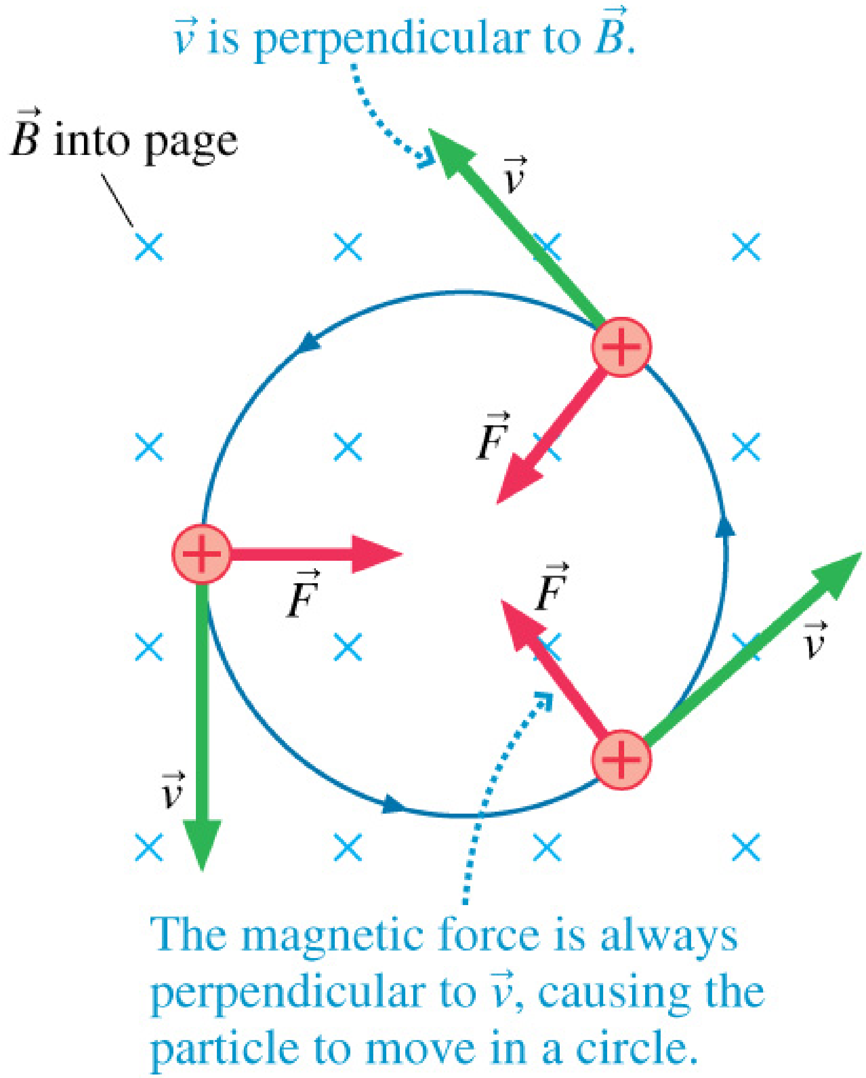
Lecture 16: Chapter 32, October 27 2005

Circular Motion



$F = qvB$

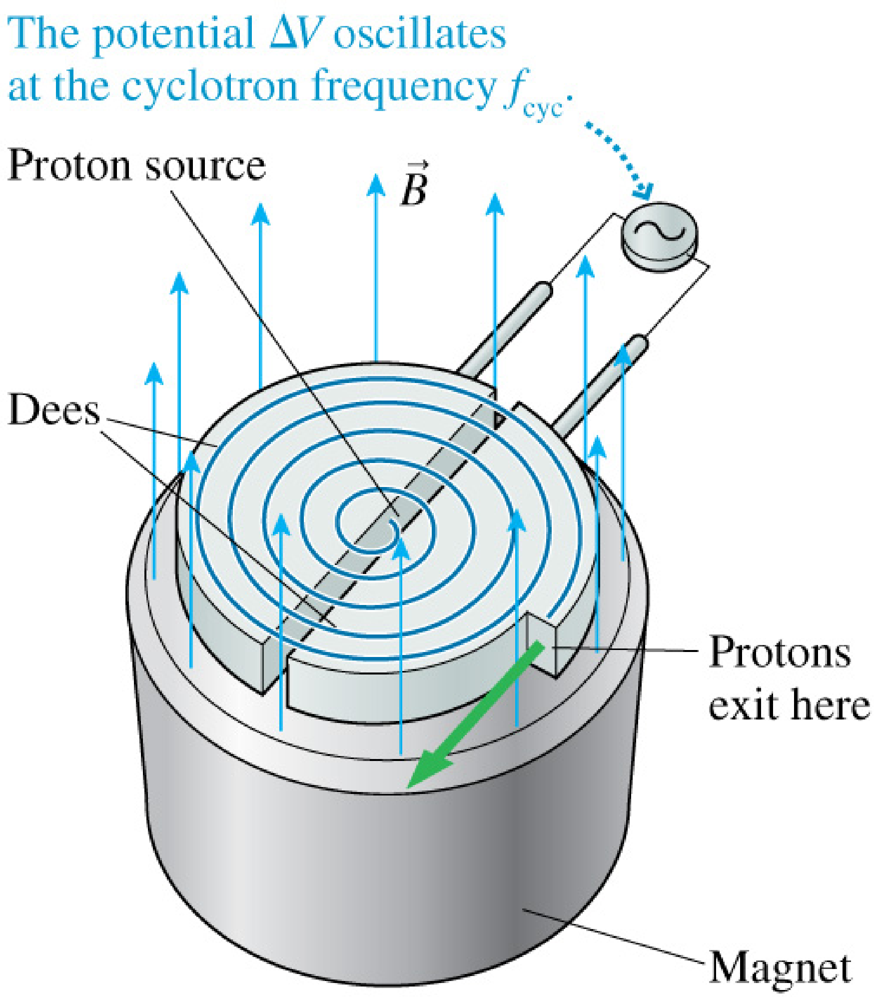
$F = ma_r = mv^2/r$

$r_{cyc} = mv/(qB)$

$f_{cyc} = v/2\pi r = qB/(2\pi m)$

- f_{cyc} is independent of the particle speed
- $r_{cyc} \sim v$

The Cyclotron

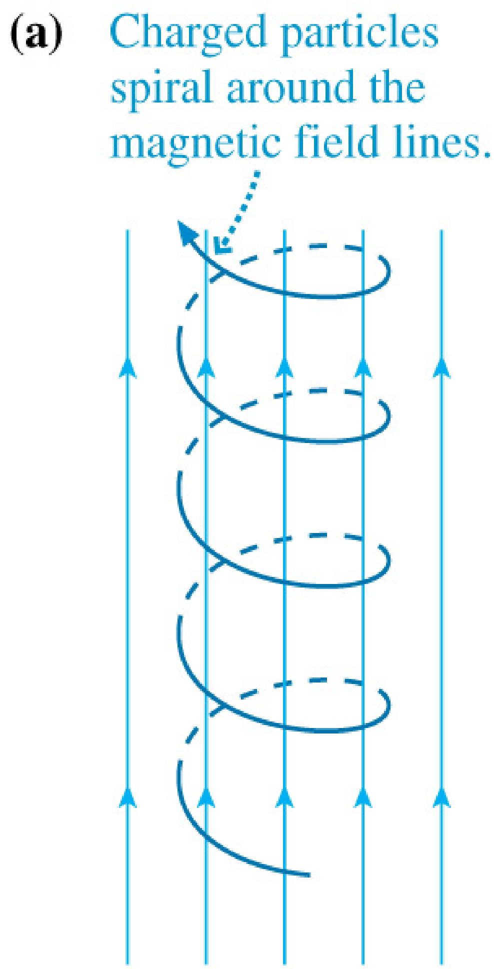


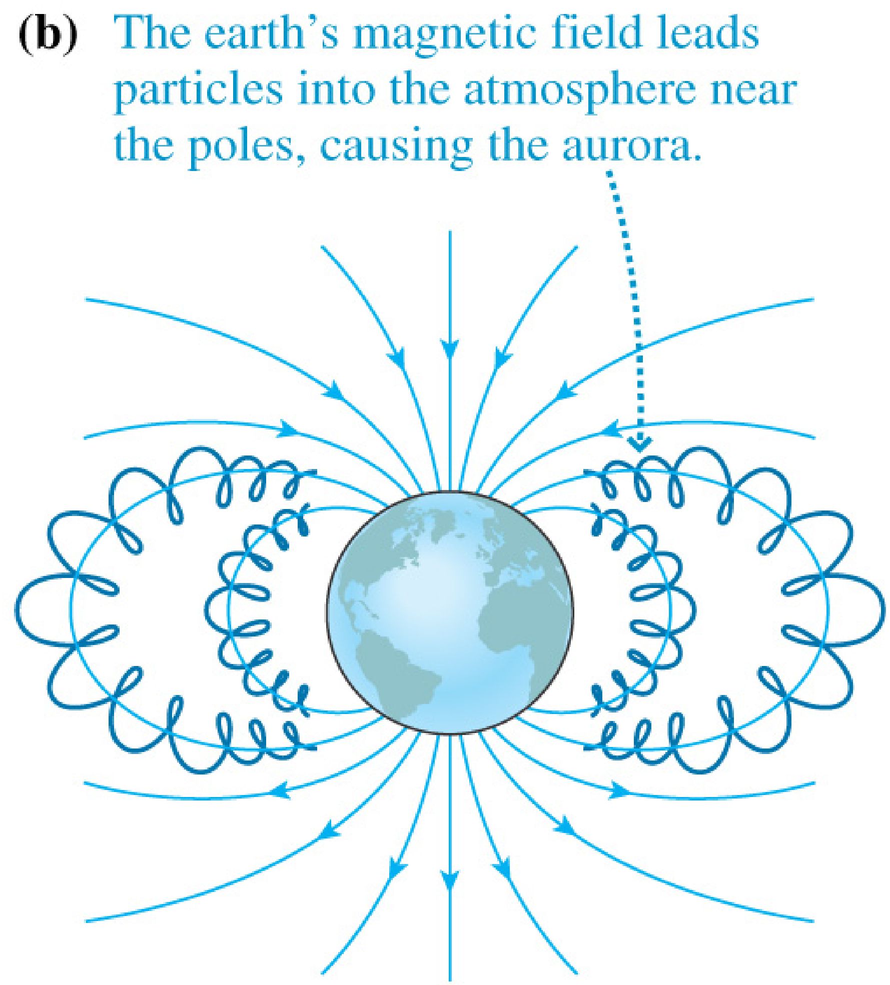
The source of high energy particles needed for fundamental studies

- Since f_{cyc} is independent of v we can apply ΔV at f_{cyc}
- Each time traversing the gap the particle gains kinetic energy $e\Delta V$
- After N orbits it will be $K = 2Ne\,\Delta V$,

ΔV~100V, N~10^4 $\Rightarrow$
K~ 1 MeV or more

More general situation with $v_{||}$ and $v_{\perp}$ components



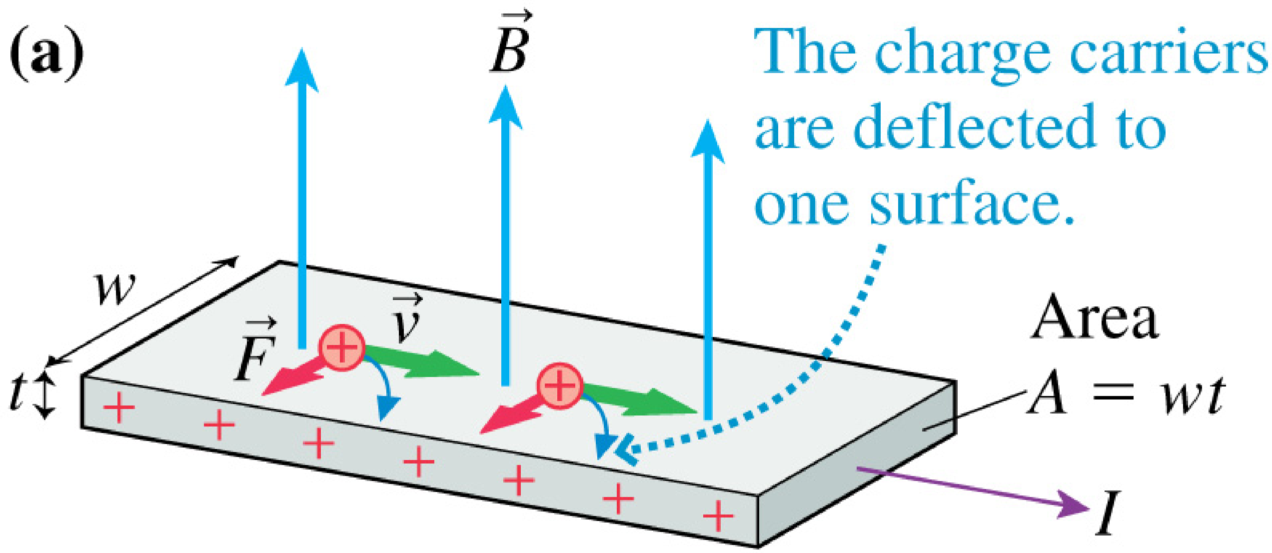


$v_{||}$ - conserved
$v_{\perp}$ - circular motion
As a result a helical trajectory

Solar wind creates electrons
They spiral along B
Auroral light

The Hall Effect

Hall Effect: Appearance of the potential difference ***across*** the direction of the current in external magnetic field

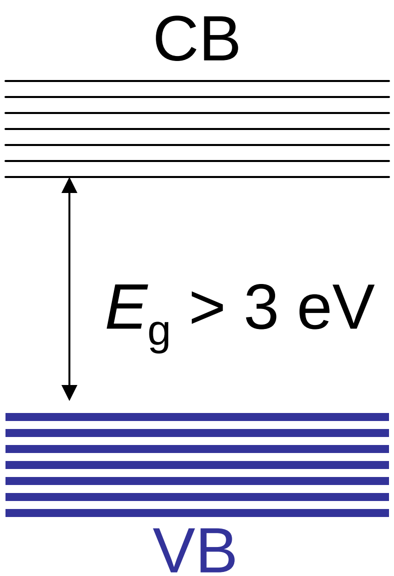


- Used to determine the sign of carriers
- To measure magnetic fields

Concept of Electronic Bands in Solids

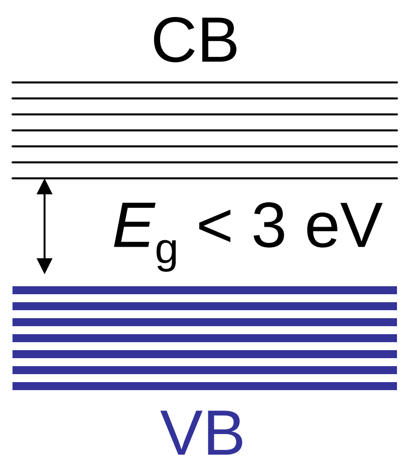
To have a conductivity we need:
- Many carriers (electrons or holes in a particular band)
- Many empty states in the same band

Dielectrics



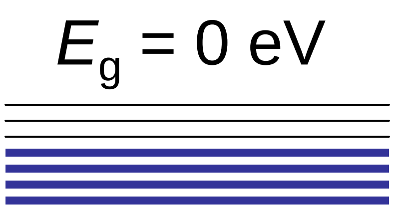
Bad conductors
No carriers in CB
No empty states in VB

Semiconductors



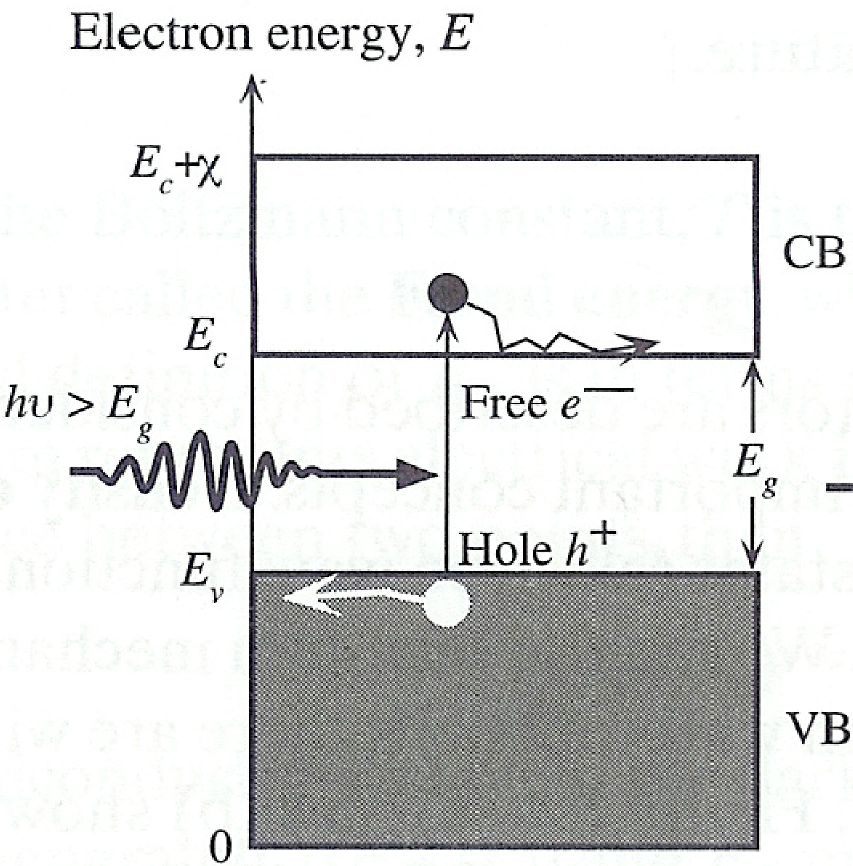
Poor conductors at T>>0
A small concentration of free electrons and holes

Metals

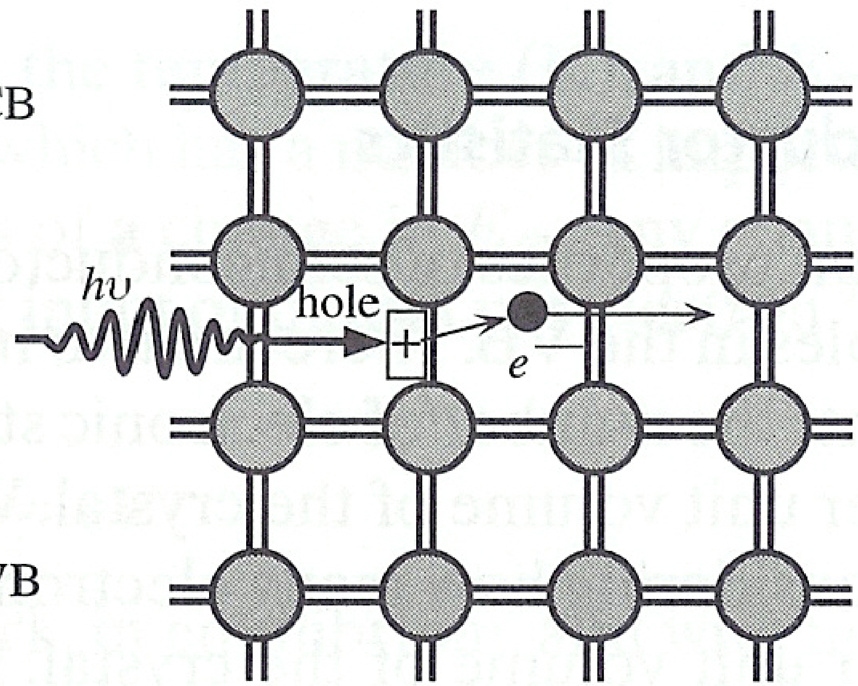


A lot of electrons and available states ⇒ Excellent conductors (carriers – electrons)

How do carriers with different sign appear in Semiconductors?

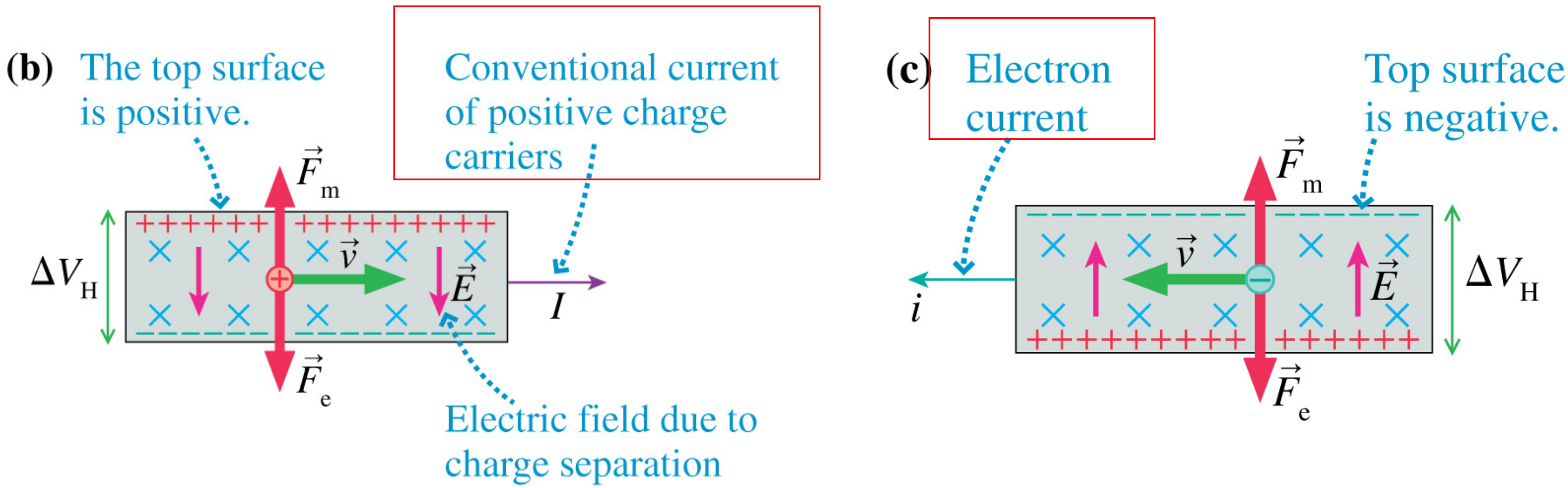


Atomic Lattice of Si



- A photon with an energy grater than E_g can excite electron from the *VB* to *CB*
- Each line between Si-Si atoms is a valence electron in a bond. When a photon breaks a Si-Si bond, a free electron and a hole in the Si-Si bond are created
- This hole, denoted h^+ can also wander around the crystal as if it were “free”. It has a positive charge +*e*.

Back to the Hall Effect



- Why is the sidewall charging different for electrons and holes?
- Why do we have an electric field ($\boldsymbol{E} = \boldsymbol{F}_e/e$) ***across*** the semiconductor?
- What can we conclude about $\boldsymbol{F}_e$ in the steady state (compared to $\boldsymbol{F}_m$)?

Calculating Hall Voltage ΔV_H

$$F_m = e v_d B = F_e = eE = e\frac{\Delta V}{w}$$

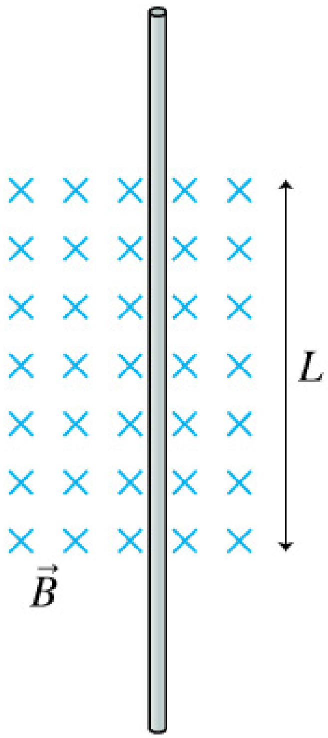
$$\Delta V_H = w v_d B$$ ← In the steady state $\Delta V = \Delta V_H$

$$v_d = \frac{J}{ne} = \frac{I/A}{ne} = \frac{I}{wtne}$$ ← Since $J = env_d$

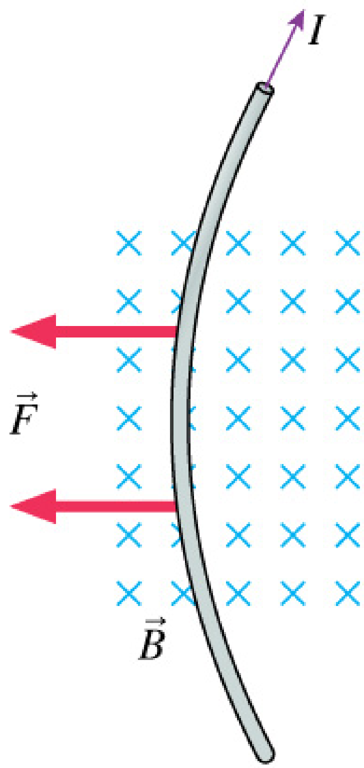
$$\Delta V_H = \frac{IB}{tne}$$

- Hall voltage ΔV_H can be used to measure B
- Its polarity indicate sign of carriers

Magnetic Force on Current-Carrying Wires



A wire is perpendicular to an externally created magnetic field.



A current through a wire that is fixed at the ends causes the wire to be bent sideways.

q – total charge in length *L*

$$I = \frac{q}{\Delta t} = \frac{q}{L/v} = \frac{qv}{L}$$

$$qv = IL$$

$$F = qvB$$

If ***L*** ⊥ ***B***

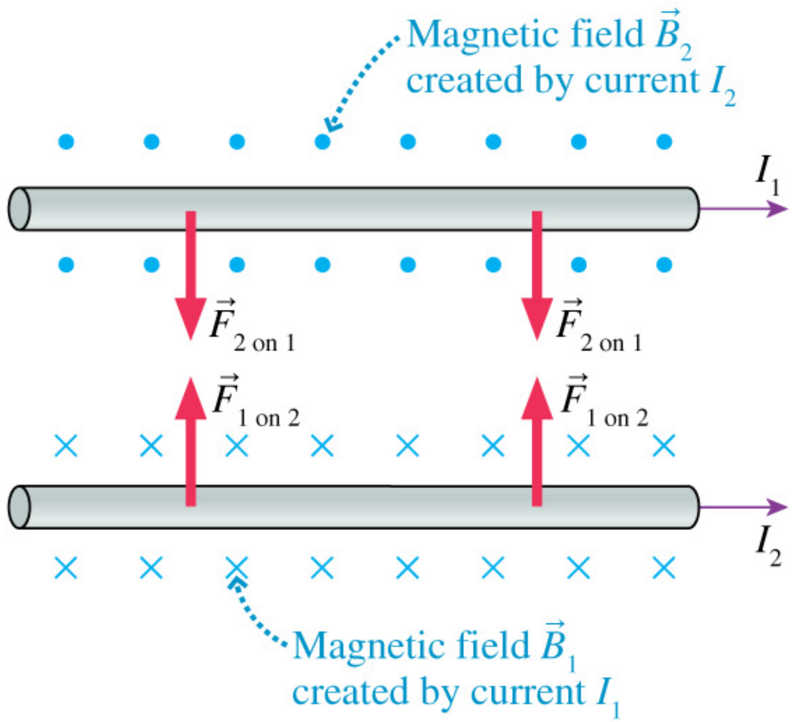
$$F_{wire} = ILB$$

$$\vec{F}_{wire} = I\vec{L} \times \vec{B}$$

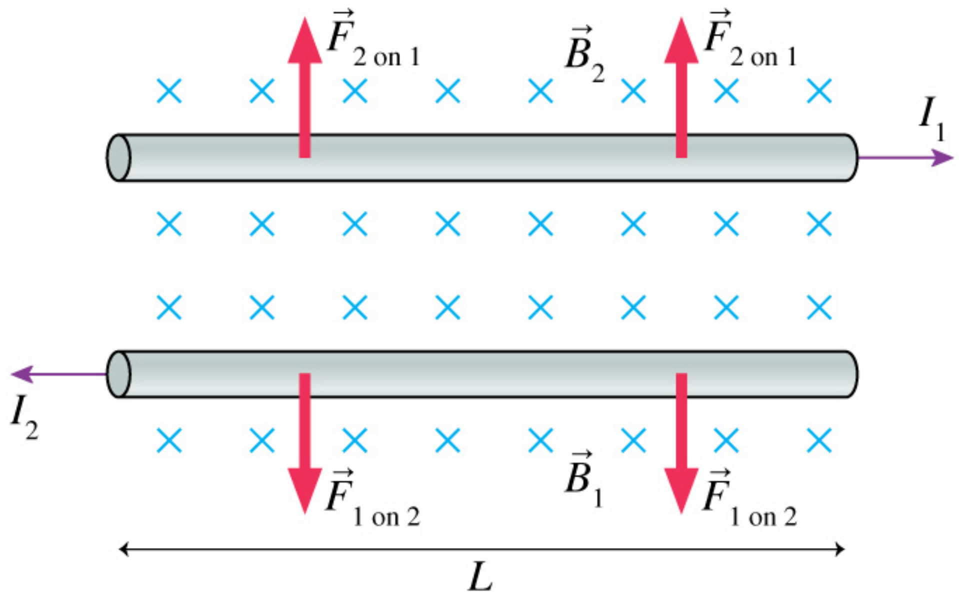
For any orientation of ***L*** and ***B***

Force Between Two Wires

(a) Currents in same direction



(b) Currents in opposite directions



Use right hand rule to check directions of B_1, B_2, $F_{2 \text{ on } 1}$ and $F_{1 \text{ on } 2}$

Calculating Force Between Two Wires

Field created by a long straight wire: $B = \mu_0 I/2\pi d$

$$F_{parallel\_wires} = I_1 L B_2 = I_1 L \frac{\mu_0 I_2}{2\pi d} = \frac{\mu_0 L I_1 I_2}{2\pi d}$$

This formula is used to define SI unit for current, 1 Ampere:
The ampere is that constant current which, if maintained in two straight, parallel wires of negligible circular cross section, and placed 1m apart in vacuum, would produce on each of these conductors a force of magnitude 2×10^{-7} newton/m

End of Lecture 16
Reading: Entire Chapter 32
HW8