Phys102 Lecture 22
Electromagnetic Waves

Key Points

- Time-varying magnetic field can induce electric field.
- Time-varying electric field can induce magnetic field.
- Production of electromagnetic waves.

References

SFU Ed: 31-1,2,3.

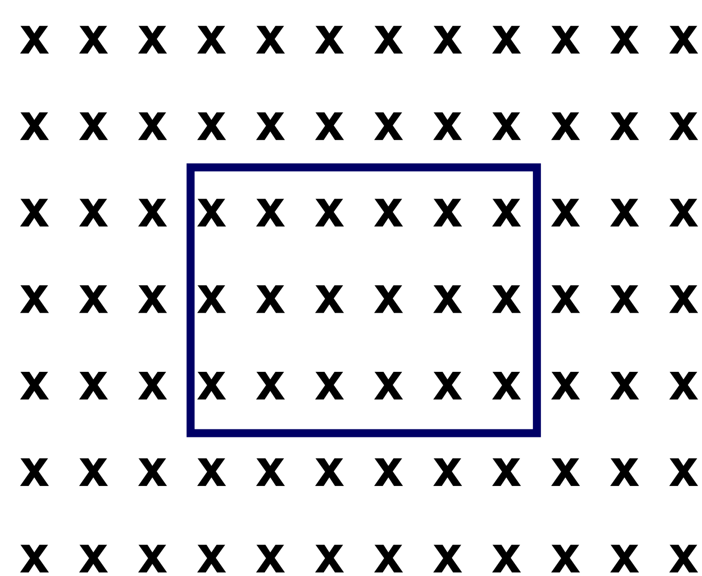
6th Ed: 22-1,2,3.

Faraday's Law

For a fixed loop in a changing magnetic field **B**(t):

$$\varepsilon_{emf} = -\frac{d\Phi_B}{dt} = -A\frac{dB}{dt}$$

$$\varepsilon_{emf} = \sum \vec{E} \cdot \Delta\vec{l}$$



A changing magnetic field can induce an electric field.

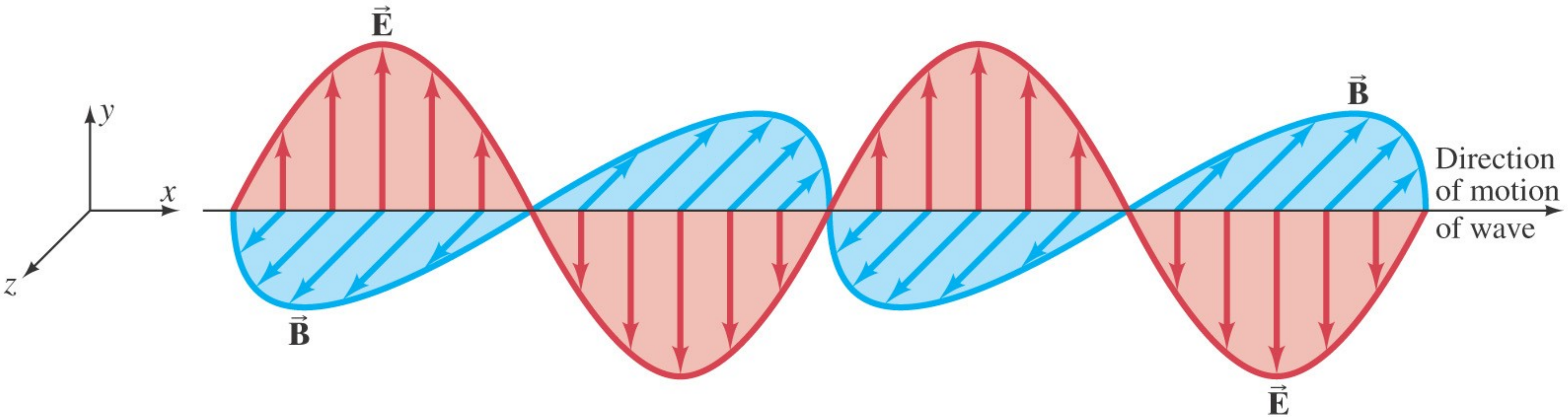
Maxwell's Idea

A changing electric field can also induce a magnetic field.

Then, the electric field and magnetic field can be induced from each other, and propagate into free space as electromagnetic waves.

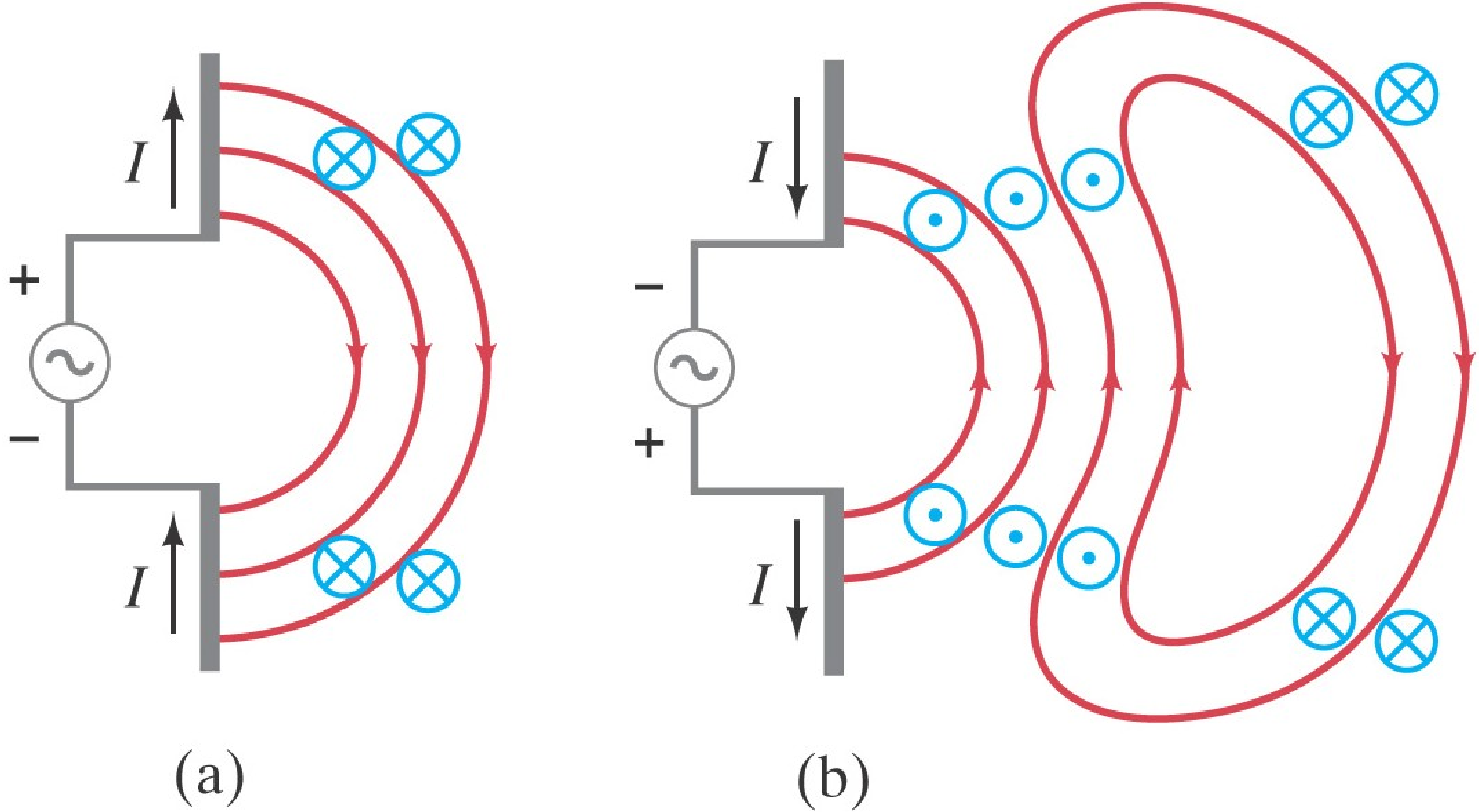
Electromagnetic Waves

In an electromagnetic wave, the electric and magnetic fields are perpendicular to each other, and to the direction of propagation (transverse wave).



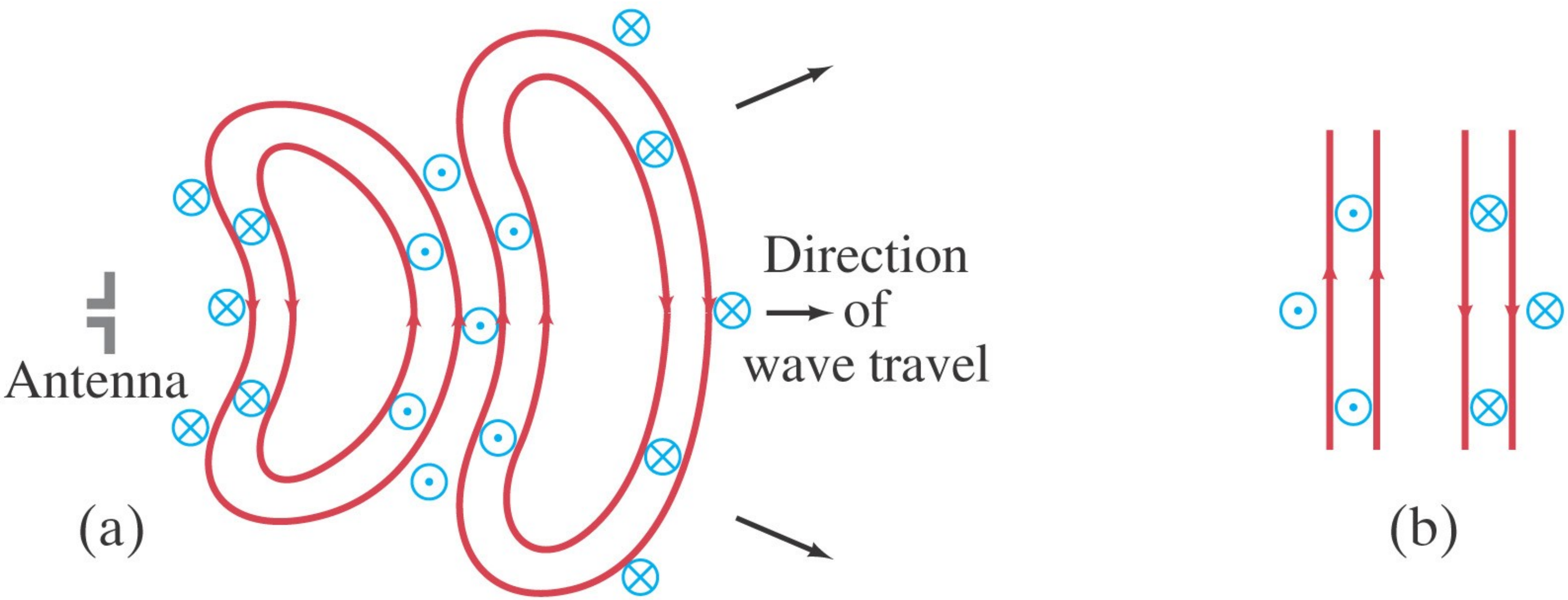
22.2 Production of Electromagnetic Waves

Oscillating charges will produce electromagnetic waves:



22.2 Production of Electromagnetic Waves

Far from the source, the waves are plane waves:



The Speed of Electromagnetic Waves

When Maxwell calculated the speed of propagation of electromagnetic waves, he found:

$$c = \frac{1}{\sqrt{\epsilon_0 \mu_0}} = \frac{1}{\sqrt{(8.85 \times 10^{-12}\,\mathrm{C^2/N \cdot m^2})(4\pi \times 10^{-7}\,\mathrm{N \cdot s^2/C^2})}}$$

$$= 3.00 \times 10^8\,\mathrm{m/s}$$

This is the speed of light in a vacuum.

Light as an Electromagnetic Wave and the Electromagnetic Spectrum

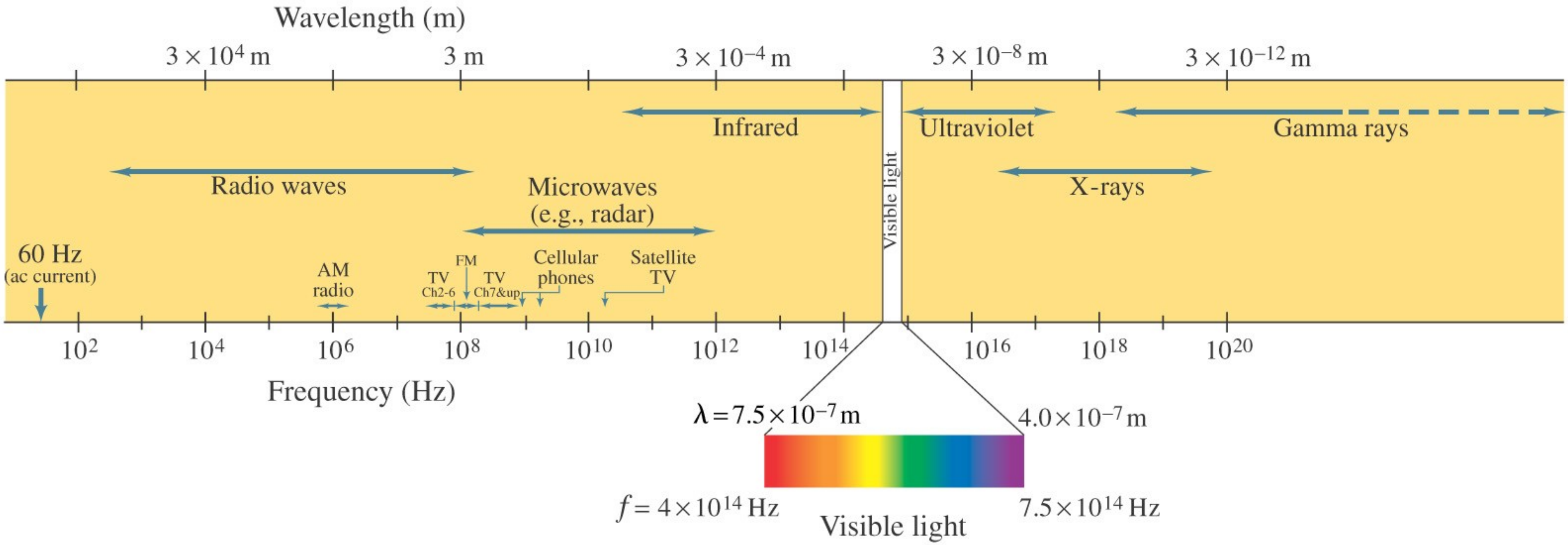
Light was known to be a wave; after producing electromagnetic waves of other frequencies, it was known to be an electromagnetic wave as well.

The frequency of an electromagnetic wave is related to its wavelength:

$$c = \lambda f \qquad \textbf{(22-4)}$$

Light as an Electromagnetic Wave and the Electromagnetic Spectrum

Electromagnetic waves can have any wavelength; we have given different names to different parts of the wavelength spectrum.



Example 31-1: Wavelengths of EM waves.

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.

Example 31-2: Cell phone antenna.

The antenna of a cell phone is often ¼ wavelength long. A particular cell phone has an 8.5-cm-long straight rod for its antenna. Estimate the operating frequency of this phone.