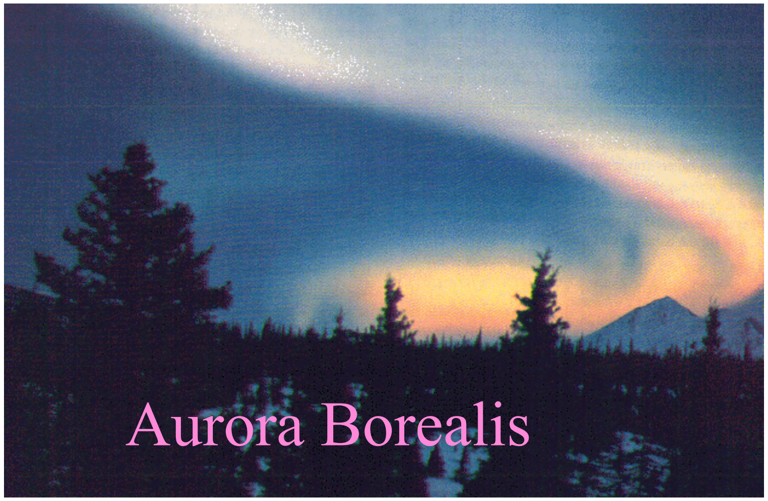
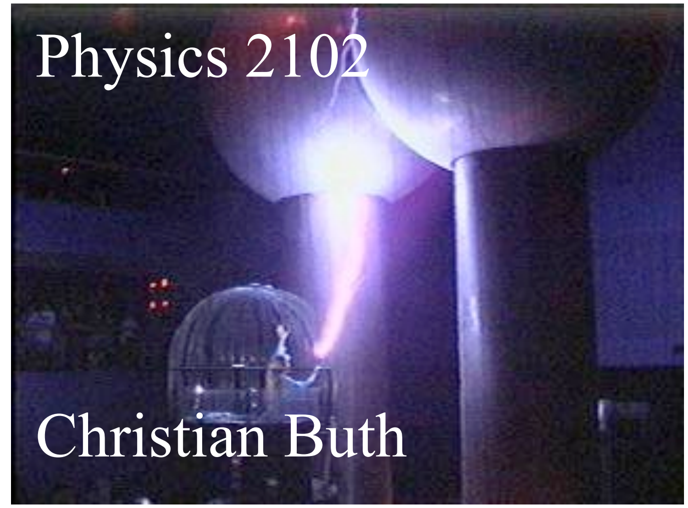




Physics 2102
Lecture 19
Magnetic fields 2

Version: 03/02/2009

PHYS2102 SECOND MIDTERM EXAM!

6–7PM THU 05 MAR 2009

Buth’s Sec. 6 in Lockett 2
(together with Section 1)

YOU MUST BRING YOUR STUDENT ID!

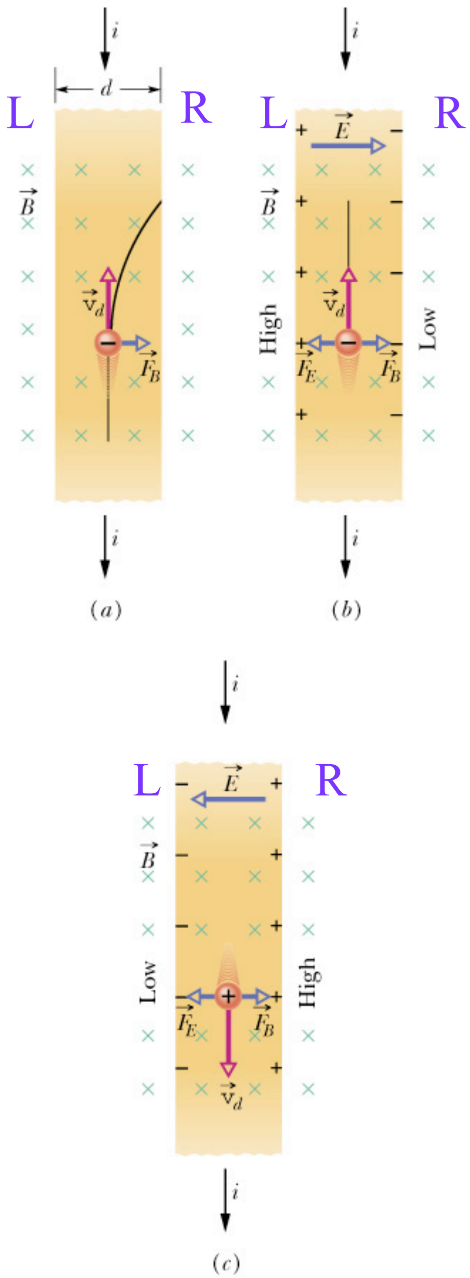
The exam will cover chapters 25 through 28, as covered in homework sets 4, 5, 6, and 7. The formula sheet for the exam can be found here:

http://www.phys.lsu.edu/classes/spring2009/phys2102/formulasheet.pdf

THERE WILL BE A REVIEW SESSION 6–7PM WED 04 MAR 2009 in Nicholson 130

Review

- Magnetic fields **exert forces** on moving charges $\boldsymbol{F}_B = q\,\boldsymbol{v} \times \boldsymbol{B}$: the force is **perpendicular** to the field and the velocity
- Magnetic field lines are used to **visualize** magnetic fields
- Magnetic field $\boldsymbol{B}$ has SI unit **tesla**
- **Right hand rule** for vector products (cross products)
- **Cathode ray tube** crossed electric and magnetic fields; lead to discovery of electron



Hall Effect

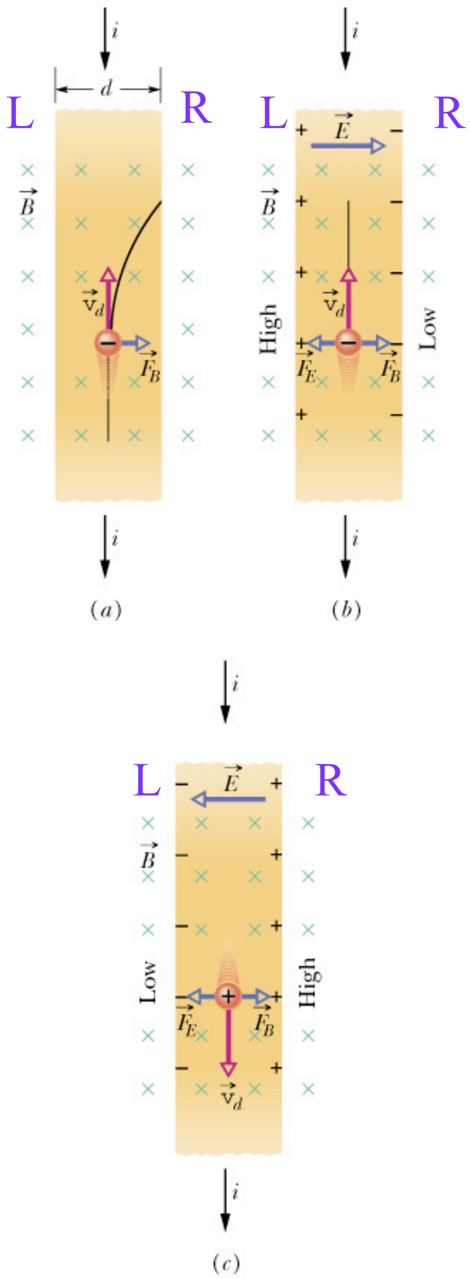
- Currents are **moving charges**
- Magnetic field **exerts force** on moving charges
- Charge carriers **accumulate** at one side; leads to the **Hall potential difference**

$$V = Ed$$

- Accumulation until force due to electric field **balances** force due to magnetic field:

$$F_E = eE = ev_d B = F_B$$

$$E = v_d B$$



Charge Carriers

- The charge carriers move with the **drift speed**

$$v_d = \frac{J}{ne} = \frac{i}{Ane} = \frac{i}{\ell dne}$$

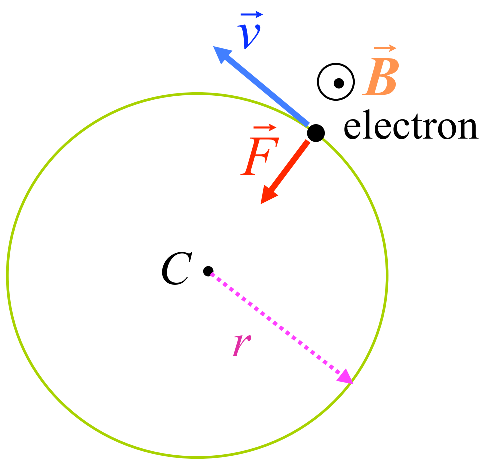
- The **number density** of charge carriers follows

$$n = \frac{Bi}{V\ell e}$$

- By measuring the Hall potential difference the **sign of the charge carriers** can be measured (in metals negative)

- Conduction in metals due to **negative charge carriers** (electrons)

Charged Particle in Magnetic Field



- Particle injected with uniform speed follows **circular orbit**; centripetal force

$$\vec{F}_{\mathrm{B}} = q\vec{v} \times \vec{B}$$

- **Radius** of circle

$$qvB = m\frac{v^2}{r} \Rightarrow r = \frac{mv}{qB}$$

- **Period** of circulation (does not depend on speed)

$$T = \frac{1}{f} = \frac{2\pi r}{v} = \frac{2\pi m}{qB}$$

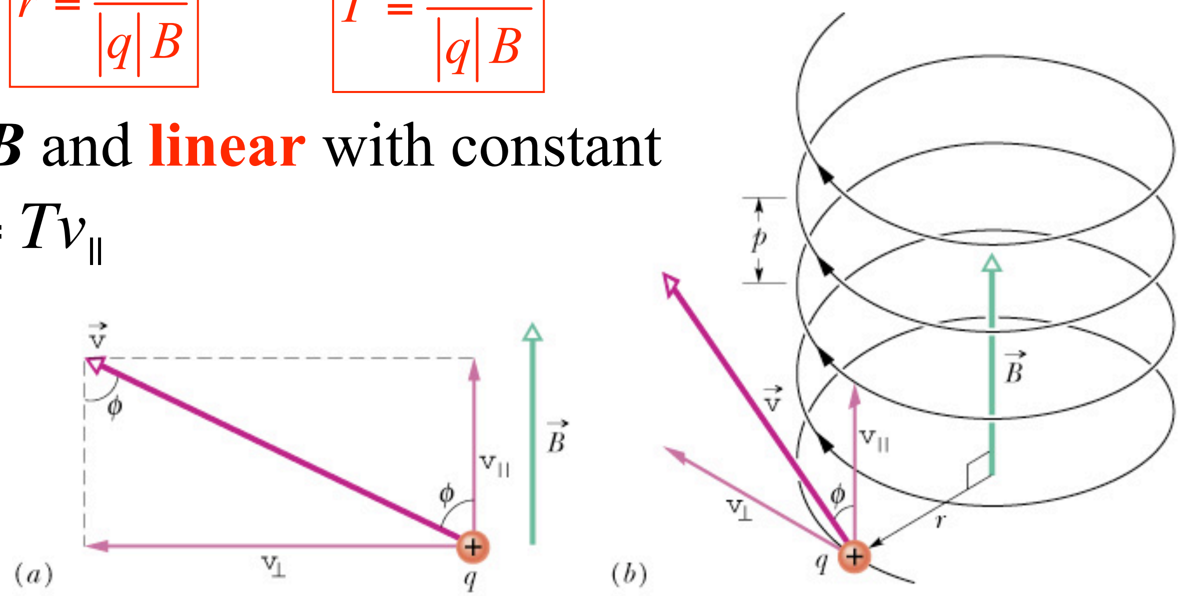
- Fast particles move on larger orbits; all particles have the **same period**

Helical Paths

- Motion of a charge in a uniform magnetic field where velocity ***v*** has an **angle** ϕ with ***B***
- Parallel to ***B*** $v_{\parallel} = v\cos\phi$ perpendicular to ***B*** $v_{\perp} = v\sin\phi$
- Two **independent** motions: first **cyclotron motion** perpendicular to ***B*** with radius *r* and period *T*

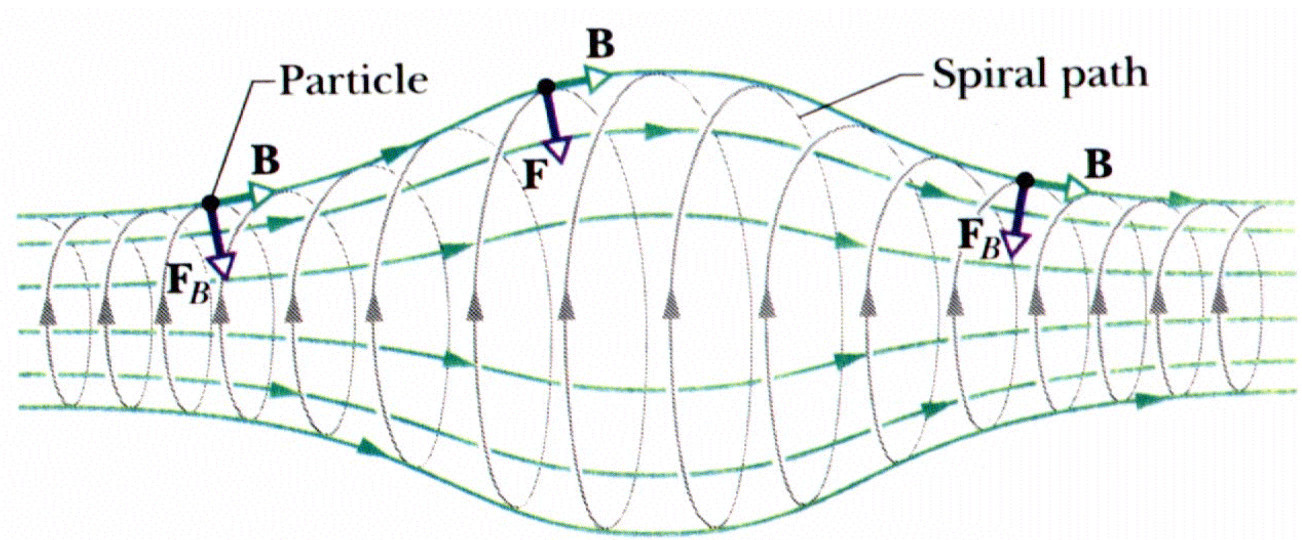
$$r = \frac{mv_{\perp}}{|q|B} \qquad T = \frac{2\pi m}{|q|B}$$

- Second motion along ***B*** and **linear** with constant speed leads to **pitch** $p = Tv_{\parallel}$



Magnetic Bottle

- Magnetic force vectors point toward the **center**
- If magnetic field strong, charged particle motion **confined**; particle reflected on both ends



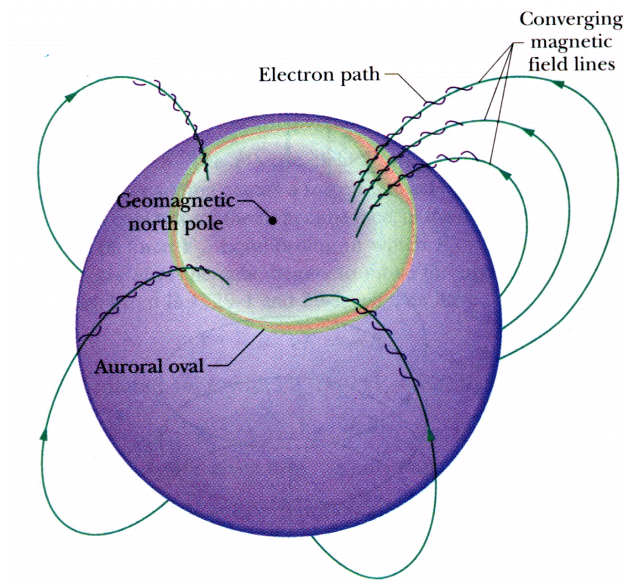
Aurora Borealis (Northern Lights)

• Electrons and protons trapped by terrestrial magnetic field: **Van Allen radiation belts**

• Belts loop above atmosphere between **geomagnetic** North and South poles

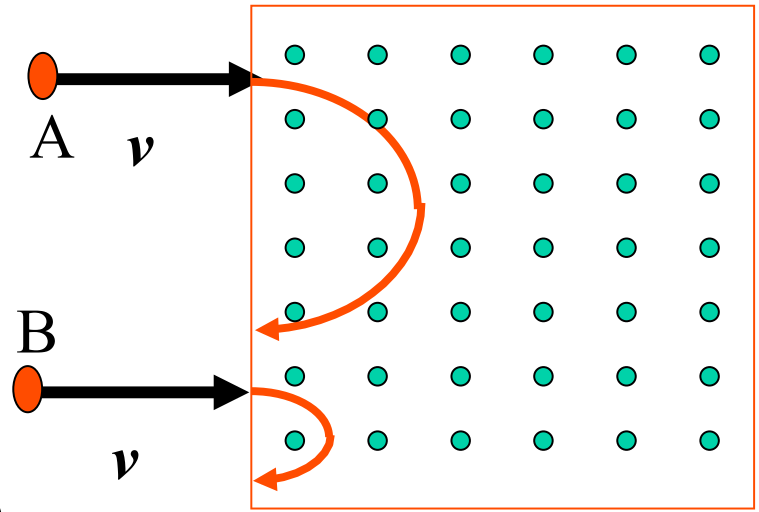
• Large solar flare shoots charged particles into belts additional field eliminates reflection

• Electrons and protons are driven into the atmosphere; collide with molecules (in **auroral oval**)



Example

Two charged ions A and B traveling with a constant velocity ***v*** enter a box in which there is a **uniform** magnetic field directed out of the page. The subsequent paths are as shown. What can you conclude?



(a) Both ions are positively charged.

(b) Ion *A* has a larger mass than *B*.

(c) Ion *A* has a larger charge than *B*.

(d) None of the above

$$r = \frac{mv}{qB}$$

Same speed v and same B for both masses.

So: ion with larger mass/charge ratio (m/q) moves in circle of larger radius. But that's all we know! Don't know m or q separately

Particle Accelerators

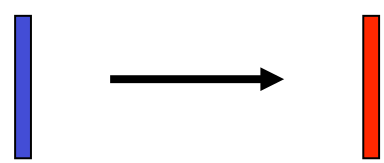
• Beams of charged particles (electrons, protons) very useful to study **fundamental structure** of nuclei and atoms

• Potential difference to **accelerate** charged particles

• **Linear arrangement** possible for light electrons

• Protons too **heavy**; need better arrangement for sufficient acceleration

• Use magnetic field to **bring back** particles in circular motion



Linear accelerator (long)

Summary

- **Hall effect** reveals that charge carriers in metals are negative (electrons)

- Charged particle with velocity perpendicular to magnetic field on **circular path**

$$r = \frac{mv_\perp}{|q|B} \qquad T = \frac{2\pi m}{|q|B}$$

- Generally linear and circular motion superimposed: a **helix** with radius r and **pitch** $p = Tv_{\parallel}$

- Charged particles trapped in **magnetic bottle**; natural phenomenon: **aurora borealis**

- **Particle accelerators** create beams of charged particles