Electricity and Magnetism

- Today
  - More on wave phenomena
    - Polarization
    - Superposition
      - Standing waves
      - Interference (proof that light is a wave)
    - Scattering of light (why is the sky blue)

Poynting Vector

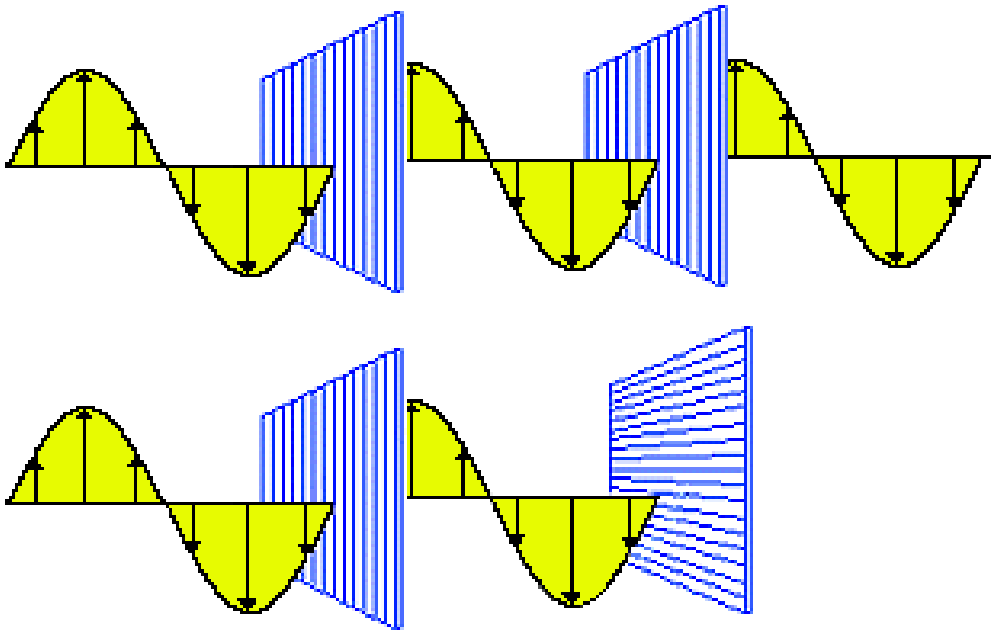
- Not a typo: John Henry Poynting (1852-1914)
- Wave: Direction + Magnitude
- Summarize using vector: Poynting Vector

$$\vec{S} = 1/\mu_0 \, \vec{E} \times \vec{B}$$

Direction: $\vec{S} \perp \vec{B}$, $\vec{S} \perp \vec{E}$

Magnitude: $|S| = 1/\mu_0 \, EB$
Power/Unit Area

Polarization



Polarization

- Polarization:
  - Oscillation of fields has well defined direction
- Polarization only possible for transverse waves
- In general, light (sun, lightbulb) is unpolarized
  - Superposition of waves with many different orientations
- Can be polarized using e.g. polarizer foils

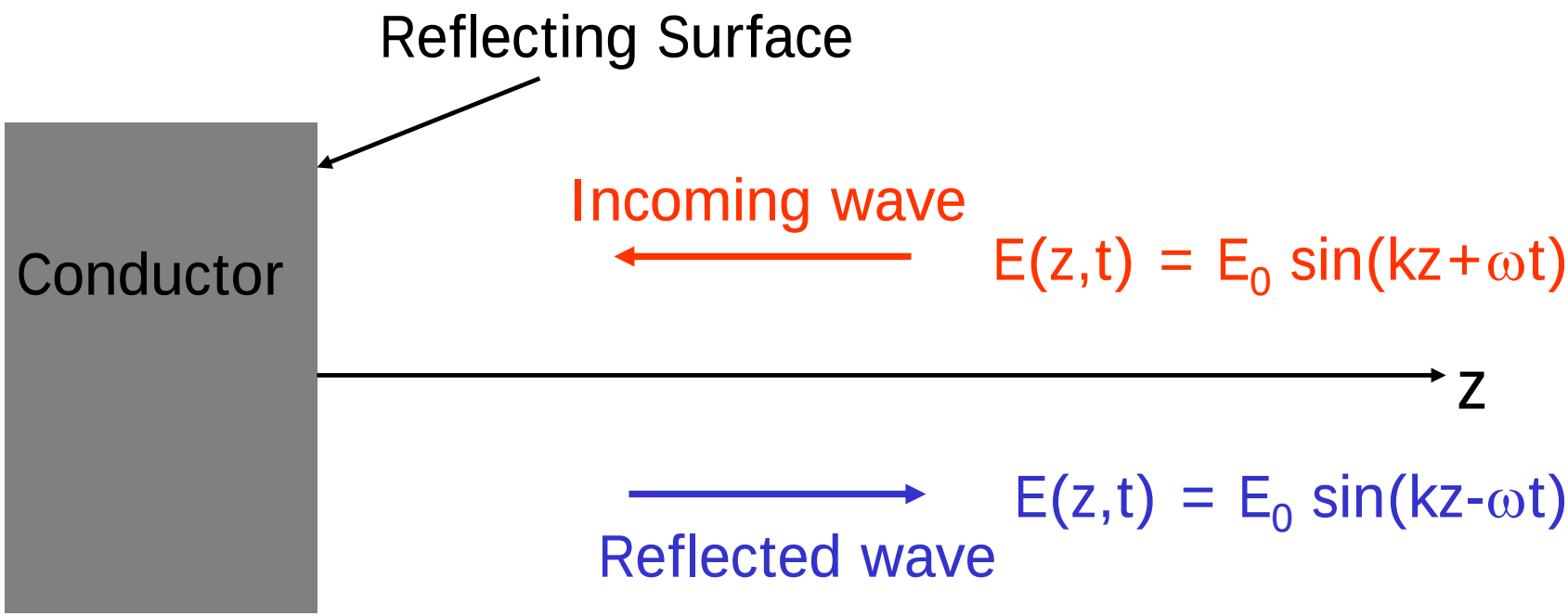
Superposition of Waves

- We saw many examples of superposition principle
- Not only true for static fields, but also for time-dependent fields

  -> Superposition of waves

Superposition of Waves

- Example: Standing waves

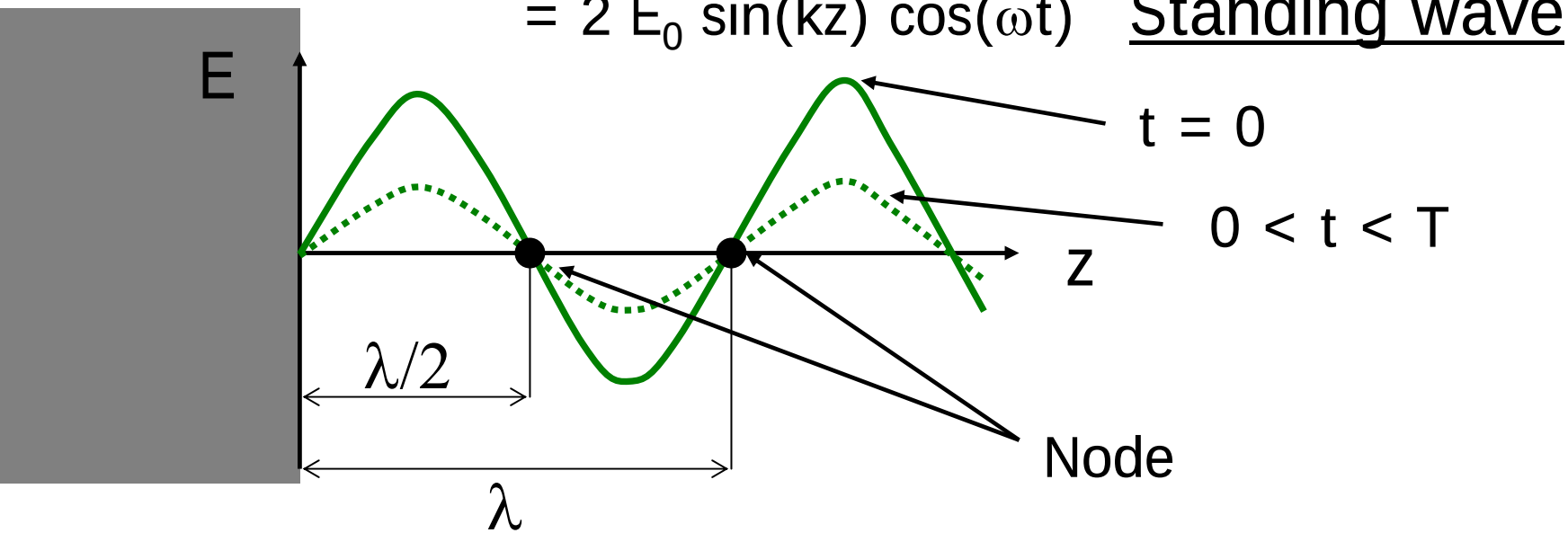


Superposition of Waves

Superposition of Incoming wave and Reflected wave

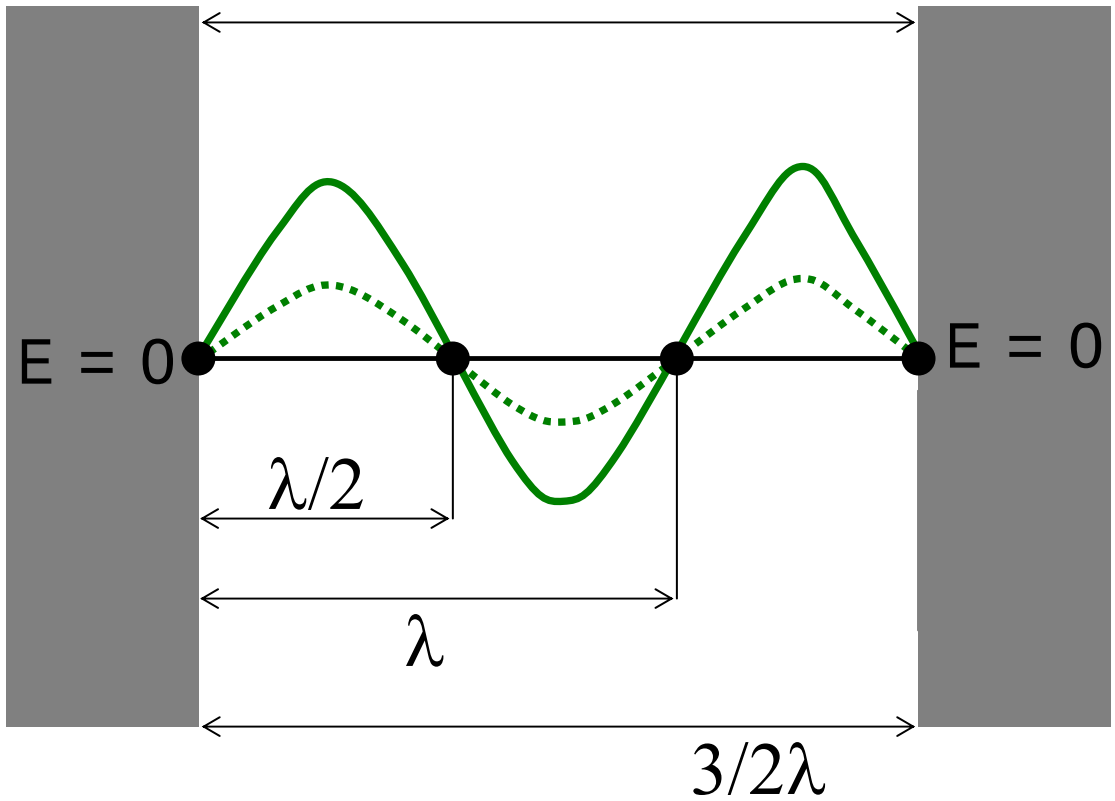
$$E_{total} = E_0 \sin(kz+\omega t) + E_0 \sin(kz+\omega t)$$

$$= 2 E_0 \sin(kz) \cos(\omega t)$$ Standing wave



Standing Wave

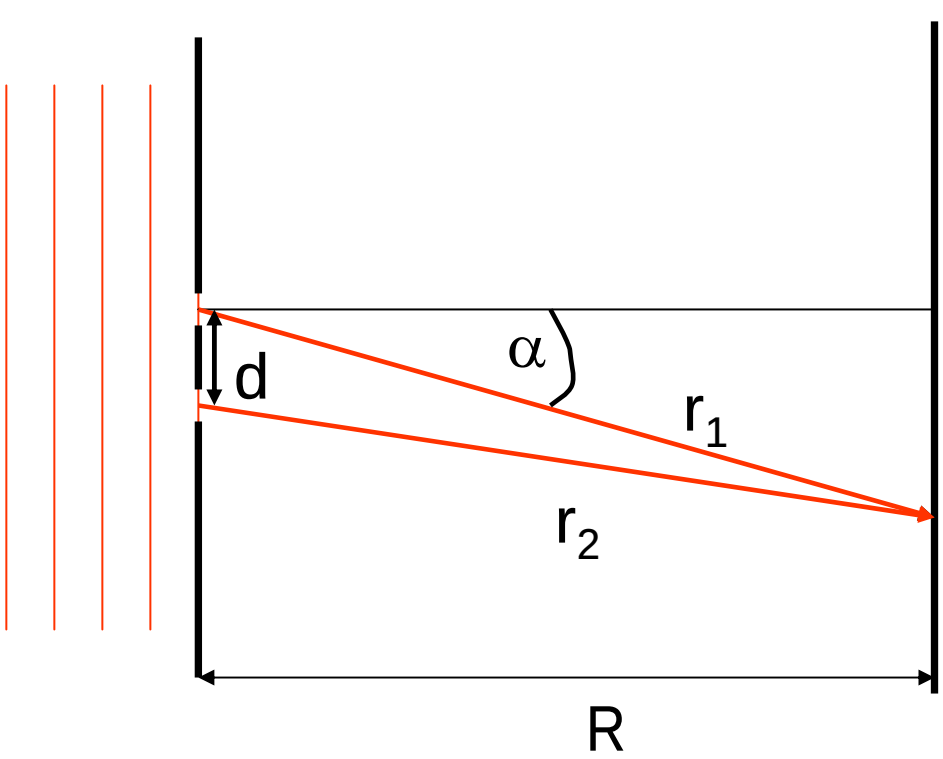
$L = M\,\lambda/2;\ M = 1,2,3\ldots$



Microwave oven:

$\lambda \sim 10\text{cm}$

Double Slit Experiment



Max. if "constructive interference"

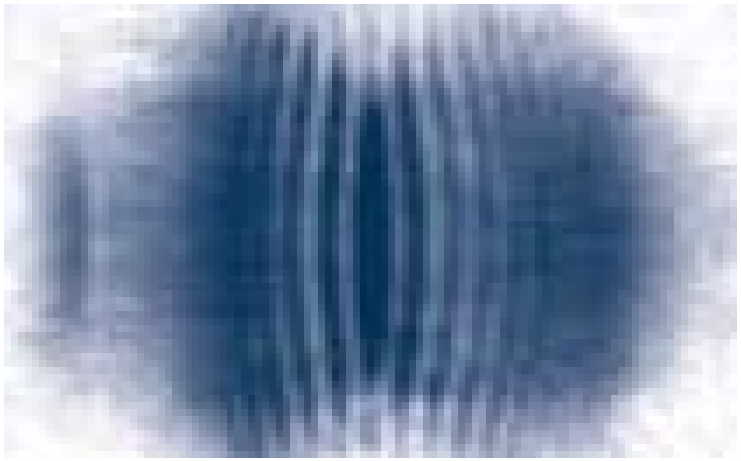
$kr_1 - \omega t = kr_2 - \omega t + M\,2\pi$

$E_{tot} = E_0 \sin(kr_1 - \omega t) + E_0 \sin(kr_2 - \omega t)$

$y_{Max} = M\,\lambda/d\,R$

$y_{Min} = (M+1/2)\,\lambda/d\,R$

Interference with *Matter*



Interference can also happen for “matter waves”

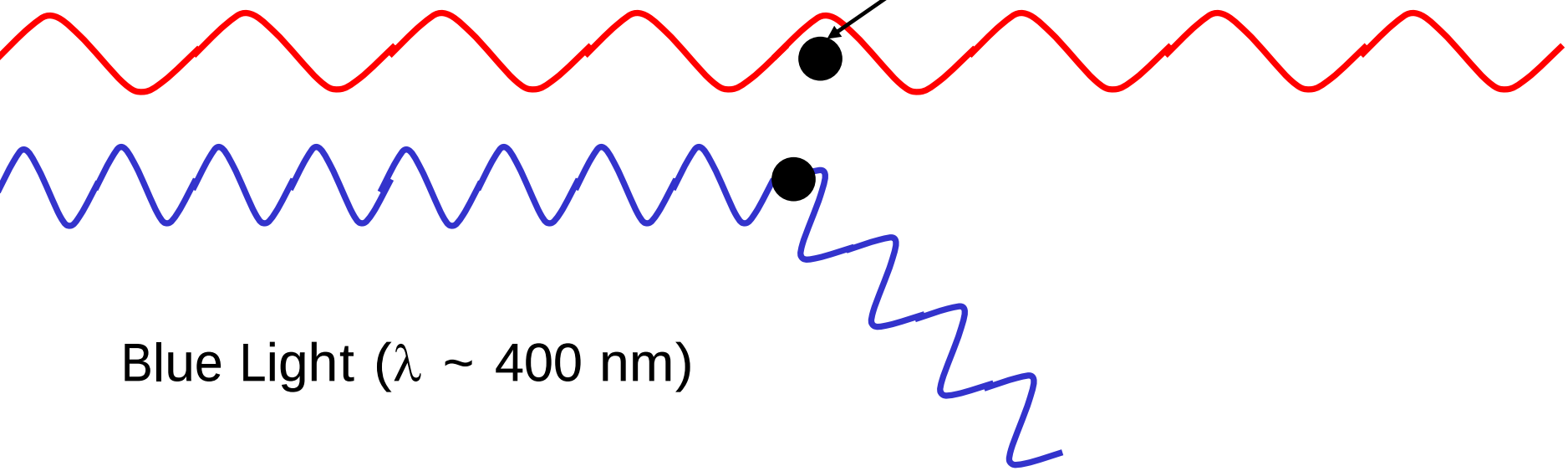
Bose-Einstein condensate of atoms (Ketterle et al, Nobel Prize ’01)

Scattering of Light

Why is the sky blue during the day and red at sunset?

Red Light (λ ~ 700 nm)

Molecules, dust (size << λ)



Blue Light (λ ~ 400 nm)

Lord Rayleigh: Scattering probability ~ $1/\lambda^4$

scattering (blue)/scattering(red): -> $700^4/400^4$ ~ 10