Module 30: Generating EM Waves, Dipole Radiation, Polarization

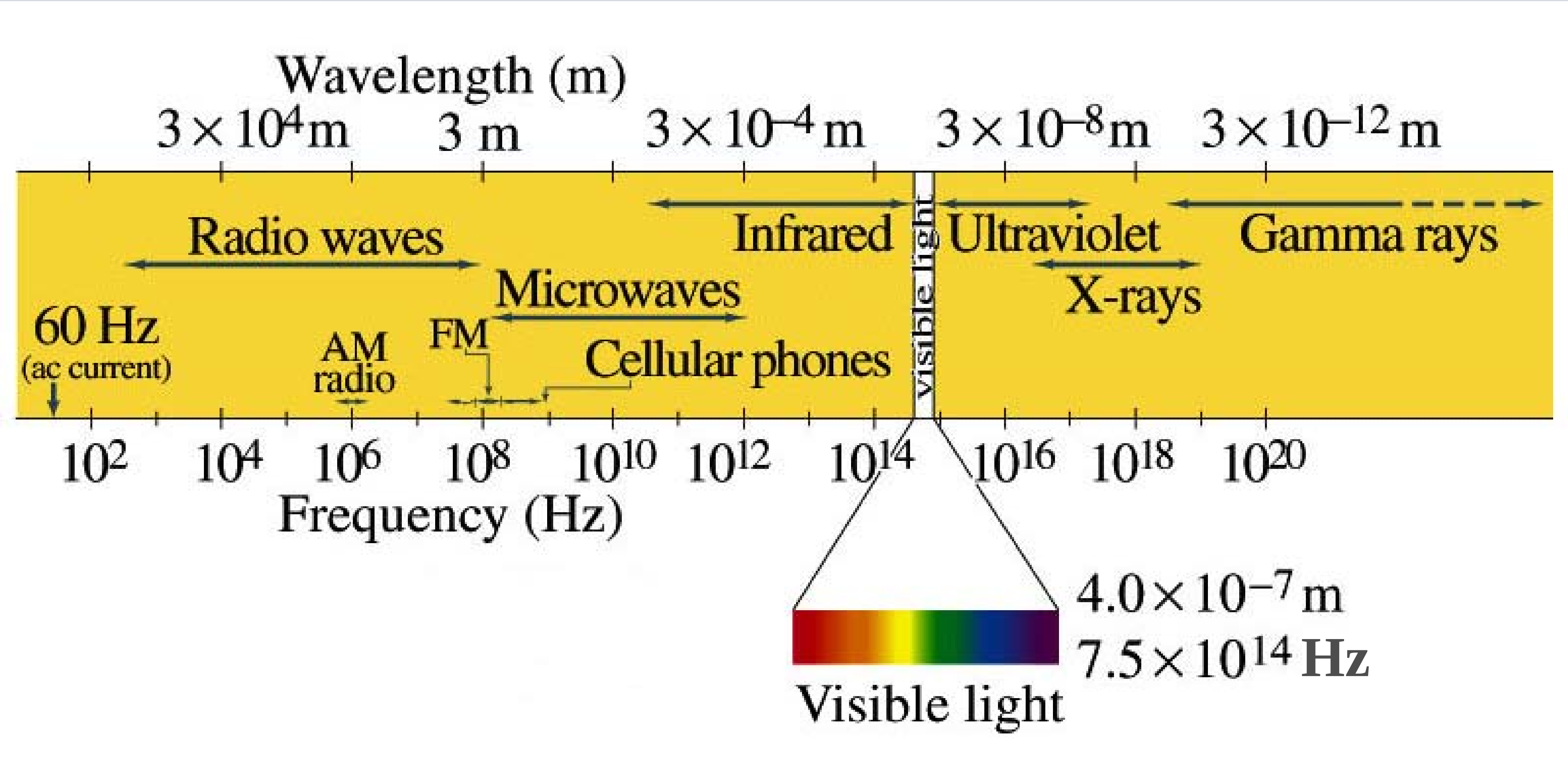
Module 30: Outline

Generating EM Waves

Electric Dipole EM Waves

Experiment 9: Microwaves

Electromagnetic Waves



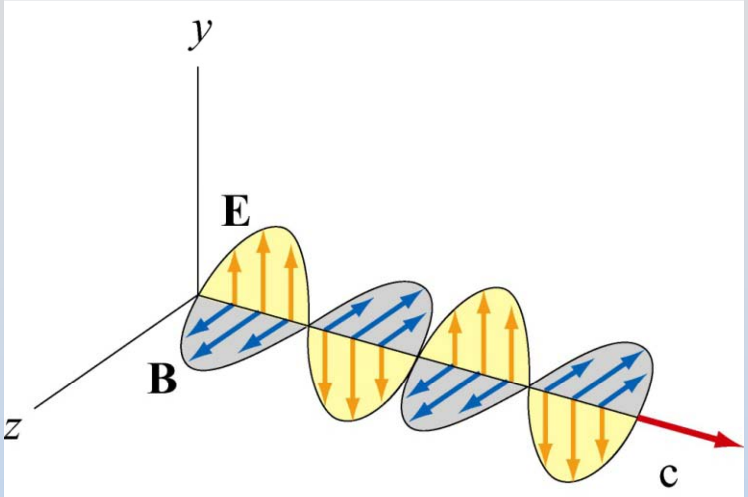
Remember: $\lambda f = c$

Summary: Traveling Electromagnetic Waves

Properties of EM Waves

Travel (through vacuum) with speed of light

$$v = c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = 3 \times 10^8 \frac{m}{s}$$



At every point in the wave and any instant of time, E and B are in phase with one another, with

$$\frac{E}{B} = \frac{E_0}{B_0} = c$$

E and B fields perpendicular to one another, and to the direction of propagation (they are **transverse**):

$$\text{Direction of propagation} = \text{Direction of } \mathbf{E} \times \mathbf{B}$$

Traveling E & B Waves

Wavelength: λ

Frequency : f

$$\vec{\mathbf{E}} = \hat{\mathbf{E}} E_0 \sin(\vec{\mathbf{k}} \cdot \vec{\mathbf{r}} - \omega t)$$

Wave Number: $k = \dfrac{2\pi}{\lambda}$

Angular Freq.: $\omega = 2\pi f$

Period: $T = \dfrac{1}{f} = \dfrac{2\pi}{\omega}$

Speed: $v = \dfrac{\omega}{k} = \lambda f$

Direction: $+\hat{\mathbf{k}} = \hat{\mathbf{E}} \times \hat{\mathbf{B}}$

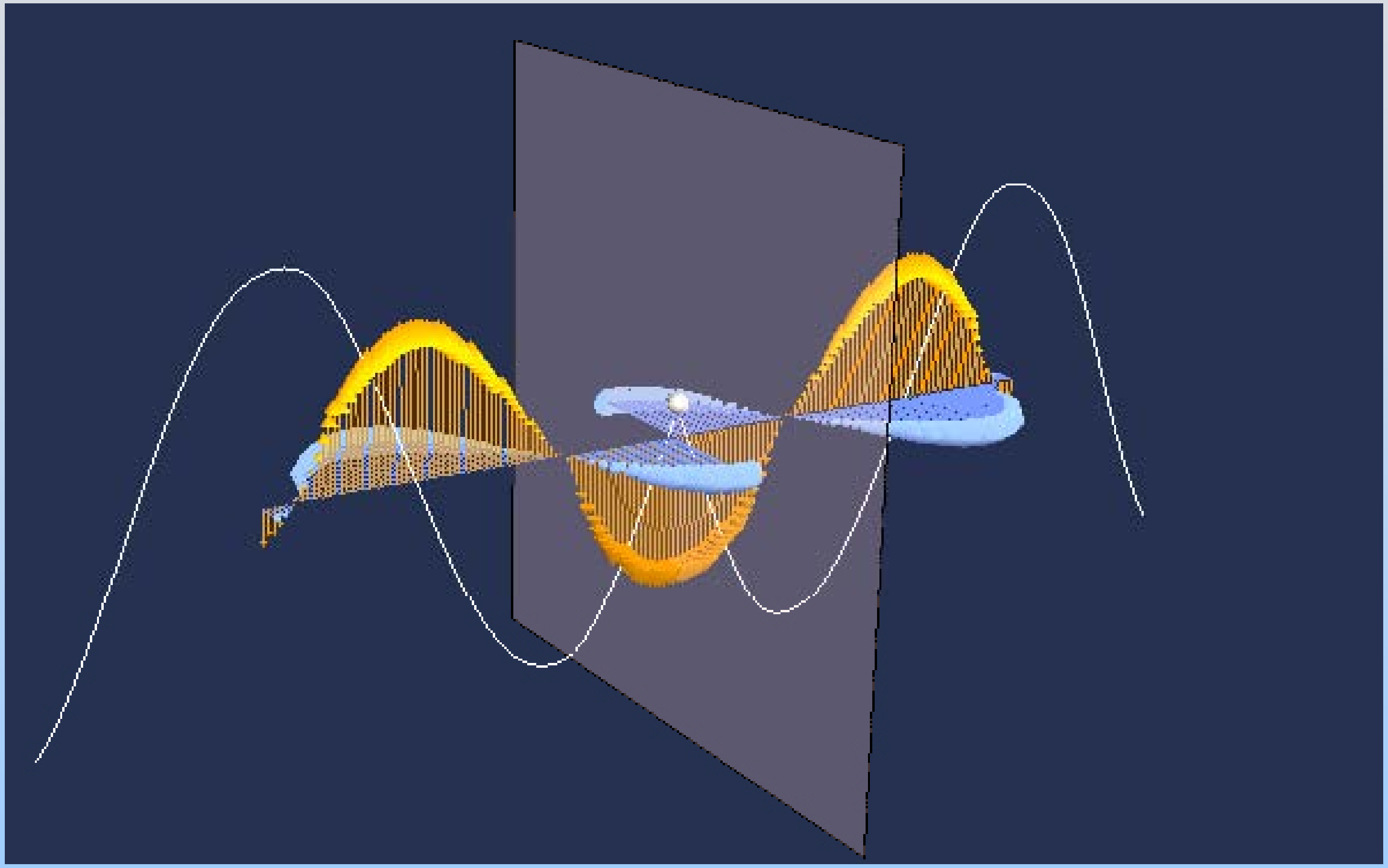
$$\frac{E}{B} = \frac{E_0}{B_0} = v$$

In vacuum...

$$= c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = 3 \times 10^8 \frac{m}{s}$$

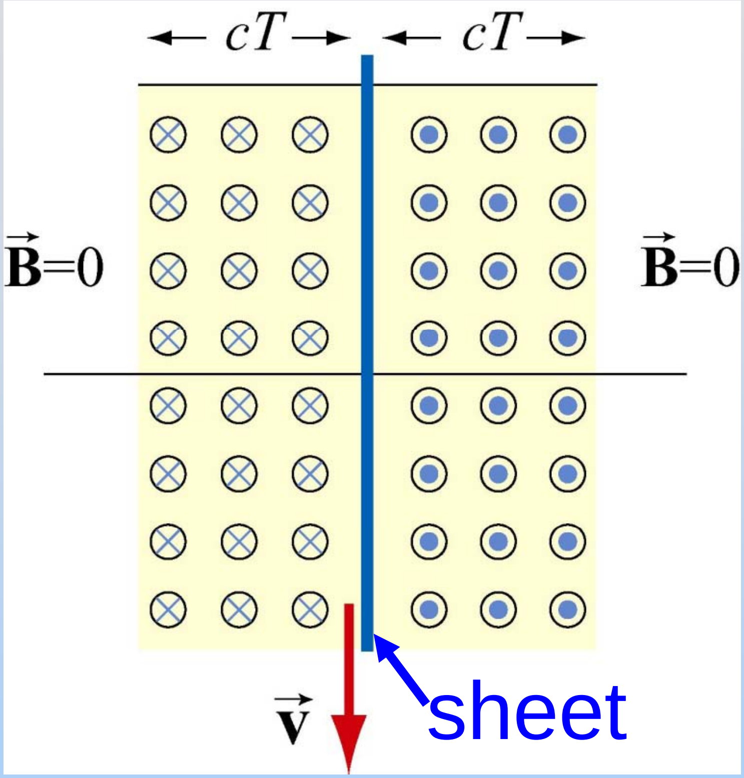
Generating Plane Electromagnetic Radiation

Shake a Sheet of Charge



Link to application

Problem: B Field Generation



Sheet (blue) has uniform charge density σ

Starting time *T* ago pulled down at velocity *v*

1) What is B field?

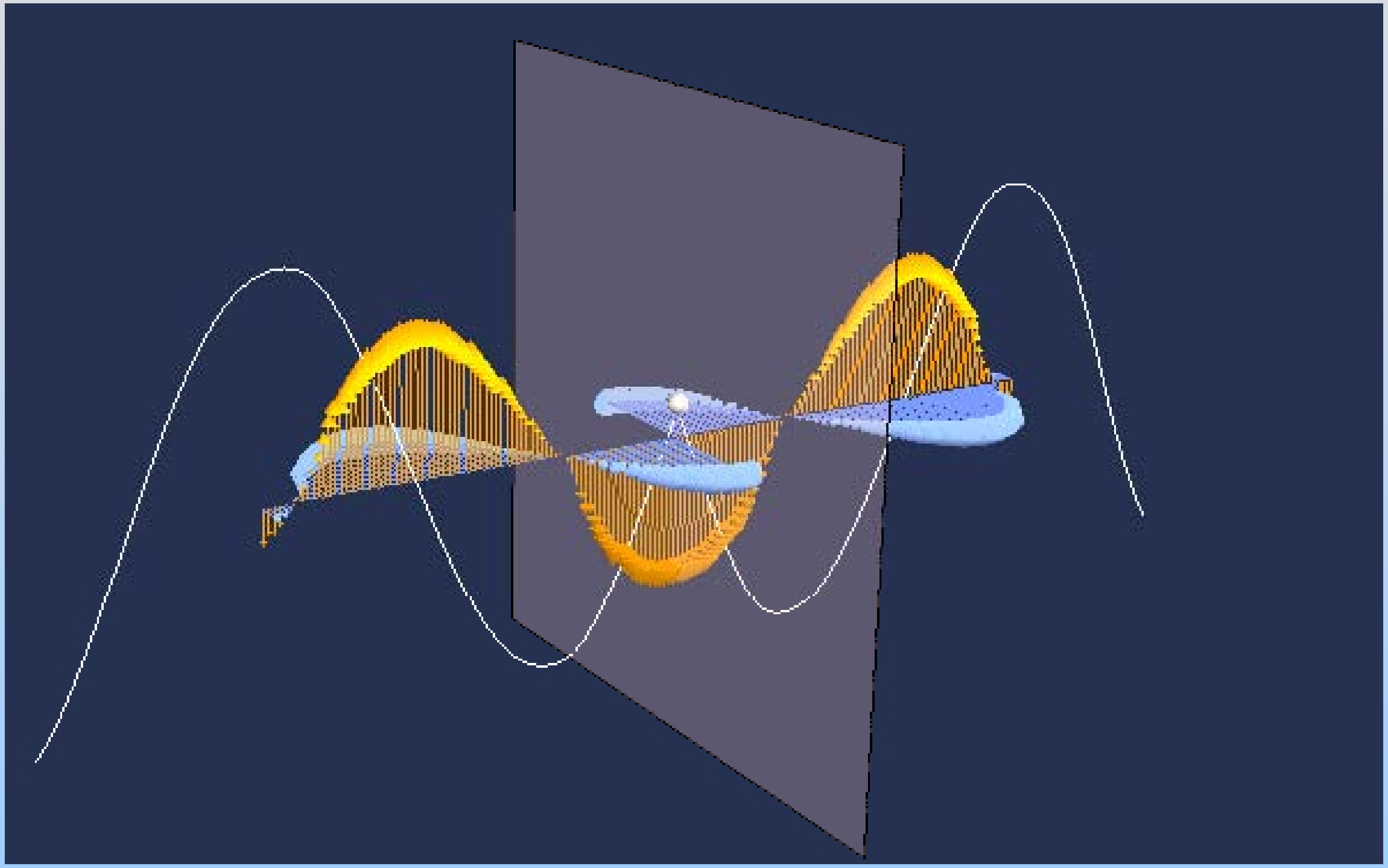
(HINT: Change drawing perspective)

2) If sheet position is $y(t) = y_0 \sin(\omega t)$

What is B(x,t)?

What is E(x,t)? What Direction?

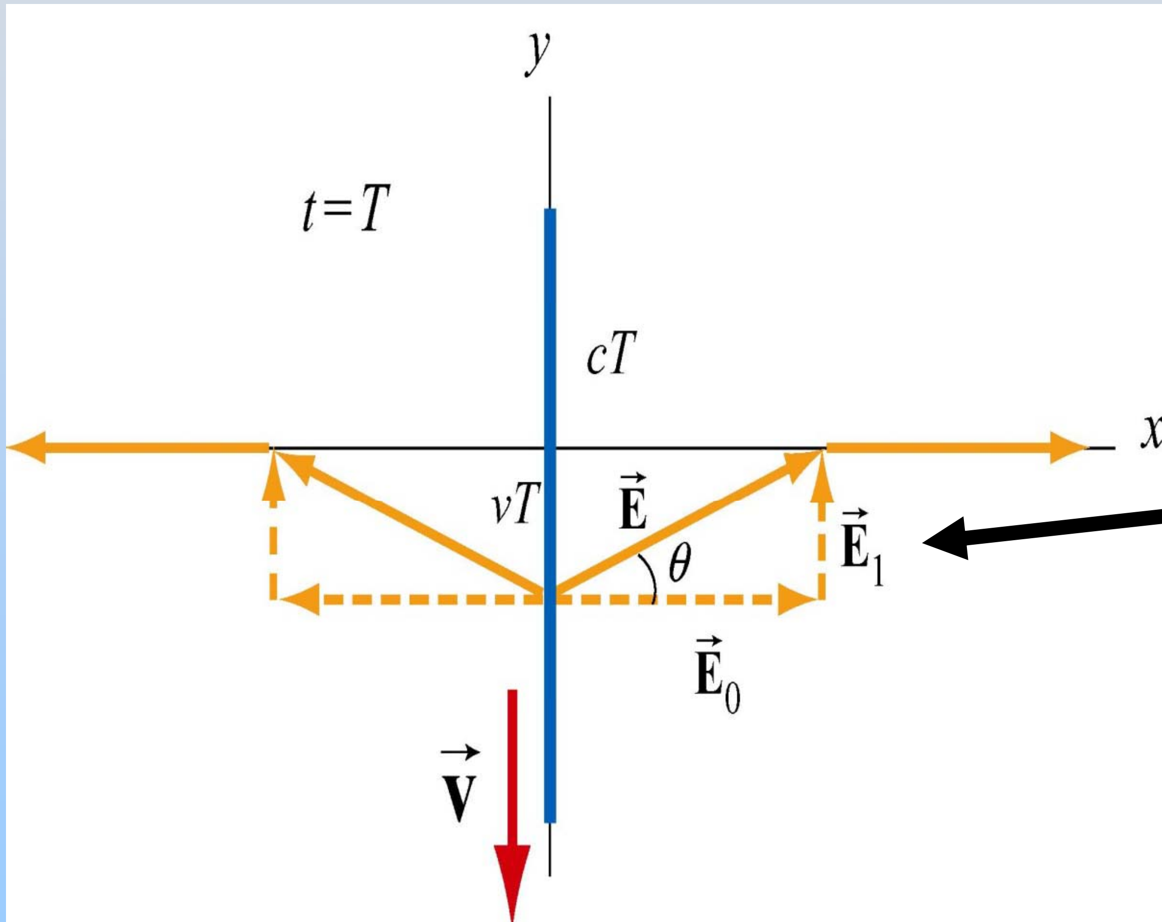
You Made a Plane Wave!



Link

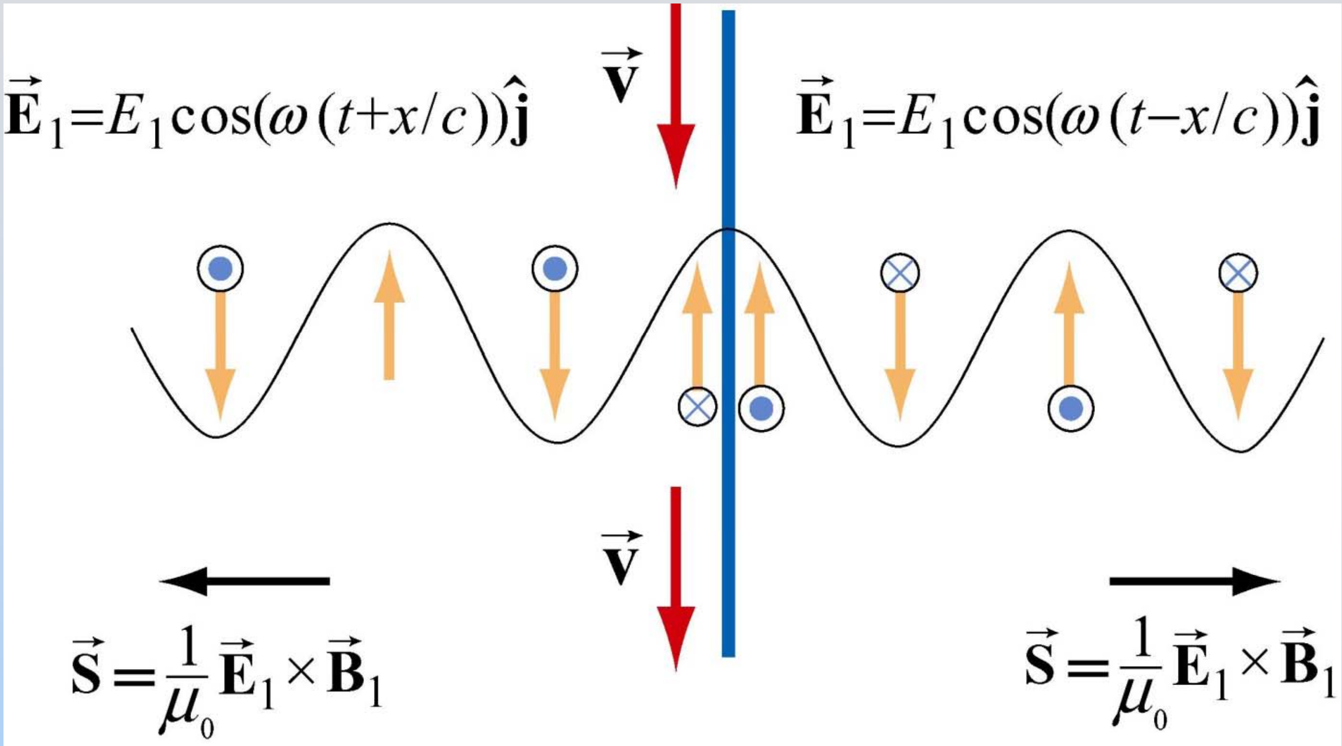
How to Think About E-Field

E-Field lines like strings tied to plane



This is the field you calculated & that propagates

Problem: Energy in Wave



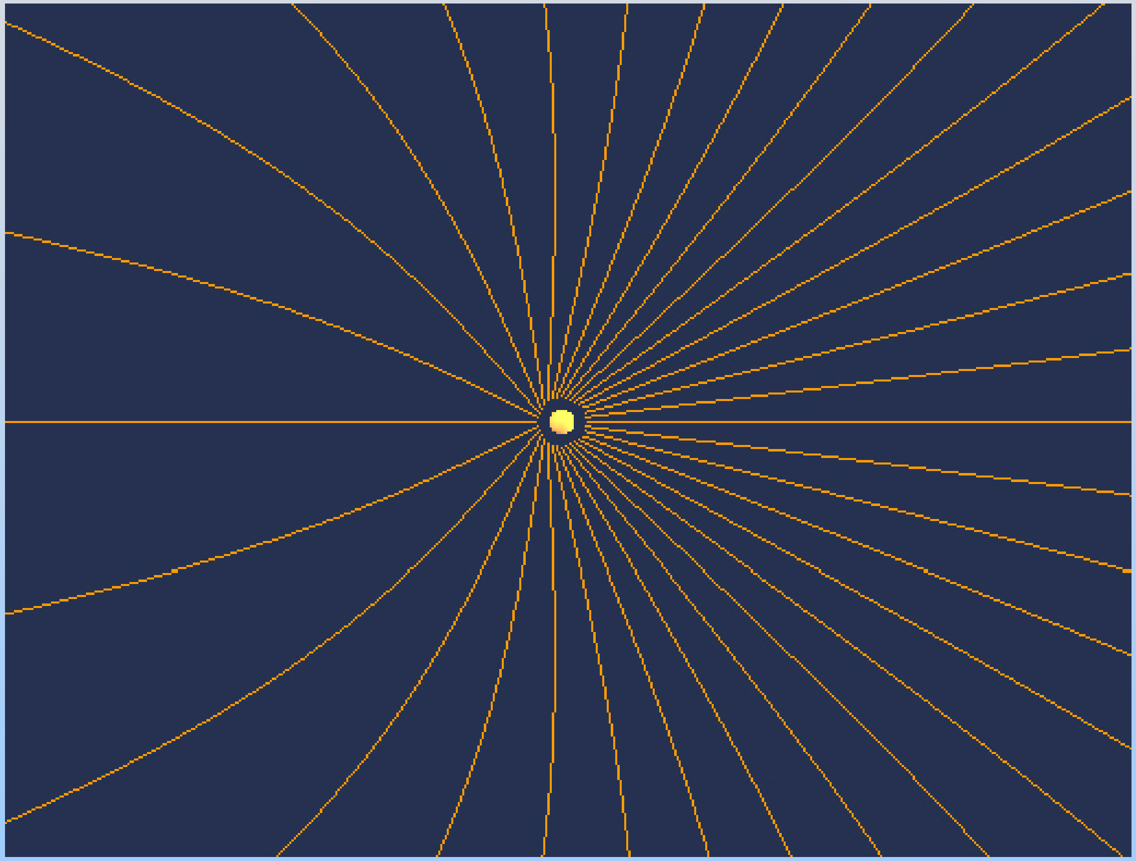
You Found:

$$B_1 = \mu_0 c\, v/2$$

1) What is total power per unit area radiated away?
2) Where is that energy coming from?
3) Calculate power generated to see efficiency

Generating Electric Dipole Electromagnetic Waves

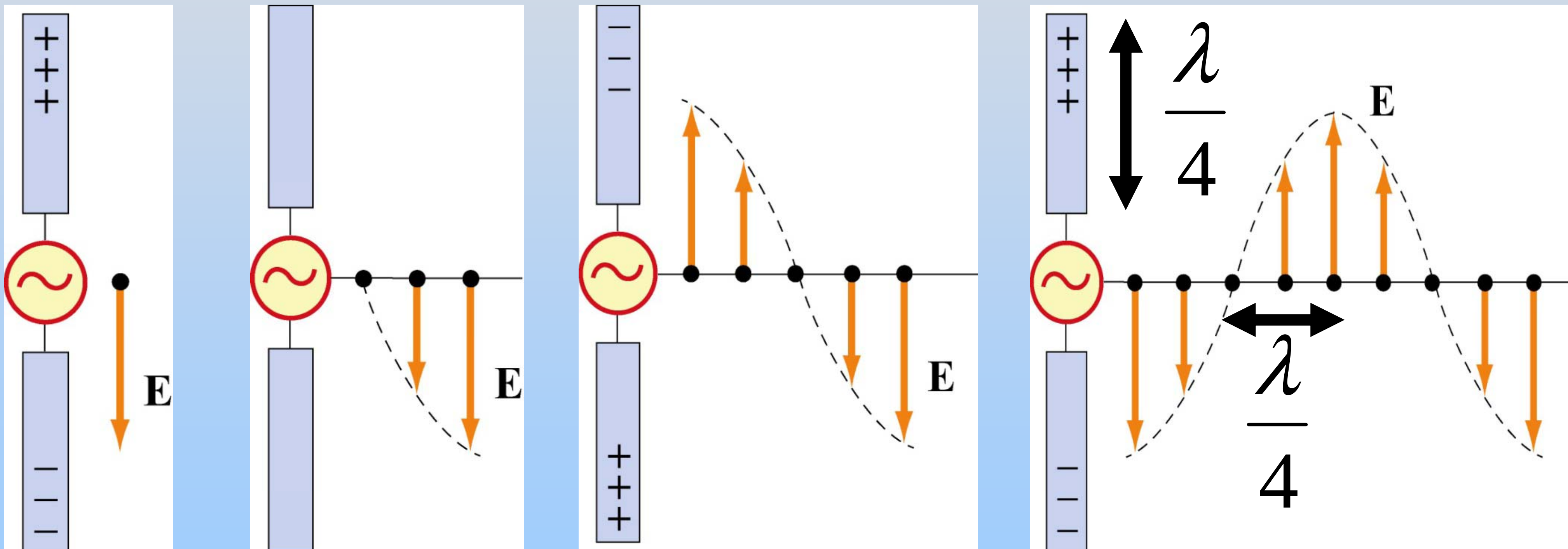
Generating Electric Dipole Radiation Applet



Link to applet

Half-Wavelength Antenna

Accelerated charges are the source of EM waves.
Most common example: Electric Dipole Radiation.



t = 0 t = T/4 t = T/2 t = T

Why are Radio Towers Tall?

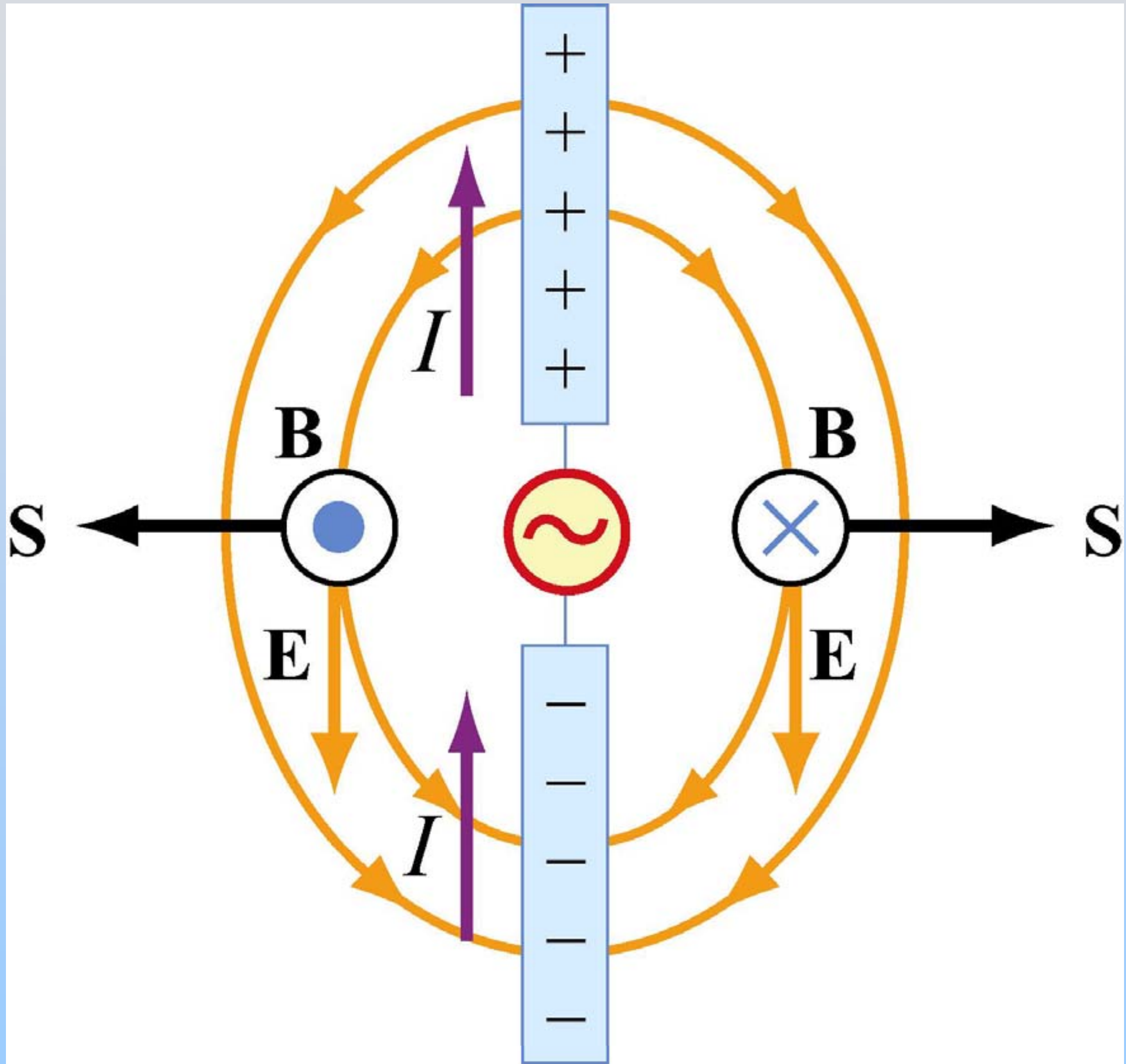
AM Radio stations have frequencies 535 – 1605 kHz. WLW 700 Cincinnati is at 700 kHz.

$$\lambda = \frac{c}{f} = \frac{3\times 10^{8}\,\mathrm{m/s}}{700\times 10^{3}\,\mathrm{Hz}} = 429\,\mathrm{m}$$

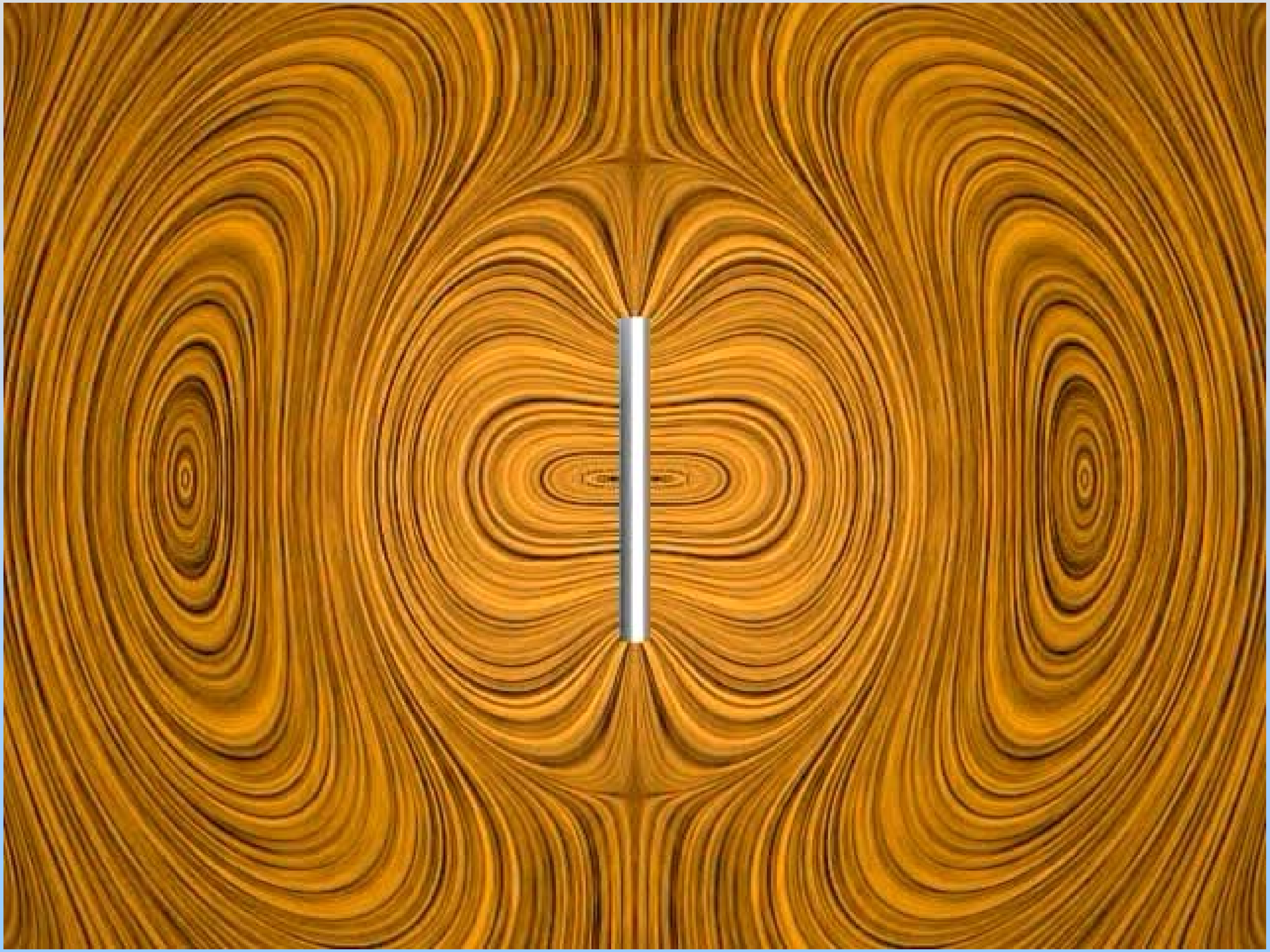
$$\lambda / 4 \approx 107\mathrm{m} \approx 350\mathrm{ft}$$

The WLW 700 Cincinnati Tower is 747 ft tall; with reflection One wavelength antenna

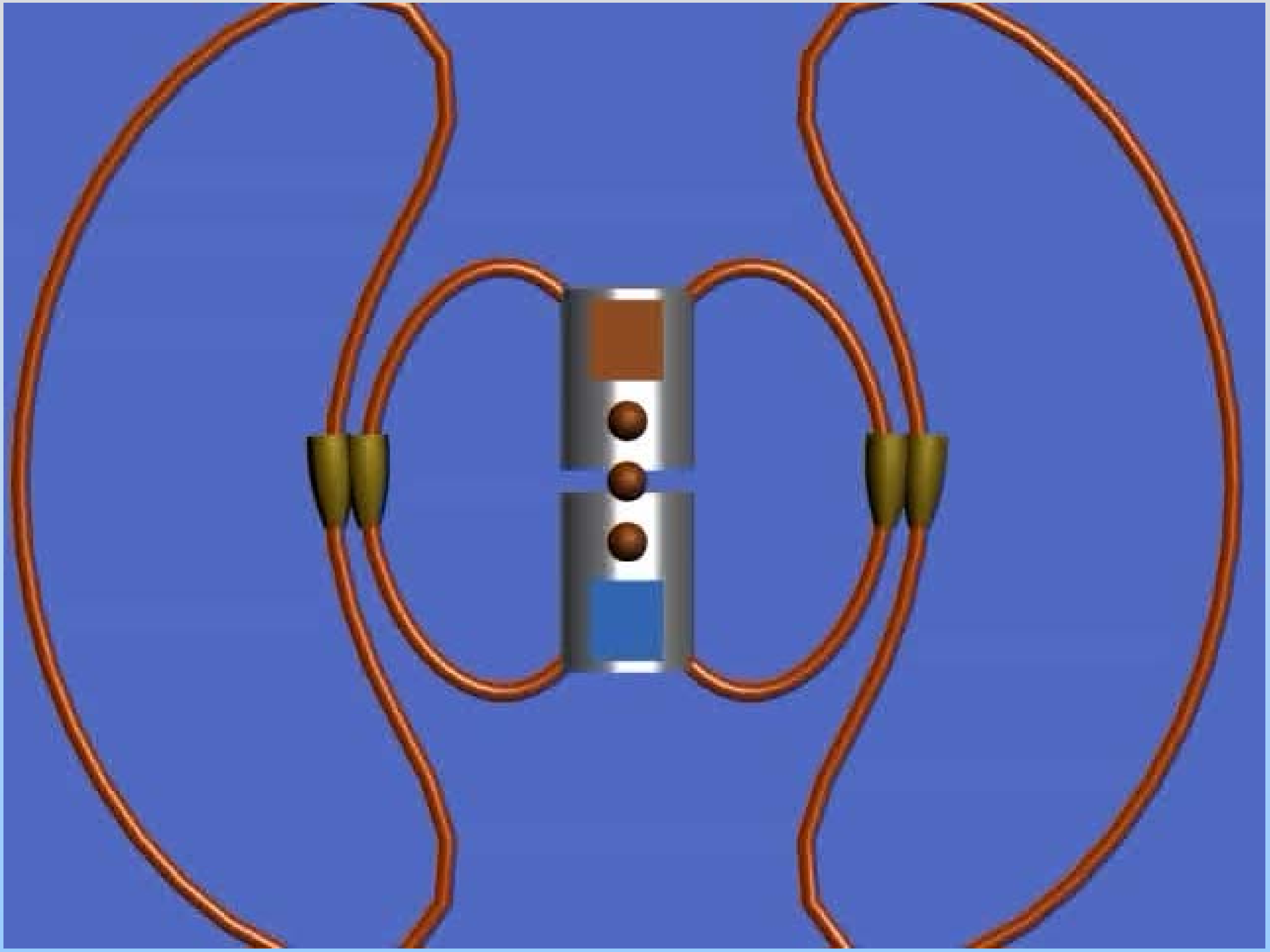
Quarter-Wavelength Antenna



Quarter-Wavelength Antenna

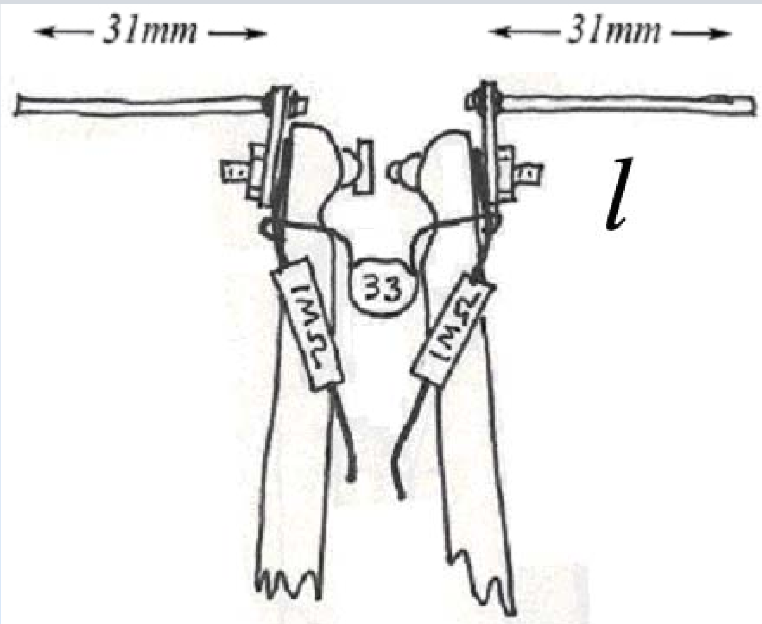


Spark Gap Transmitter

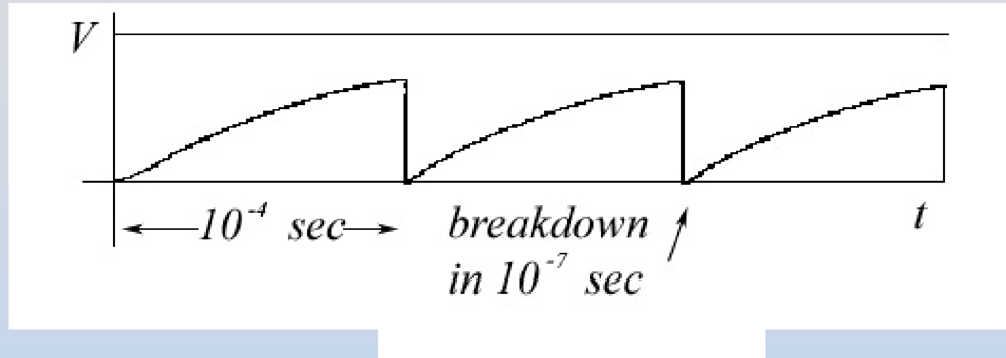


Spark Gap Generator: An LC Oscillator

Spark Gap Antenna



1) Charge gap (RC)

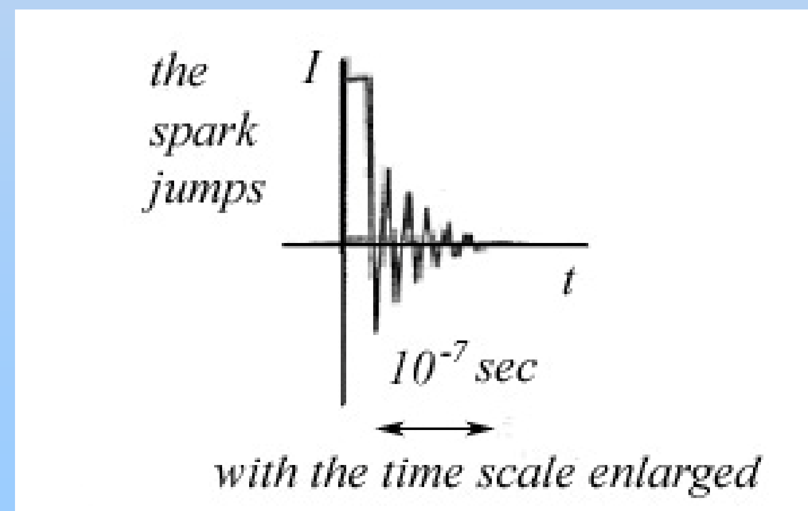


$$\tau = RC = (4.5\times10^{6}\,\Omega)(33\times10^{-12}\,\mathrm{F}) = 1.5\times10^{-4}\,\mathrm{s}$$

2) Breakdown! (LC)

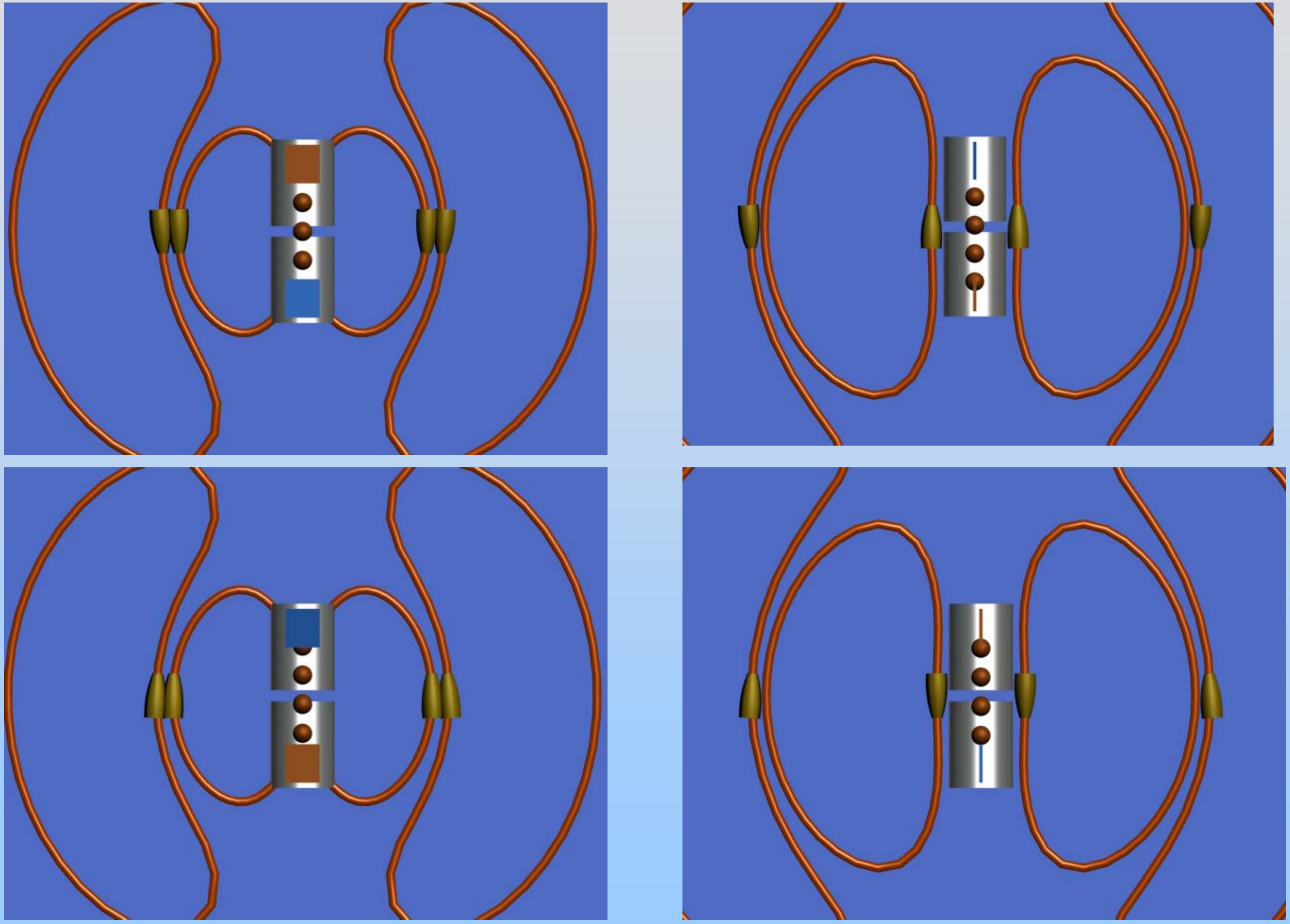
$$f_{\mathrm{rad}} - \frac{1}{T} - \frac{c}{4l} = \frac{3\times10^{10}\,\mathrm{cm/s}}{12.4\,\mathrm{cm}}$$

$$= 2.4\times10^{9}\,\mathrm{Hz} = 2.4\,\mathrm{GHz}$$



3) Repeat

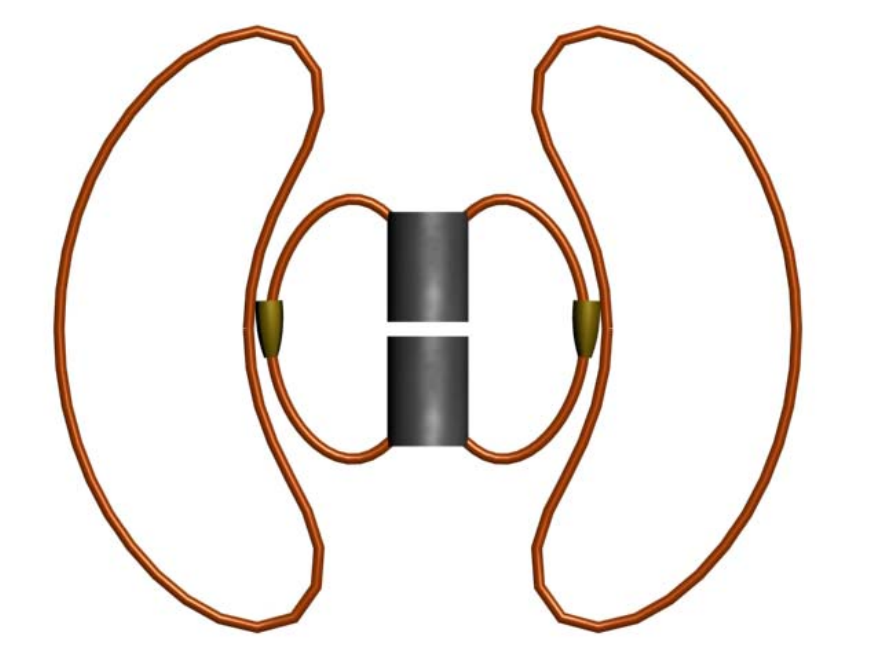
Spark Gap Transmitter



Concept Question Question: Spark Gap Antenna

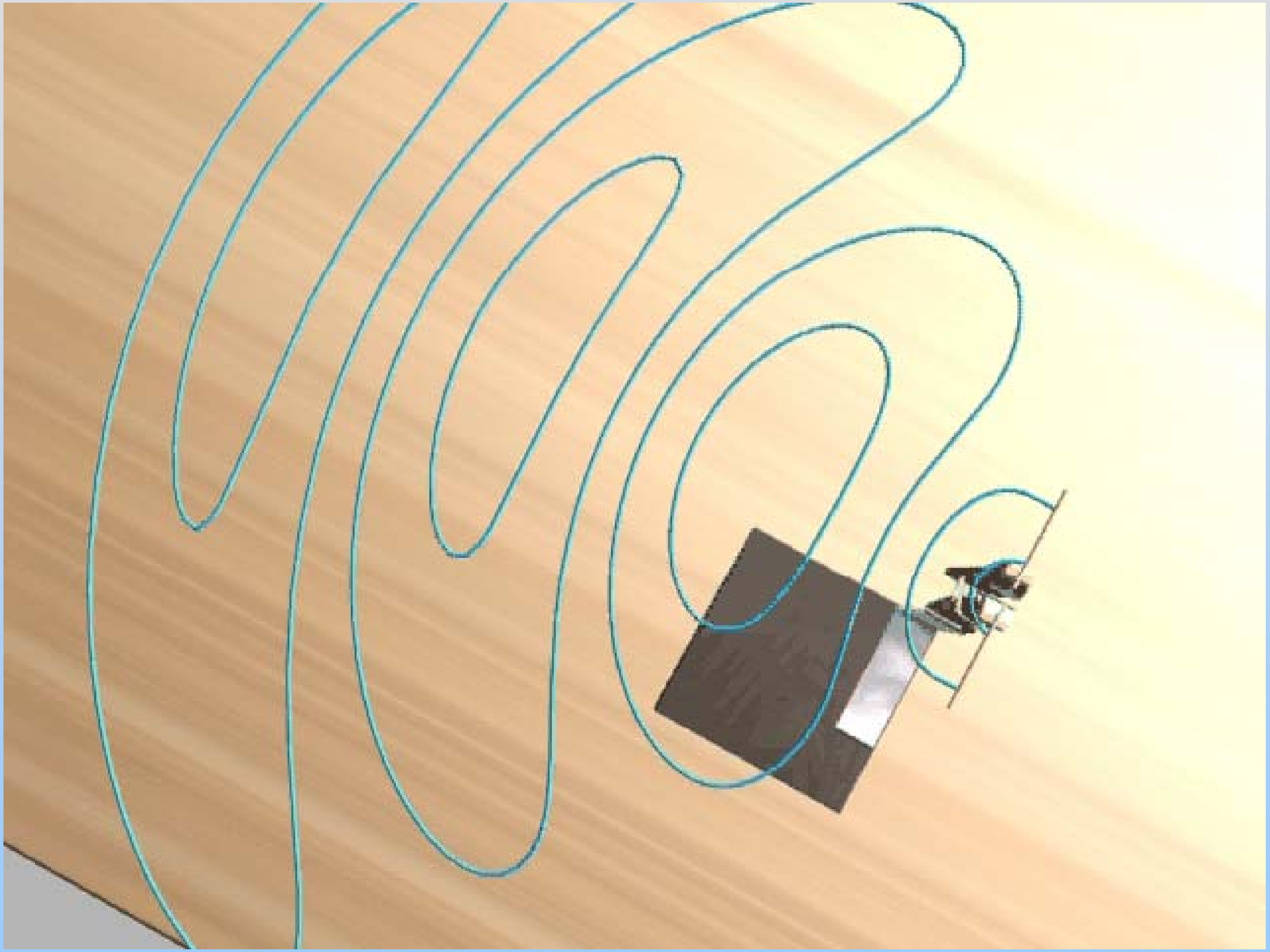
Concept Question: Spark Gap

At the time shown the charge on the top half of our 1/2 wave antenna is positive and at its maximum value. At this time the current across the spark gap is

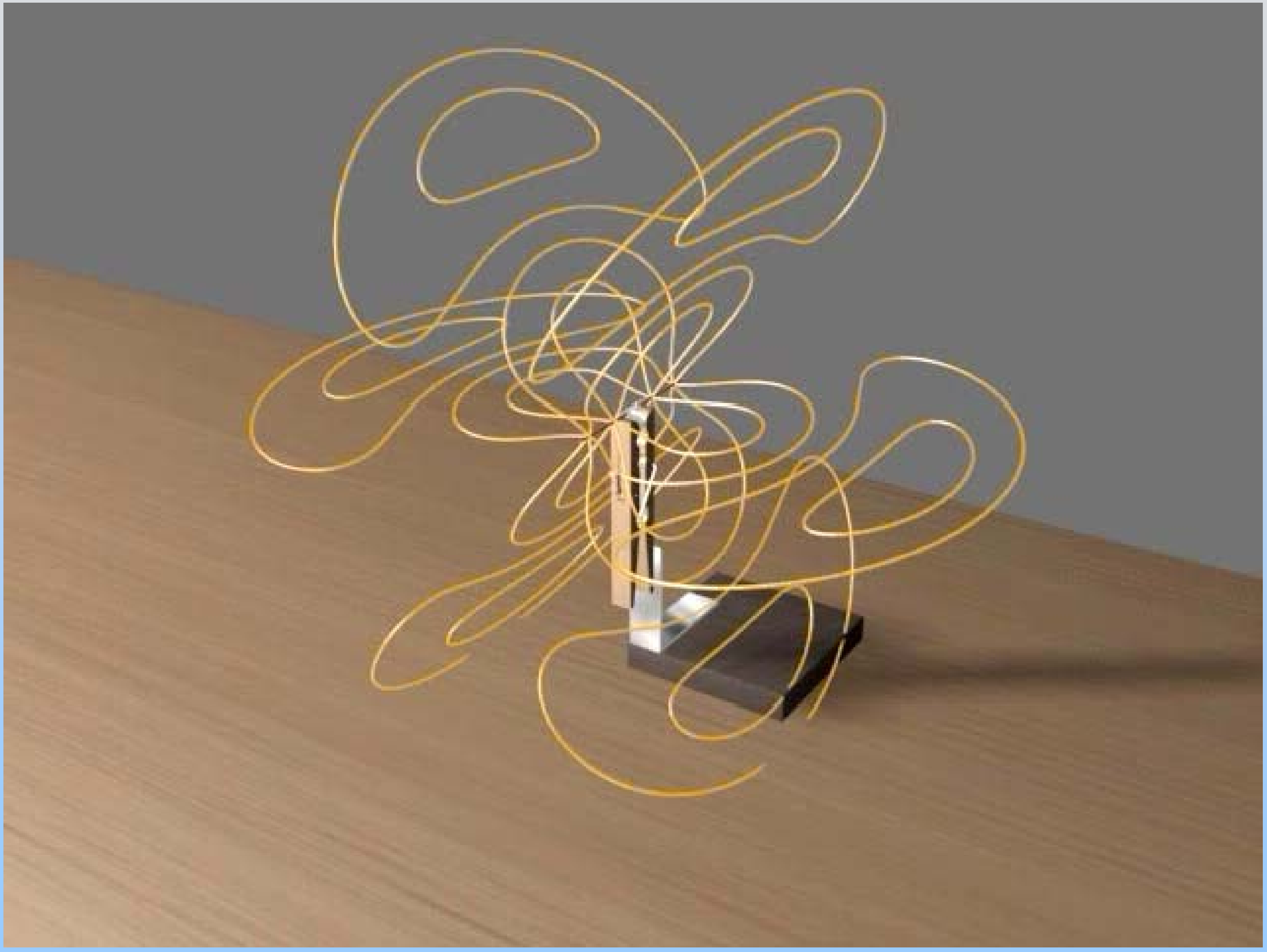


1. Zero
2. A maximum and downward
3. A maximum and upward
4. Can’t tell from the information given
5. I don’t know

Spark Gap Antenna



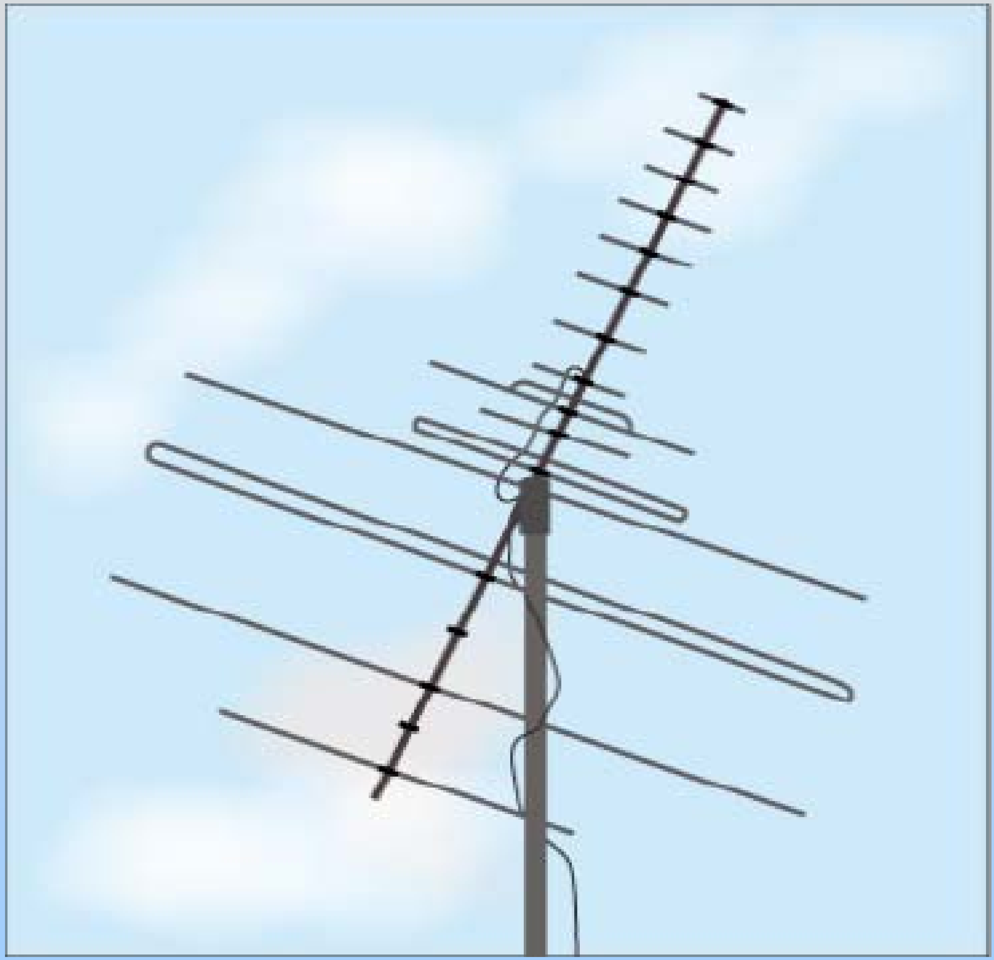
Spark Gap Antenna



Demonstration: Antenna

Polarization

Polarization of TV EM Waves



Why oriented as shown?

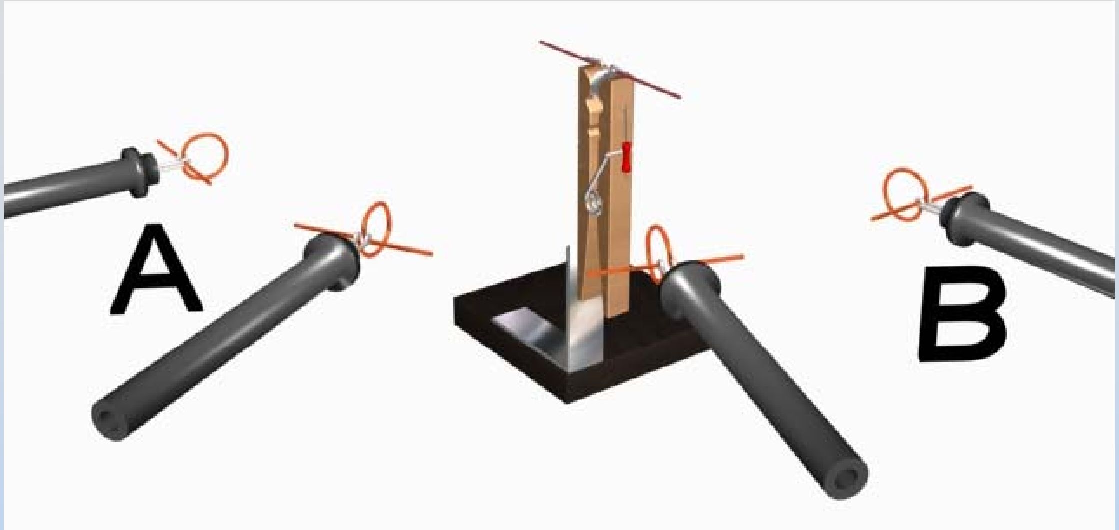
Why different lengths?

Demonstration: Microwave Polarization

Experiment 10: Microwaves

Concept Question Questions: Angular Distribution & Polarization of Radiation

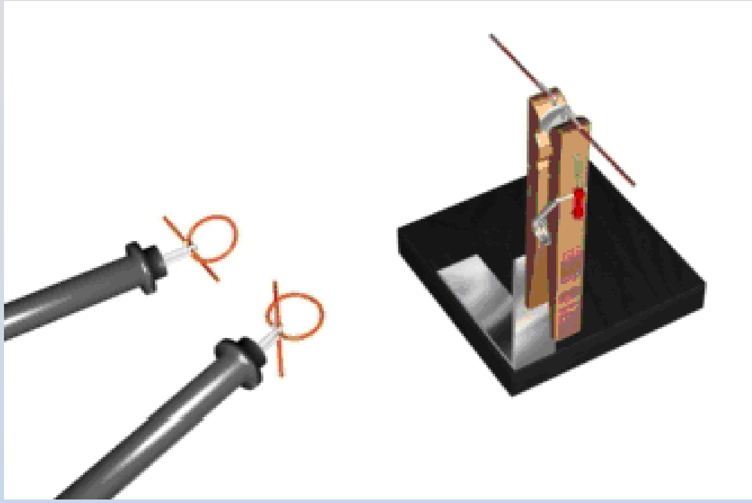
Concept Q.: Angular Dependence



As you moved your receiving antenna around the spark gap transmitting antenna as above, you saw

1. Increased power at B compared to A
2. Decreased power at B compared to A
3. No change in power at B compared to A
4. I don't know

Concept Question: Polarization



When located as shown, your receiving antenna saw maximum power when oriented such that

1. Its straight portion was parallel to the straight portion of the transmitter
2. Its straight portion was perpendicular to the straight portion of the transmitter
3. I don't know

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