

Changing Magnetic Fields

- We learned: Moving charges produce magnetic field...
 - Wires, loops, coils...
 - Even true in permanent magnets
- ...and magnetic fields change motion of charges (sideways)...
 - Deflection of electron beams
 - Electric motors
 - Electric generators! (IAF)
- New phenomenon: Changing magnetic fields!
 - Can make charges move!
 - Just like generators - it doesn't matter whether the magnet moves or the wire!
 - It also doesn't matter whether the magnet moves or simply changes strength
- ...a new source for ELECTRIC fields!

Faraday's Law

- A changing magnetic field induces an electric field \mathbf{E} circling around it:
 - Larger if the field fills a larger area
 - Larger if the magnitude of the field changes more rapidly
 - We can “harness” this as a source of electric energy - if we use a coil with many windings, the same \mathbf{E} -field can be used repeatedly
 - Total voltage induced in the coil is also proportional to the number of windings in the coil
- An infinite source of energy?!?
Unfortunately not: Lenz' Law says that the effect of a changing magnetic field will oppose the change

Examples for Lenz' Law

- Generator
 - More windings - more voltage -> GOOD
 - But current flowing in coil will repel magnet -> BAD
 - You need as much mechanical energy to keep a generator running as you can extract electrical energy from it -> NO FREE LUNCH
- Fall tube, Induction brake,... (Demos)
- Jumping ring
- Sparking

Applications for Induction

- Generators (AC)
- Magnetic information storage (tape, hard disk,...)
- Electric guitar
- Electric brakes, esp. regenerative ones (hybrid cars!)
- Transformers - closing the loop (mutual induction)
 - Current in primary coil creates magnetic field
 - Changing current -> Changing magnetic field
 - Changing magnetic field induces electric field in secondary coil
 - Electric field pushes current in secondary coil
 - “Step up” and “Step down” transformers, HV power grid,...
- Inductors: Coils with changing current can induce electric field in themselves!
 - Spark plugs powered by coil and distributor