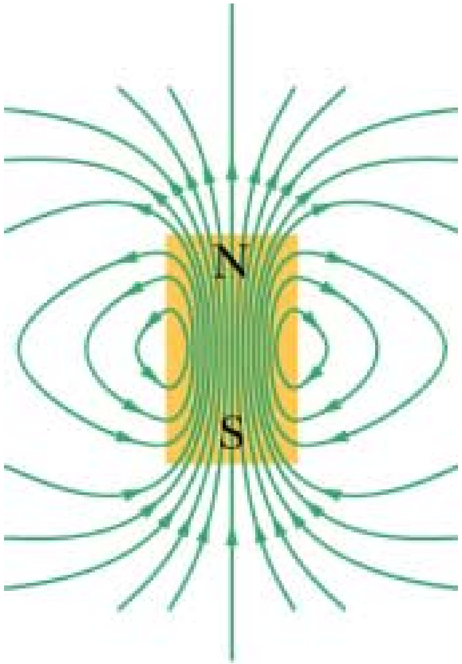
October 2nd/3rd

Magnetic Fields - Chapter 29

Magnetic Fields (Fig. 29-4a)

- Analogous to electric field, a magnet produces a magnetic field, *B*

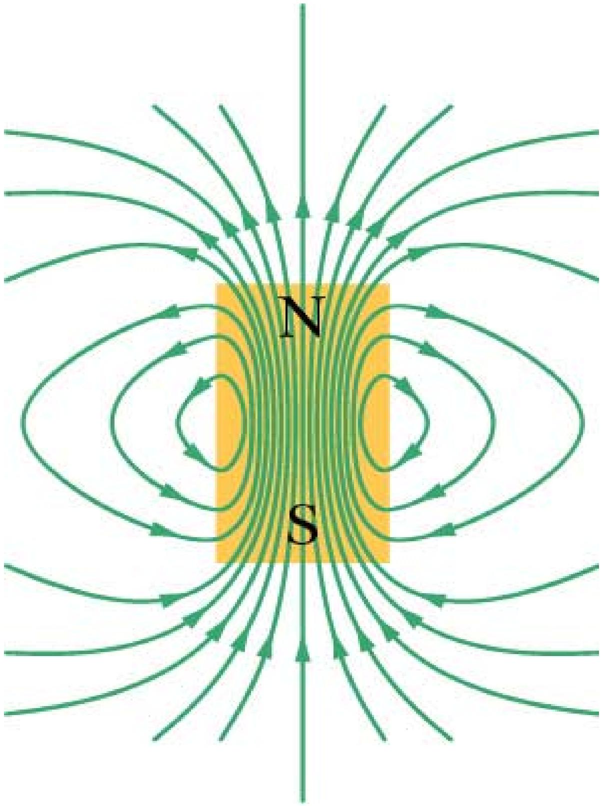
- Set up a *B* field two ways:
- Moving electrically charged particles
  - Current in a wire
- Intrinsic magnetic field
  - Basic characteristic of elementary particles such as an electron



(*a*)

Magnetic Fields (Fig. 29-4)

- Magnetic field lines
- Direction of tangent to field line gives direction of *B* at that point
- Denser the lines the stronger the *B* field

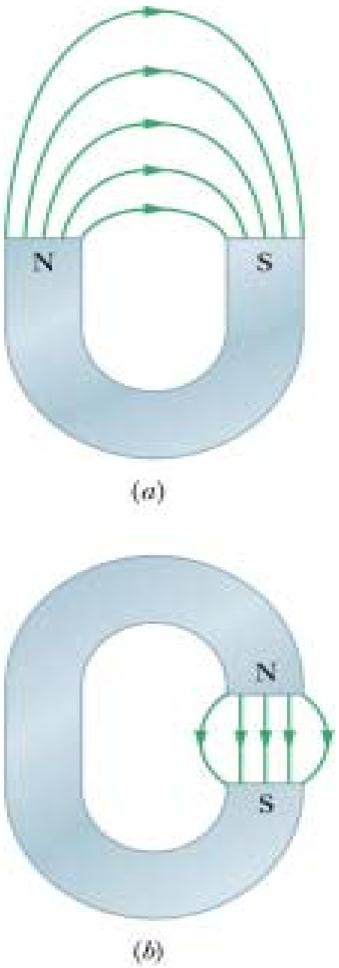


(*a*)

Magnetic Fields (Fig. 29-5)

- Magnetic field lines enter one end (south) of magnet and exit the other end (north)

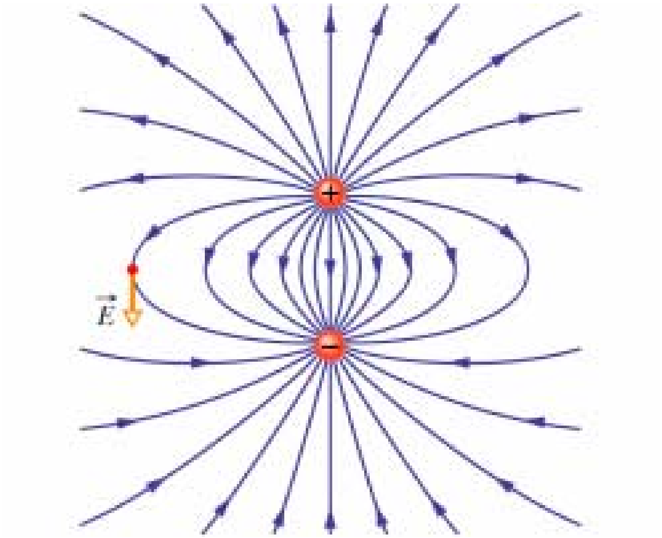
- Opposite magnetic poles attract
- like magnetic poles repel

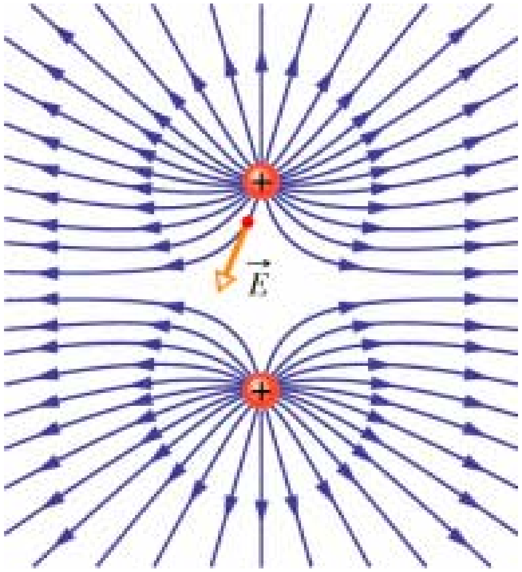


(a)

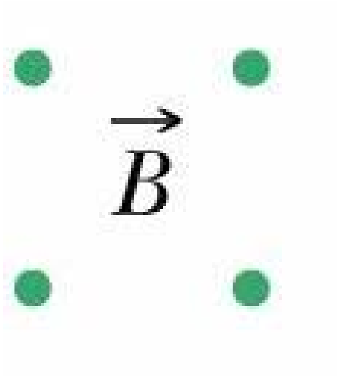
(b)

Like the electric field lines, but there are no “magnetic charges”

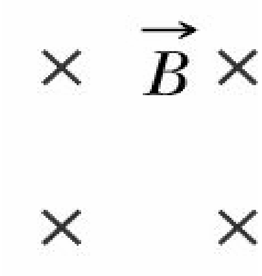




Magnetic fields



This shows the tips of magnetic field vector lines (green) pointed out of the screen (towards you).

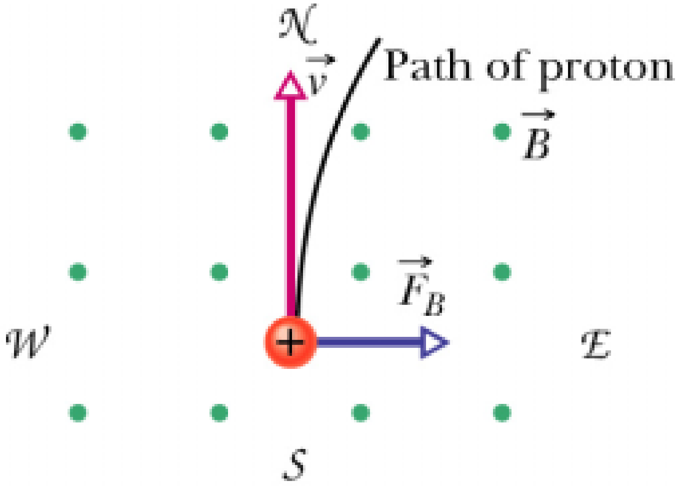


This shows the tails of magnetic field vector lines (black) pointed into the screen (away from you).

Magnetic Fields (Fig. 29-6)

- When charged particle moves through *B* field, a force acts on the particle

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



- Magnitude of F_B is

$$F_B = |q| vB \sin\phi$$

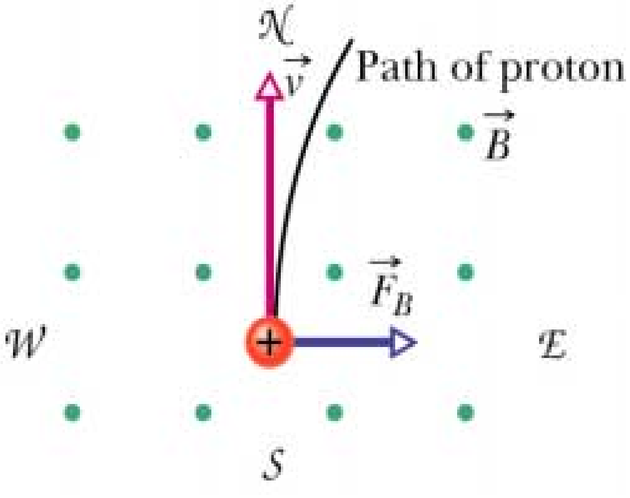
- where ϕ is the angle between *v* and *B*

- SI unit for *B* is tesla, T

$$1T = 1\frac{N}{C \cdot m/s} = 1\frac{N}{A \cdot m}$$

Magnetic Fields (Fig. 29-6)

$$\vec{F}_B = q\vec{v} \times \vec{B} = qvB\sin\phi$$

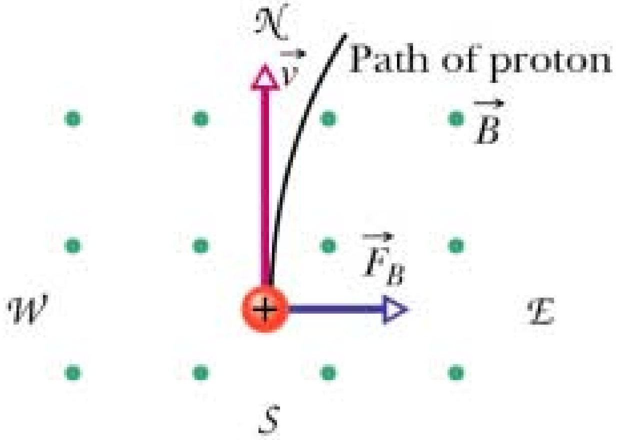


- F_B = 0 if
  - Charge, q = 0
  - Particle is stationary
  - v and B are parallel (ϕ=0) or anti-parallel (ϕ=180)

- F_B is maximum if
  - v and B are ⊥ to each other

Magnetic Fields (Fig. 29-6)

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



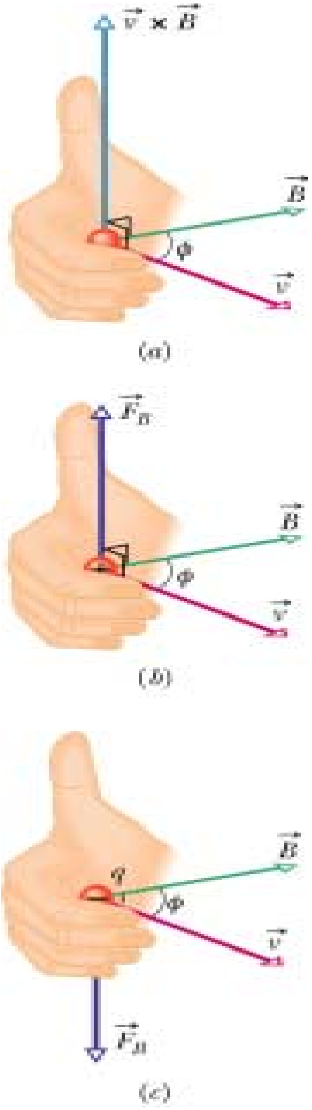
- F_B acting on charged particle is always ⊥ to v and B

- F_B never has component || to v
- F_B cannot change v or K.E. of particle
- F_B can only change direction of v

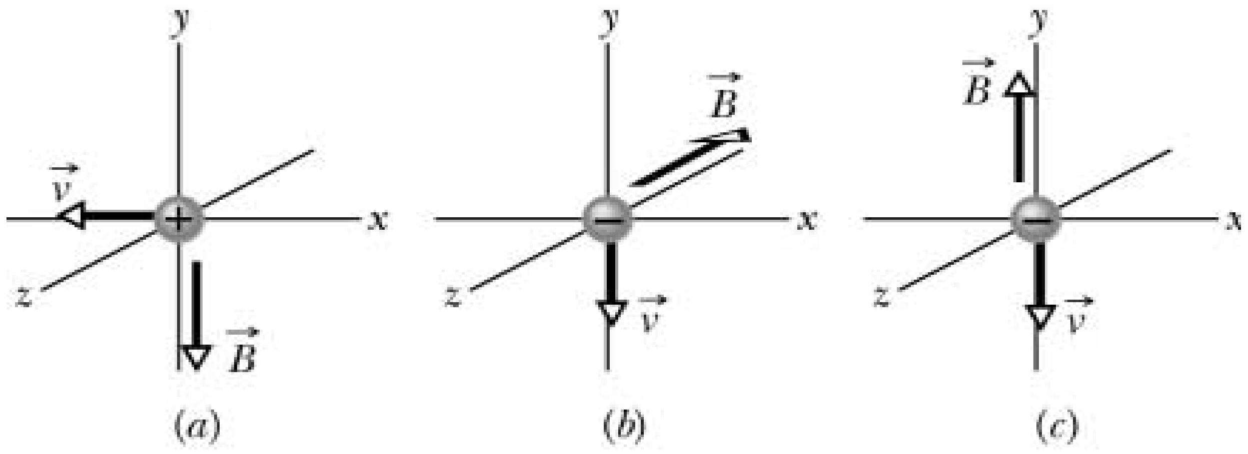
Magnetic Fields (Fig. 29-2)

- Right-hand rule – For positive charges - when the fingers sweep v into B through the smaller angle ϕ the thumb will be pointing in the direction of F_B

- For negative charges F_B points in opposite direction



Checkpoint #1



- What is the direction of F_B on the particle with the v and B shown?
- Use right-hand rule - don’t forget charge

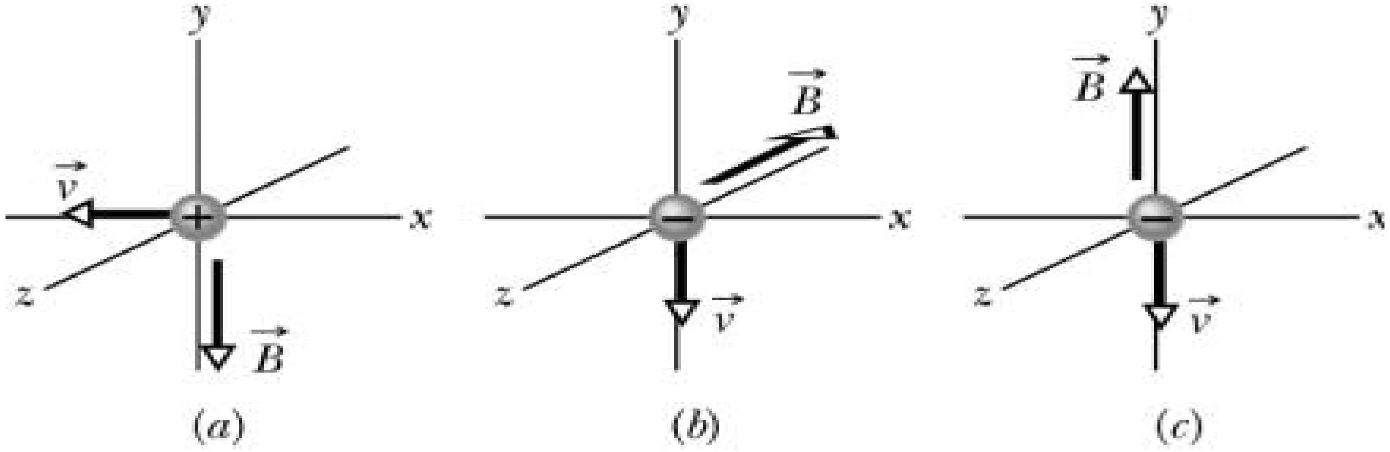
A) +z

B) -x

C) zero

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

Magnetic Fields



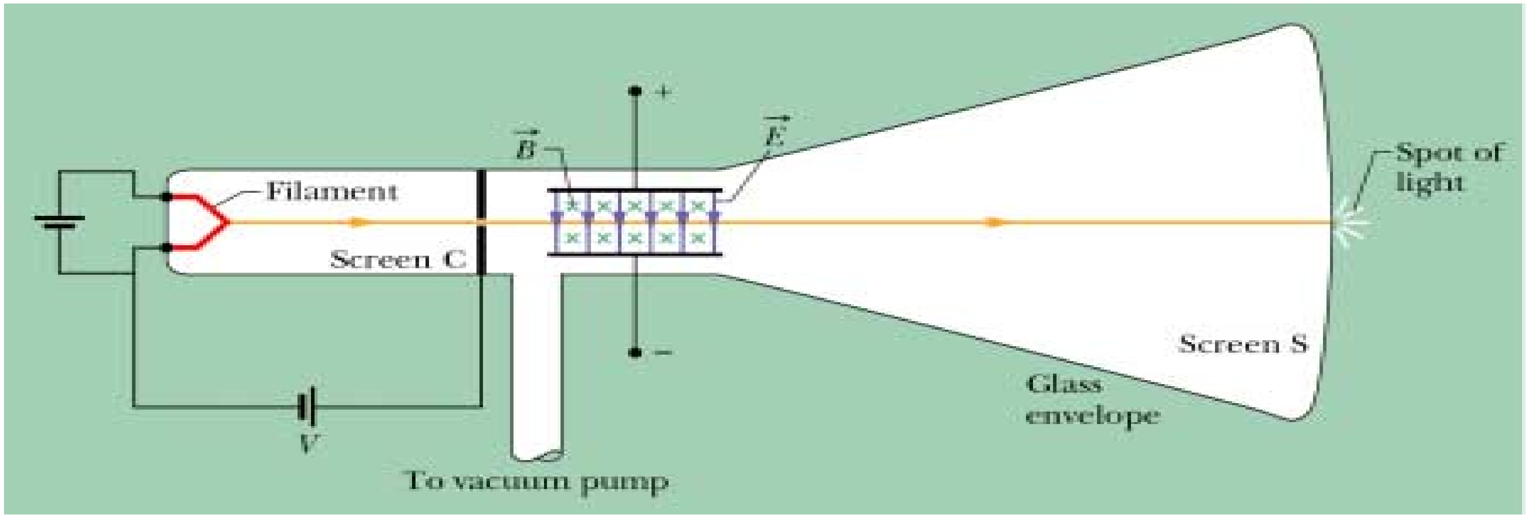
- Check yourself using matrix notation
- Write vectors for *v* and *B*

$$\vec{a}\times\vec{b}=\begin{vmatrix}\hat{i} & \hat{j} & \hat{k}\\ a_x & a_y & a_z\\ b_x & b_y & b_z\end{vmatrix}=\left(a_yb_z-b_ya_z\right)\hat{i}-\left(a_xb_z-b_xa_z\right)\hat{j}+\left(a_xb_y-b_xa_y\right)\hat{k}$$

Magnetic Fields

- What happens if there is both an *E* field and a *B* field?
- Both fields produce a force on a charged particle
- If the two fields are ⊥ to each other call them crossed fields

Magnetic Fields (Fig. 29-7)



- Cathode ray tube – used in television
- Can deflect a beam of electrons by
  - *E* field from charged parallel-plates
  - *B* field from magnet
- Adjust *E* and *B* fields to move electron beam across fluorescent screen

Checkpoint #2

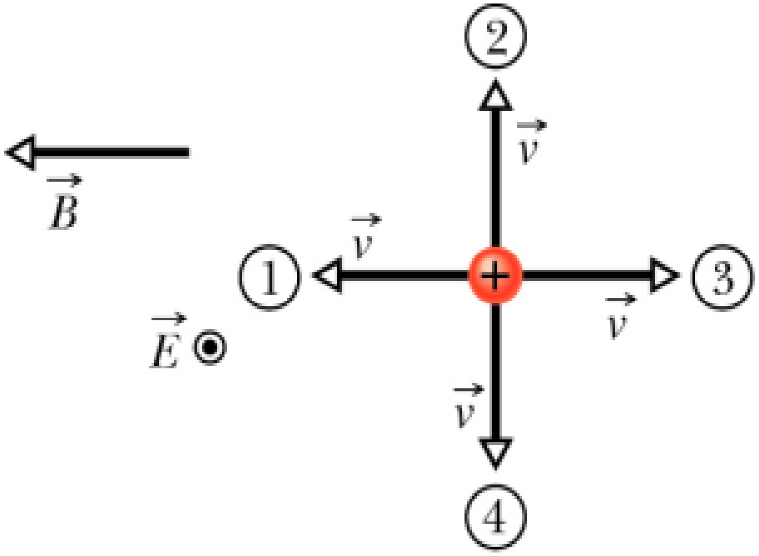
- *E* field out of page, *B* field to left
- A) Rank 1,2, and 3 by magnitude of net *F* on particle, greatest first

- What direction is F_E for 1?

Out of page

- Is it the same for all directions of *v*?

YES



Checkpoint #2

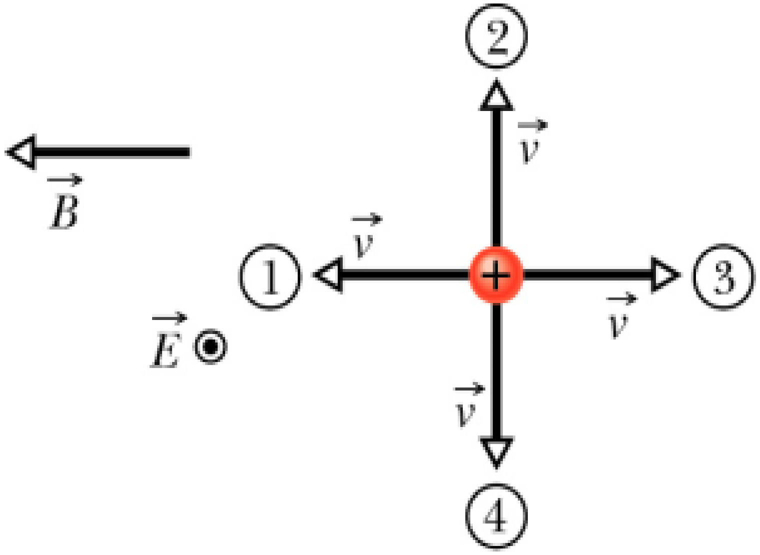
- What is direction of F_B for 1,2,3 and 4?

1) $F_B = 0$

2) F_B out of page

3) $F_B = 0$

4) F_B into page



- A) Rank magnitude of net *F* for 1, 2 and 3.

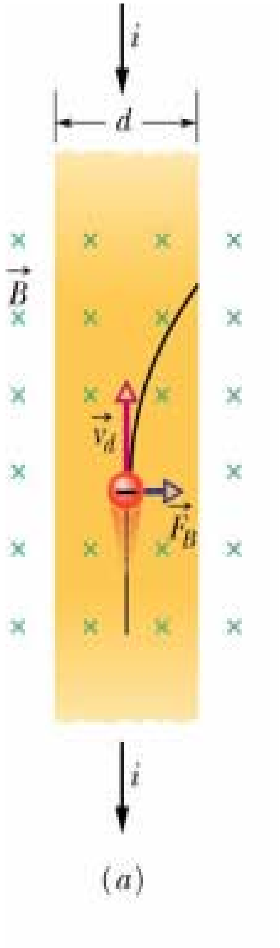
2, then 1 & 3 tie

- B) Which direction could have net *F* of zero?

Direction 4

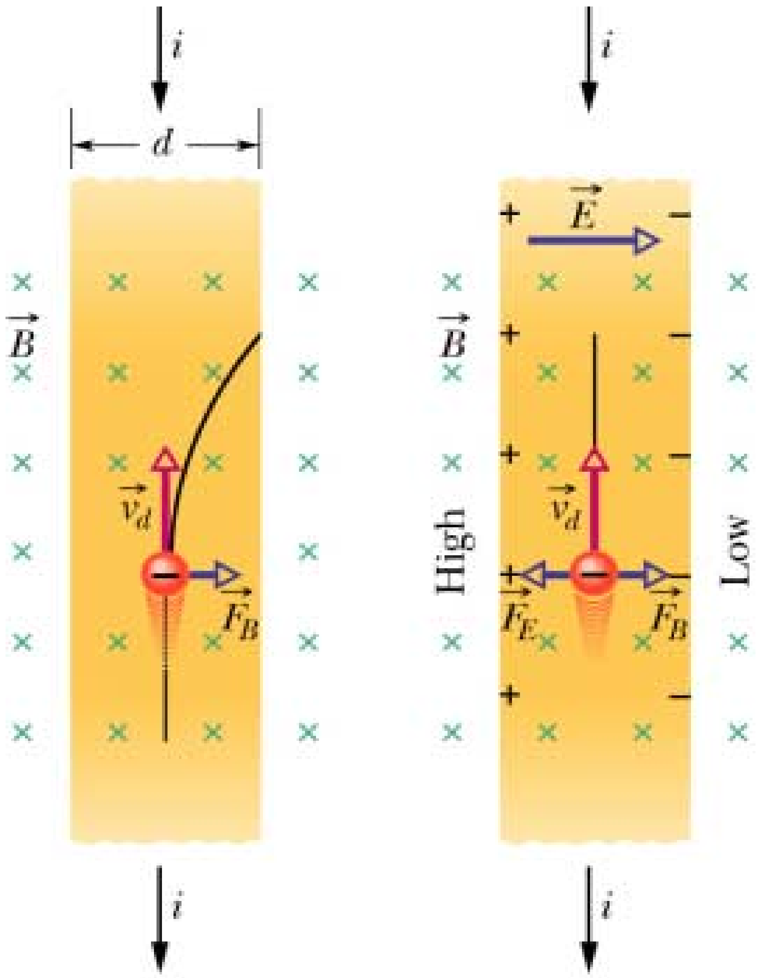
Magnetic Fields (Fig. 29-8a)

- Electrons moving in a wire. In this case the wire is a rectangular slab with width, d, and thickness, l.
- The total cross sectional area of the wire is $A = l\,d$.
- B field points into the screen.



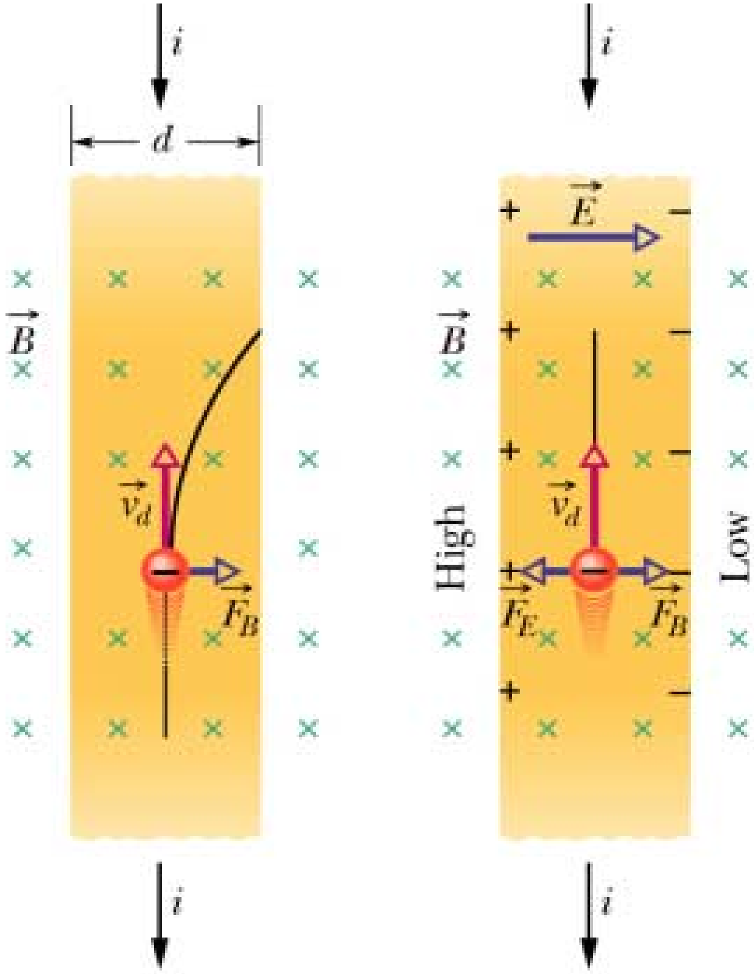
Magnetic Fields (Fig. 29-8a,b)

- Electrons moving in a wire (= current) can be deflected by a B field called the Hall effect
- Creates a Hall potential difference, V, across the wire
- Can measure the wire's charge density when at equilibrium $F_E = F_B$



Magnetic Fields (Fig. 29-8a,b)

- Electrons have drift velocity, v_d in direction opposite the current, i
- B field into page causes force, F_B to right
- Electrons pile up on right hand side of strip
- Leaves + charges on left and produce an E field inside the strip pointing to right

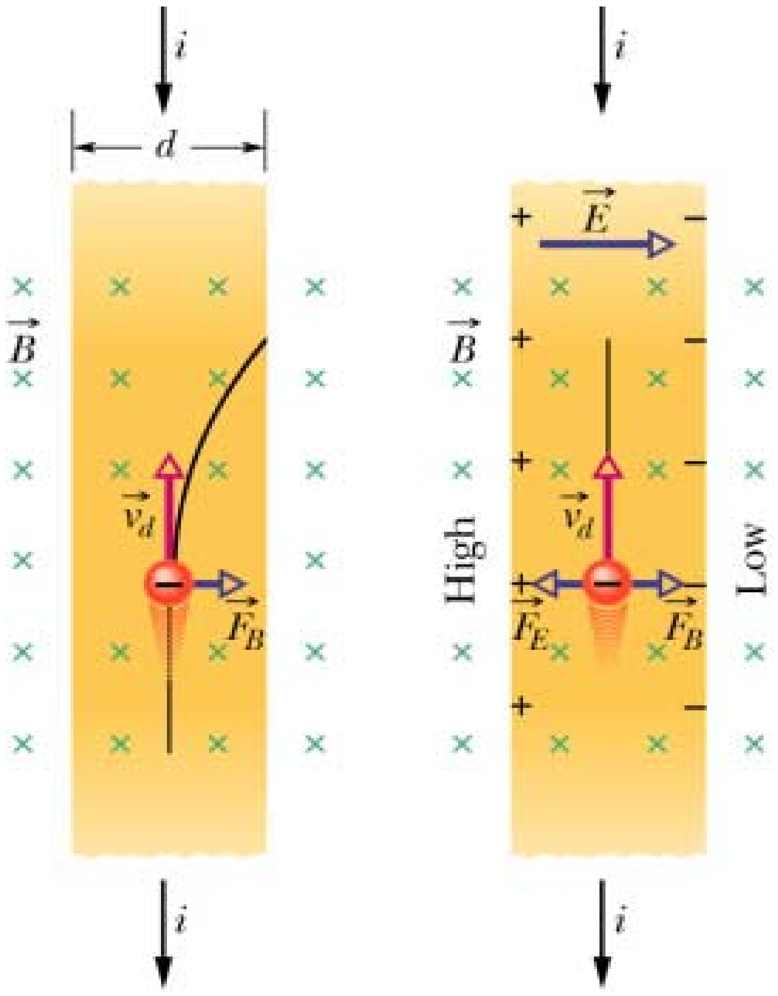


Magnetic Fields (Fig. 29-8a,b)

- E field on electron produces a F_E to the left
- Quickly have equilibrium where $F_E = F_B$
- E field gives a V across the strip

$$V = Ed$$

- Left side is at a higher potential



Magnetic Fields (Fig. 29-8a,b)

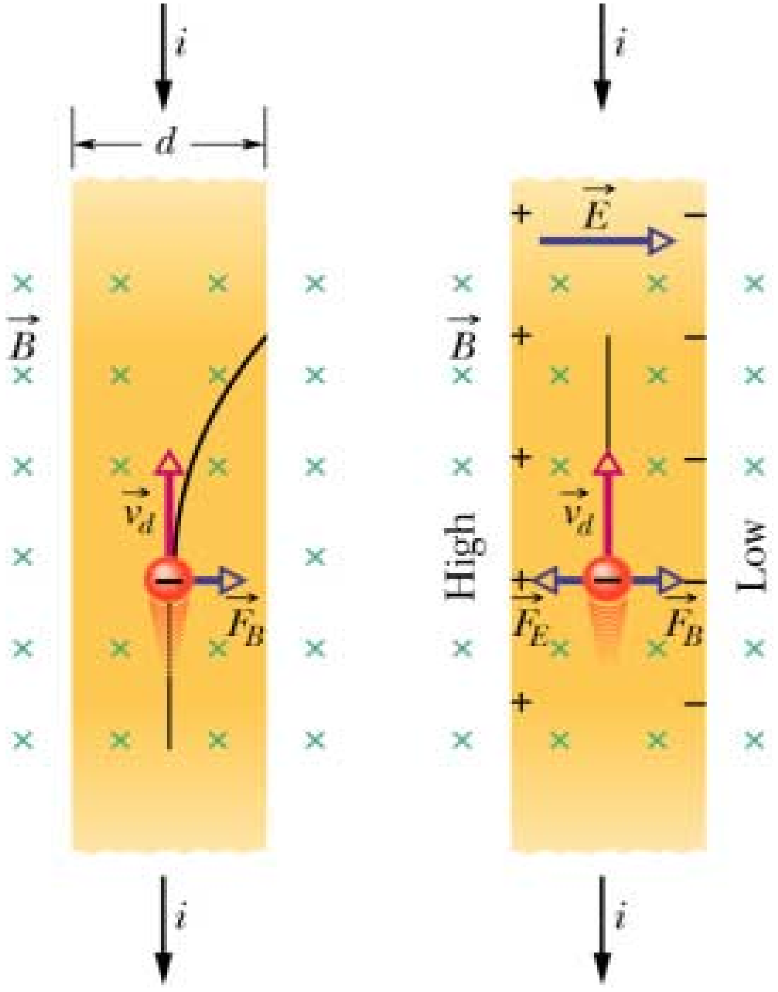
- Can measure the number of charge carriers per unit volume, *n*, at equilibrium

$$F_E = F_B$$

$$F_E = qE \qquad F_B = |q\vec{v}\times\vec{B}|$$

$$eE = ev_d B\sin(90)$$

$$E = v_d B$$



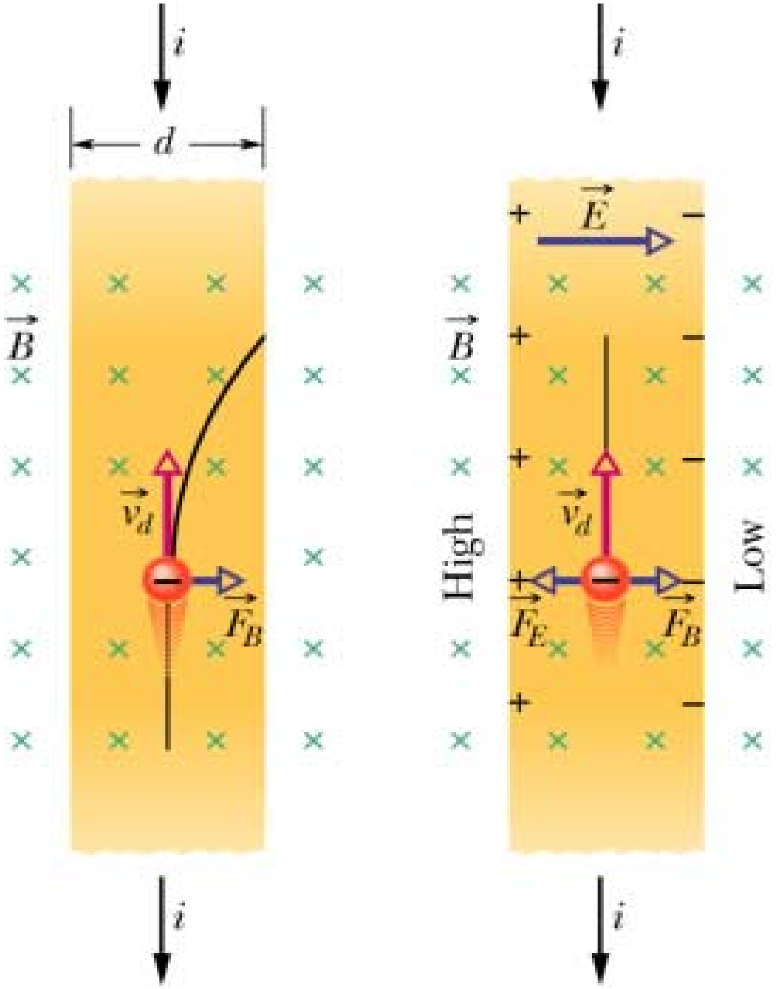
Magnetic Fields (Fig. 29-8a,b)

- Remember from Chpt. 27 that drift speed is

$$v_d = \frac{J}{ne} = \frac{i}{neA}$$

$$E = v_d B = \frac{iB}{neA}$$

$$n = \frac{iB}{EeA}$$

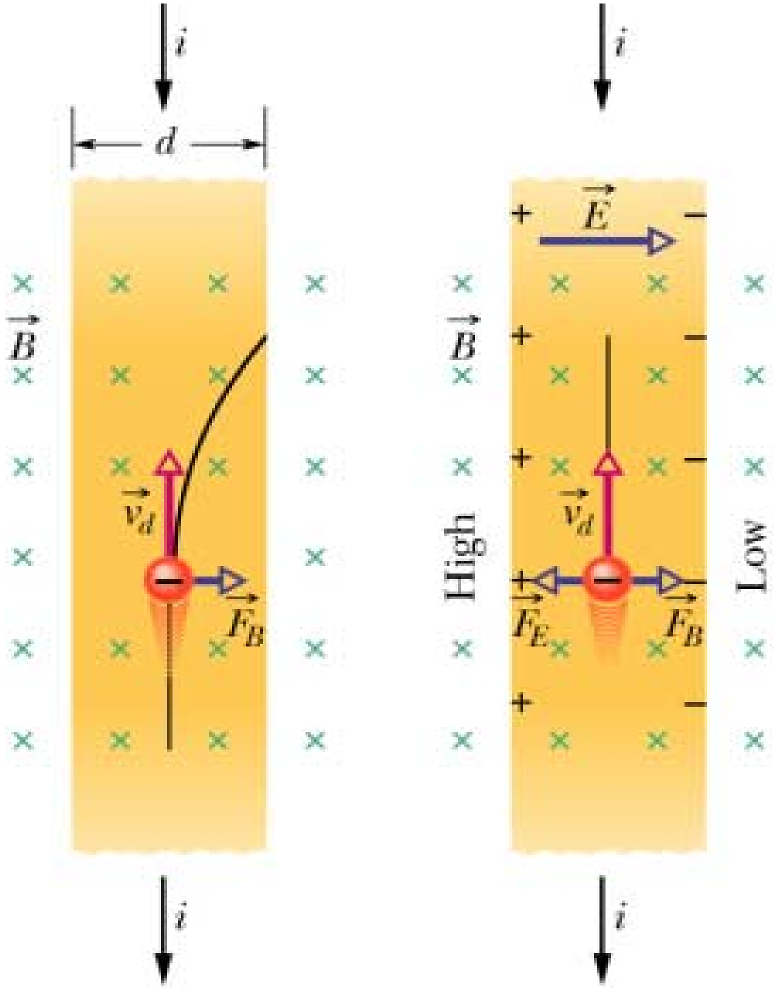


Magnetic Fields (Fig. 29-8a,b)

- Replacing *E* by

$$V = Ed$$

$$n = \frac{iB}{EeA} = \frac{iBd}{VeA}$$



Magnetic Fields (Fig. 29-8a,b)

- If *l* is the thickness of the strip

$$l = \frac{A}{d}$$

- Finally get

$$\boxed{n = \frac{iB}{Vle}}$$