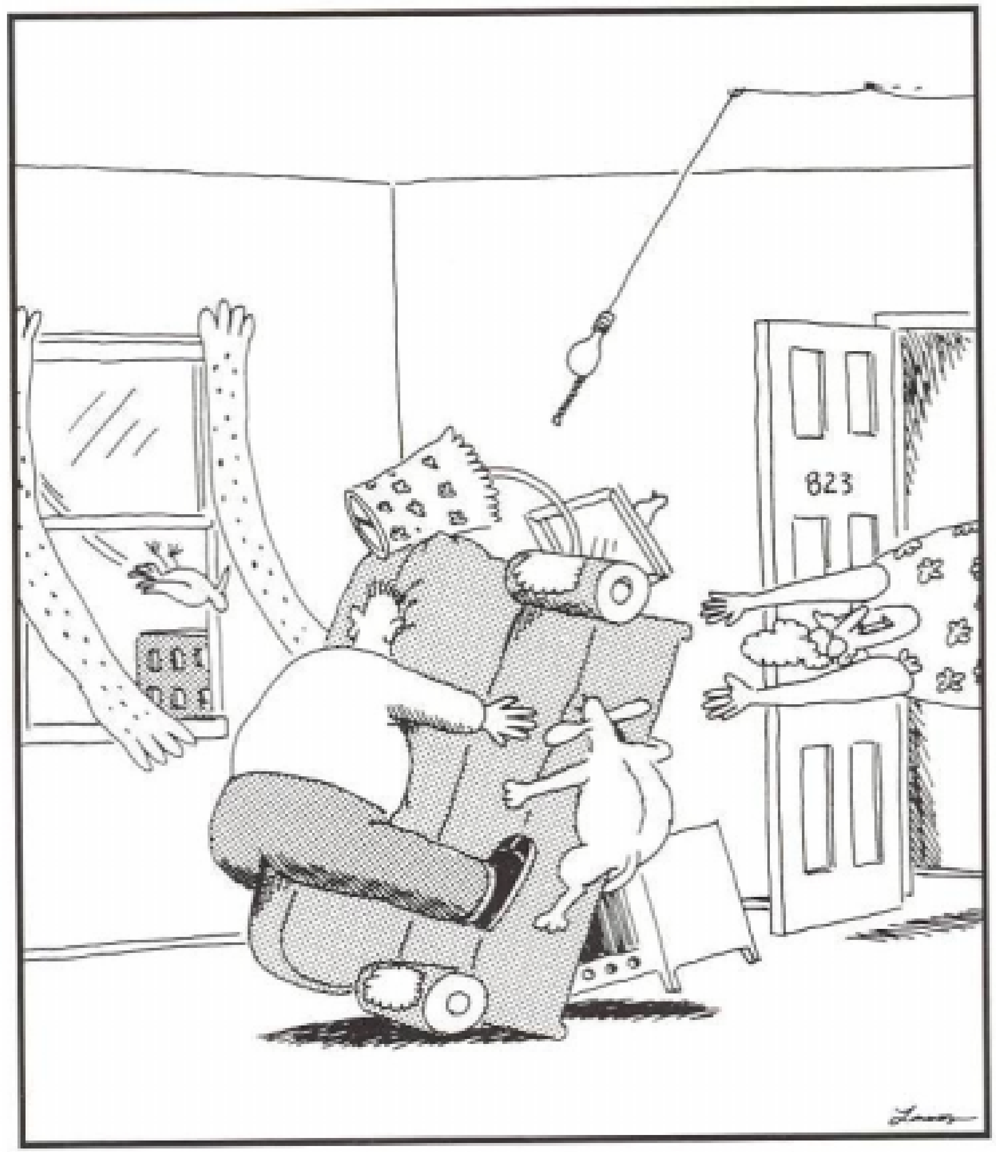
October 23/24th

Chapter 32

Magnetism of Matter



Suddenly, through forces not yet fully understood, Darren Belsky's apartment became the center of a new black hole.

Midterm-2

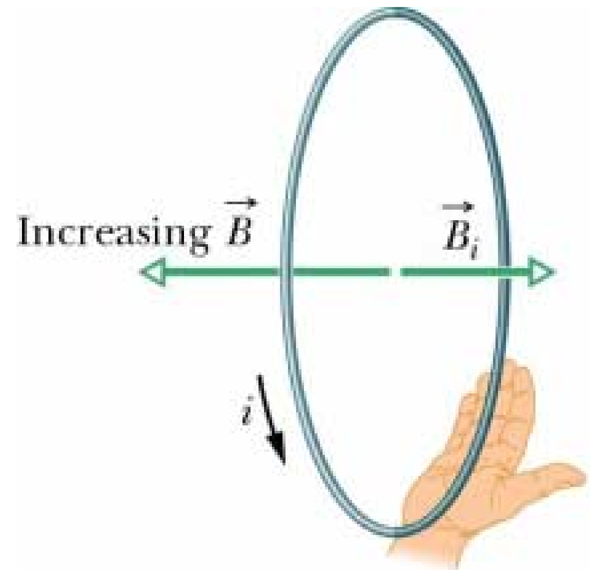
- Wednesday October 29 at 6pm
  - Sec 1 – N100 BCC (Business College)
  - Sec 2 – 158 NR (Natural Resources)
- Allowed one sheet of notes (both sides) and calculator
- Covers Chapters 27-31 and homework sets #5-8
- Send an email to your professor if you have a class conflict and need a make-up exam

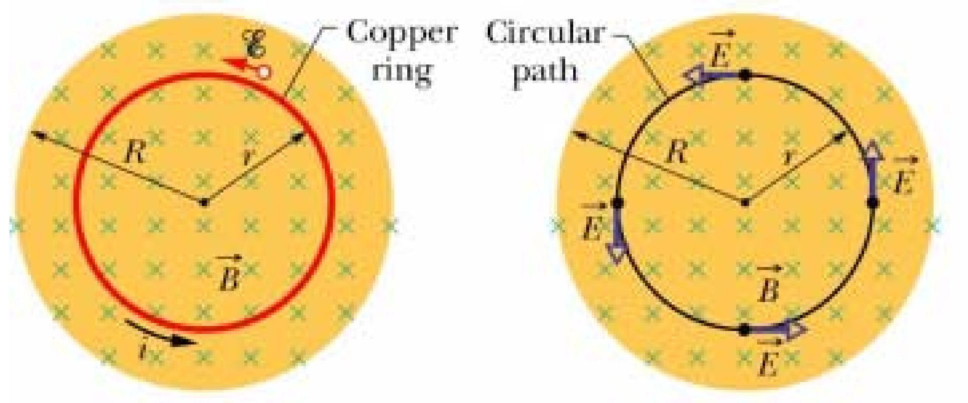
Induced Electric Fields

- Put a copper ring in a uniform *B* field which is increasing in time so the magnetic flux through the copper ring is changing

- By Faraday's law an induced emf and current are produced

- If there is a current there must be an *E* field present to move the conduction electrons around ring

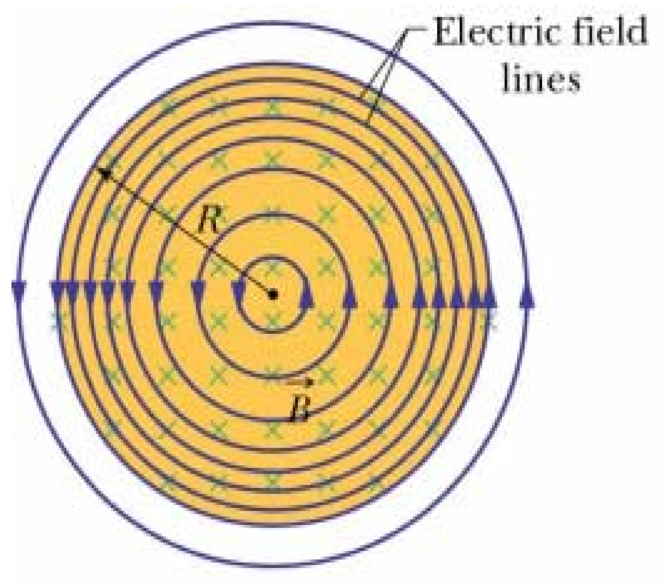




(a) (b)

Induced Electric Fields (Fig. 31-13)

- Induced *E* field acts the same way as an *E* field produced by static charges, it will exert a force, *F=qE*, on a charged particle
- True even if there is no copper ring (the picture shows a region of magnetic field increasing into the board which produces circular electric field lines).
- Restate Faraday's law – A changing *B* field produces an *E* field given by



$$\oint \vec{E} \bullet d\vec{s} = -\frac{d\Phi_B}{dt}$$

Induced E fields

- Solenoid with radius $r = 0.1$ m and $n = 1000$ turns/m has current ramping up at a rate of 50 Amp/s. An electron is sitting outside the solenoid 1 m away. What is the magnitude of the force the electron feels while the current is ramping up?

- Charge feels force when in an E field

$$\vec{F} = q\vec{E}$$

- E field is induced when B field is changing

$$\oint \vec{E} \bullet d\vec{s} = -\frac{d\Phi_B}{dt}$$

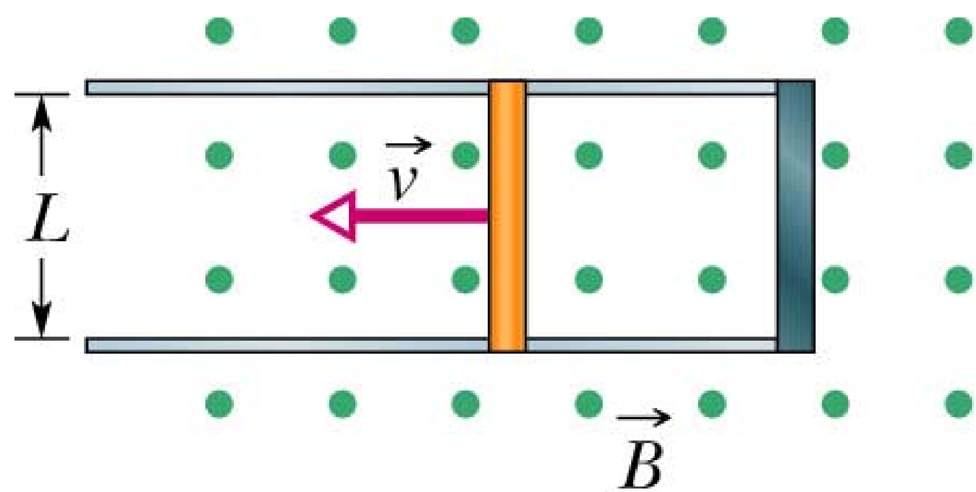
- Current ramping up so B field of solenoid is changing

$$\Phi_B = \int \vec{B} \bullet d\vec{A} = BA$$

$$B_{solenoid} = \mu_0 i n$$

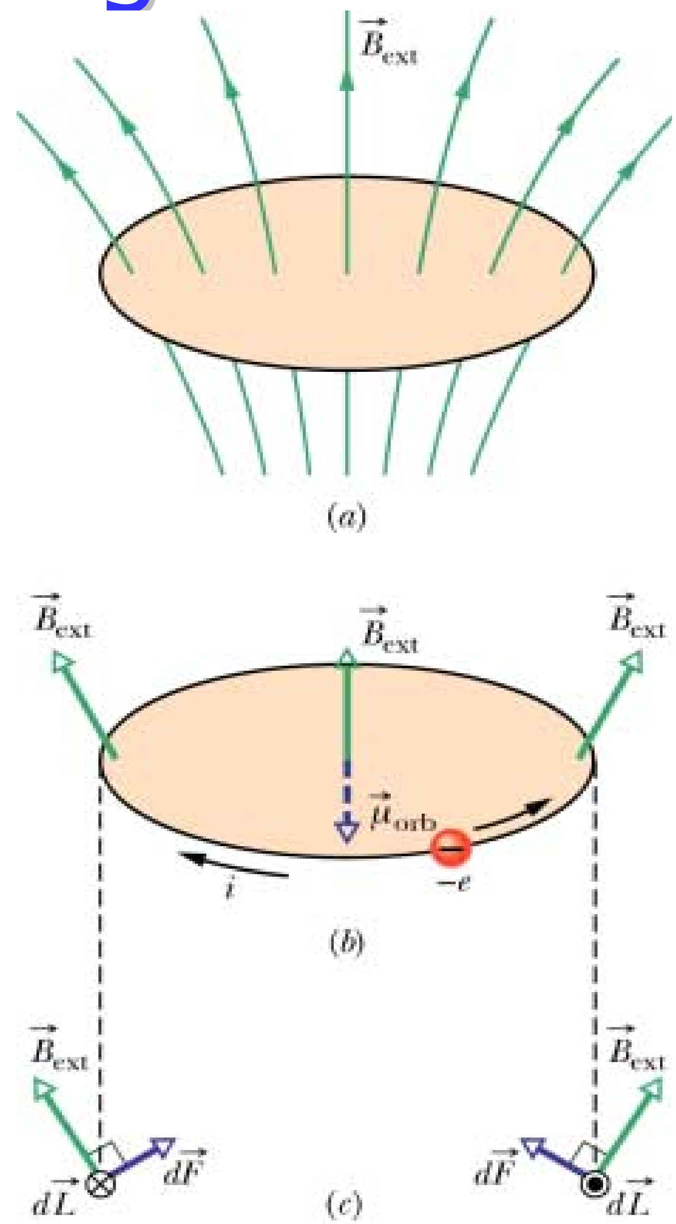
Problem 27E

- Metal rod forced to move with constant velocity along 2 metal rails which are connected at one end. B field points out of the page of 0.350 T. A) If the rails are separated by 25 cm and v=55 cm/s what emf is generated? B) If the rod has resistance of 18 Ω, what is the current in the rod? C) At what rate is energy transferred to thermal energy?



Jumping Ring

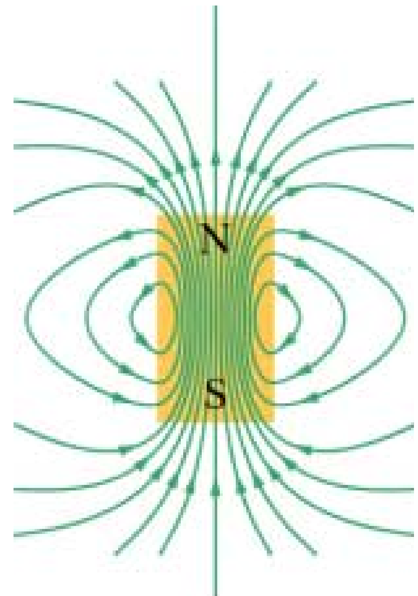
- Explanation for jumping ring
  - Real solenoid *B* field not uniform - near top of solenoid leakage of *B* field
  - As current ramps up in solenoid *B* field points up at top of solenoid, induce a current (and B_i field) to oppose *B* field from solenoid
  - Use right hand rule to find net force is upward on ring

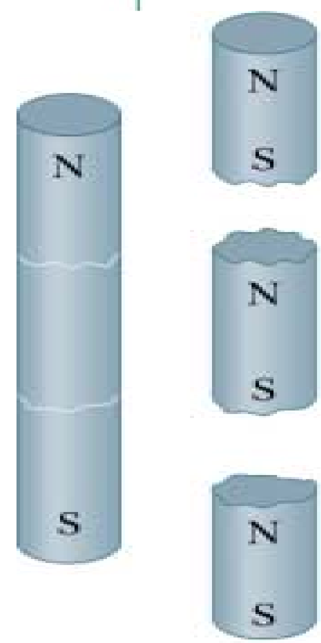


Magnetism

- What makes some materials magnetic?

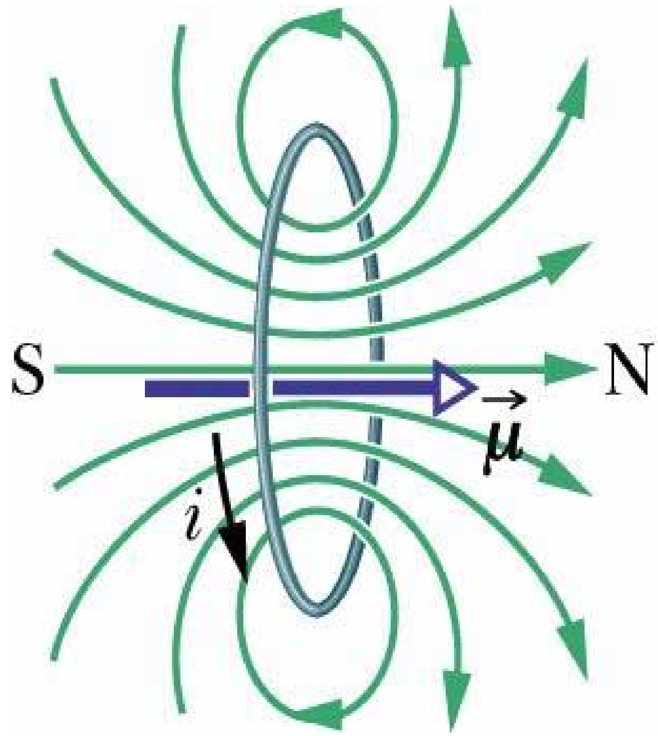
- Magnets are magnetic dipoles
  - have north and south pole
- If we break a magnet we still have magnetic dipoles
- Magnetic monopoles do not exist





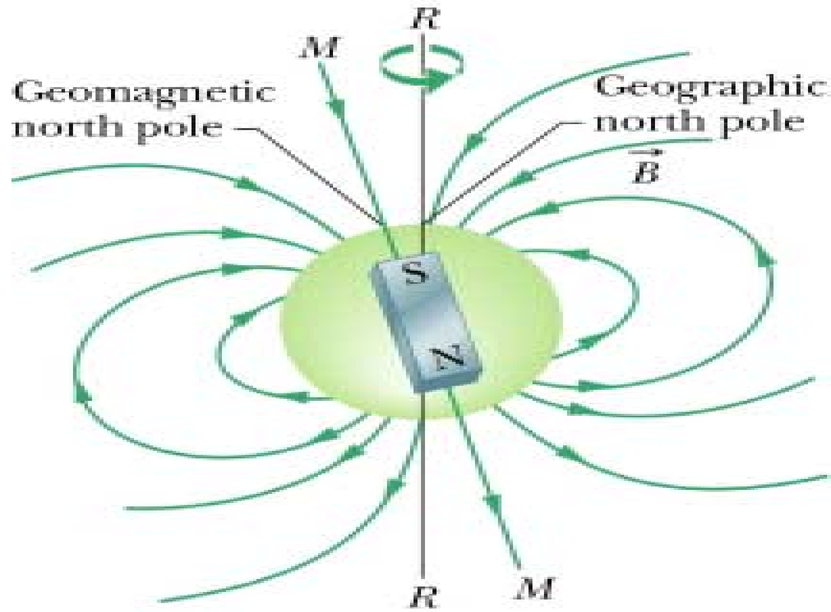
Magnetism

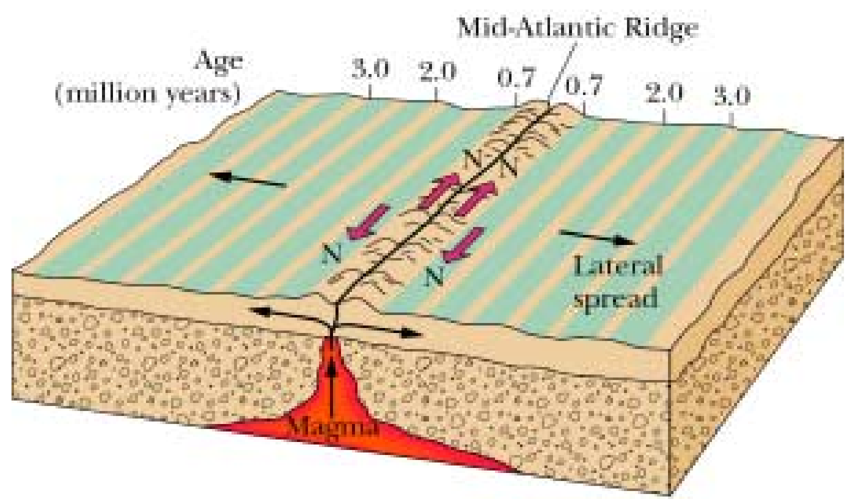
- The orbital motion of electrons around the nucleus generates magnetic dipole fields.
- In some materials these all cancel and there is no net magnetic field.
- In a permanent magnet these are all oriented in the same direction to give the resulting field.



Magnetism

- Earth acts as huge bar magnet
- Geomagnetic pole at angle of 11.5 degrees from rotational axis
- North pole is actually south pole of Earth's magnetic dipole
- Polarity has reversed about every million years





Magnetism

- Electrons moving (a current) set up B fields
- Electrons also responsible for B fields of magnetic materials

- Electrons have 2 types of magnetic dipoles:
  - Spin magnetic dipole (intrinsic to electron)
  - Orbital magnetic dipole (due to motion of electron around the nucleus)
- Full explanation needs quantum physics

Magnetism

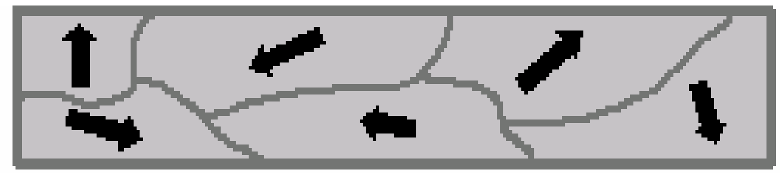
- Three types of magnetism:
- Ferromagnetism
  - Property of iron, nickel, neodymium
  - Strongest type of magnetism
- Paramagnetism
  - Exhibited by materials containing transition, rare earth or actinide elements
- Diamagnetism
  - Exhibited by all common materials but masked if other two types of magnetism are present

Ferromagnets

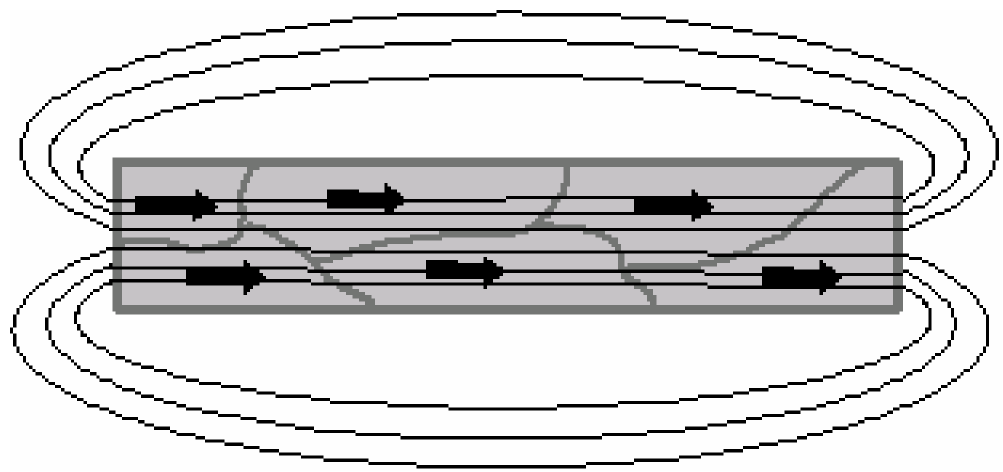
- Electron spins of one atom in the material interact with those of neighboring atoms
- Process of coupling causes alignment of magnetic dipole moments of the atoms despite thermal agitations
- This alignment gives material its permanent magnetism

Ferromagnets

- If coupling produces strong alignment of adjacent atomic dipoles, why aren't all pieces of iron strong magnets?



- As a whole the material's magnetic domains are oriented randomly and effectively cancel each other out



- If B_{ext} applied, domains align giving a strong net B field in same direction as B_{ext}
- Net B field partially exists even when B_{ext} is removed

Ferromagnets

- If we place ferromagnetic material (e.g. iron) inside a solenoid with field B_0, increase the total B field inside coil to

$$B = B_0 + B_M \qquad B_0 = \mu_0 i n$$

- B_M is magnitude of B field contributed by iron core
- B_M result of alignment of the domains
- B_M increases total B by large amount - iron core inside solenoid increases B by typically about 5000 times
- For the electromagnetic core we use “soft” iron where the magnetism is not permanent (goes away when the external field is turned off).