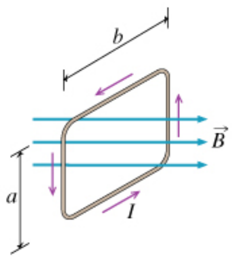
PHYSQ 126, Quiz 6 (19 mars 2015)

Interaction of a Current Loop with a Magnetic Field

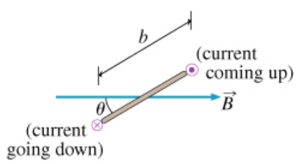
The effects due to the interaction of a current-carrying loop with a magnetic field have many applications, some as common as the electric motor. This problem illustrates the basic principles of this interaction.

Fig 1



View from the side

Fig 2



View from above

Consider a current I that flows in a plane rectangular current loop with height a = 4.00cm and horizontal sides b = 2.00cm . (Figure 1) The loop is placed into a uniform magnetic field $\vec{B}$ in such a way that the sides of length a are perpendicular to $\vec{B}$, and there is an angle θ between the sides of length b and $\vec{B}$, as shown in the figures. (Figure 2)

Part A

Will the interaction of the current through the loop with the magnetic field cause the loop to rotate?

[+] Hints (2)

ANSWER:

- ○ Yes, the net torque acting on the loop is negative and tends to rotate the loop in the direction of decreasing angle θ (clockwise).
- ◉ Yes, the net torque acting on the loop is positive and tends to rotate the loop in the direction of increasing angle θ (counterclockwise).
- ○ No, the net torque acting on the loop is zero and the loop is in equilibrium.
- ○ No, the net force acting on the loop is zero and the loop is in equilibrium.

For parts B and C, the loop is initially positioned at $\theta = 30^\circ$.

Part B

Assume that the current flowing into the loop is 0.500A . If the magnitude of the magnetic field is 0.300T , what is τ, the net torque about the vertical axis of the current loop due to the interaction of the current with the magnetic field?

Express your answer in newton-meters.

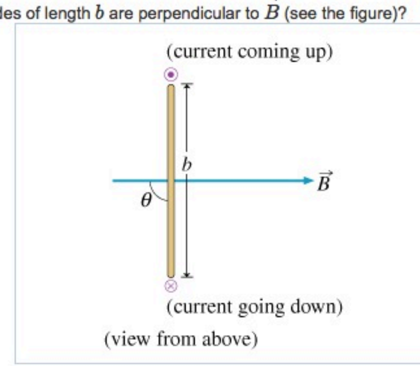
[+] Hints (3)

ANSWER:

$\tau = ab\sin\left(\frac{60\pi}{180}\right) B_0 I_0 = 1.04\times10^{-4}$ $\mathrm{N \cdot m}$

Part C

What happens to the loop when it reaches the position for which $\theta = 90^\circ$, that is, when its horizontal sides of length b are perpendicular to $\vec{B}$ (see the figure)?



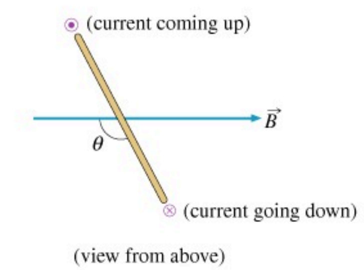
[+] Hints (1)

ANSWER:

- ○ The direction of rotation changes because the net torque acting on the loop causes the loop to rotate in a clockwise direction.
- ◉ The net torque acting on the loop is zero, but the loop continues to rotate in a counterclockwise direction.
- ○ The net torque acting on the loop is zero; therefore it stops rotating.
- ○ The net force acting on the loop is zero, so the loop must be in equilibrium.

Part D

Now suppose that you change the initial angular position of the loop relative to $\vec{B}$, and assume that the loop is placed in such a way that initially the angle between the sides of length b and $\vec{B}$ is $\theta = 120^\circ$, as shown in the figure. Will the interaction of the current through the loop with the magnetic field cause the loop to rotate?



[+] Hints (2)

ANSWER:

- (•) Yes, the net torque acting on the loop is negative and tends to rotate the loop in the direction of decreasing angle θ (clockwise).
- ( ) Yes, the net torque acting on the loop is positive and tends to rotate the loop in the direction of increasing angle θ (counterclockwise).
- ( ) No, the net torque acting on the loop is zero and the loop is in equilibrium.
- ( ) No, the net force acting on the loop is zero and the loop is in equilibrium.

Depending on the initial position of the loop relative to $\vec{B}$, the direction of rotation of the loop will be different. If initially $0^\circ < \theta < 90^\circ$, then the net torque acting on the loop will cause the loop to rotate in the counterclockwise direction. If instead, $90^\circ < \theta < 180^\circ$, then the net torque will rotate the loop in the opposite direction.