PHY385-H1F Introductory Optics

Class 4 – Outline: Sec. 3.3, 3.4

- Finishing Spherical Waves
- Poynting Vector
- Irradiance
- Photons
- Radiation Pressure and Momentum
- Electric Dipole Radiation

Brightness

- When light is shining in your eyes, sometimes you might squint your eyes due to too much "brightness". Which property of the light incident on your eye listed below is most closely related to "brightness"?

1. Intensity [Watts per steradian]
2. Irradiance [Watts per m^2]
3. Power [Watts]
4. Radiant Energy Density [Joules per m^3]

Poynting Vector

- John Poynting
- 1884 published a paper describing a vector which is "pointing" in the direction of energy flow of an electromagnetic wave!
- This was 20 years after Maxwell first described electromagnetic waves.

John Henry Poynting

Poynting Vector

$$\vec{S} = \vec{E} \times \vec{H}$$

or

$$\vec{S} = \varepsilon_0 c^2 \left(\vec{E} \times \vec{B} \right)$$

Units: W/m²

In a propagating sinusoidal electromagnetic plane wave of a fixed frequency, the Poynting vector oscillates, always pointing in the direction of propagation. The time-averaged magnitude of the Poynting vector is:

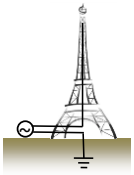
$$\langle S \rangle = \frac{1}{2\mu_0 c} E_0^2 = \frac{\varepsilon_0 c}{2} E_0^2$$

where E_0 is the amplitude of the electric field oscillations.

Discussion Question

Consider a big transmitting tower, which is aligned with the vertical +*z* axis. Choose coordinates so that +*z* is up, +*x* is East, and +*y* is North.
An AC generator is connected to the tower, sending a current up and down its length.
If you are in a car 1 km East of the tower:
Along which direction will the **electric** field oscillate near your car?

1. ±*x*
2. ±*y*
3. ±*z*
4. I'm not sure…



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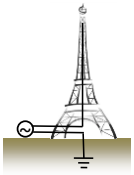
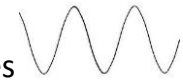
An AC generator is connected to the tower, sending a current up and down its length.
If you are in a car 1 km East of the tower:
Along which direction will the **magnetic** field oscillate near your car?

1. ±*x*
2. ±*y*
3. ±*z*
4. I'm not sure…



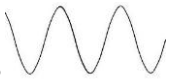
Harmonic Waves



- Which of these properties of a harmonic wave is determined by the angular frequency ω ?

1. Colour
2. Wavelength
3. Energy of individual photons
4. Momentum of individual photons
5. All of the above

Harmonic Waves



- Which of these properties of a harmonic wave is determined by the amplitude E_0 ?

1. Brightness
2. Number of photons per second per m^2 cross-section
3. Irradiance
4. Radiation Pressure
5. All of the above