Your Comments

You know, I really wish the homework was do-able without arcane mastery of geometry...

i don't understand how to use magnetic dipole moment at all

Those eyes in the prelecture look so sad, even though the physics is so exciting.

Can you PLEASE go over RC Circuits again because it doesn't really make sense to me

How do we chose a direction on the vector length L? Is it arbitrary?

I did not understand the dipole moment and potential energy part. Also can you please clarify how to find direction of things using various right hand rules. I'm getting confused!

Today (26 Feb) is my birthday, so I wanted to send out a message to celebrate my 19th.

Torque was hard in 211...I don't even want to think about it in 212 :(

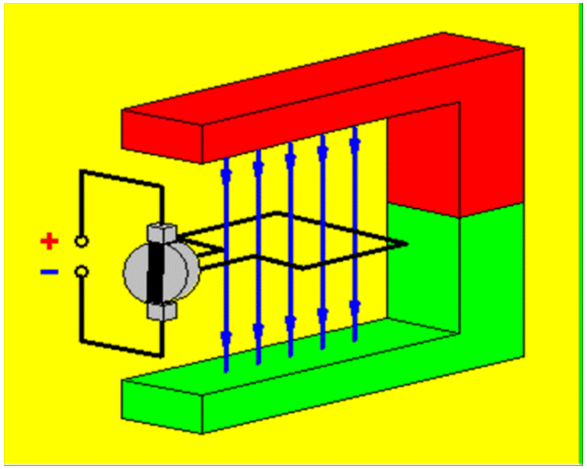
Is the area (A) in the equation (for dipole moment and torque) actually the cross sectional area? So is it just the amount of area that the magnetic field passes through? Or is it the total area enclosed by the loop?

You know, I don't say this often, but this magnetism stuff is kind of interesting. Almost makes me wish I wasn't a bioengineer and I was an ECE major. Almost.

Physics 212
Lecture 13

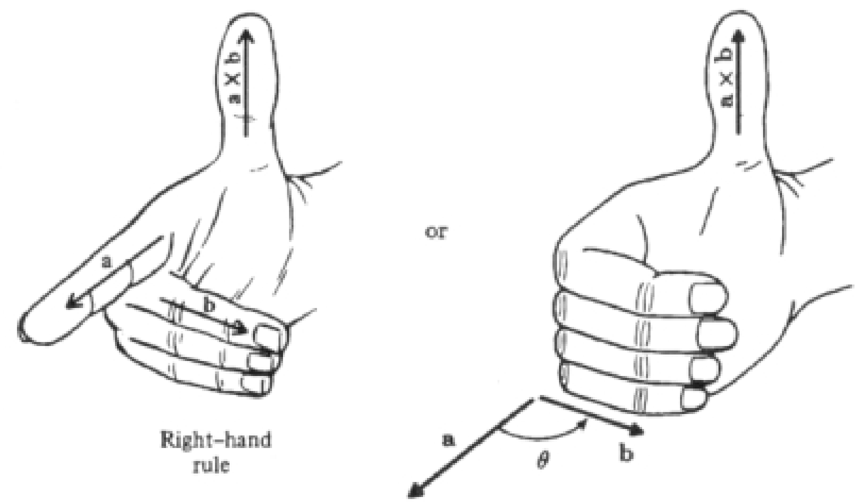
Today's Concept:

Torques



Last Time:

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



This Time:

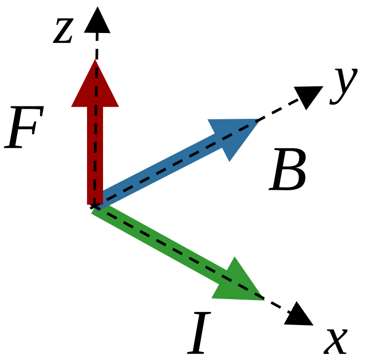
$$\vec{F} = q\sum_i \vec{v}_i \times \vec{B}$$

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

$$N = nAL$$

$$I = qnAv_{avg}$$

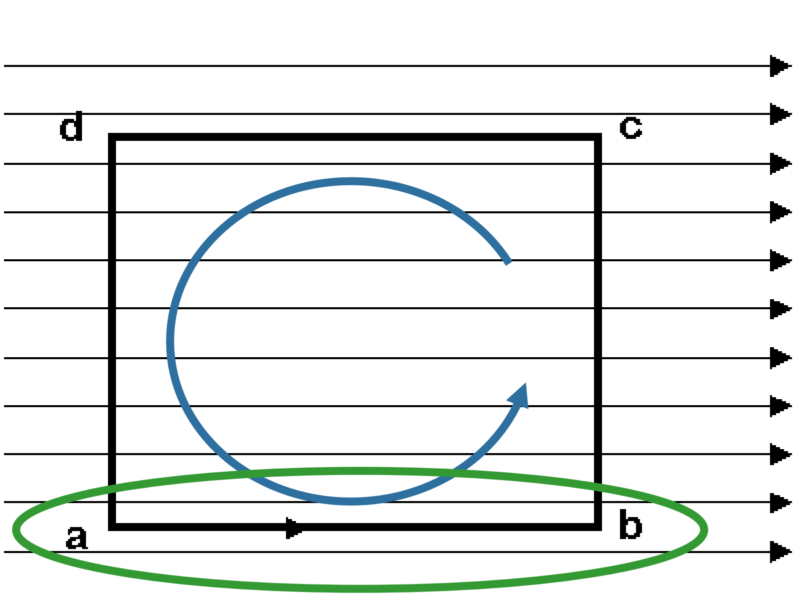
$$\vec{F} = I\vec{L} \times \vec{B}$$



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.

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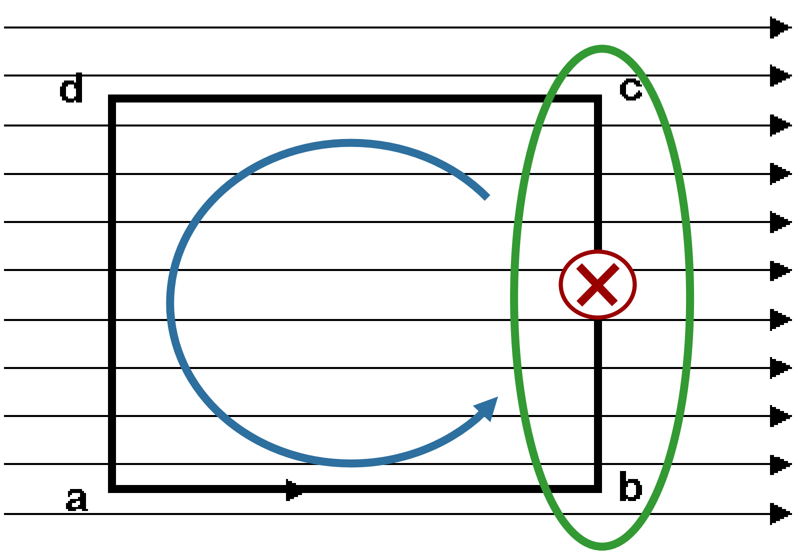


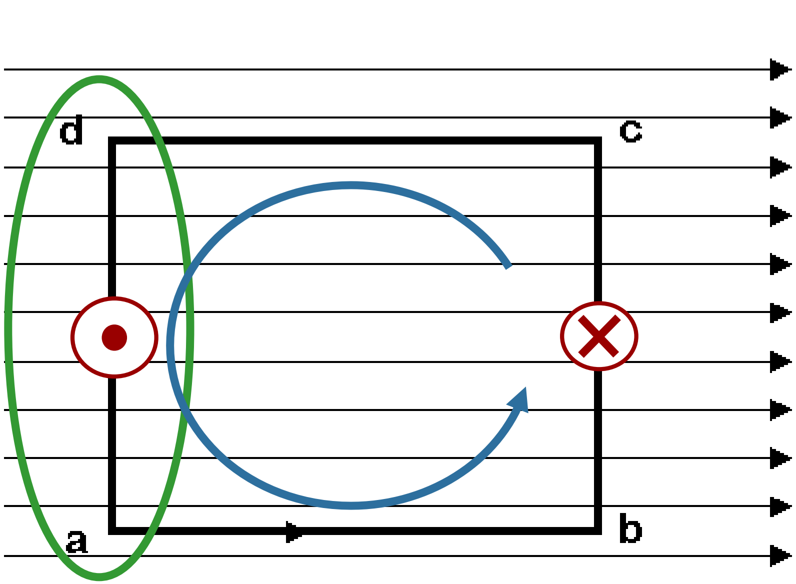
What is the force on section b-c of the loop?

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.

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

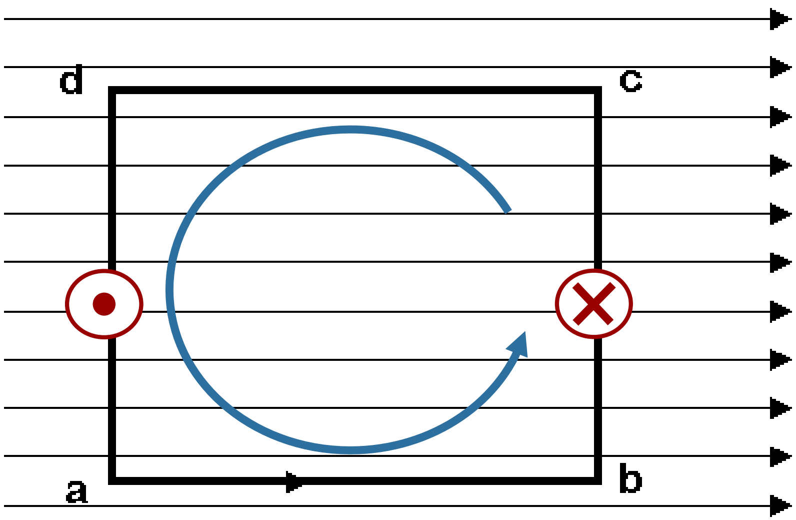


What is the force on section d-a of the loop?

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

CheckPoint 1a

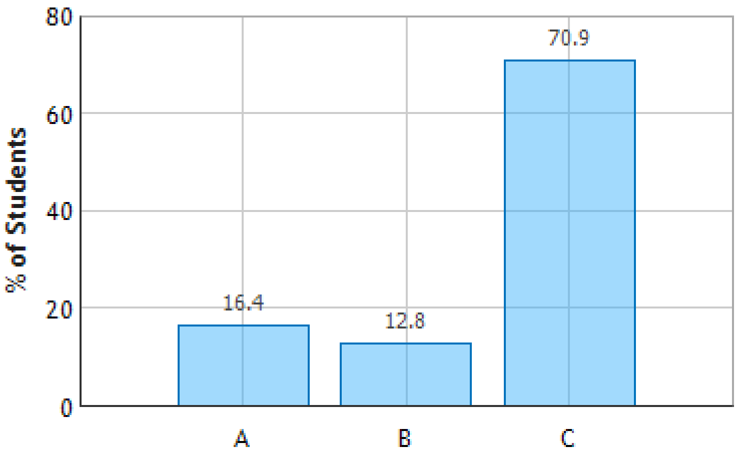
A square loop of wire is carrying current in the counterclockwise direction. There is a horizontal uniform magnetic field pointing to the right.



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

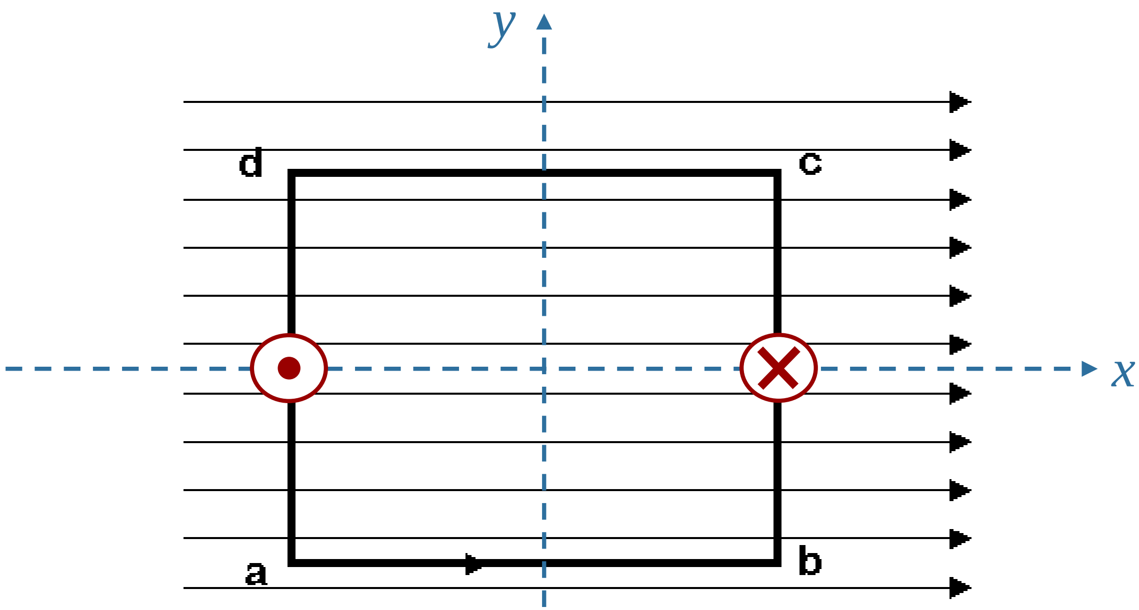
C. The net force on the loop is zero

"it is a closed loop (length vector is 0) so the net force is 0 F = ILxB = 0



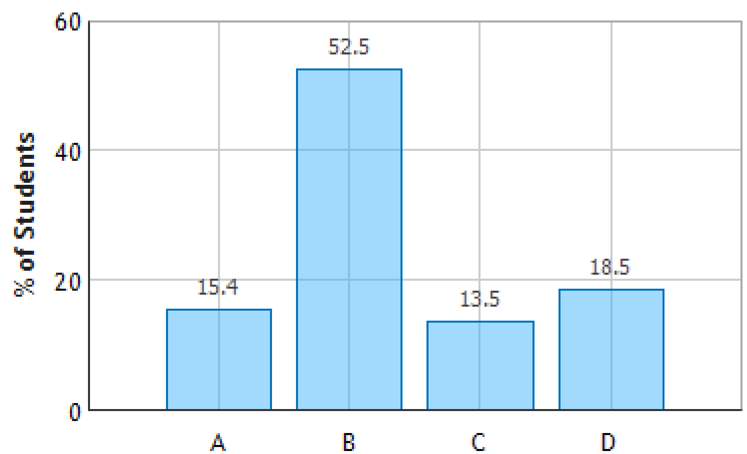
CheckPoint 1b

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



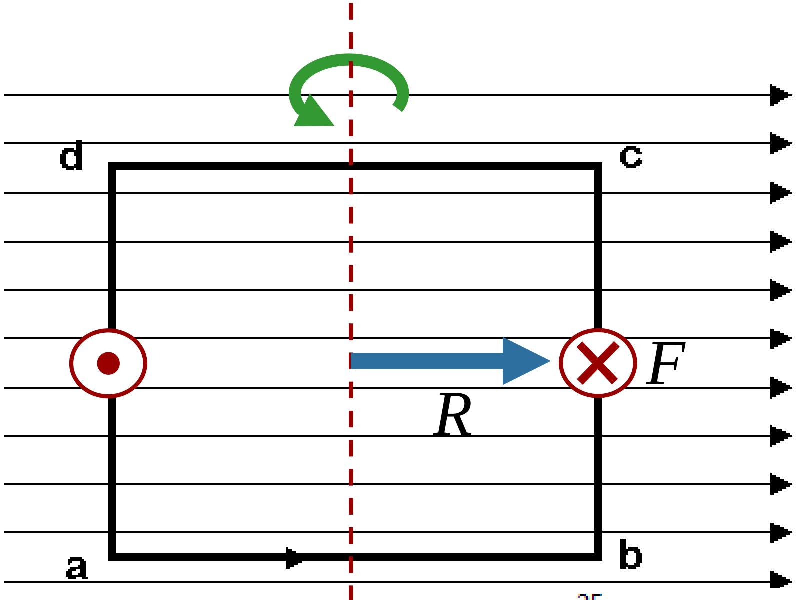
In which direction will the loop rotate?
(assume the z axis is out of the page)

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



CheckPoint 1c

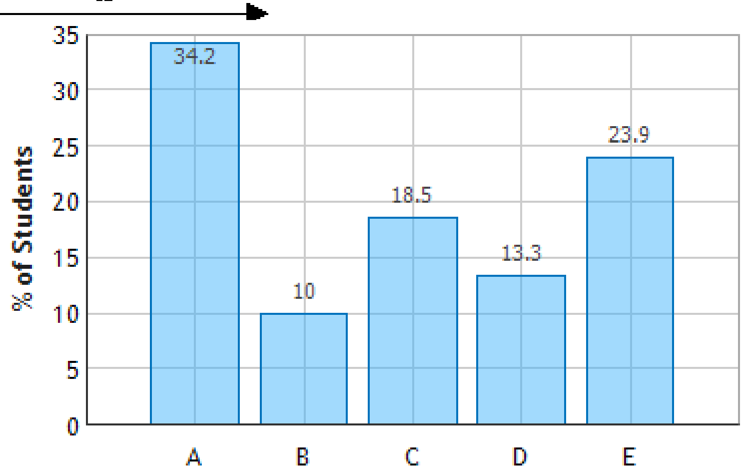
A square loop of wire is carrying current in the counterclockwise direction. There is a horizontal uniform magnetic field pointing to the right.



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

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

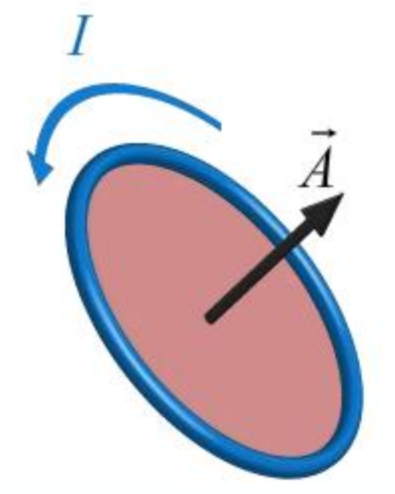
A. Up
B. Down
C. Out of the page
D. Into the page
E. The net torque is zero



r x f = torque

Magnetic Dipole Moment

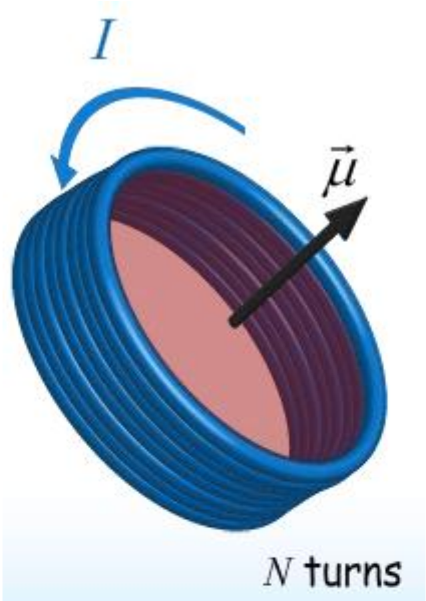
EXPLAIN THE MAGNETIC DIPOLE... What IS IT?!?!?!?!!?!?!



Area vector

Magnitude = Area

Direction uses R.H.R.



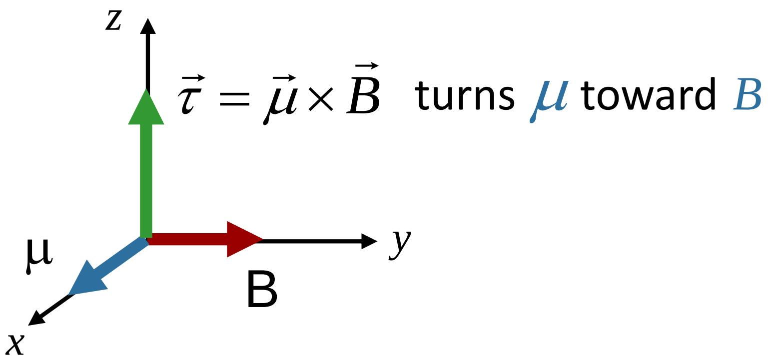
Magnetic Dipole moment

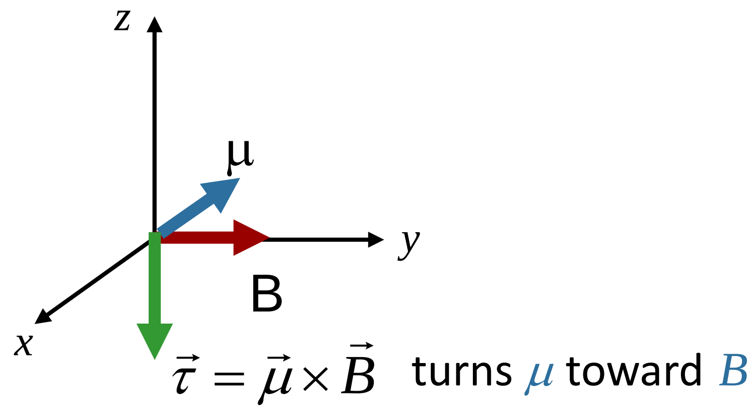
$$\vec{\mu} \equiv NI\vec{A}$$

μ Makes Torque Easy!

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

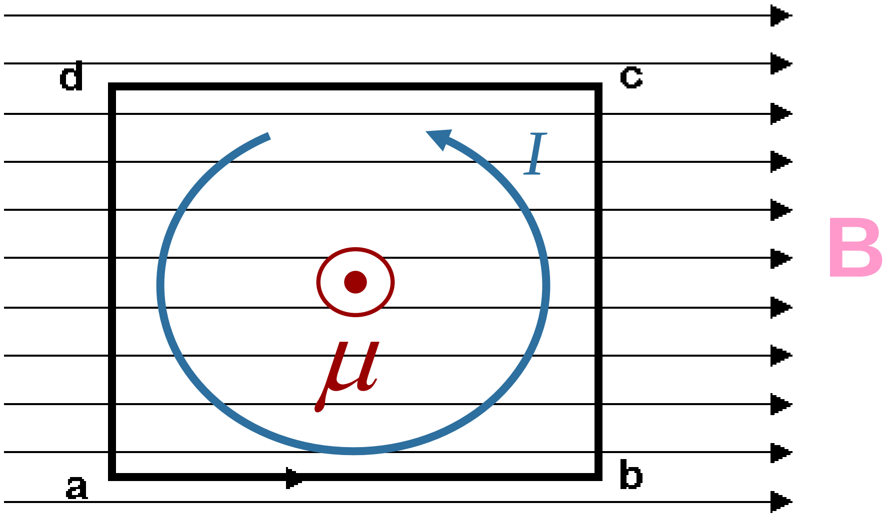
The torque always wants to line μ up with B!



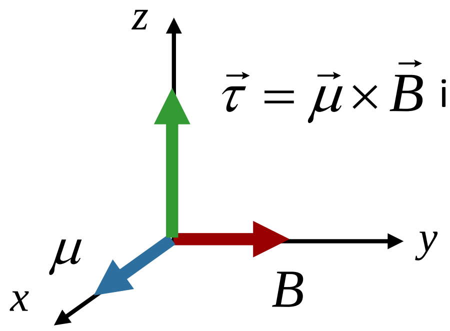


Practice with μ and τ

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



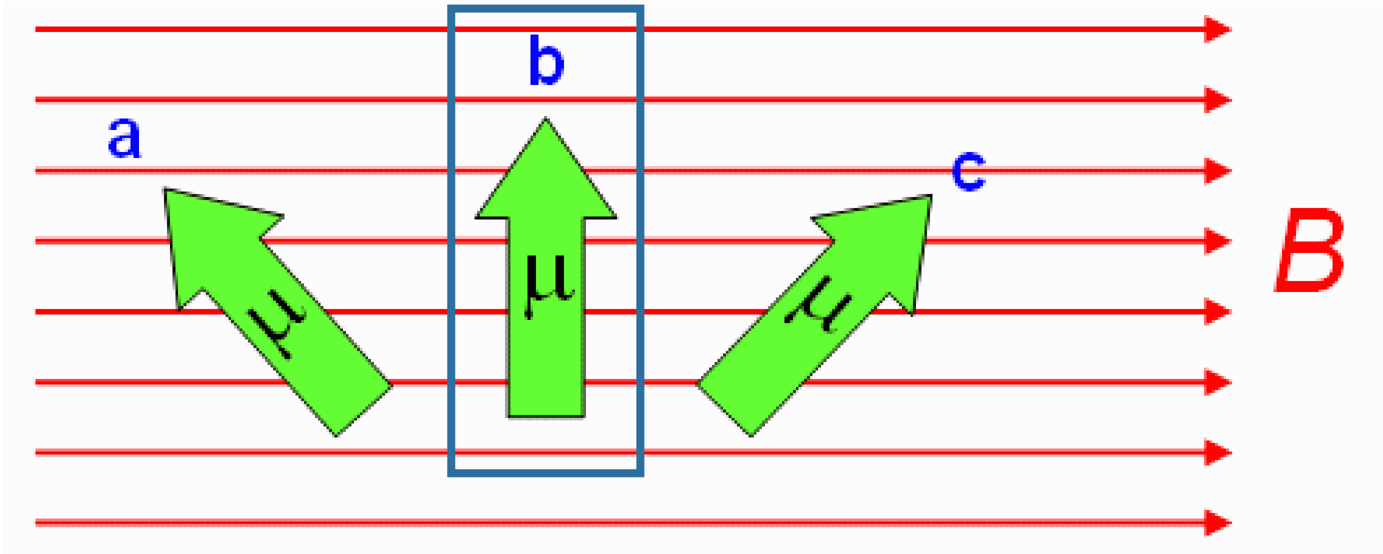
In this case μ is out of the page (using right hand rule)



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

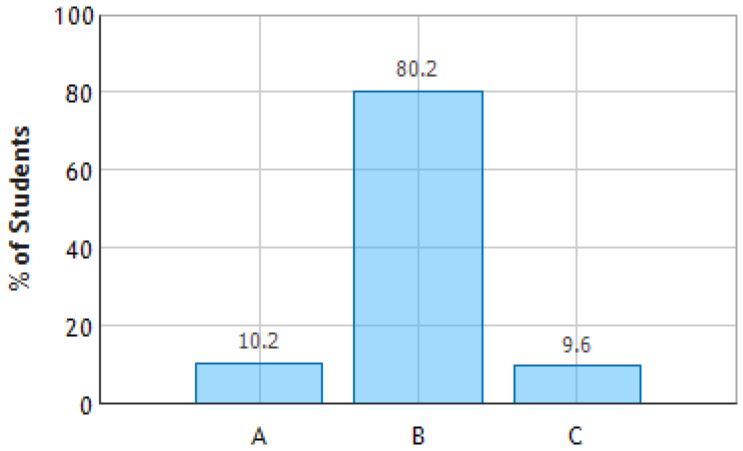
CheckPoint 2a

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 Current

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

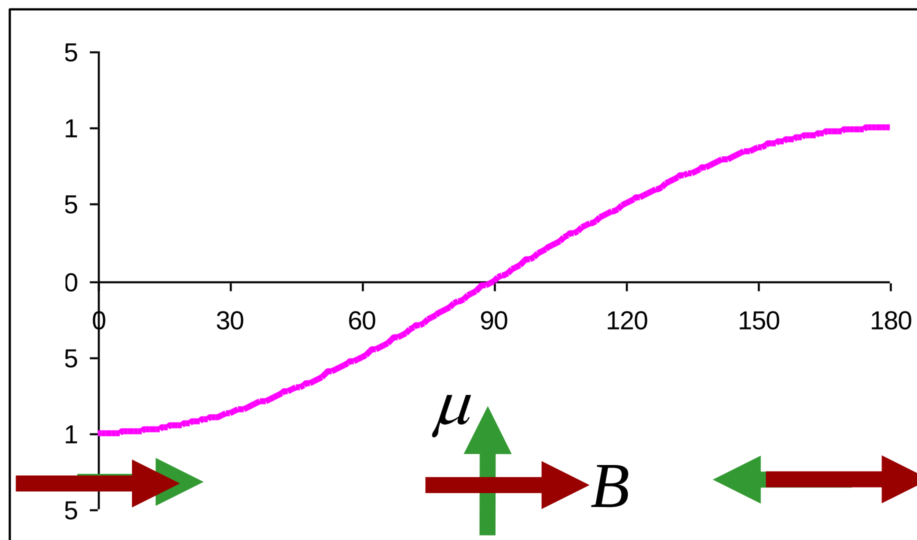
From Physics 212: $\vec{\tau} = \vec{\mu} \times \vec{B} = \mu B \sin(\theta)$

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

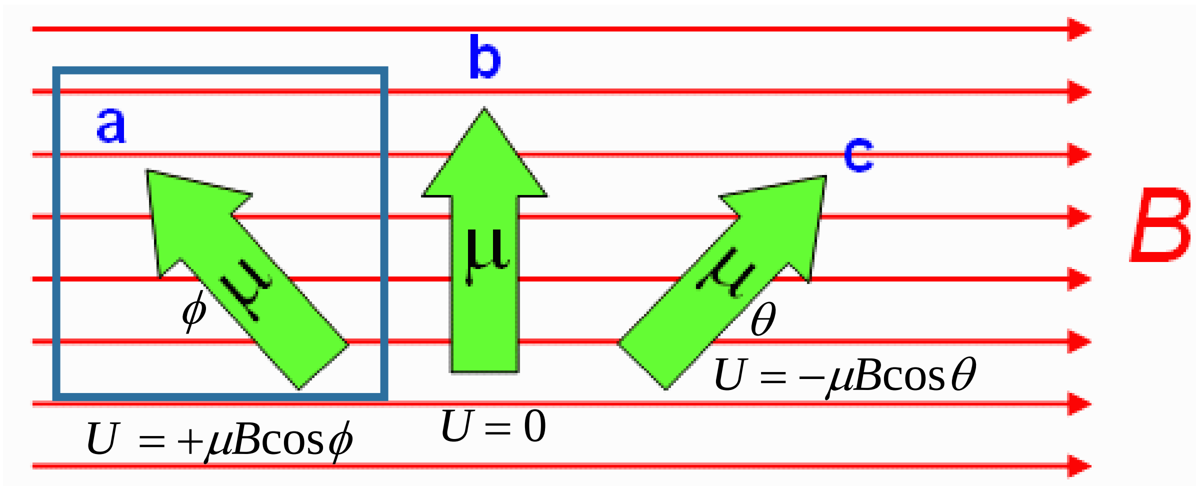
$$\Delta U = -W$$

Define $U = 0$ at position of maximum torque

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

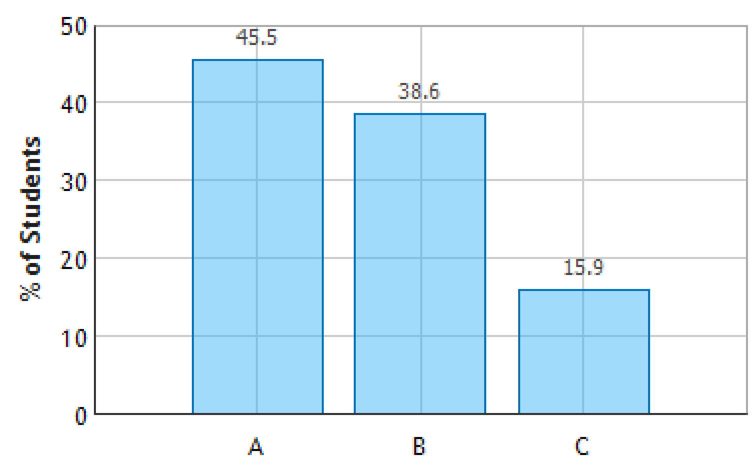


CheckPoint 2b



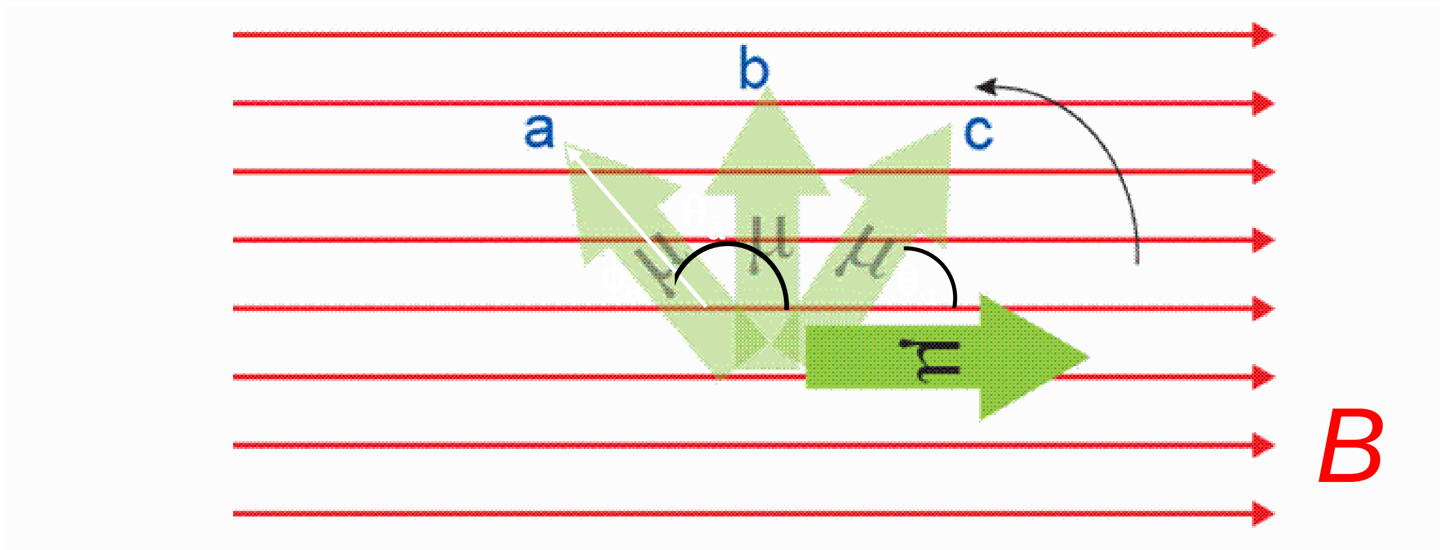
Which orientation has the most potential energy?

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



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) $W_{you} > 0$, $W_{field} < 0$

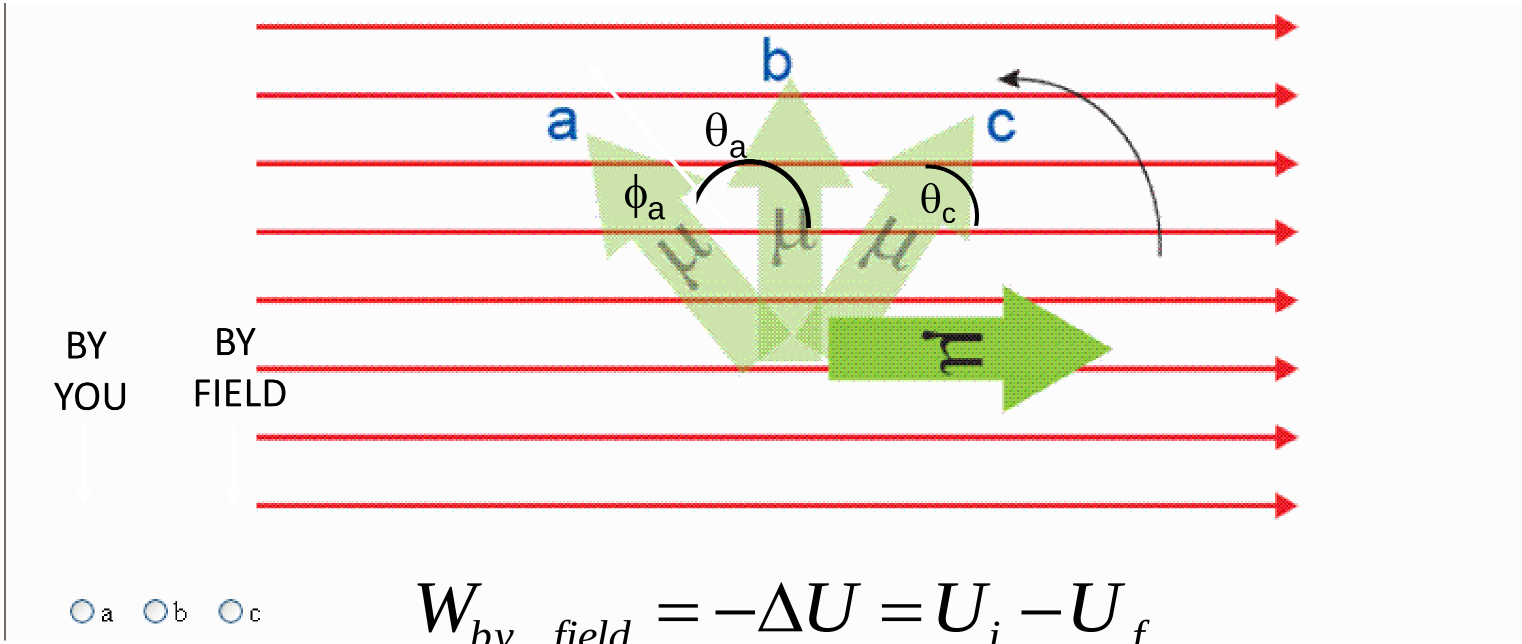
C) $W_{you} < 0$, $W_{field} > 0$

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?



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

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

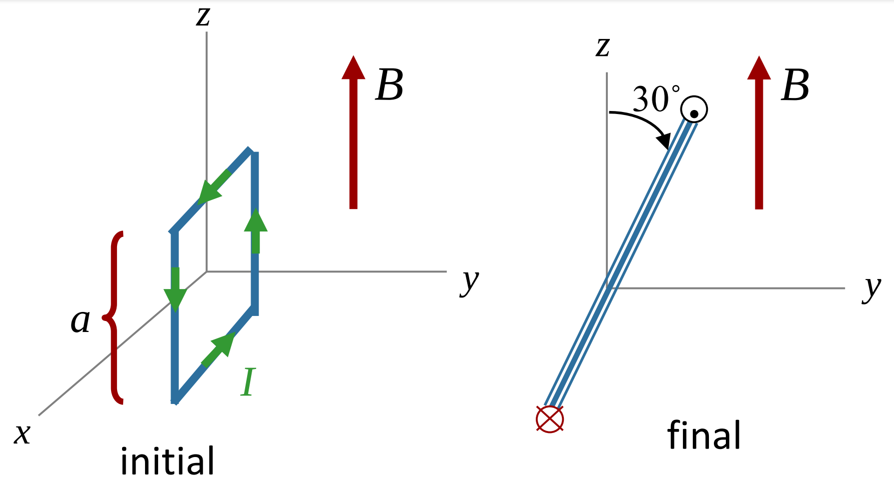
C): $W_{by\_field} = -\mu B - (-\mu B \cos\theta_c) = -\mu B(1 - \cos\theta_c)$

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

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

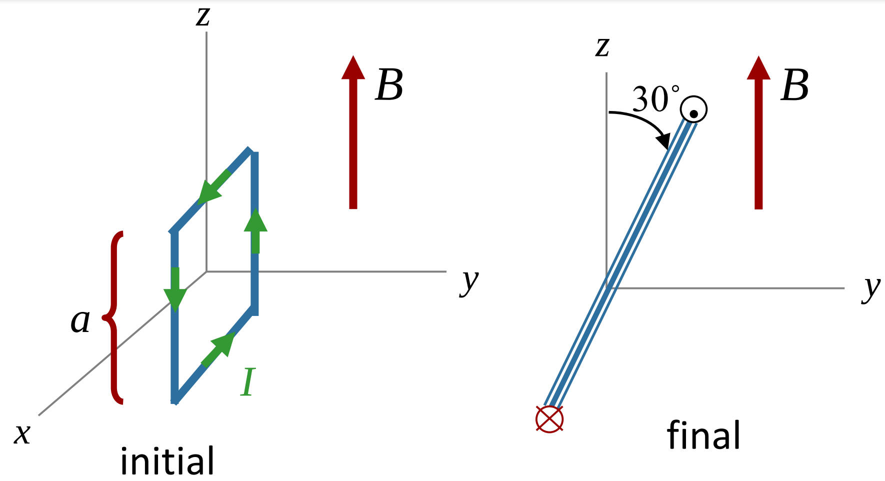
Strategic Analysis

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.



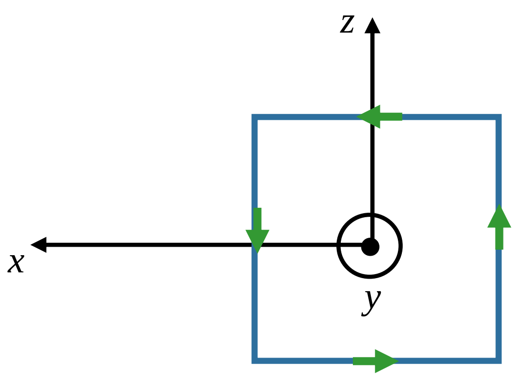
What is the direction of the magnetic moment of this current loop in its initial position?

A) $+x$

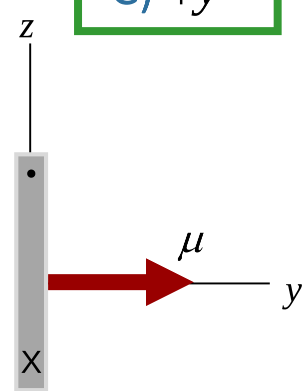
B) $-x$

C) $+y$

D) $-y$



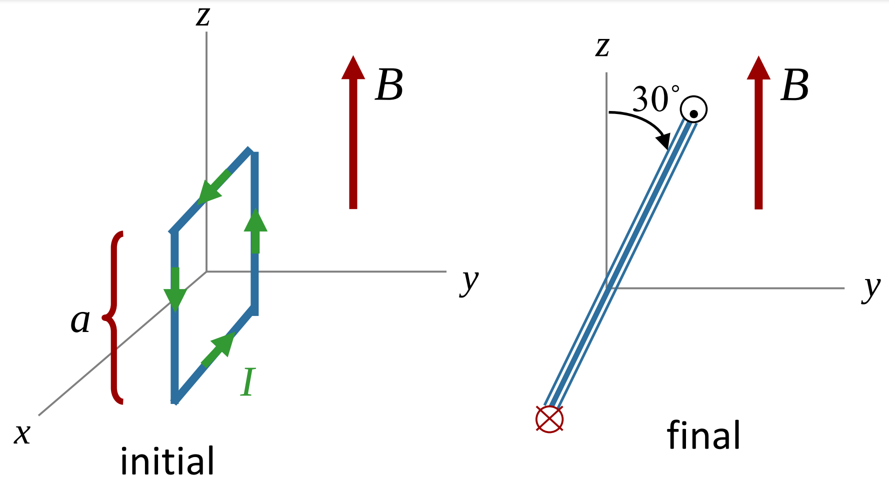
$$\vec{\mu} = L\vec{A}$$



Right Hand Rule

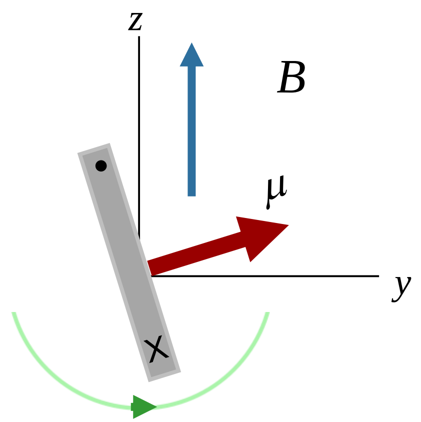
Calculation

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?

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



Calculation

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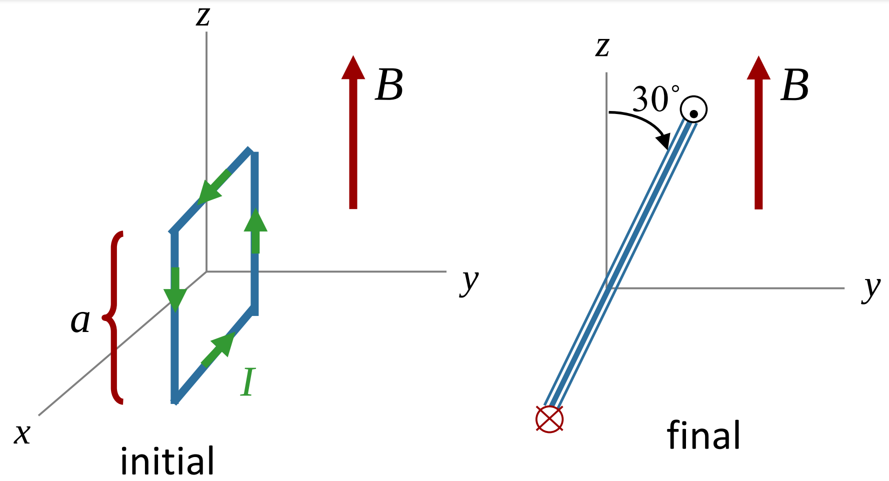


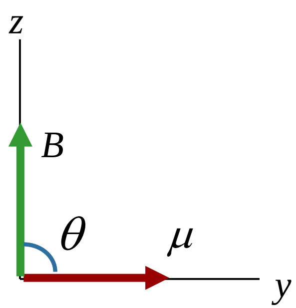
$$U = -\vec{\mu} \cdot \vec{B}$$

What is the potential energy of the initial state?

A) $U_{initial} < 0$

B) $U_{initial} = 0$

C) $U_{initial} > 0$

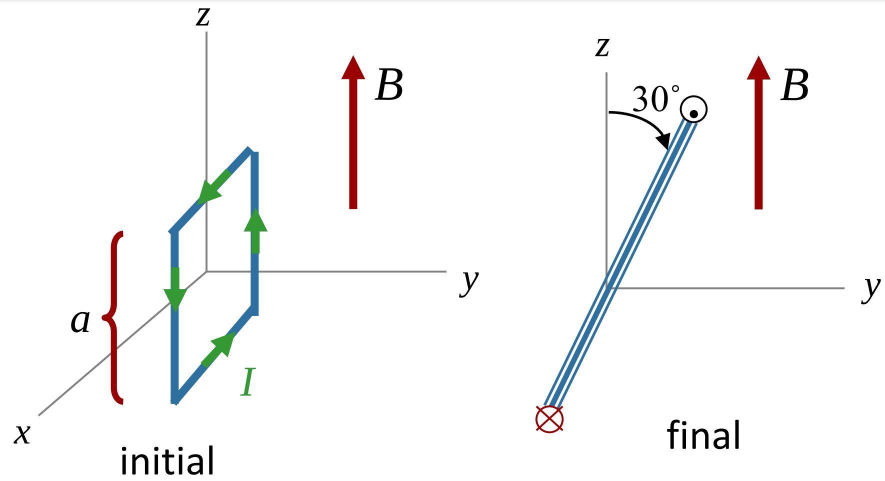


$$\theta = 90^0 \rightarrow \vec{\mu} \bullet \vec{B} = 0$$

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?

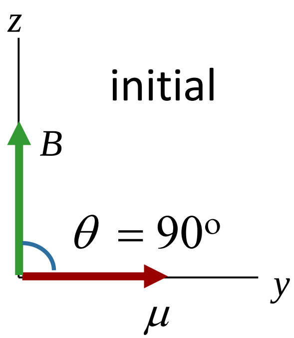
A) $U_{final} < 0$

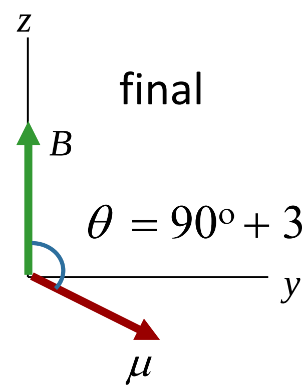
B) $U_{final} = 0$

C) $U_{final} > 0$

Check: μ moves away from B

Energy must increase !





$$\theta = 120^0$$

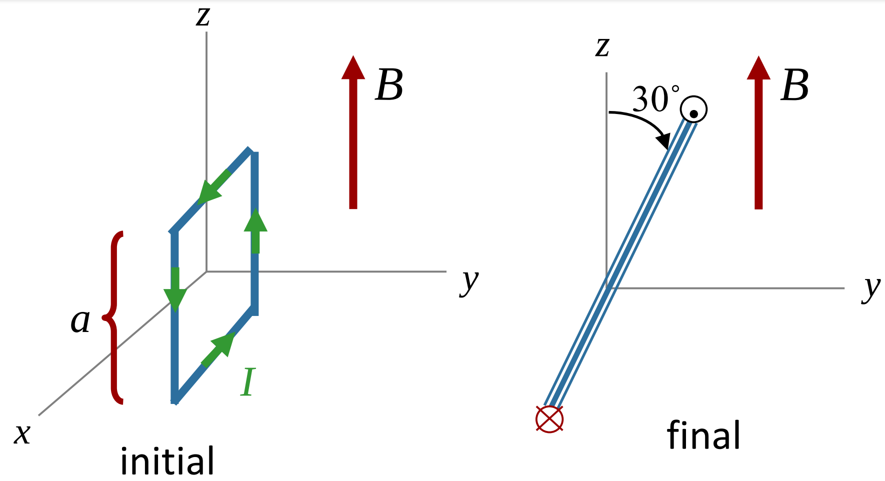
$$\vec{\mu} \bullet \vec{B} < 0$$

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

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.

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

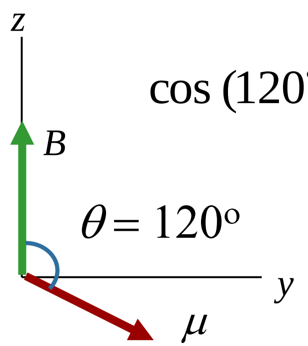


What is the potential energy of the final state?

A) $U = Ia^2B$

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

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



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

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

$$\mu = Ia^2$$

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