4.2: EM Waves from an Accelerating Charge

Tutorial 4.2: Accelerated Charge Radiation

Electric charges have electric fields. The simulation first shows a moving positive charge and the electric field around it in two dimensions. If the charge is accelerated there will be a disturbance in the field. This is the origin of electromagnetic waves. Note that the energy carried by the disturbance comes from the input energy needed to accelerate the charge.

Accelerating Charge

Questions:

Exercise 4.2.1

Run the simulation. Change the speed, v, and describe what you see. How does the *change* in speed (acceleration) affect the initial disturbance of the field (try changing the speed slowly versus rapidly)?

Exercise 4.2.2

What happens at constant speed? Is there still a disturbance? What happens if you suddenly slow the charge down?

Exercise 4.2.3

Now click the Animation 2 button. Describe what you see. Explain what you would notice about the field over time if you were measuring it at a point along the x-axis and compare that with what you would measure at a distant point along the y-axis.

A charge oscillating in the y-direction will produce an electromagnetic wave traveling in the x-direction as seen in Animation 2. For directions other than along the x-axis the wave has a lower amplitude (smaller variation from equilibrium), dropping to a zero amplitude along the y-direction. This configuration is called a **dipole antenna**. (To be technically correct a single wire with an oscillating charge is a monopole antenna. A dipole is created from two wires with opposite polarities, one in the x-direction the other in the $-x$-direction but in the present context we can ignore this subtlety.) Dipole antennas emit the strongest signal in a direction perpendicular to the antenna as Animation 2 shows (remember, the field is the same strength in both directions but the *change* in the field is zero in y-direction, largest along the x-axis). FM radio, AM radio, TV, cell phone, WiFi and short wave radio sending antennas are dipole or approximately dipole antennas.

Exercise 4.2.4

Why are sending antennas usually oriented vertically?

Note

Short wave antennas are sometimes oriented horizontally so that the signal can bounce off the ionosphere and return to earth a large distance away.

Exercise 4.2.5

Try different oscillation speeds for Animation 2. If you were measuring the field on the x-axis, how would the frequency of the wave compare with the frequency of oscillation of the charge in the antenna?

Exercise 4.2.6

Now try Animation 3. How would the amplitude of the wave at points along the x-axis compare with the amplitude of the wave along the y-axis for this case?