



Magnetic Dipole Moment

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

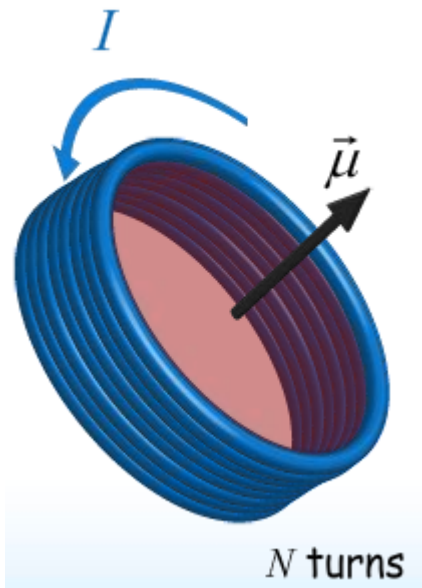


Area vector

Magnitude = Area

Direction uses R.H.R.

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



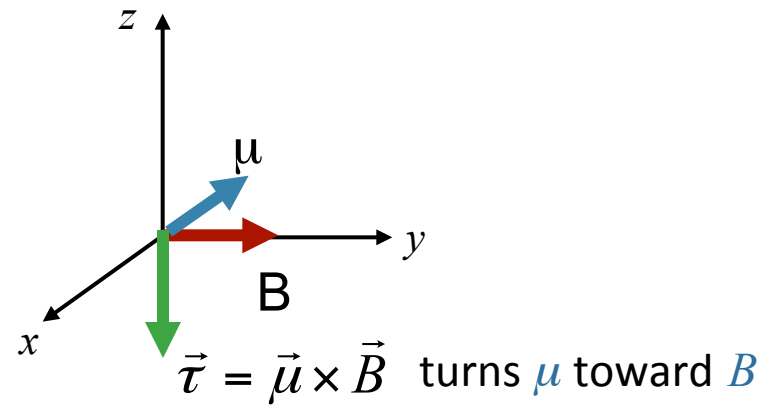
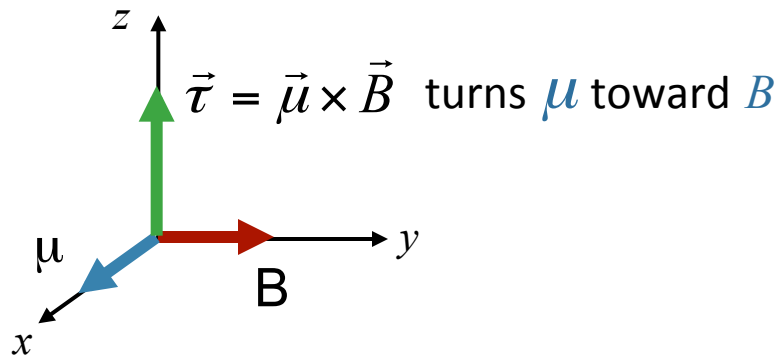
Magnetic Dipole moment

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

μ Makes Torque Easy!

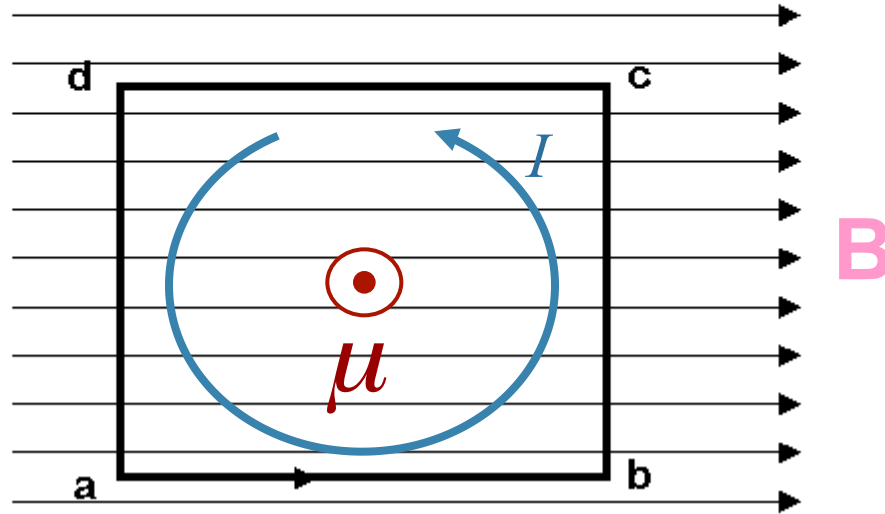
$$\vec{\tau} = \vec{\mu} \times \vec{B}$$

The torque always wants to line μ up with B !

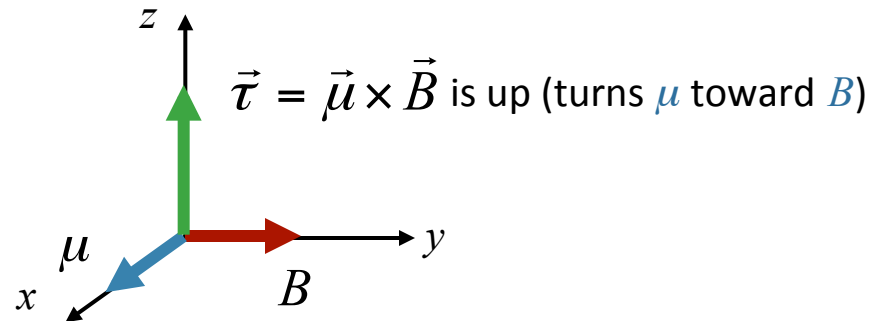


Practice with μ and τ

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

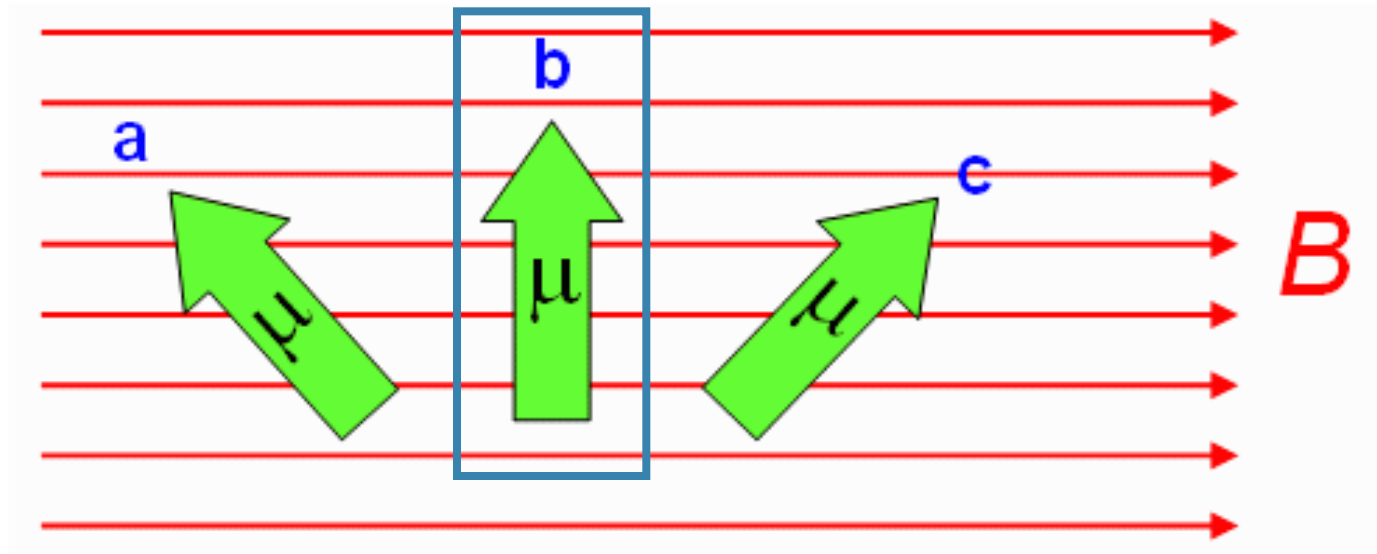


In this case μ is out of the page (using right hand rule)



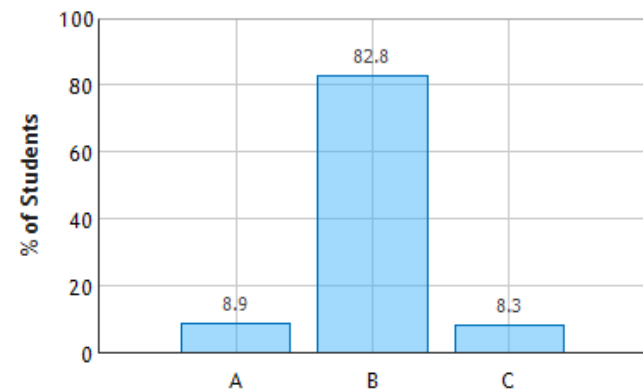
CheckPoint 2a

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: $W = \int \tau d\theta$

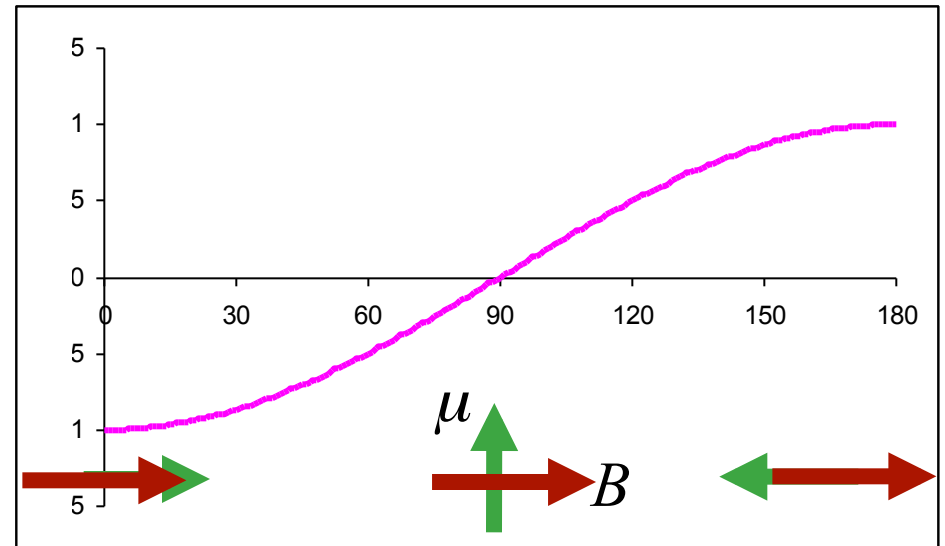
From Physics 212: $\vec{\tau} = \vec{\mu} \times \vec{B} = \mu B \sin(\theta)$

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

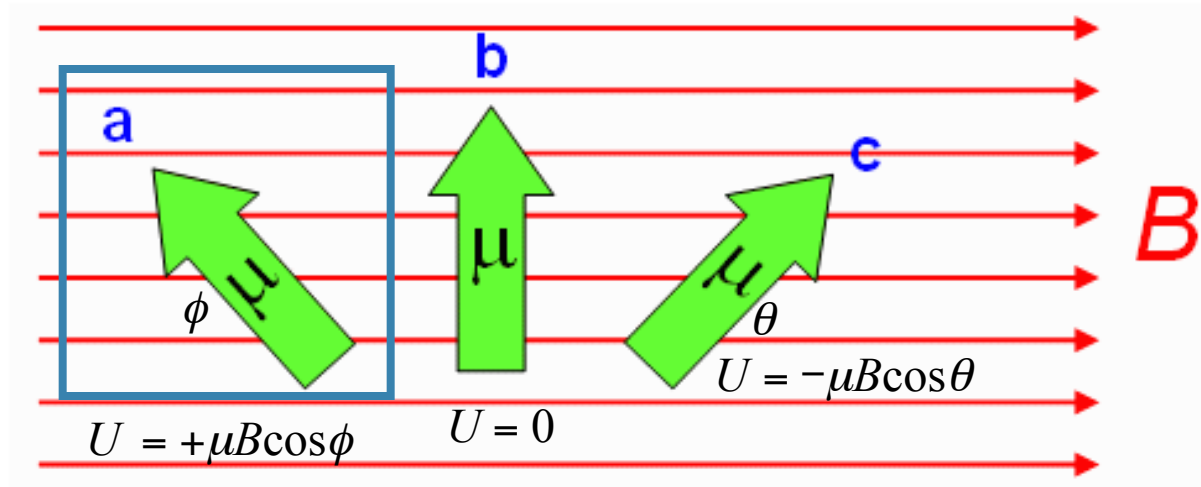
$$\Delta U = -W$$

Define $U = 0$ at position of maximum torque

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

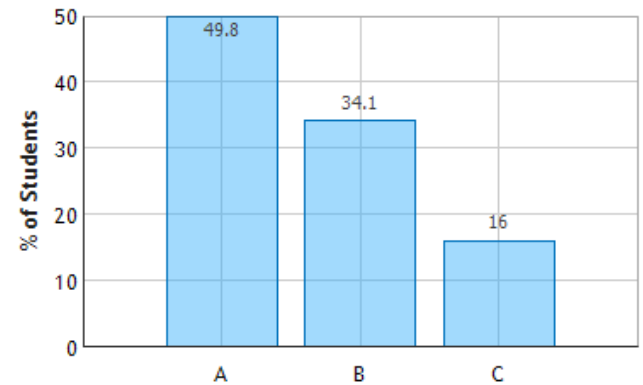


Checkpoint 2b



Which orientation has the most potential energy?

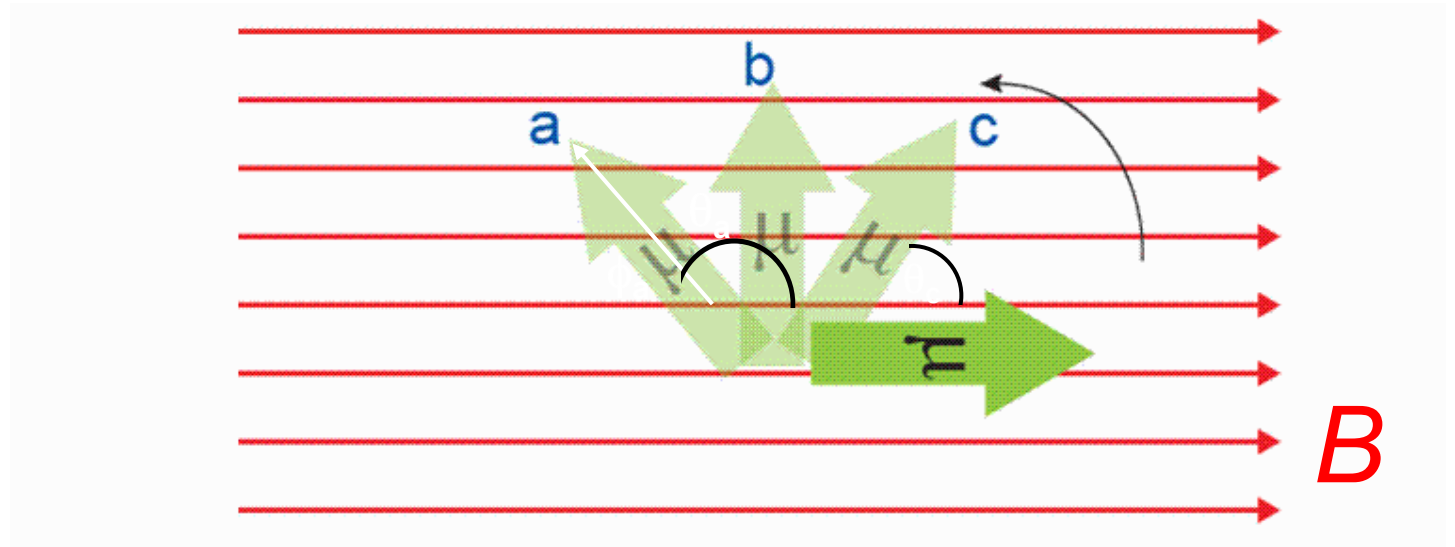
$$U = -\vec{\mu} \cdot \vec{B}$$



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?

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

A) $W_{\text{you}} > 0, W_{\text{field}} > 0$

B) $W_{\text{you}} > 0, W_{\text{field}} < 0$

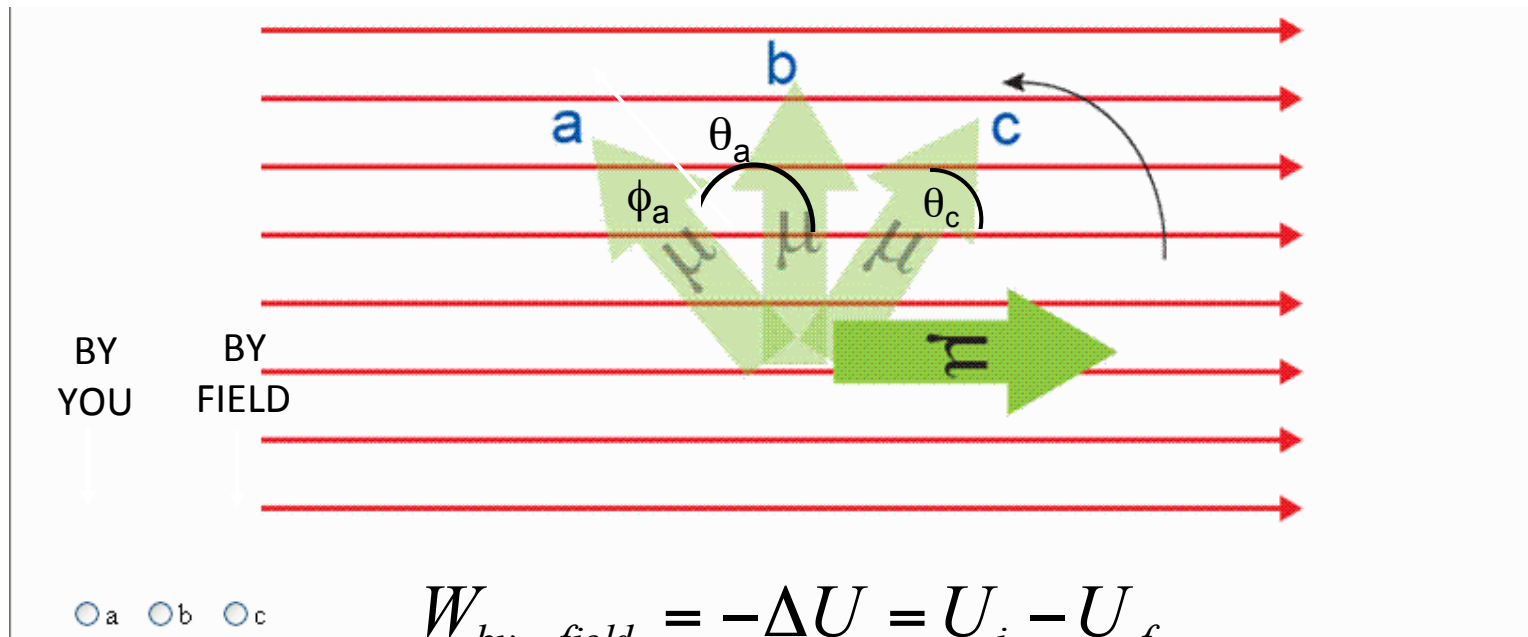
C) $W_{\text{you}} < 0, W_{\text{field}} > 0$

D) $W_{\text{you}} < 0, W_{\text{field}} < 0$

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

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?



$$W_{by_field} = -\Delta U = U_i - U_f$$

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

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

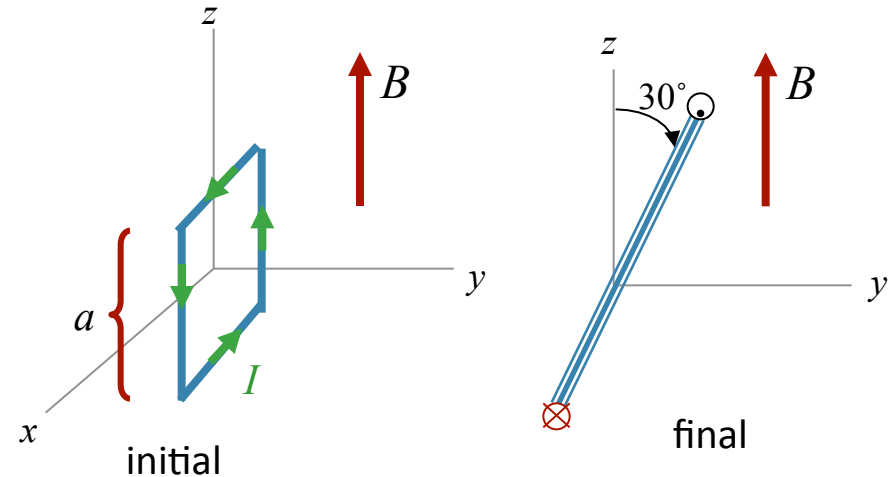
B): $\rightarrow W_{by_field} = -\mu B - 0 = -\mu B$

A): $\rightarrow W_{by_field} = -\mu B - (-\mu B \cos \theta_a) = -\mu B(1 + \cos \phi_a)$

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

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

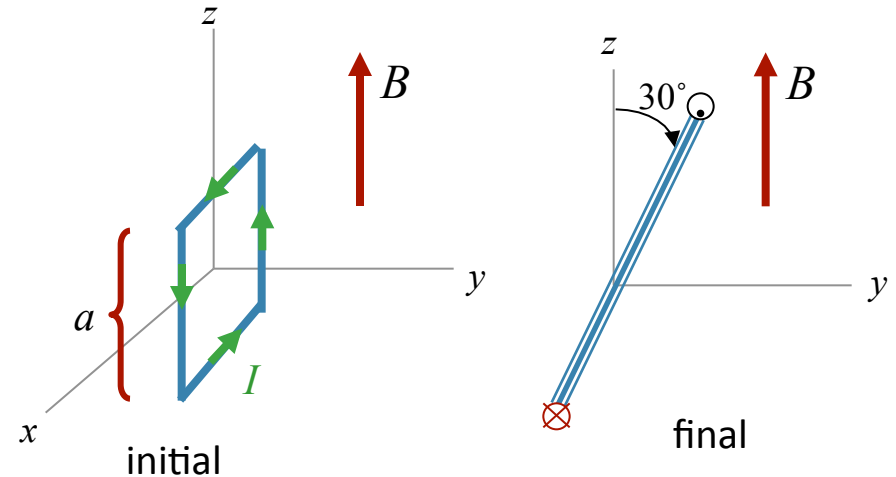
Strategic Analysis

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.



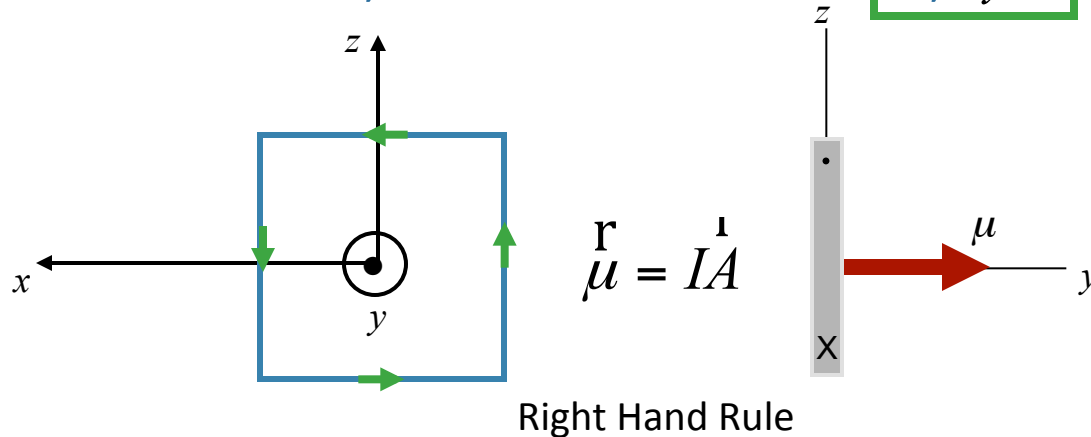
What is the direction of the magnetic moment of this current loop in its initial position?

A) $+x$

B) $-x$

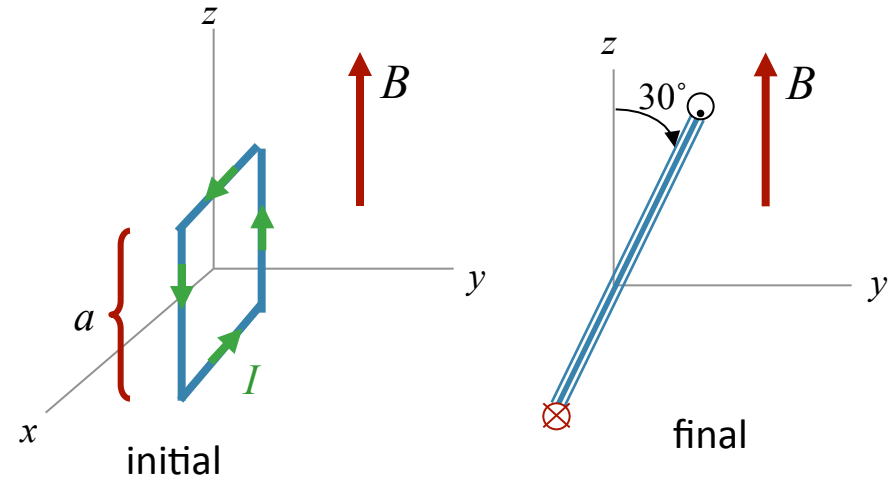
C) $+y$

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.



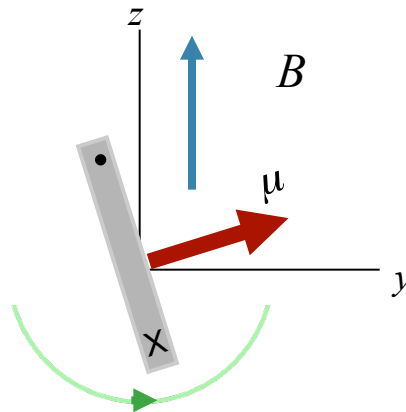
What is the direction of the torque on this current loop in the initial position?

A) $+x$

B) $-x$

C) $+y$

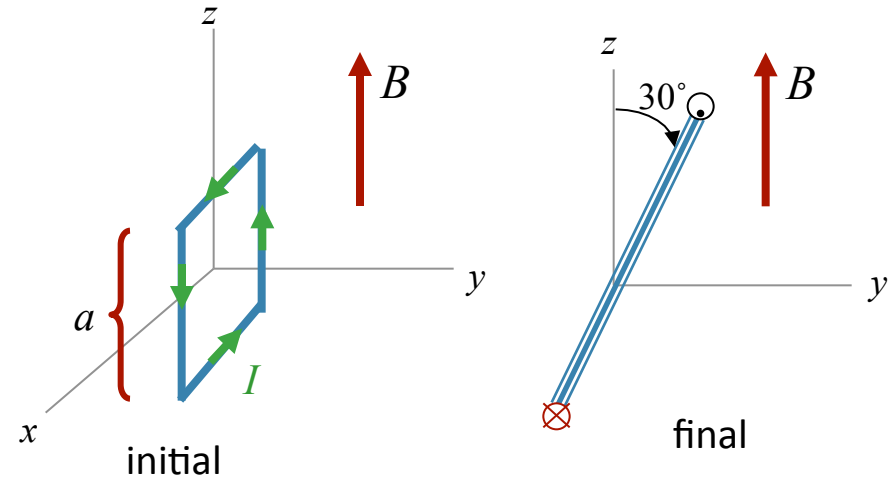
D) $-y$



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.

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

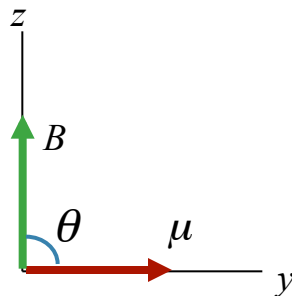


What is the potential energy of the initial state?

A) $U_{initial} < 0$

B) $U_{initial} = 0$

C) $U_{initial} > 0$

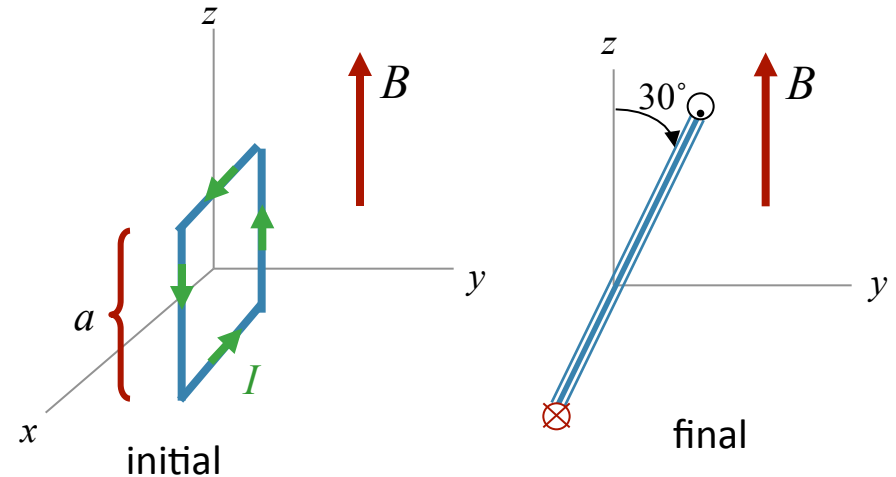


$$\theta = 90^\circ \rightarrow \vec{\mu} \cdot \vec{B} = 0$$

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.

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

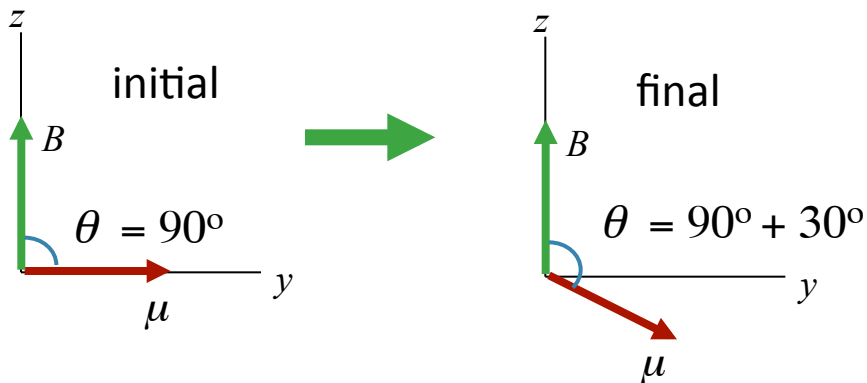


What is the potential energy of the final state?

A) $U_{final} < 0$

B) $U_{final} = 0$

C) $U_{final} > 0$



Check: μ moves away from B

Energy must increase !

$\theta = 120^\circ$

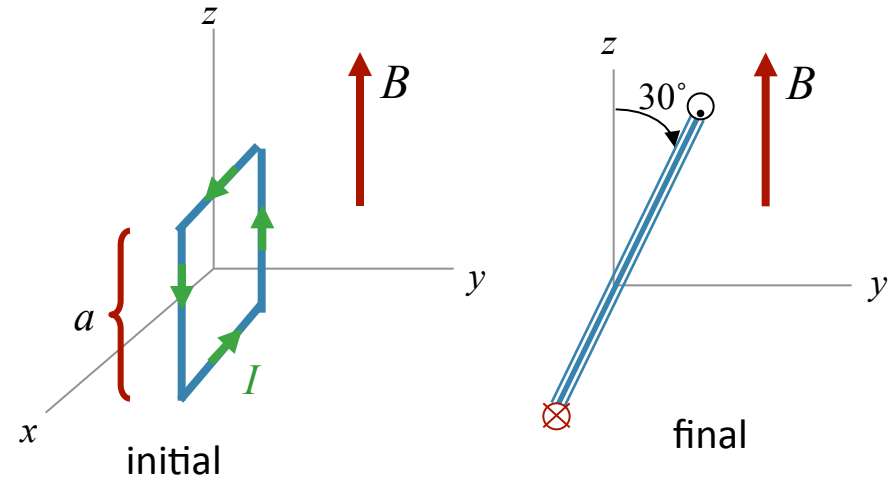
$\vec{\mu} \cdot \vec{B} < 0$

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

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.

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

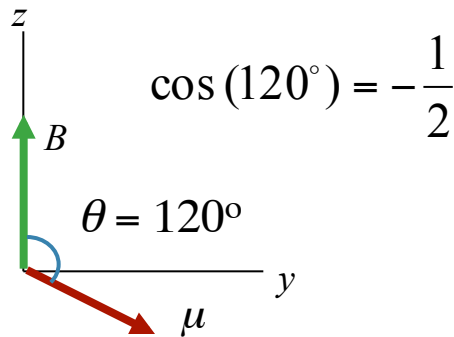


What is the potential energy of the final state?

A) $U = Ia^2 B$

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

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



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

$$\mu = Ia^2$$

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