Chapter 29

1

Magnetic Fields

1

Lecture 04

2

Torque On A Current Loop

2

Torque on a Current Loop

3

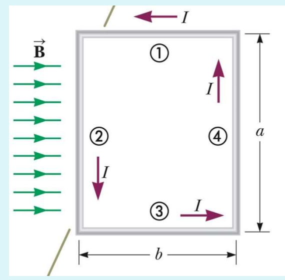
The rectangular loop carries a current I in a uniform magnetic field.

No magnetic force acts on sides 1 & 3.

There is a force on sides 2 & 4 since they are perpendicular to the field.

The direction of F_2 is out of the page.

The direction of F_4 is into the page.

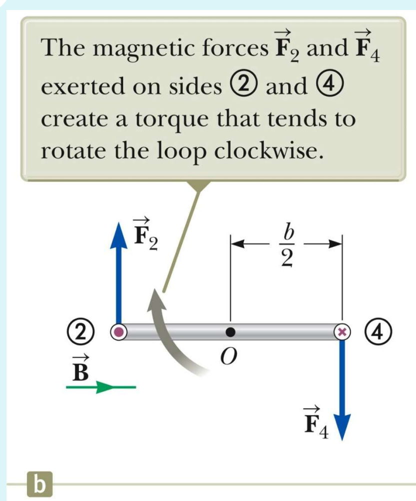


3

Torque on a Current Loop, 3

4

- The forces are equal and in opposite directions, but not along the same line of action.
- The forces produce a torque around point O.



4

Torque on a Current Loop

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- The torque has a maximum value when the field is perpendicular to the normal to the plane of the loop.
- The torque is zero when the field is parallel to the normal to the plane of the loop.

$$\vec{\tau} = I\vec{A} \times \vec{B}$$

  - $\vec{A}$ is perpendicular to the plane of the loop and has a magnitude equal to the area of the loop.

Magnetic Dipole Moment

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- The product $I\vec{A}$ is defined as the magnetic dipole moment, $\vec{\mu}$, of the loop:

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

- SI units: $A.m^2$
- It has the same direction as the normal to the plane of the loop.
- Torque in terms of magnetic moment:

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

Potential Energy

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- The potential energy of the system of a magnetic dipole in a magnetic field depends on the orientation of the dipole in the magnetic field given by

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

  - The minimum potential energy is ($U_{min.} = -\mu B$) and occurs when the dipole moment (the normal to the plane of the loop) is in the same direction as the field.
  - The maximum potential energy is ($U_{max.} = +\mu B$) and occurs when the dipole moment (the normal to the plane of the loop) is in the direction opposite the field.

Mustafa Al-Zyout - Philadelphia University 10/5/2025

7

The Magnetic Dipole Moment of a Coil

Thursday, 4 February, 2021 16:04

Lecturer: Mustafa Al-Zyout, Philadelphia University, Jordan.

R. A. Serway and J. W. Jewett, Jr., *Physics for Scientists and Engineers*, 9th Ed., CENGAGE Learning, 2014.
J. Walker, D. Halliday and R. Resnick, *Fundamentals of Physics*, 10th ed., WILEY,2014.
H. D. Young and R. A. Freedman, *University Physics with Modern Physics*, 14th ed., PEARSON, 2016.
H. A. Radi and J. O. Rasmussen, *Principles of Physics For Scientists and Engineers*, 1st ed., SPRINGER, 2013.

A rectangular coil of dimensions $5.40\ cm\ \times\ 8.50\ cm$ consists of $25\ turns$ of wire and carries a current of $15.0\ mA$. A $0.350 - T$ magnetic field is applied parallel to the plane of the coil.

- Calculate the magnitude of the magnetic dipole moment of the coil.
- What is the magnitude of the torque acting on the loop?

SOLUTION

The magnetic moment of the coil is independent of any magnetic field in which the loop resides, so it depends only on the geometry of the loop and the current it carries.

calculate the magnetic moment:

$$\mu_{coil} = NIA = (25)(15.0 \times 10^{-3}A)(0.0540m)(0.0850m) = 1.72 \times 10^{-3}A \cdot m^2$$

SOLUTION

noting that $\vec{B}$is perpendicular to $\vec{\mu}_{coil}$, the magnitude of the torque:

$$\tau = \mu_{coil}B = (1.72 \times 10^{-3}A \cdot m^2)(0.350T)$$
$$= 6.02 \times 10^{-4}N \cdot m$$

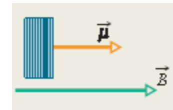
Rotating a magnetic dipole in a magnetic field

Monday, 1 March, 2021 21:51

Lecturer: Mustafa Al-Zyout, Philadelphia University, Jordan.

- [ ] R. A. Serway and J. W. Jewett, Jr., *Physics for Scientists and Engineers*, 9th Ed., CENGAGE Learning, 2014.
- [x] J. Walker, D. Halliday and R. Resnick, *Fundamentals of Physics*, 10th ed., WILEY,2014.
- [ ] H. D. Young and R. A. Freedman, *University Physics with Modern Physics*, 14th ed., PEARSON, 2016.
- [ ] H. A. Radi and J. O. Rasmussen, *Principles of Physics For Scientists and Engineers*, 1st ed., SPRINGER, 2013.

The figure shows a circular coil with $250\ turns$, an area $A = 2.52 \times 10^{-4}\ m^2$, and a current of $100\ \mu A$. The coil is at rest in a uniform magnetic field of magnitude $B = 0.85\ T$, with its magnetic dipole moment $\vec{\mu}$ initially aligned with $\vec{B}$.



- What is the direction of the current in the coil?
- How much work would the torque applied by an external agent have to do on the coil to rotate it 90° from its initial orientation, so that $\vec{\mu}$ is perpendicular to $\vec{B}$ and the coil is again at rest?

Right-hand rule: Imagine cupping the coil with your right hand so that your right thumb is outstretched in the direction of $\vec{\mu}$. The direction in which your fingers curl around the coil is the direction of the current in the coil. Thus, in the wires on the near side of the coil, the current is from top to bottom.

(b) How much work would the torque applied by an external agent have to do on the coil to rotate it 90° from its initial orientation, so that $\vec{\mu}$ is perpendicular to $\vec{B}$ and the coil is again at rest?

The work W_a done by the applied torque would be equal to the change in the coil's orientation energy due to its change in orientation.

From $(W_a = U_f - U_i)$, we find

$$W_a = U(90^\circ) - U(0^\circ)$$
$$= -\mu B \cos 90^\circ - (-\mu B \cos 0^\circ) = 0 + \mu B$$
$$= \mu B.$$

Substituting for μ from $(\mu = NiA)$, we find that

$$W_a = (NiA)B$$
$$= (250)(100 \times 10^{-6} A)(2.25 \times 10^{-4} m^2)(0.85T)$$
$$= 5.355 \times 10^{-6} J \approx 5.4 \mu J.$$