Course and Section_____ Names _____

Date_____ _____

ELECTROMAGNETIC WAVES SIMULATION

Introduction

An electromagnetic wave consists of oscillating electric and magnetic fields traveling at the speed of light. The wave carries both energy and momentum.

Submit your answers using Blackboard.

1 – Preliminary Questions

For an electromagnetic wave traveling along the *x*-axis direction

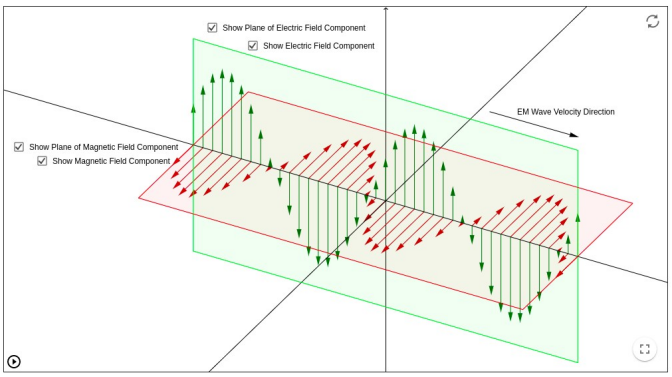
$$E(x,t) = E_0 \cos(kx - \omega t + \varphi) \quad \text{and} \quad B(x,t) = B_0 \cos(kx - \omega t + \varphi)$$

Where E_0 and B_0 indicate the maximum values of the amplitudes.

1. What is k?
2. What are the units of the k?
3. What is ω?
4. What are the units of the ω?
5. What is φ?
6. What are the units of φ?
7. If as said above the wave travels directed along the *x*- axis, what are the directions of oscillation of *E* and *B?*
8. How is the wave length related to the wave vector?
9. How is the angular frequency related to the frequency?

2 – The Traveling Wave

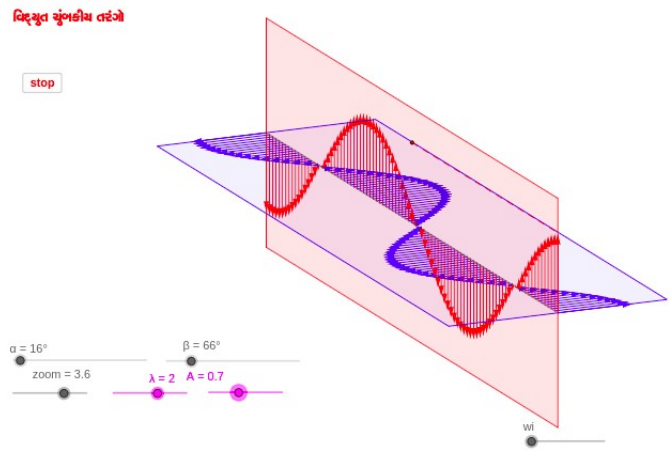
Open the animation (https://www.geogebra.org/m/xhYwXSsHSsH)



and press the play button located at the bottom left corner.

10. Which kind of wave is it?
11. How are the amplitudes of the electric field and the magnetic field related?
12. What is the relation between between E_0 and B_0 ?
13. How is the direction the wave is traveling, $\vec{v}$, related to the direction of $\vec{E}$ and $\vec{B}$?
14. If the wave is traveling in the *y*-direction and the magnetic field is polarized in the *x*-direction what is the direction of the polarization of the electric field?

Open the simulation (https://www.geogebra.org/m/mEweX3HF#material/GR2RxX4m)

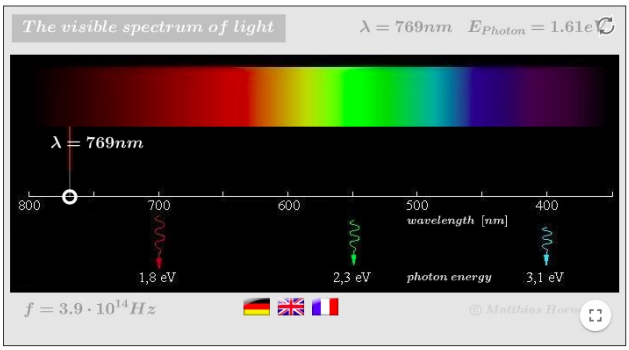


Changing the values of α = 16° and β = 66° gives different visualizations.

15. Set β = 25°, which field does the red wave represent?
16. Set α = 5°, how does varying the value of the wavelength λ effect the speed of the wave?
17. How does increasing the amplitude *A* change the amplitudes of *E* and *B?*
18. How does increasing the amplitude *A* change the velocity of the wave?

3 – Spectrum of Light

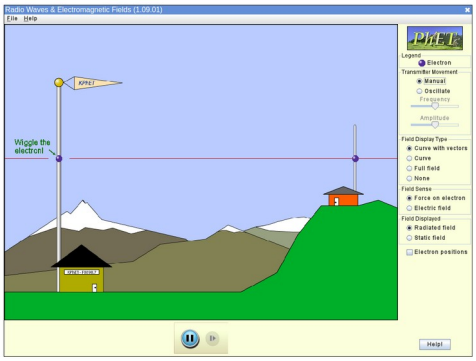
Open the simulation (https://www.geogebra.org/m/fp4vfggc)



19. Which color does the wavelength λ = 585 nm correspond to?
20. Which frequency does the wavelength λ = 585 nm correspond to? (Thz) T-Terra x 10^{12}
21. Calculate the product of λ = 585 nm with the corresponding frequency. (Mm/s) M-Mega x 10^{6}
22. Calculate the product of λ = 664 nm with the corresponding frequency. (Mm/s) M-Mega x 10^{6}
23. How does the wavelength of the blue color compare to the red color?
24. How does the frequency of the blue color compare to red color?
25. What is the name of the radiation to the far right?
26. What is the name of the radiation to the far left?

5 – The Antenna

Open the simulation (https://phet.colorado.edu/sims/cheerpj/radio-waves/latest/radio-waves.html?simulation=radio-waves)



Select on the right *Field Sense: Electric field.* Wiggle the electron on the source antenna on the left.
27. When the radiation reaches the antenna to the right, what happens to the electron?
28. How does the amplitude of oscillation of the receiving electron compare to the amplitude of the source electron?
29. If the motion of the electron were a constant speed (difficult to do in the simulation) will a signal be produced?

Select *Oscillate* (instead of *Manual*) and run the simulation.

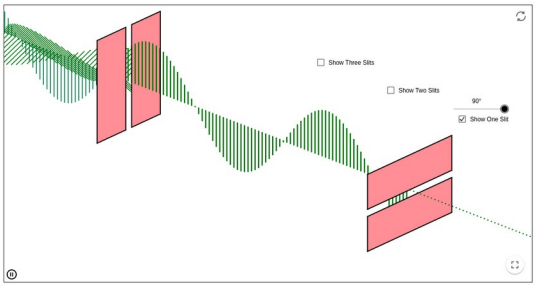
30. If you increase the frequency of oscillation, how does the amplitude of the source signal change?
31. How does the amplitude of the radiation change as the signal travels to the right?
32. How does the frequency of the electron in the receiving antenna compare to the frequency of the electron in the source antenna (you can use a stopwatch to count the period)?

4 – Polarization of Light

According to Malus Law the intensity of light as it passes through a polarized filter changes as

$$I = I_0 \cos^2(\theta)$$

Open the simulation (https://www.geogebra.org/m/E6jZ52vK)



and select Show One Slit.

Answer 33-36 as a fraction of the initial intensity. i.e. $I=x\ I_0$, answer is x.
33. If I_0 is the intensity of unpolarized light on the far left of the screen, what is the intensity of the light after it passes through the first filter?
34. Set the angle of the slit to 0°. What is the intensity of the light after it passes through the filter?
35. Set the angle of the slit to 45°. What is the intensity of the light after it passes through the filter?
36. Set the angle of the slit to 90°. What is the intensity of the light after it passes through the filter?

Select Show Two Slits.
37. Set the angle of the far right slit to 90 and the slit in the middle to 0. What is the intensity of the light coming out to the right?
38. Keep the angle of the far right slit to 90. Which angle of the slit in the middle gives the max possible amplitude for the light coming out to the right?
39. What is the intensity of light coming out on the far right compared to the initial unpolarized light?

6 – Intensity of Light

The *intensity* of the wave, which is power per unit area, is given by

$$I = \frac{1}{2\mu_0} E_m B_m$$

Using the relationship between the intensities of the fields $E = cB$, we can also write

$$I = \frac{E_m^2}{2\mu_0 c} = \frac{cB_m^2}{2\mu_0}$$

When we shine light of a certain intensity on an area then we deposit energy at a rate given by the power $P = I A$. Suppose a physicist can measure the energy of light deposited per second on an aperture whose area (A) can be changed. The physicist measures the following data,

P (J/s)	2.54	7.5	11.96	17.69	22.05	27.9	31.47	36.47	43.09
A (m)	0.1	0.3	0.5	0.7	0.9	1.1	1.3	1.5	1.7

Plot the data in excel, libreoffice etc. and find a line of best fit.

40. What does the slope correspond to?
41. What is the intensity of the light in the physicists experiment? (J/m^2)
42. Knowing the intensity of the light what is the magnitude of the electric field which makes up this light wave? (N/C)
43. What is the magnitude of the magnetic field which makes up this light wave? (μT)
44. With the given data is it possible to extract what the polarization of the light was?