Electromagnetic Waves

DD Owned by David Cherney DISH •••
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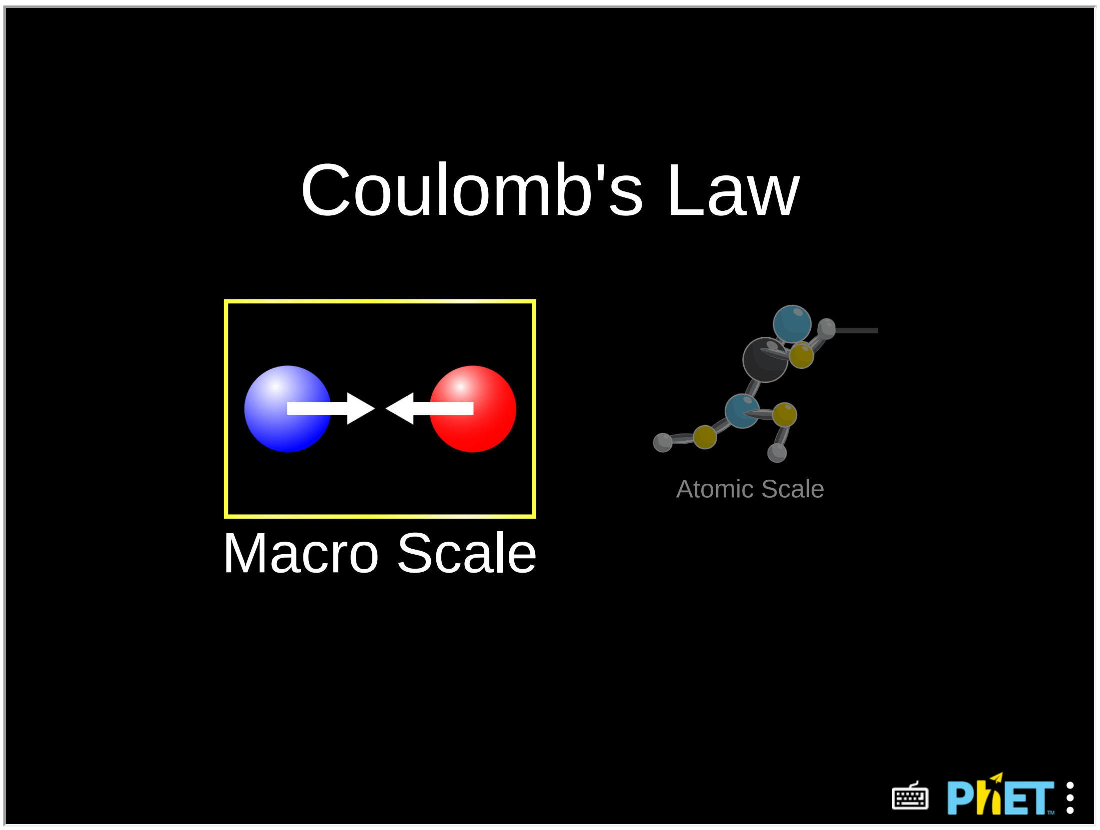
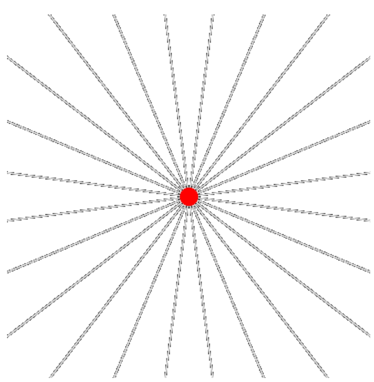
Radio waves are electromagnetic waves. Lets unfold what that means.

Objects with electric charge attract and repel each other with a force depending on the distance between them.



Thus, when the distance between them changes, the force they exert on each other changes. However, since the communication of that force is not instantly propagated across space, but rather at the speed of light, that change in force propagates as a wave. In the animation below, the speed of the kink in the electric field travels at the speed of light. That kink, traveling across space, is a wave.

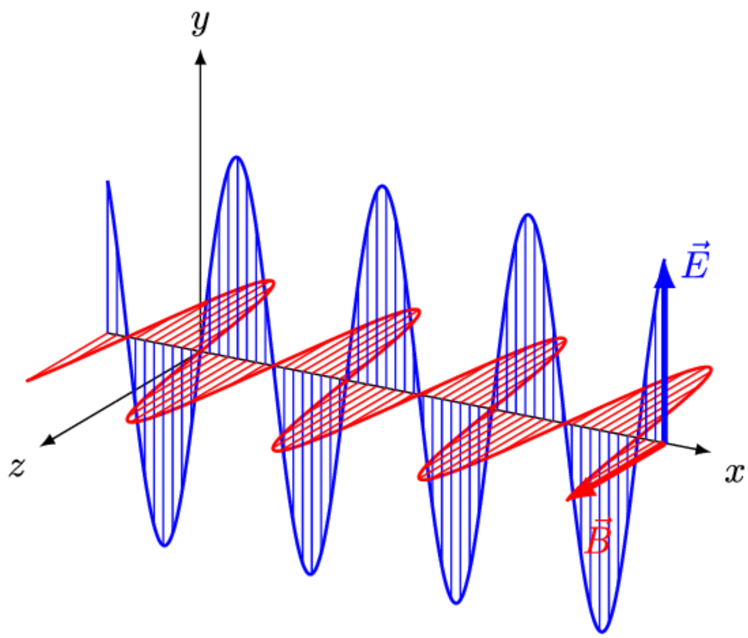


Accelerating electric charge creates electric waves.

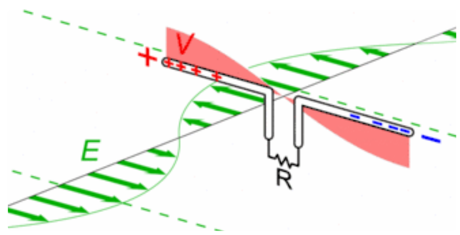
The wave depicted above is a wave in an electric field. However, we use the term “electromagnetic waves” because of the following pair of laws of physics that apply at every point in space:

1. changing electric field creates magnetic field
2. changing magnetic field creates electric field.

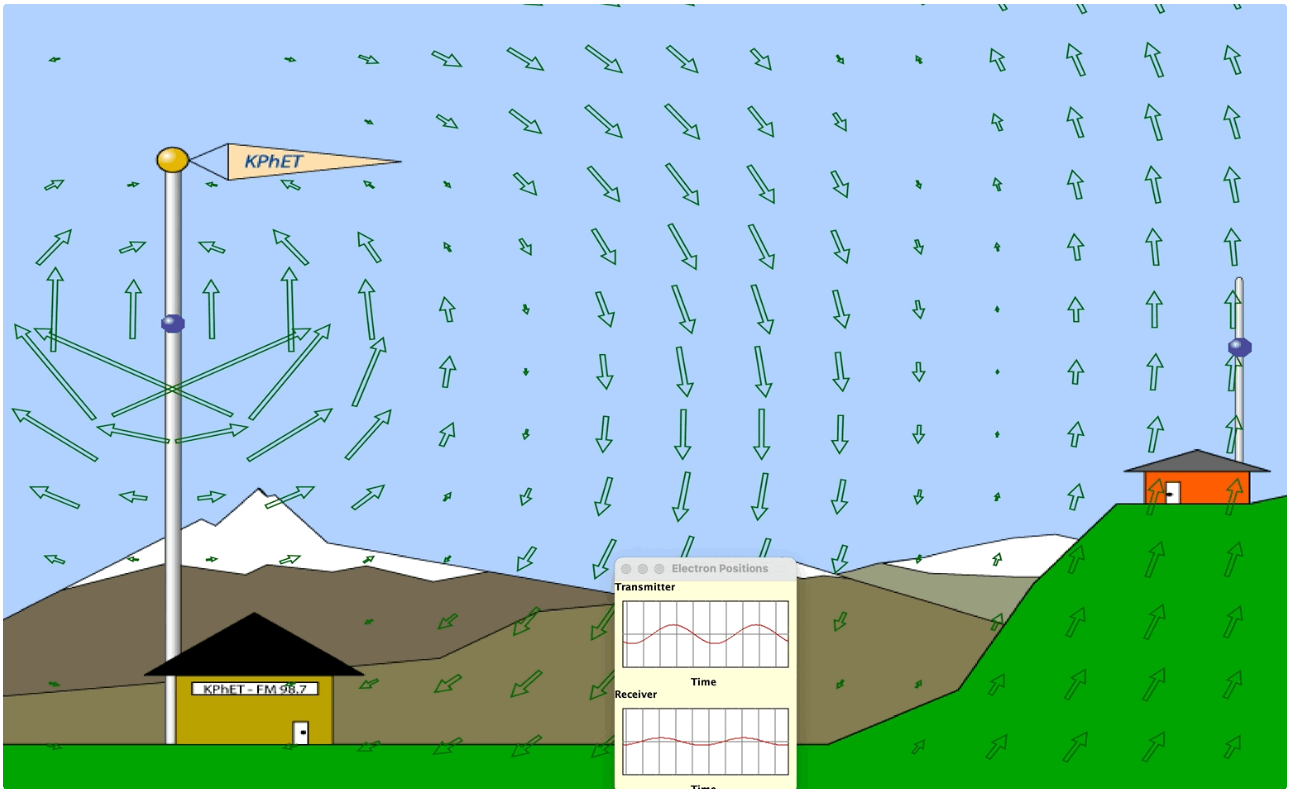
Thus, a moving electric charge creates an electric field wave, creating a flow back and forth between electric and magnetic field, which amounts to a pair of waves, one electric and one magnetic, that keep each other moving forward at the speed of light. In the animation below, E is the electric field and B the magnetic field.



When such a wave encounters an antenna (a metal rod in which electric charge can move) the electric field wave part (E) moves the electric charge in the antenna. The pressure exerted by the electric field on the electric charge in the antenna is voltage. That voltage can be measured.



That is how electromagnetic waves (of a wide variety of frequencies) are used to transmit information from transmitter to receiver. The animation below shows the electric field as the tower at the left transmits to the tower at the right.



Decibels

Definition: The <u>attenuation</u> of a signal is the loss of strength of that signal.

There are several ways to quantify attenuation.

Definition: If a signal is transmitted with power P_t and received with power P_r then the ratio $L = P_r/P_t$ is called the <u>loss</u>.

Loss is one measurement of attenuation. Note that is loss, a ratio of powers, is dimensionless; it has dimension of power per power, and so no units like meters or watts are needed to report it. Another common way to measure attenuation is on a logarithmic scale called the decibel scale.

Definition: If a signal is transmitted with power P_t and received with power P_r then $L_{dB} = 10 \log_{10}(P_r/P_t)$ is <u>decibel loss</u>.

People often wonder about the name "decibel"; it is descendant from the bell scale $L_B = \log_{10}(P_r/P_t)$ which is extremely rare now; the "deci" prefix comes from the multiplicative factor of 10, which was put in because humans like to deal with numbers between 0 and 100.

The following facts are commonly used:

- Doubling of loss is a change of 3 dB in decibel loss.
- A multiplicative factor of 10 increase in loss is an increase of 10 dB in decibel loss.

Loss and decibel loss compare two powers. The decibel scale also provides a way to describe just one power; by reference to a standard power like a milliwatt.

Milliwatt Decibels

Definition: The power P on the watt scale is the power $P_{dBm} = 10 \log_{10}[\ P\ /\ (1\ mW)\ ]$ on the milliwatt decibel scale.

So, for example, 10W = 40dBm.

Note that the m needs to be at the end of dBm to indicate milliwatt decibels; the notation mdB means one-one-thousandth of a decibel.