UBC Physics 102

Lecture 11

Rik Blok

Outline

- ▷ Magnetic field
- ▷ Electric currents
- ▷ Force on current
- ▷ Force on a charge
- ▷ Torque on a current loop
- ▷ End

Magnetic field [Text: Sect. 27-1]

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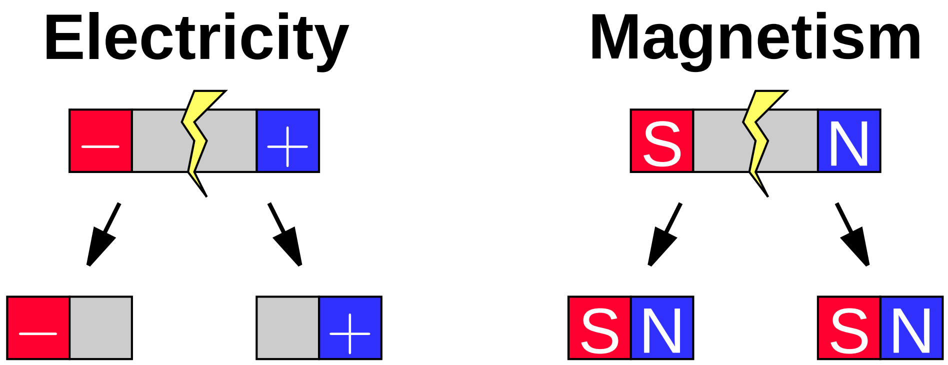

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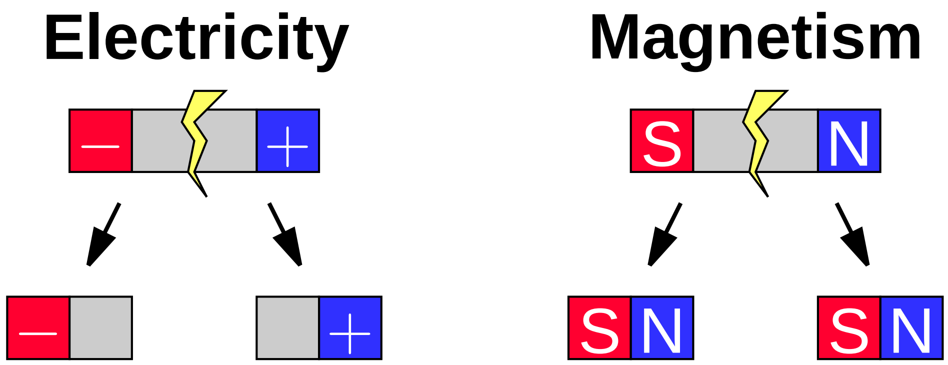

  - Is the main (only?) difference between electricity and magnetism.

Magnetic field, contd

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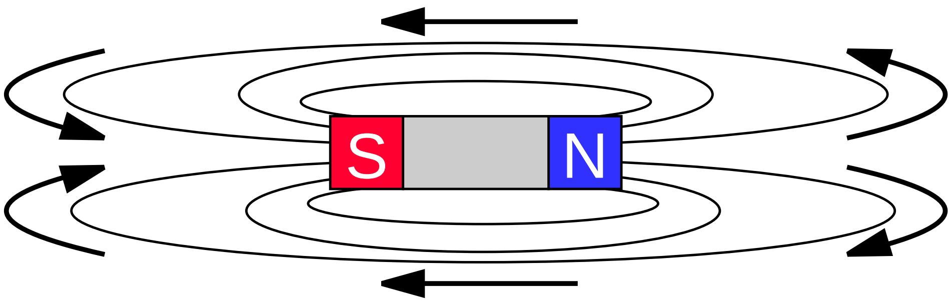

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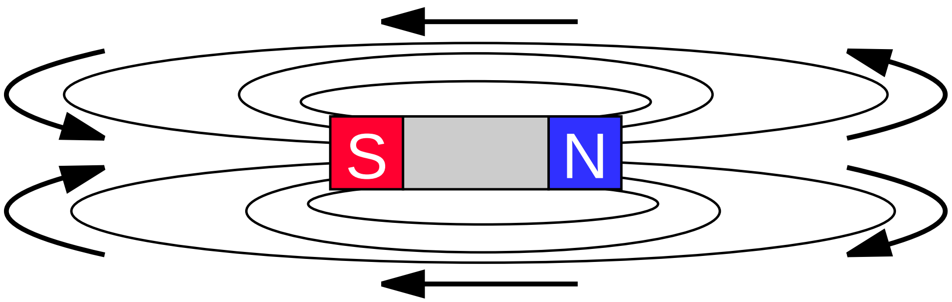

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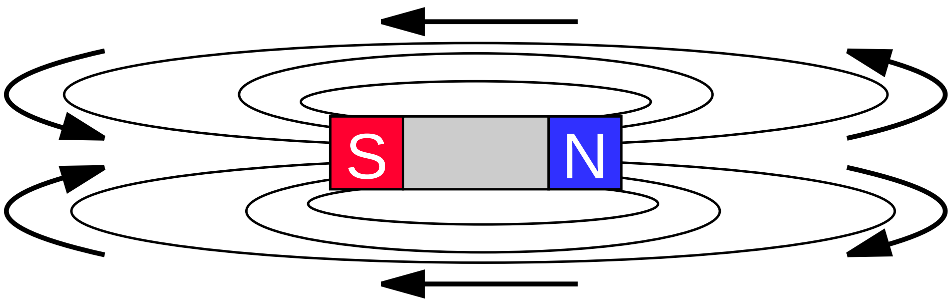

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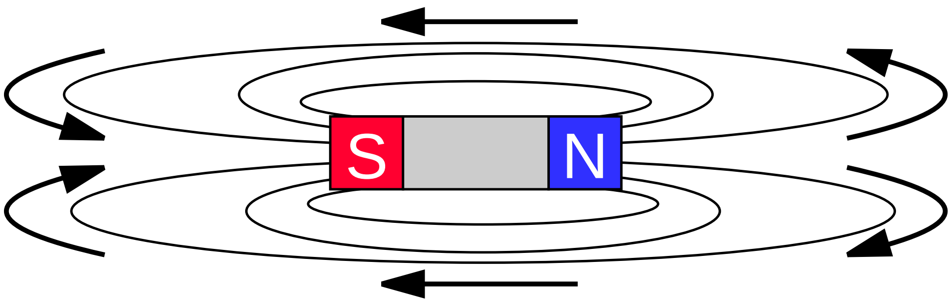

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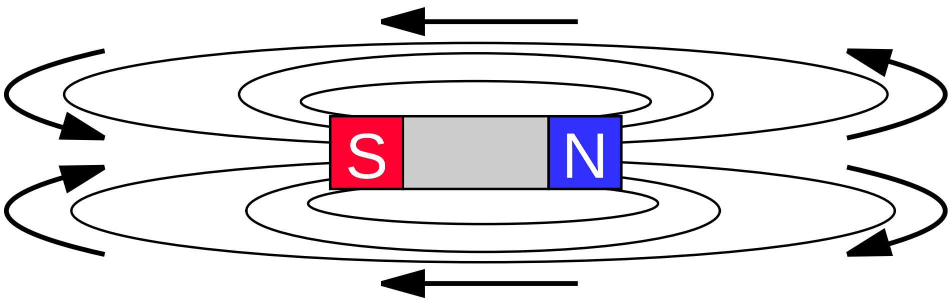

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- **Interactive Quiz: PRS 11a**

Magnetic field, contd

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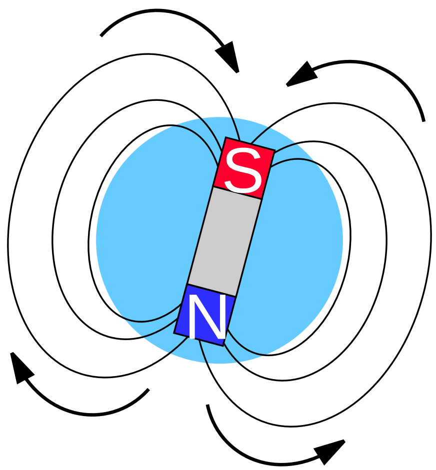

Magnetic field, contd

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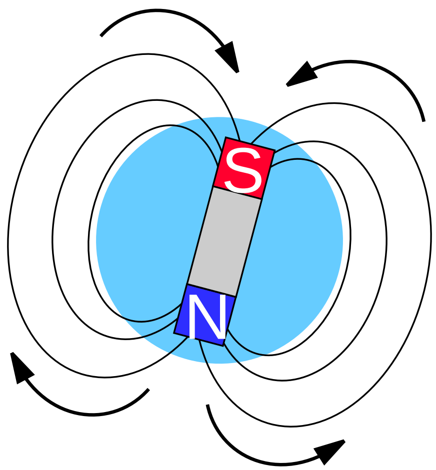

  - Maybe due to currents of ionized molten metal (http://istp.gsfc.nasa.gov/earthmag/dynamos2.htm).

Electric currents [Text: Sect. 27-2]

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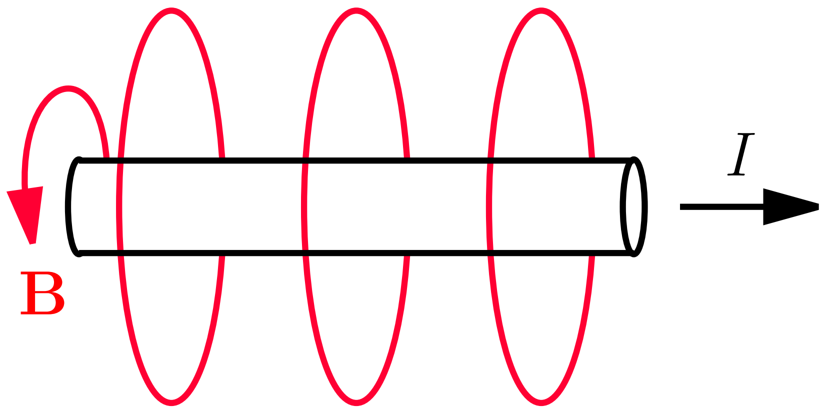
  - Direction of B-field found to be $\perp$ to current.
  - In straight wire field has to circle around wire.
  - But which way?



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- **Definition:** *Right-hand field rule*
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  - Point thumb in direction of current.

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- **Definition:** *Right-hand field rule*
  - “Grasp” wire in **right** hand.
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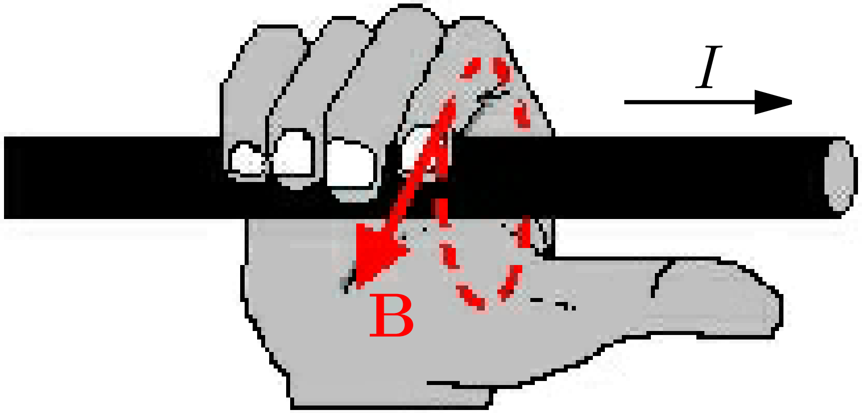
  - Then fingers wrap around in direction of field.



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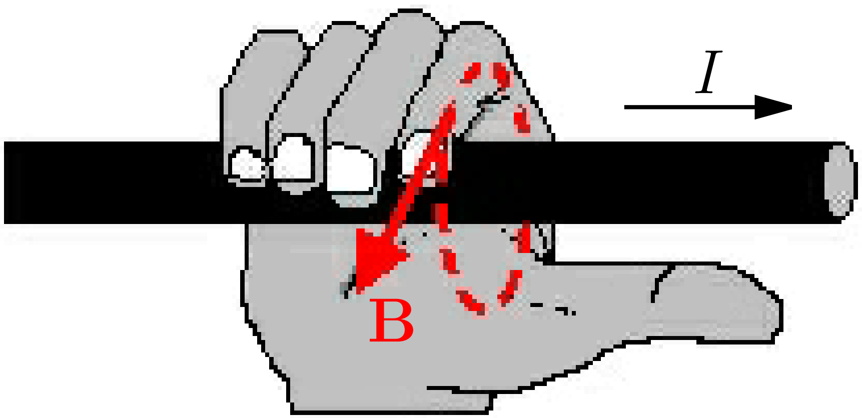

- **Interactive Quiz: PRS 11b**

Force on current [Text: Sect. 27-3]

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  - Force $\perp$ to both current and B-field.
  - But that still leaves 2 possible directions...

Force on current, contd

- **Definition:** *Right-hand force rule*

Force on current, contd

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  - Point index finger of **right** hand in direction of current, I.

Force on current, contd

- **Definition:** *Right-hand force rule*
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  - Bend middle finger to direction of B-field.

Force on current, contd

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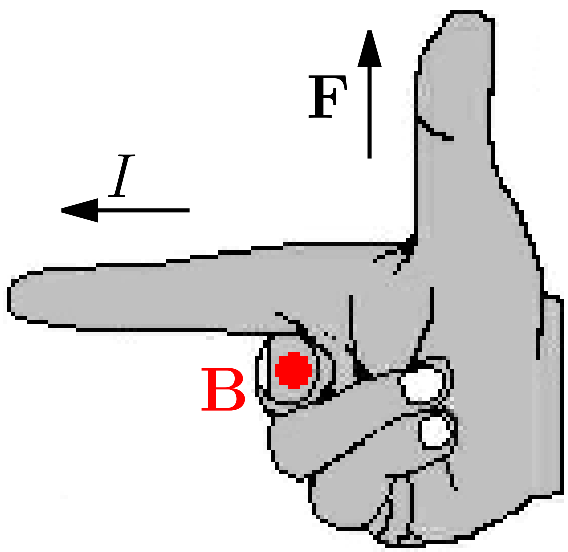
  - Then thumb points in direction of force, $\mathbf{F}$.



Force on current, contd

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  - $\odot =$ arrow coming **out** of page (looking at it head-on).

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- **Interactive Quiz: PRS 11c**

Force on current, contd

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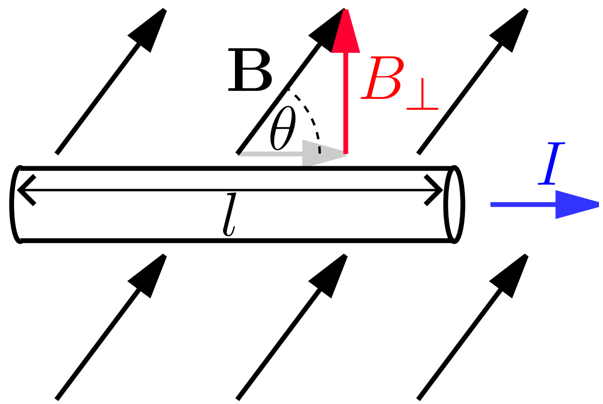

Force on current, contd

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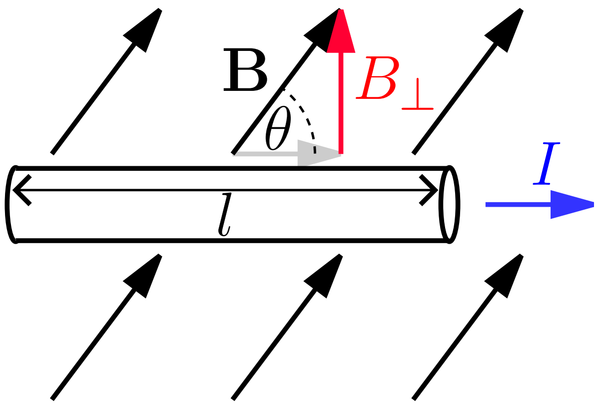

  - B-field defined by force it exerts on current,

$$\boxed{F = IlB_\perp.}$$

Force on current, contd

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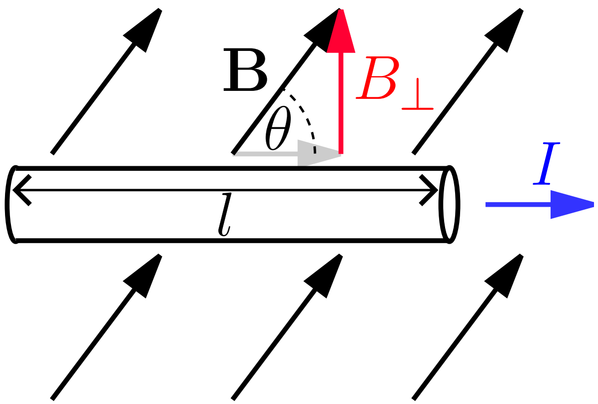

- B-field defined by force it exerts on current,

$$F = IlB_\perp.$$

- $B_\perp = B\sin\theta$ is component of $\mathbf{B}$ perpendicular to I.

Force on current, contd

- **Unit: Tesla, T, and Gauss, G**

Force on current, contd

- **Unit: Tesla, T, and Gauss, G**
  - Units of magnetic field strength.

$$\boxed{\begin{aligned} 1\,\mathrm{T} &= 1\,\mathrm{N/A\cdot m}, \\ 1\,\mathrm{G} &= 10^{-4}\,\mathrm{T}. \end{aligned}}$$

Force on a charge [Text: Sect. 27-4]

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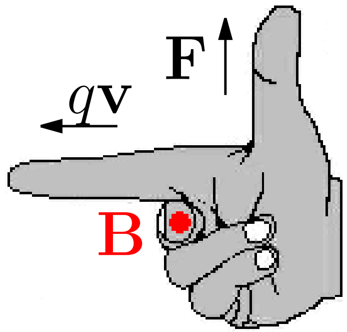
$$F = qvB_{\perp}.$$

  - Direction again given by right-hand force rule, by substituting $I \rightarrow q\mathbf{v}$.



Force on a charge, contd

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  - Note: index finger along $q\mathbf{v}$ so if $q < 0$ then finger points *against* direction of velocity, $\mathbf{v}$.

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- **Interactive Quiz: PRS 11d**

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- **Interactive Quiz: PRS 11d**
- **Example: Path in a uniform magnetic field**

Force on a charge, contd

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  - Describe the path of a charged particle, q, moving at speed v in a magnetic field perpendicular to a magnetic field $\mathbf{B}$.

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- **Solution: Path in a uniform magnetic field**

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- **Example: Path in a uniform magnetic field**
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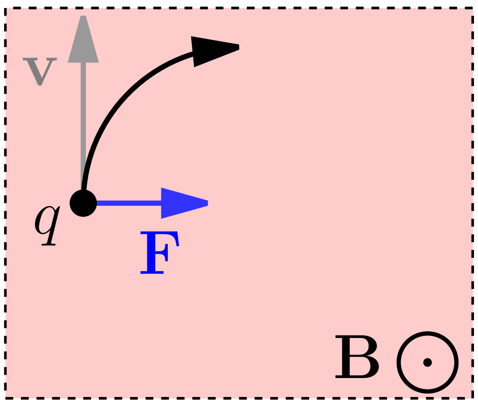
- **Solution: Path in a uniform magnetic field**
  - If the particle's velocity is $\perp$ to $\mathbf{B}$ then the force is $F = qvB$ and $\perp$ to both $\mathbf{v}$ and $\mathbf{B}$.

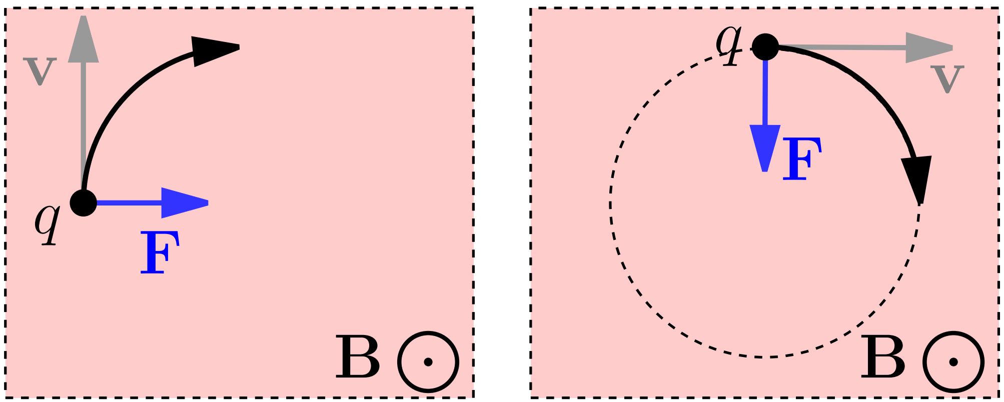
Force on a charge, contd

- **Solution: Path in a uniform magnetic field, contd**
  - This will cause the particle to accelerate sideways from its original path.



Force on a charge, contd

- **Solution: Path in a uniform magnetic field, contd**
  - This will cause the particle to accelerate sideways from its original path.
  - But B is still $\perp$ to $\mathbf{v}$ so will accelerate sideways relative to new path.



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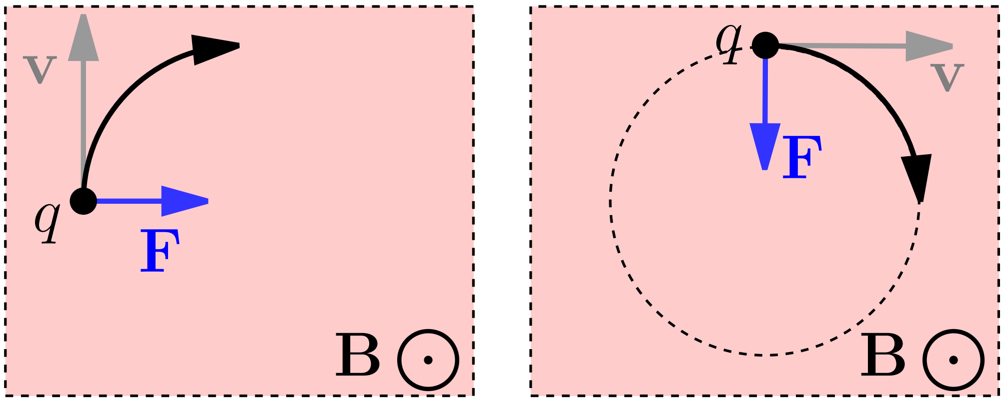

  - Particle feels constant force, always pulling to the side.

Force on a charge, contd

- **Solution: Path in a uniform magnetic field, contd**

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  - Motion is a circle. Recall, acceleration towards the center of a circle is $a = \frac{v^2}{r}$.

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  - Motion is a circle. Recall, acceleration towards the center of a circle is $a = \frac{v^2}{r}$.
  - From $F = ma$ can find radius of circle,

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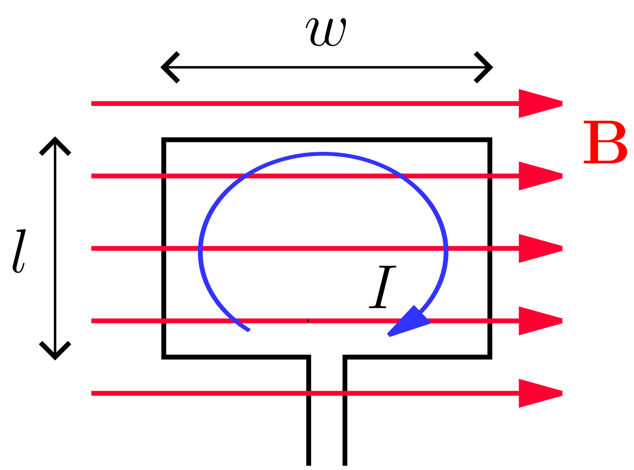
  - So motion is a circle with radius r. □

Torque on a current loop [Text: Sect. 27-5]

- **Discussion: Current loop in B-field**



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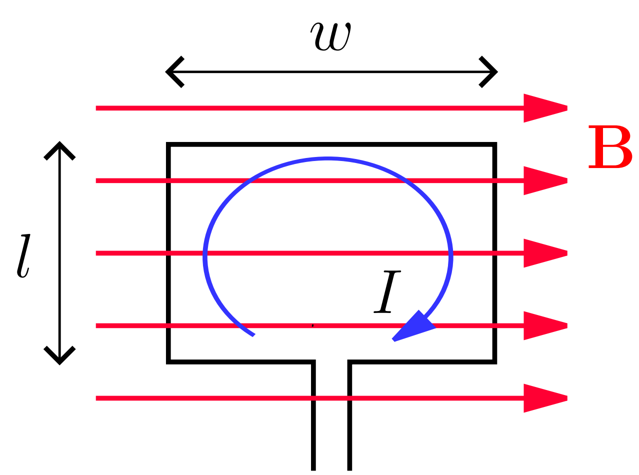
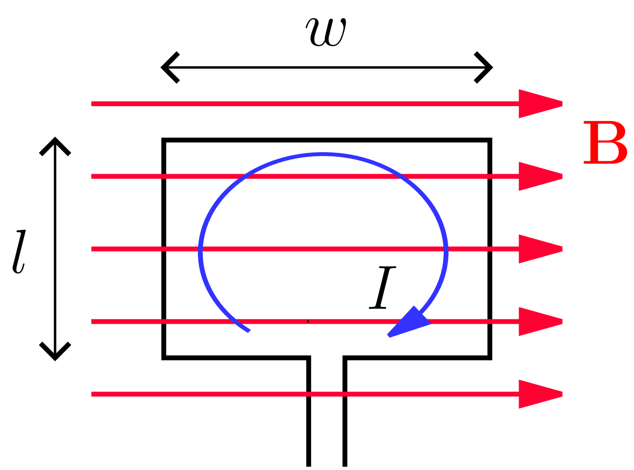


  - Force $F = IlB$ into page on left side and out of page on right.

Torque on a current loop [Text: Sect. 27-5]

- **Discussion: Current loop in B-field**



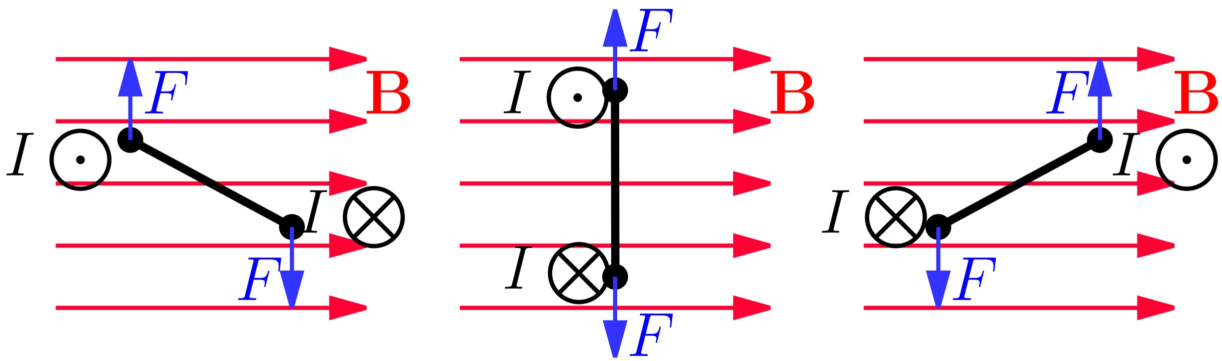
- Force $F = IlB$ into page on left side and out of page on right.
- Causes loop to turn around center axis (torque or "angular force," see Ch. 10).

Torque on a current loop, contd

- **Discussion: Electric motors**

Torque on a current loop, contd

- **Discussion: Electric motors**
  - Looking at loop from top-down:



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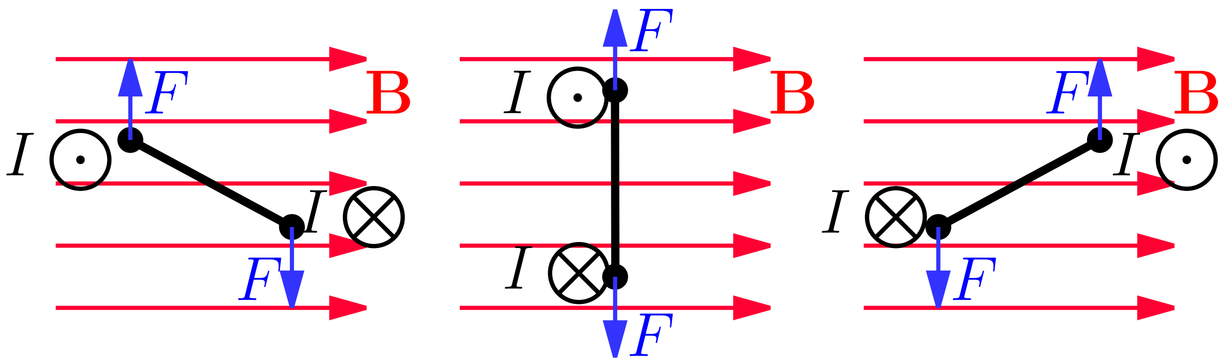

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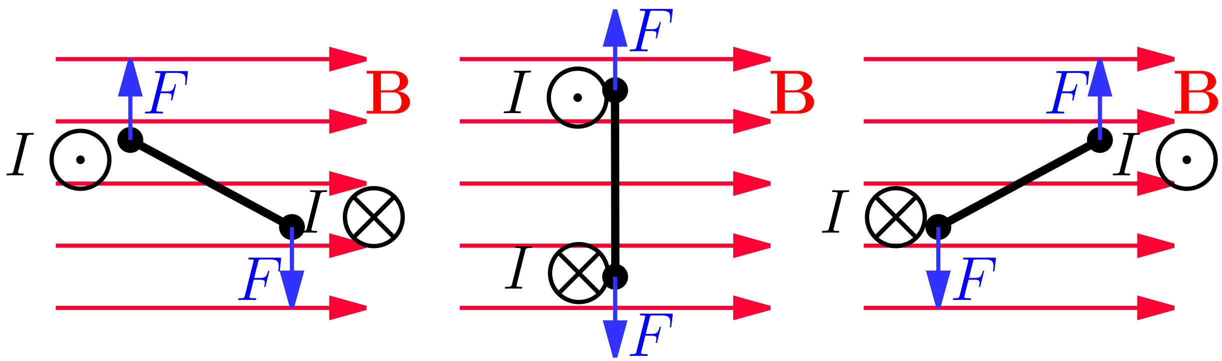
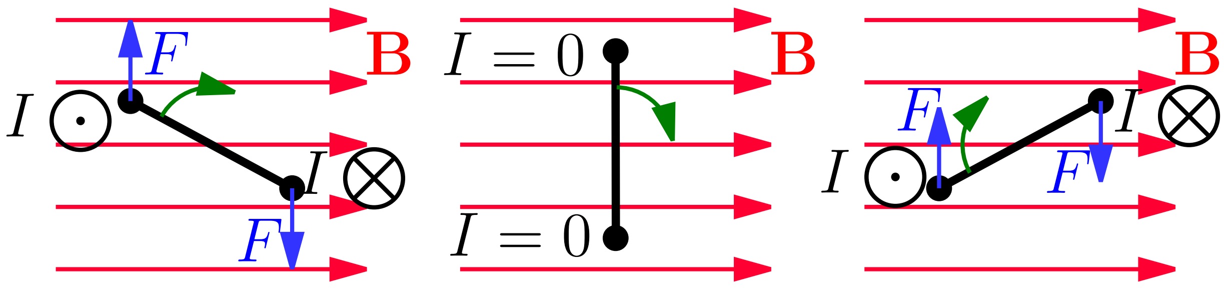


  - So loop won't keep rotating.
  - But if we reverse direction of current when at middle:



Torque on a current loop, contd

- **Discussion: Electric motors, contd**

Torque on a current loop, contd

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  - Causes loop to spin, which can do work.

Torque on a current loop, contd

- **Discussion: Electric motors, contd**
  - Causes loop to spin, which can do work.
  - Basic principle of electric motors.

End

- **Practice Problems:**
  - Ch. 27: Q. 1, 3, 5, 7, 9, 11, 15, 17, 19, 21, 23, 25.
  - Ch. 27: Pr. 1, 3, 5, 7, 9, 13, 15, 21, 23, 25, 31, 35, 51, 55, 57, 61, 63, 65, 67.

End

- **Practice Problems:**
  - Ch. 27: Q. 1, 3, 5, 7, 9, 11, 15, 17, 19, 21, 23, 25.
  - Ch. 27: Pr. 1, 3, 5, 7, 9, 13, 15, 21, 23, 25, 31, 35, 51, 55, 57, 61, 63, 65, 67.
- **Interactive Quiz: Feedback**

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  - Ch. 27: Q. 1, 3, 5, 7, 9, 11, 15, 17, 19, 21, 23, 25.
  - Ch. 27: Pr. 1, 3, 5, 7, 9, 13, 15, 21, 23, 25, 31, 35, 51, 55, 57, 61, 63, 65, 67.
- **Interactive Quiz: Feedback**
- **Tutorial Question: tut11**