UBC Physics 102

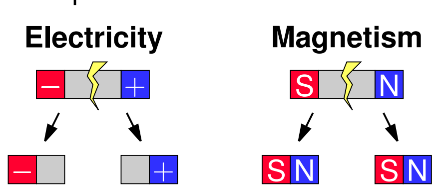
Lecture 11

Rik Blok

Outline

Magnetic field [Text: Sect. 27-1]

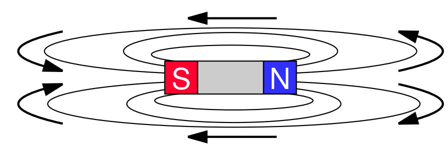
- **Definition:** *dipole*
  - Object with two opposite ends.
  - Magnetic "charges" always come as dipoles.
  - Ends are called **North** (+) and **South** (−).
  - Unlike electricity, magnetic dipoles cannot be separated into poles.



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

Magnetic field, contd

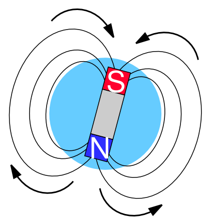
- **Discussion: Magnetic field, $\mathbf{B}$**
  - Analogous to electric field. Denoted by $\mathbf{B}$.
  - Comes out of N end of magnet, goes into S.



  - Magnetic field creates force on nearby magnets.
  - Like poles repel, opposites attract.
  - N end of compass (magnet) points along direction of magnetic field (N to S).
- **Interactive Quiz: PRS 11a**

Magnetic field, contd

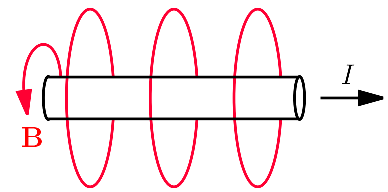
- **Discussion: The earth as a magnet**
  - Compasses point north so earth has magnetic field.
  - But compasses point from N to S!
  - Because earth's "north" pole is really magnetic S.



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

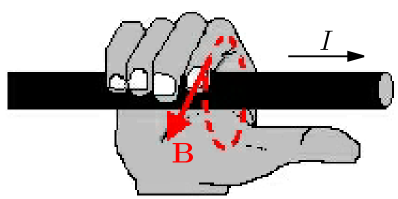
Electric currents [Text: Sect. 27-2]

- **Discussion: Electric currents**
  - Moving charges produce magnetic field.
  - Current (moving charges in wire) does too.
  - Direction of B-field found to be $\perp$ to current.
  - In straight wire field has to circle around wire.
  - But which way?



Electric currents, contd

- **Definition:** *Right-hand field rule*
  - "Grasp" wire in **right** hand.
  - Point thumb in direction of current.
  - Then fingers wrap around in direction of field.



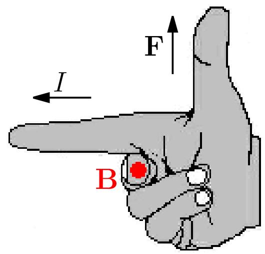
- **Interactive Quiz: PRS 11b**

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

- **Discussion: Force on current**
  - Current exerts force on magnet (eg. turns compass to line up with B-field).
  - Opposite holds too: magnet exerts force on current-carrying wire.
  - Force $\perp$ to both current and B-field.
  - But that still leaves 2 possible directions. . .

Force on current, contd

- **Definition:** *Right-hand force rule*
  - Point index finger of **right** hand in direction of current, I.
  - Bend middle finger to direction of B-field.
  - Then thumb points in direction of force, $\mathbf{F}$.

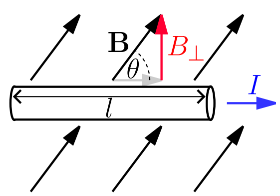


Force on current, contd

- **Discussion: 3d convention**
  - Dealing with 3 $\perp$ directions, 3-dimensions.
  - Convention for drawing 3d arrows on paper.
  - $\odot$ = arrow coming **out** of page (looking at it head-on).
  - $\otimes$ = arrow going **into** page (looking at the tail).
- **Interactive Quiz: PRS 11c**

Force on current, contd

- **Definition:** *Magnetic field,* $\mathbf{B}$



  - 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**
  - Units of magnetic field strength.

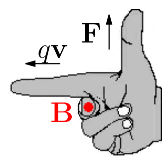
$$\begin{aligned} 1\,\mathrm{T} &= 1\,\mathrm{N/A\cdot m}, \\ 1\,\mathrm{G} &= 10^{-4}\,\mathrm{T}. \end{aligned}$$

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

- **Discussion: Force on a charge**
  - Current-carrying wire contains charges q moving at speed v.
  - Can work out that force on each charge must be

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

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

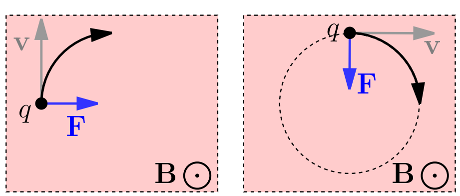


Force on a charge, contd

- **Discussion: Force on a charge, contd**
  - Note: index finger along $q\mathbf{v}$ so if $q < 0$ then finger points *against* direction of velocity, $\mathbf{v}$.
- **Interactive Quiz: PRS 11d**
- **Example: Path in a uniform magnetic field**
  - Describe the path of a charged particle, q, moving at speed v in a magnetic field perpendicular to a magnetic field $\mathbf{B}$.
- **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.
  - But $\mathbf{B}$ is still $\perp$ to $\mathbf{v}$ so will accelerate sideways relative to new path.



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

Force on a charge, contd

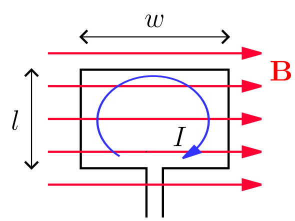
- **Solution: Path in a uniform magnetic field, contd**
  - Motion is a circle. Recall, acceleration towards the center of a circle is $a = \frac{v^2}{r}$.
  - From $F = ma$ can find radius of circle,

$$\begin{aligned} F &= ma \\ qvB &= m\frac{v^2}{r} \\ r &= \frac{mv}{qB}. \end{aligned}$$

  - So motion is a circle with radius r. □

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

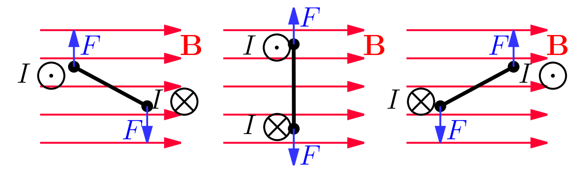
- **Discussion: Current loop in B-field**



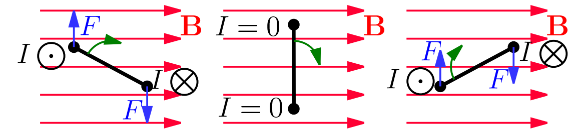
  - Force $F = IlB$ into page on left side and out of page on right.
  - Causes loop to turn around center axis (torque or "angular force," see Ch. 10).

Torque on a current loop, contd

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



  - 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**
  - 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.
- **Interactive Quiz: Feedback**
- **Tutorial Question: tut11**