Chapter 8: Finish E & M

Brief review of Electric Field

- Quizzes on Electrostatics, Ohm's Law, and Electric Field
- Magnetism – only a few examples/demos

Chapter 9: Waves, Light, other Electromagnetic Radiation

- Waves – generalities
- Interference – important!
- Light
- Electromagnetic waves/radiation

CONCEPT CHECK 13 A proton is placed at rest in the middle of a "vacuum chamber," an enclosure that has been emptied of all matter. Consider some point X near a particular corner of the chamber. Neglect all influences other than the proton. Then at point X there is (a) an electric field; (b) an electric force; (c) a magnetic field; (d) a magnetic force; (e) none of the above, because there is nothing at point X.

CONCEPT CHECK 14 In the preceding question, suppose that the proton is made to shake back and forth. Then at point X there is (a) an electric field; (b) an electric force; (c) a magnetic field; (d) a magnetic force; (e) none of the above, because there is nothing at point X.

CONCEPT CHECK 15 Suppose that, as in Concept Check 13, a proton is placed at rest in the middle of a vacuum chamber, and also that an electron is placed at rest at point X. Then the electron (a) feels an electric force due to the electric field created by the proton; (b) feels a magnetic force due to the magnetic field created by the proton; (c) feels no electromagnetic force.

<u>Quiz # 65</u>: How does the electrostatic force between <u>two hydrogen nuclei</u> placed a certain distance apart compare with the force between <u>two helium (atomic # 2) nuclei</u> placed <u>*half*</u> as far apart?

(a) It's the same.

(b) For hydrogen twice as large as for helium.

(c) For helium four as large as for hydrogen.

(d) For helium sixteen times as large as for hydrogen.

(e) For hydrogen four times as large as for helium.

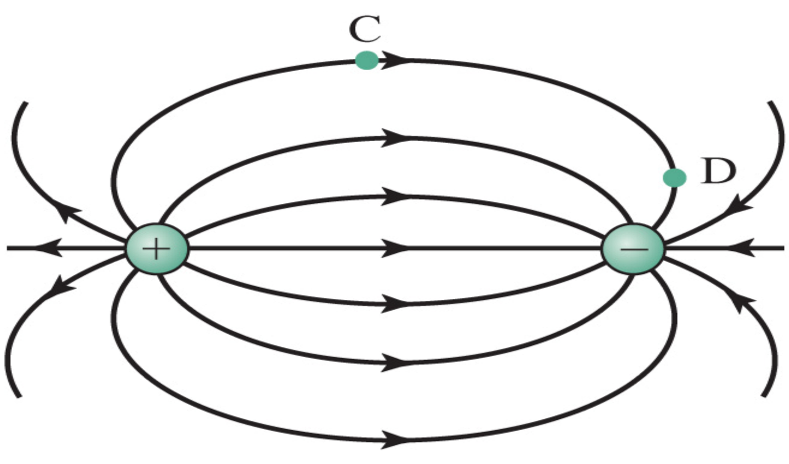
<u>Quiz # 66</u>: The direction of the force on a <u>*negative*</u> charge placed at point C would be

(a) upward

(b) downward

(c) leftward

(d) rightward



(a)

Quiz # 67: A single electron at rest sets up an electrostatic field around itself. A positron (anti-electron) sits some distance d away from the electron, feeling a certain $F_{Coulomb}$. A 2nd positron is brought on top of the electron. The magnitude of the new $F_{Coulomb}$ on the initial positron

(a) is unchanged.
(b) is zero.
(c) is twice the original $F_{coulomb}$.
(d) is half the original $F_{coulomb}$.

Quiz # 68: A light bulb, obeying Ohm's law, has a resistance R = 220 ohms and a voltage of 110 V(olts) across it. How much electrical current flows through the bulb?

(a) 0.5 A(mps) (b) 1.1 A (c) 2.2 A (d) 2.0 A

(Electro)**<u>MAGNETISM</u>**: Fascinating from early childhood on and *enormous societal impact* (electrical power generation, modern electronic data storage, your credit card, etc……)

Experiments clearly demonstrate that ***moving*** charges create an <u>additional</u> force/field, <u>separate</u> from electric, although tied together in that electric charges are required for both. In the end, different aspects of a single **electromagnetic force** – the first great unification of fundamental forces in the history of physics.

Three important points:

1) No magnetic monopoles! (in contrast to electric charges)

2) <u>Intrinsic magnetism</u> of <u>magnetic materials</u>, such as <u>permanent magnets</u> (coming from the atomic motions/”orbits” of electrons and their intrinsic “spin”), but also

3) <u>magnetism from</u> macroscopically moving charges (not within atoms), such as <u>electrical currents</u>.

In the language of ***fields:*** moving charges create magnetic fields, and feel a force due to the magnetic fields of other moving charges.

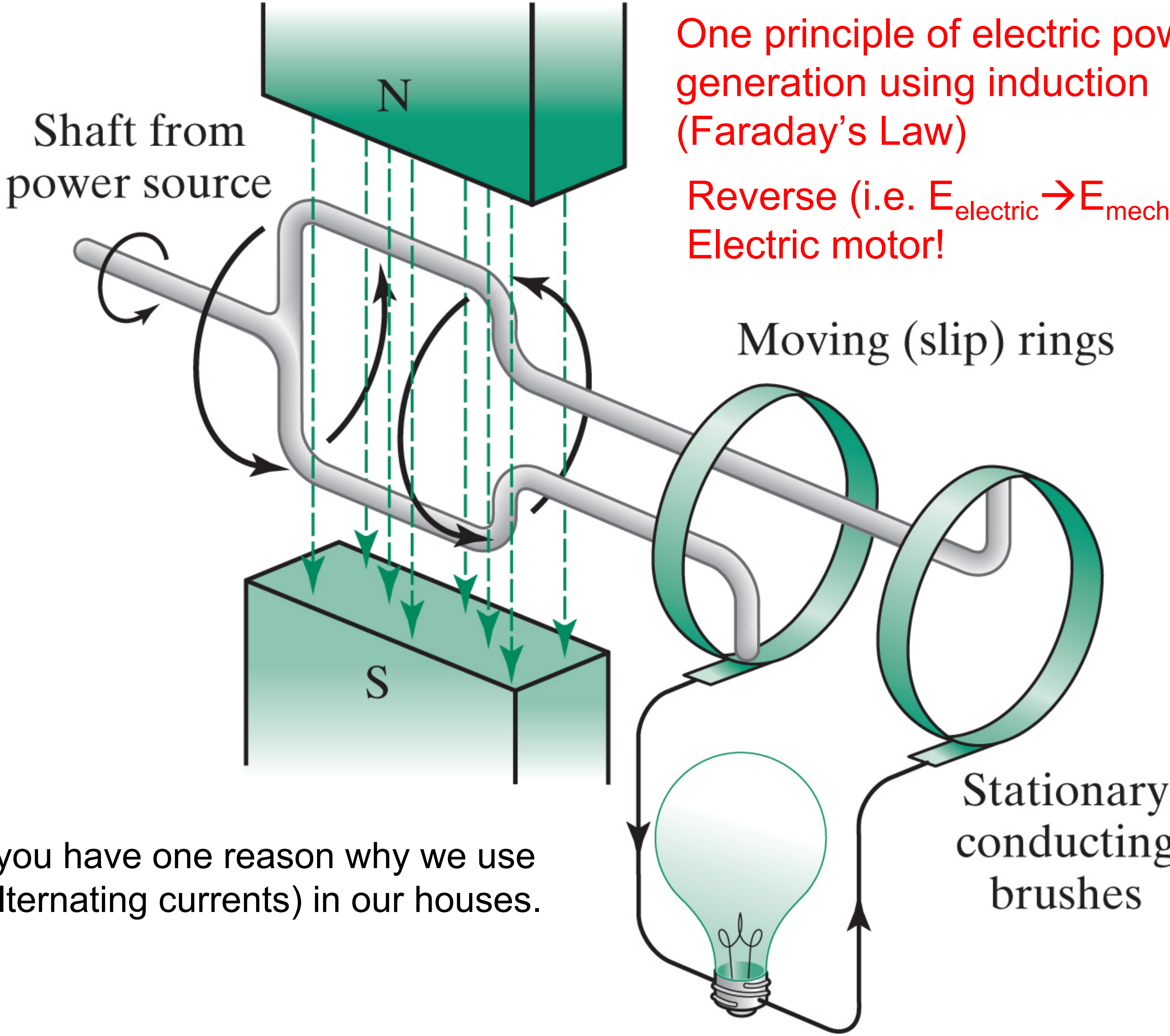
Plenty more to electromagnetism, but for us one more phenomenon shall suffice: Faraday's Law, a.k.a. *electromagnetic induction*

Whenever the magnetic field through a wire loop changes (say, by moving either), an electric current is induced in said loop, and for as long as the change continues. *Demos!*

In other words: A changing magnetic field creates an electric field. And, it turns out, a changing electric field creates a magnetic field. (→ formal unification of e&m via the famous Maxwell equations)

One principle of electric power generation using induction (Faraday's Law)

Reverse (i.e. $E_{electric} \rightarrow E_{mechanical}$)? Electric motor!



Here you have one reason why we use AC (alternating currents) in our houses.

WAVES: Familiar to everyone, but let's be careful about what is a true wave in physics.

Example: a breaker at the beach is *not* a real wave!

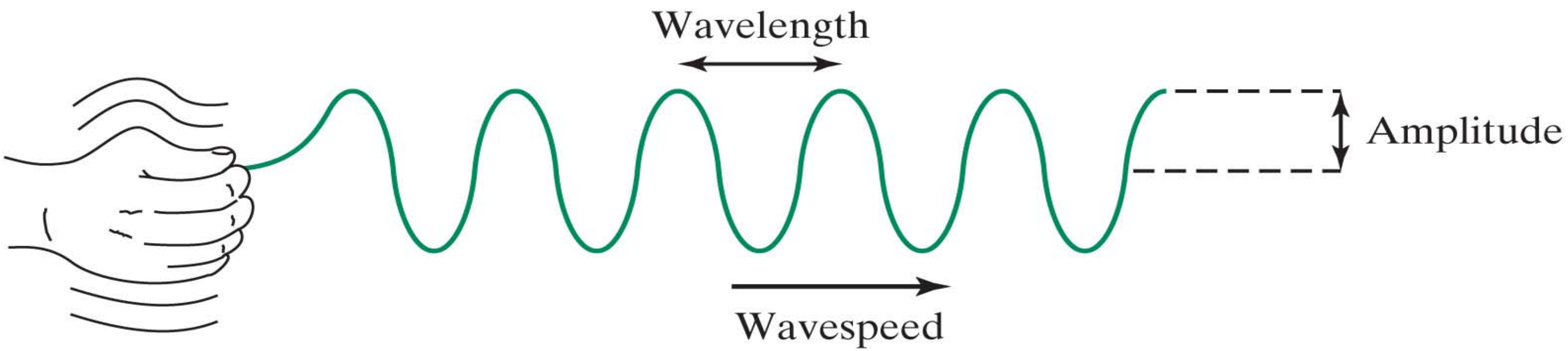
Best to start with demos……

Note the connection with ***oscillations/vibrations.***

What is (not) moving along? What is being transferred?

→ Clearly different from particle motion!

In Physics: A wave is a disturbance (or dislocation or shape or configuration) that travels through a medium, with *no* transfer of matter but with energy transfer.



Terminology for proper wave description:

- amplitude (= maximum swing; remember: wave has + and −)
- frequency f (measured in Hertz, Hz = second^{-1})
- wavelength λ (distance crest to crest or trough to trough)
- wavespeeds (typically $s = f \times \lambda$, depends upon medium, i.e. type of wave – water wave different from sound, sound in air different from sound in water, etc.)

Light = e&m wave – why do we see lightning before we hear it?

C.E. 1 & 2: No (water itself moves); Yes (wheat is the medium)

Quiz # 69: Which of the following are true waves?

(a) The wave a surfer rides on & a row of falling dominoes

(b) Ripples on water (from a rock dropped into the water) & falling dominoes

(c) Row of falling dominoes & a mountain stream flowing downhill

(d) Ripples on water as in (b) & a large breaker at the beach

Problems 7 & 8:

Quiz # 70: Radio waves travel at the speed of light, $c = 3 \times 10^8$ m/s. The wavelength λ of an FM radio wave with a frequency of $f = 100$ MHz (1 MHz = 1 MegaHz = 10^6 Hz) is

(a) 300 m
(b) 3 m
(c) 1/3 m
(d) 10 m
(e) 1 m