Chapter 32: Electromagnetic Waves

Faraday introduced the idea of electric and magnetic fields.

Maxwell unified all the phenomena of electricity and magnetism.

Maxwell showed that all electric and magnetic phenomena can be described using only four equations known as **Maxwell's equations**.

Waves of electromagnetic fields can travel through space.

Light is one kind of electromagnetic wave. Optics is a branch of electromagnetism.

Communication: wireless telegraph, radio, TV, cell phones, remote control.

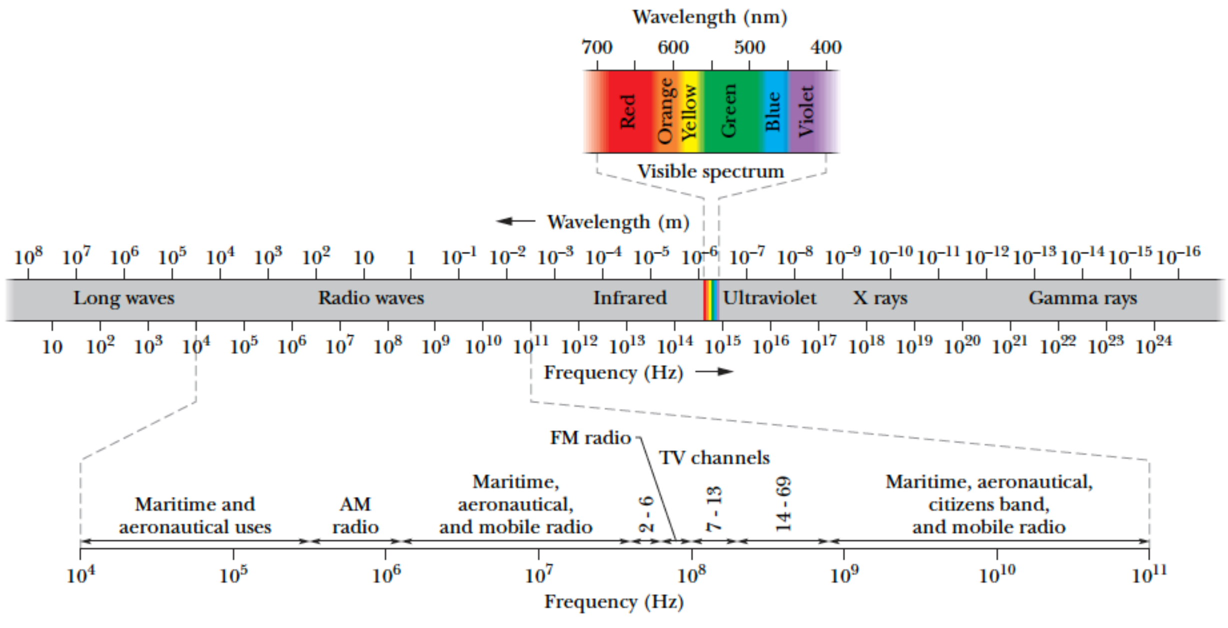


Fig. 33-1 The electromagnetic spectrum.

Maxwell's Equations

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\varepsilon_0}$$

$$\nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

$$\nabla \times \mathbf{B} = \mu_0 \mathbf{j} + \frac{1}{c^2}\frac{\partial \mathbf{E}}{\partial t}$$

Faraday: An electric field is produced by a changing magnetic field

Maxwell: An magnetic field is produced by an electric current or by a changing electric field

Maxwell argued that if a changing magnetic field produces an electric field, as given by Faraday's law, then the reverse might be true a well: a changing electric field will produce a magnetic field.

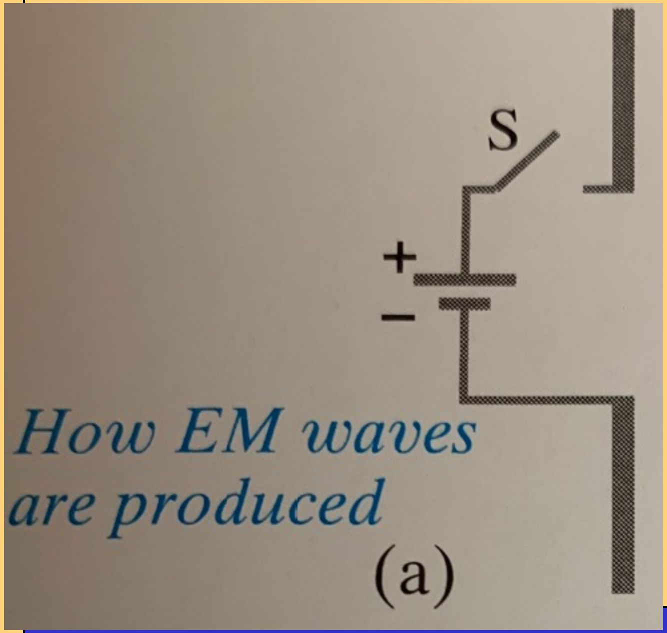
Production of Electromagnetic Waves

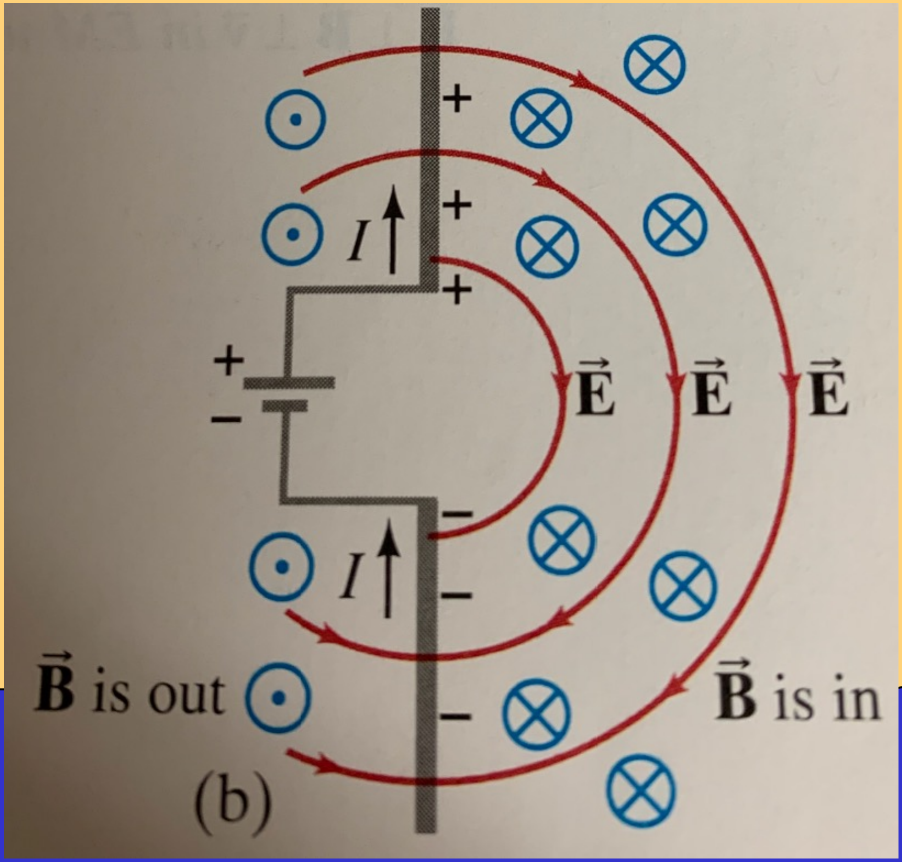
Consider two conducting rods that will serve as an “antenna”.
As the switch is closed, the upper rod becomes positively charged and the lower rod becomes negatively charged.

Electric field lines are formed.

While the charges are flowing, a magnetic field is produced.

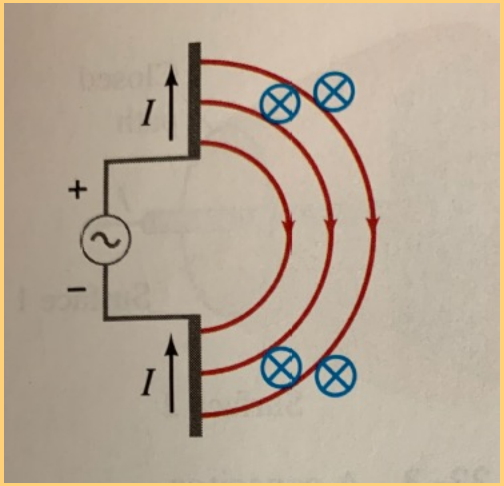
When the switch is closed, the fields quickly appears nearby, but it takes time for them to reach distant points.

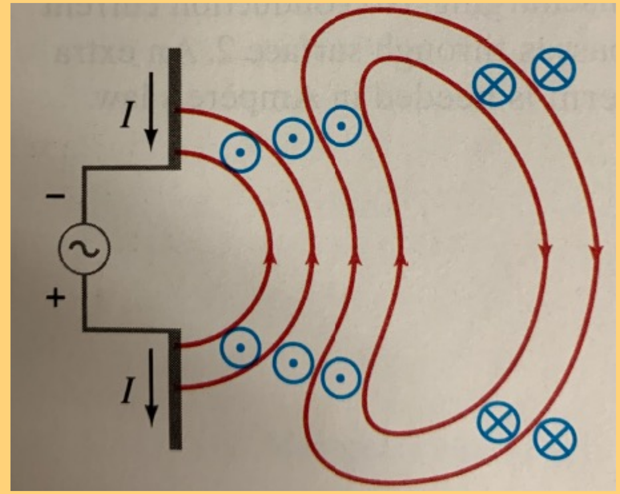




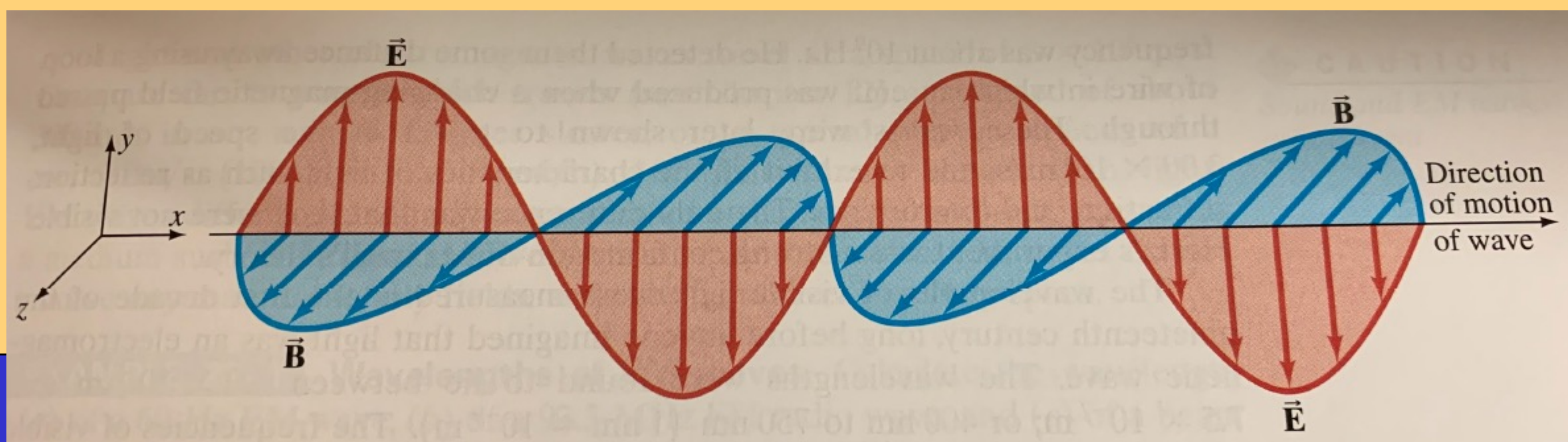
Production of Electromagnetic Waves

But now suppose we have an AC generator

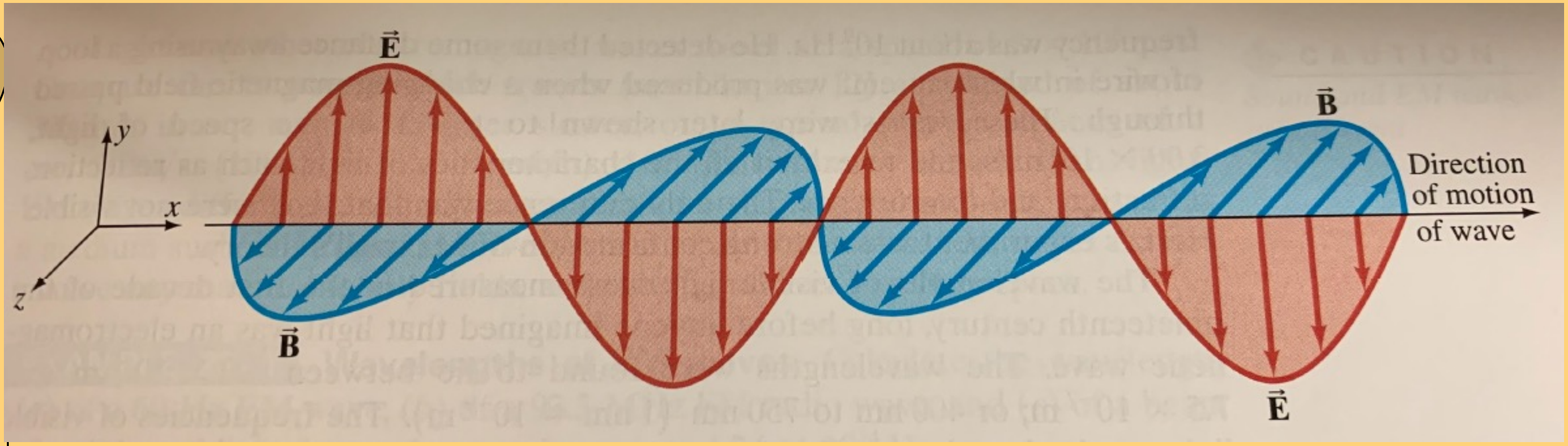




Fields far from the antenna, which we refer to as the **radiation field**.



Electromagnetic Wave



Remember that both electric and magnetic fields store energy.
The energy carried by the electromagnetic wave is proportional to E^2 and B^2

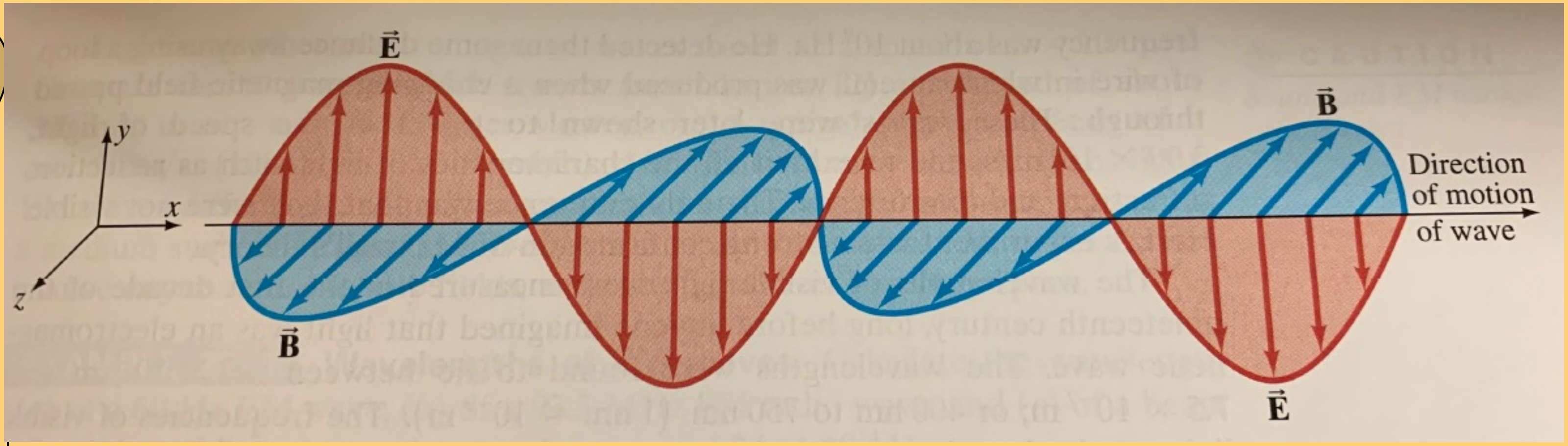
The electric and magnetic fields at any point are perpendicular to each other and to the direction of wave travel.
The electric and magnetic fields are in phase.

The electromagnetic waves are transverse waves.

Accelerating electric charges give rise to electromagnetic waves.

Electromagnetic waves can travel in empty space

Speed of Electromagnetic Wave



$$v = c = \frac{E}{B}$$

$$c = \frac{1}{\sqrt{\epsilon_0 \mu_o}}$$

$$c = 3.00 \times 10^8 m/s$$

$$c = \lambda f$$

Problems

Ex. Calculate the wavelength (a) of a 60-Hz EM wave, (b) of a 93.3 MHz FM radio wave, and (c) of a beam of visible red light from a laser at frequency 4.74×10^{14} Hz

(a) 5.0×10^{6} m
(b) 3.22 m
(c) 6.33×10^{-7} m = 633 nm

Ex. When you speak on the telephone from Los Angeles to a friend in New York some 4000 km away, how long does it take the signal carrying your voice to travel that distance?
[The signal is carried on a telephone wire or in the air via satellite. In either case it is an EM. Electronics as well as wire or cable slow things down, but as a rough estimate we can take the speed to be $c = 3.0 \times 10^{8}$ m/s.]

1.3×10^{-2} s