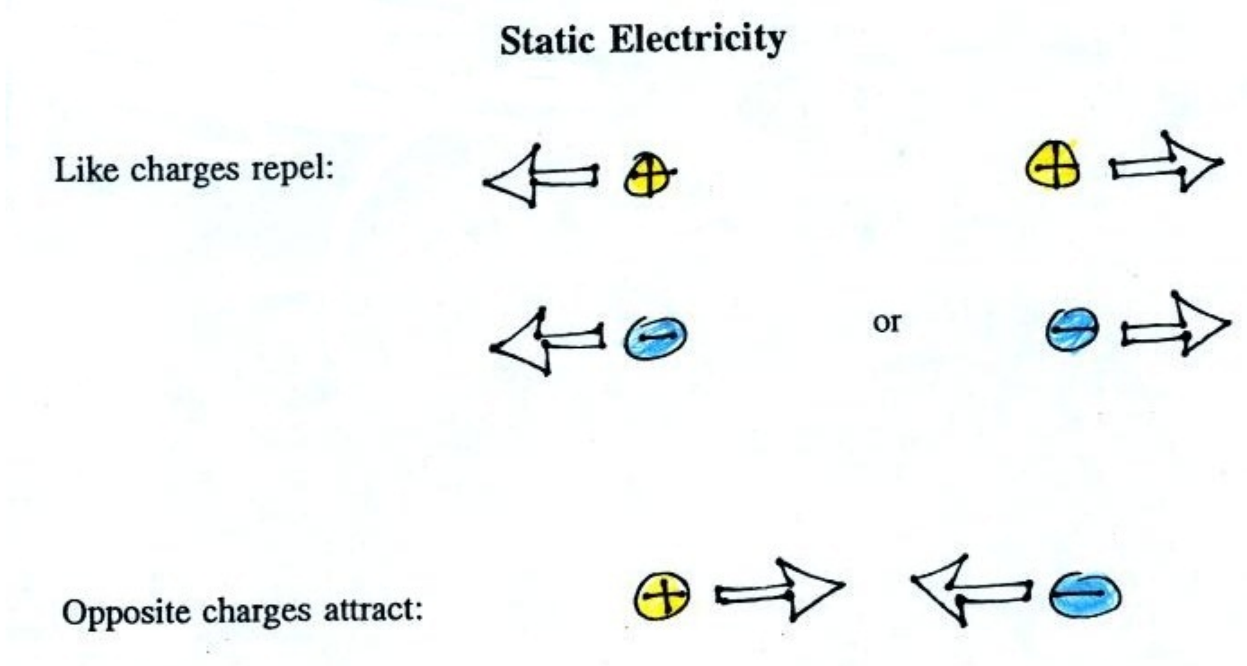
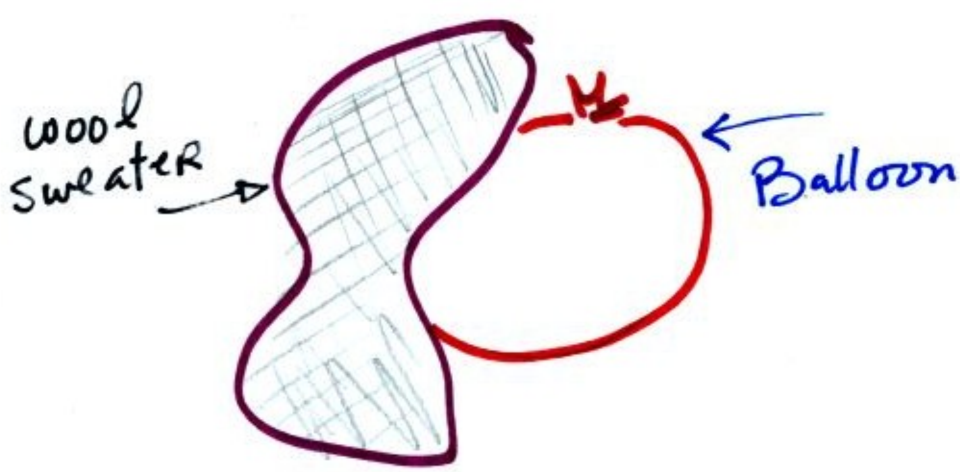
Module 4 - Lecture 12

Electromagnetic (EM) radiation is the most important energy transport process in the atmosphere because EM can travel through empty space.

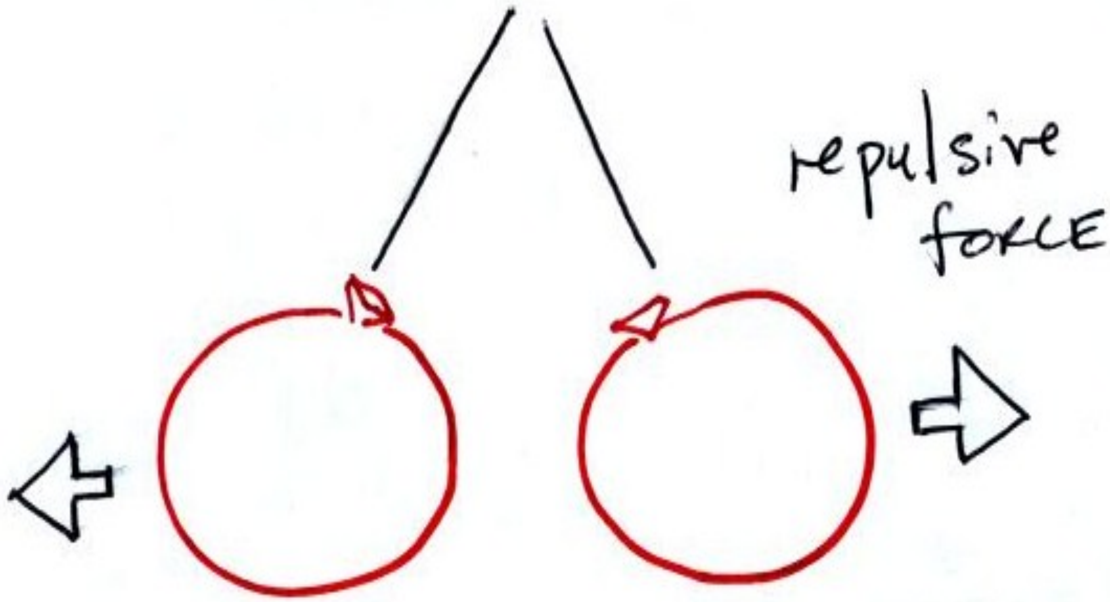
To really understand EM radiation you first need to know something about electric fields. First we will discuss static electricity.



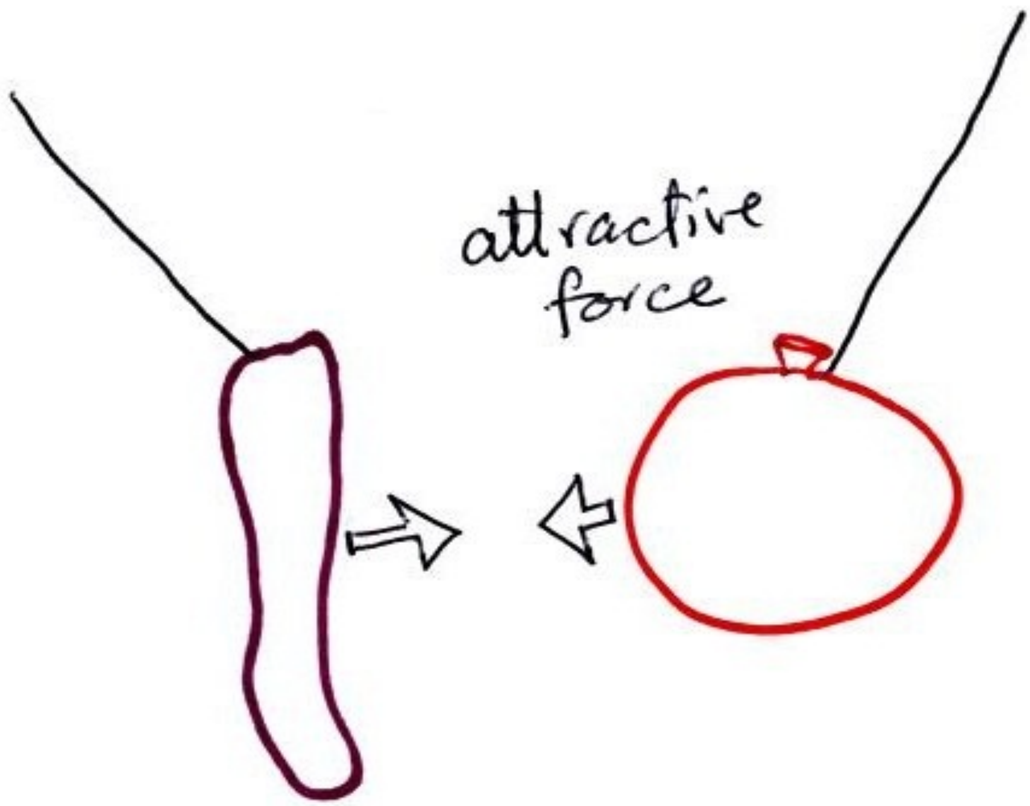
You can demonstrate these rules using a sweater and two balloons. Each balloon was rubbed with the sweater (acrylic fiber and wool). The balloons and the sweater became electrically charged (the balloons had one polarity of charge, the sweater had the other).



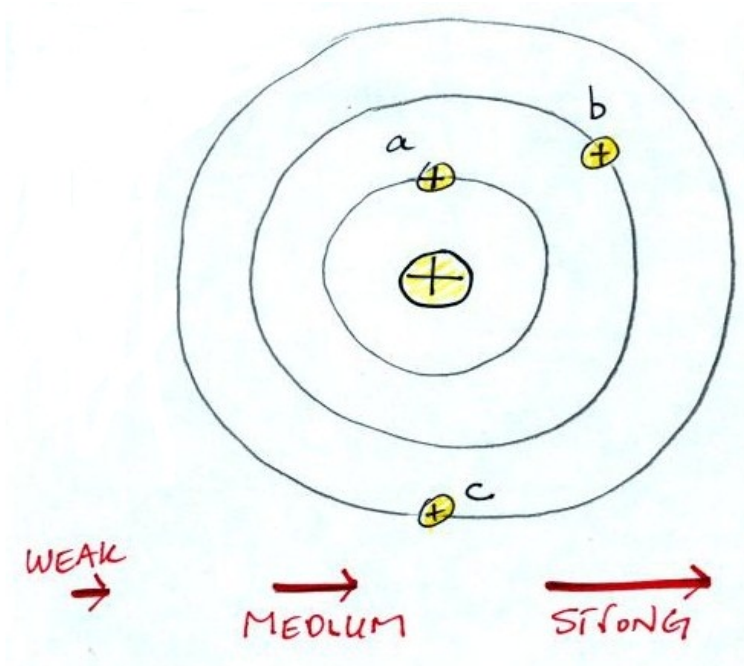
If you bring the balloons close to each other they are pushed apart by a repulsive electrical force.



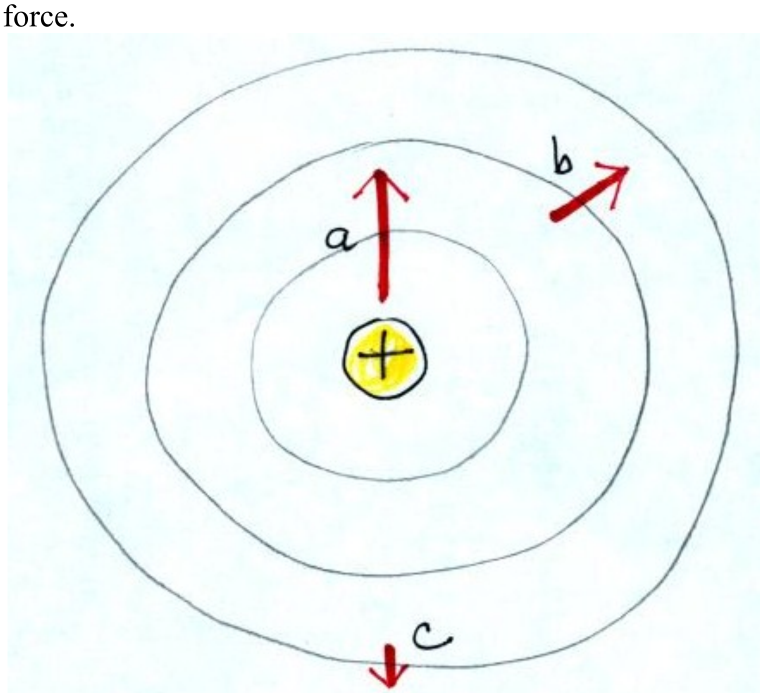
The sweater and the balloon carry opposite charges. IF they are brought together they experience an attractive electrical force.



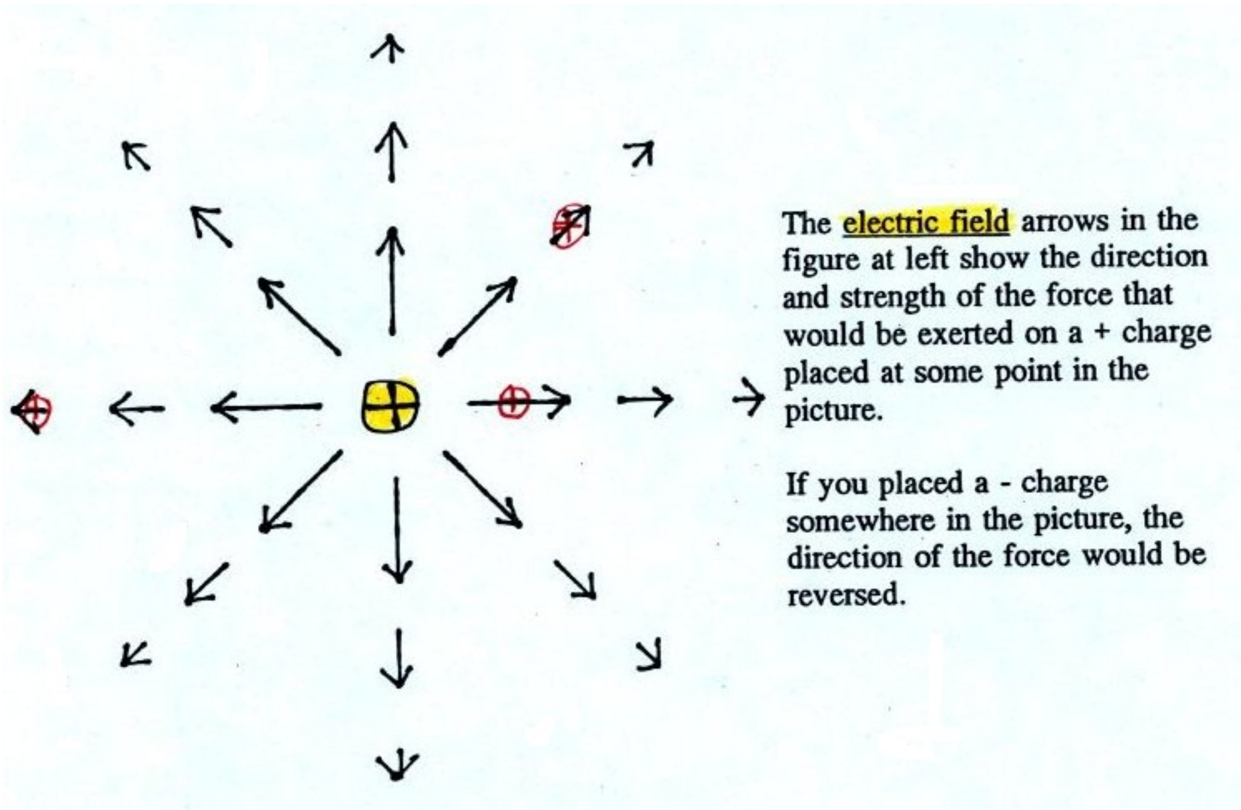
Our next step in understanding EM is to learn about electric field arrows. Imagine placing a + charge at the three positions shown in the figure below. The three arrows below represent strong, medium and weak charges. The next step is to match the arrows with positions a, b and c. You also need to orient the arrows in the right direction.



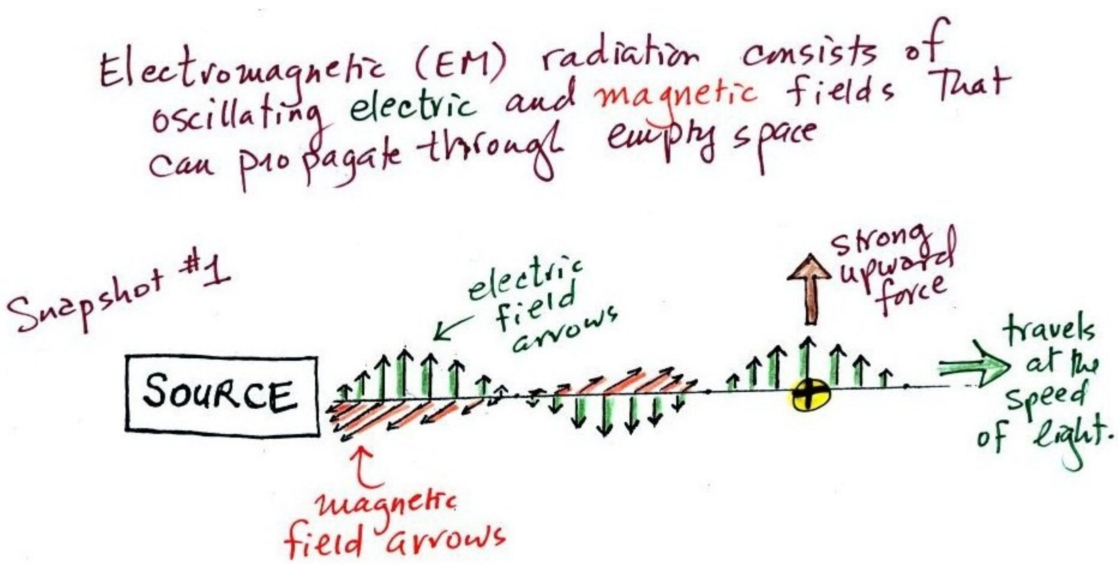
Here is the answer. The closer the charge is to the center, the greater the strength of the outward force.



If you were to place + charges at other positions, you would obtain a figure that looks like the pattern below. The electric field arrows show the direction and give an idea of the strength that would be exerted on a positive charge at any position in the figure.

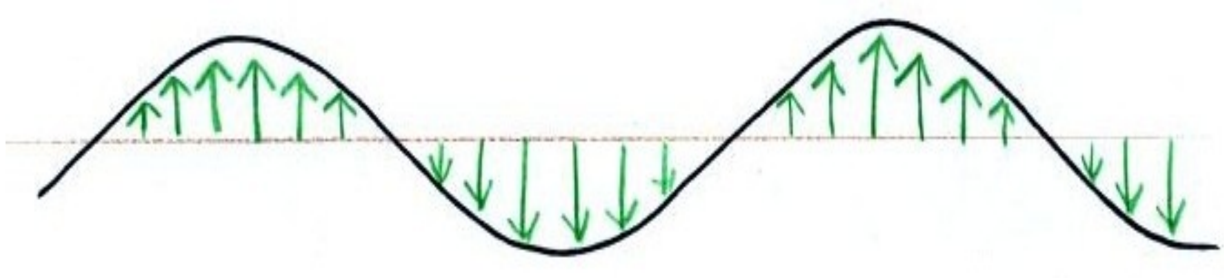


We will use electric field arrows to illustrate the transport of EM radiation.

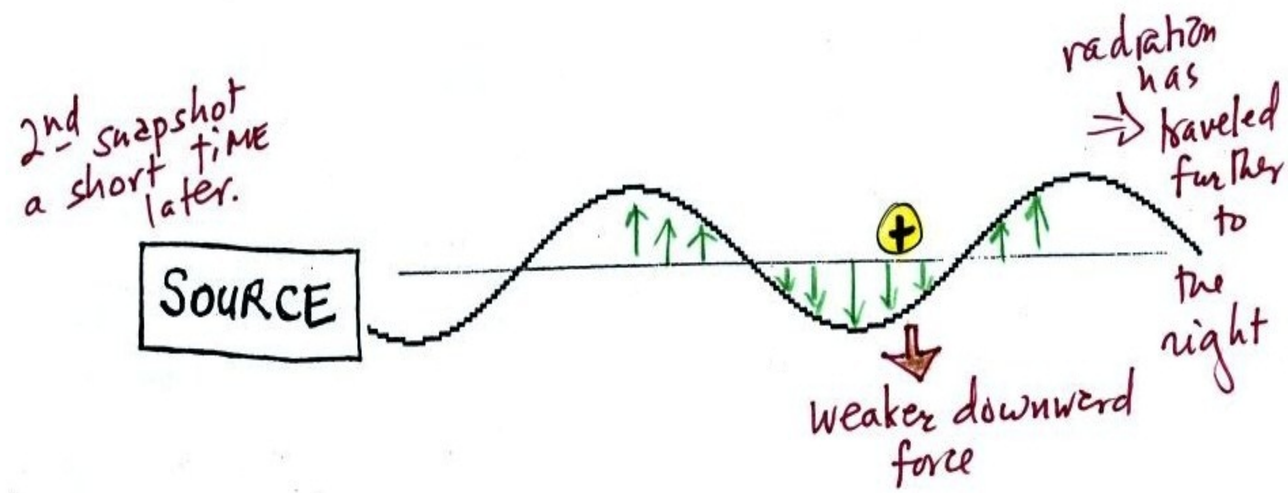


Imagine turning on a source of EM radiation and then taking a snapshot a short time later. The EM radiation is a wavy pattern of electric and magnetic field arrows. We will ignore the magnetic field lines. The E field lines sometimes point up, sometimes down. The pattern of electric field arrows repeats itself.

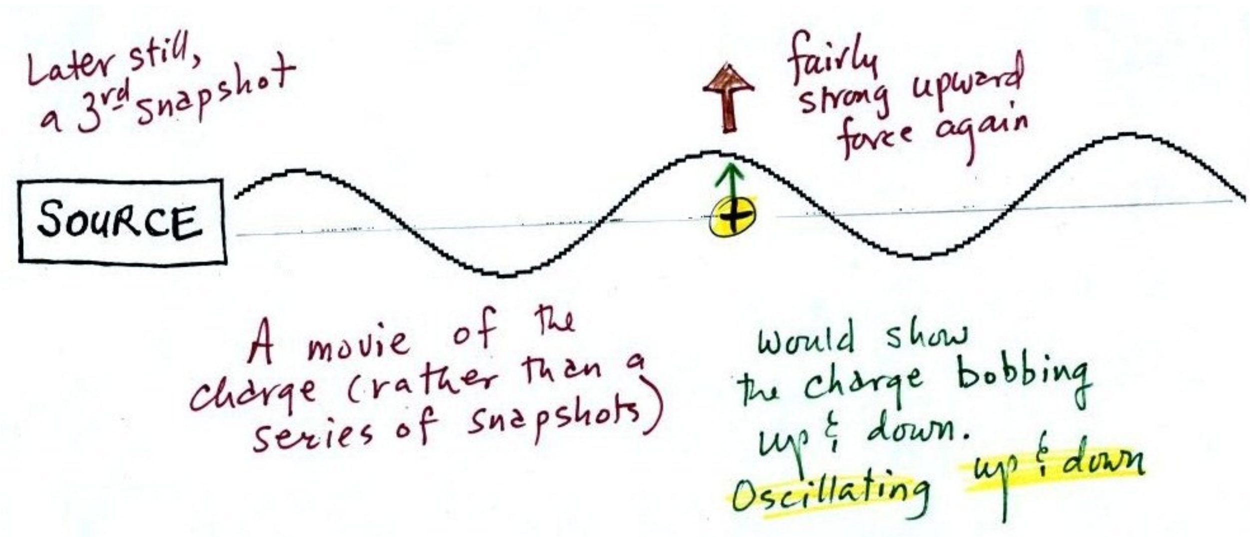
Textbooks often represent EM radiation with a wavy line like shown above. But what does that represent? The wavy line just connects the tips of the electric field arrows.



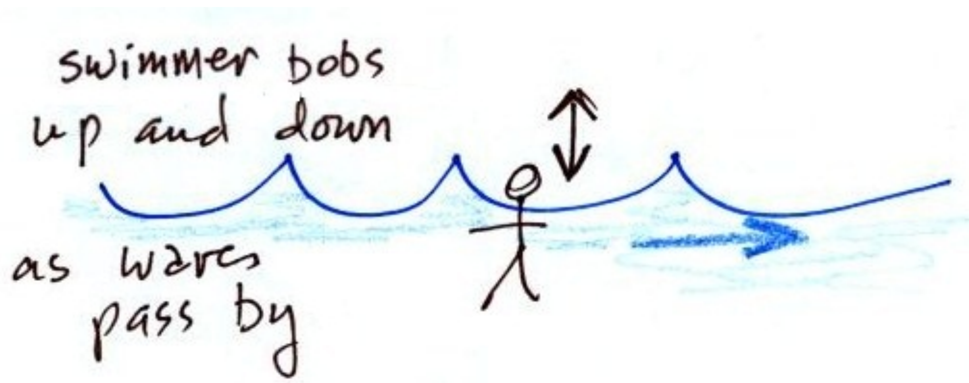
Now back to the earlier picture. Note the + charge near the right side of the picture. In the picture above, the EM radiation exerts a fairly strong upward force on the + charge. When this picture was taken a short time later the radiation had traveled a little further to the right. The EM radiation now exerts a somewhat weaker downward force on the + charge.



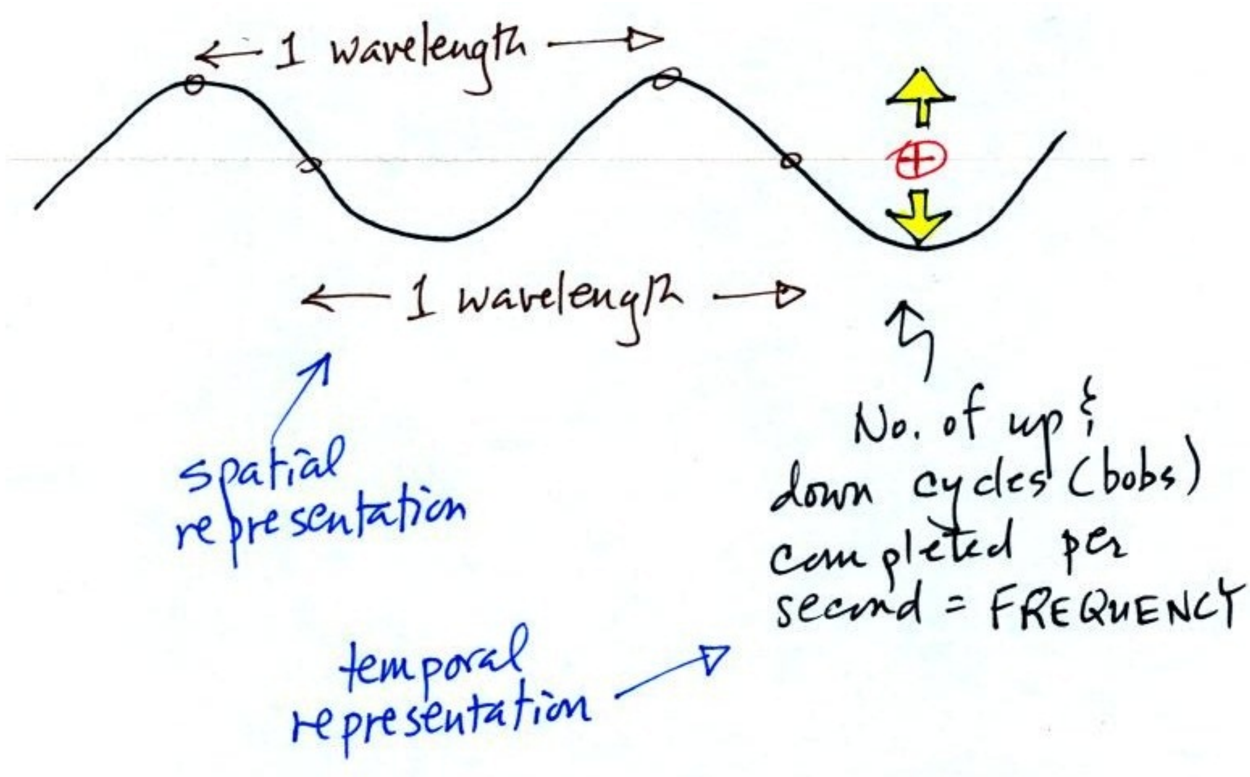
In a third snapshot, the + charge is now being pushed upward again.



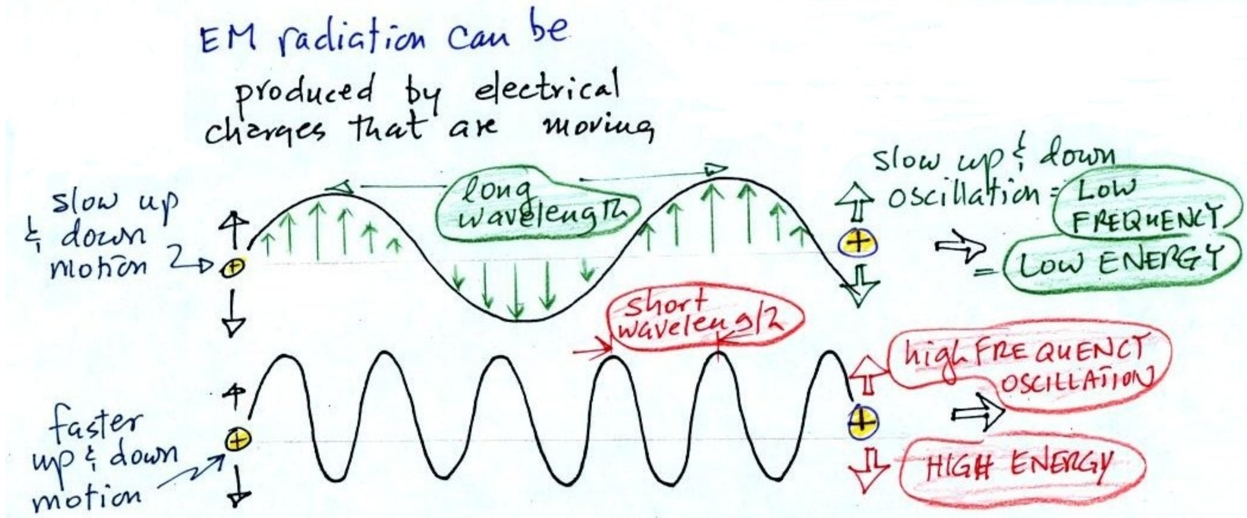
A movie of the + charge, rather than just a series of snapshots, would show the charge bobbing up and down much like a swimmer in the ocean would do as waves passed by.



The wavy pattern used to depict EM radiation can be described spatially in terms of its wavelength, the distance between identical points on the pattern. By spatially we mean you look at different parts of the radiation at one particular instant in time.

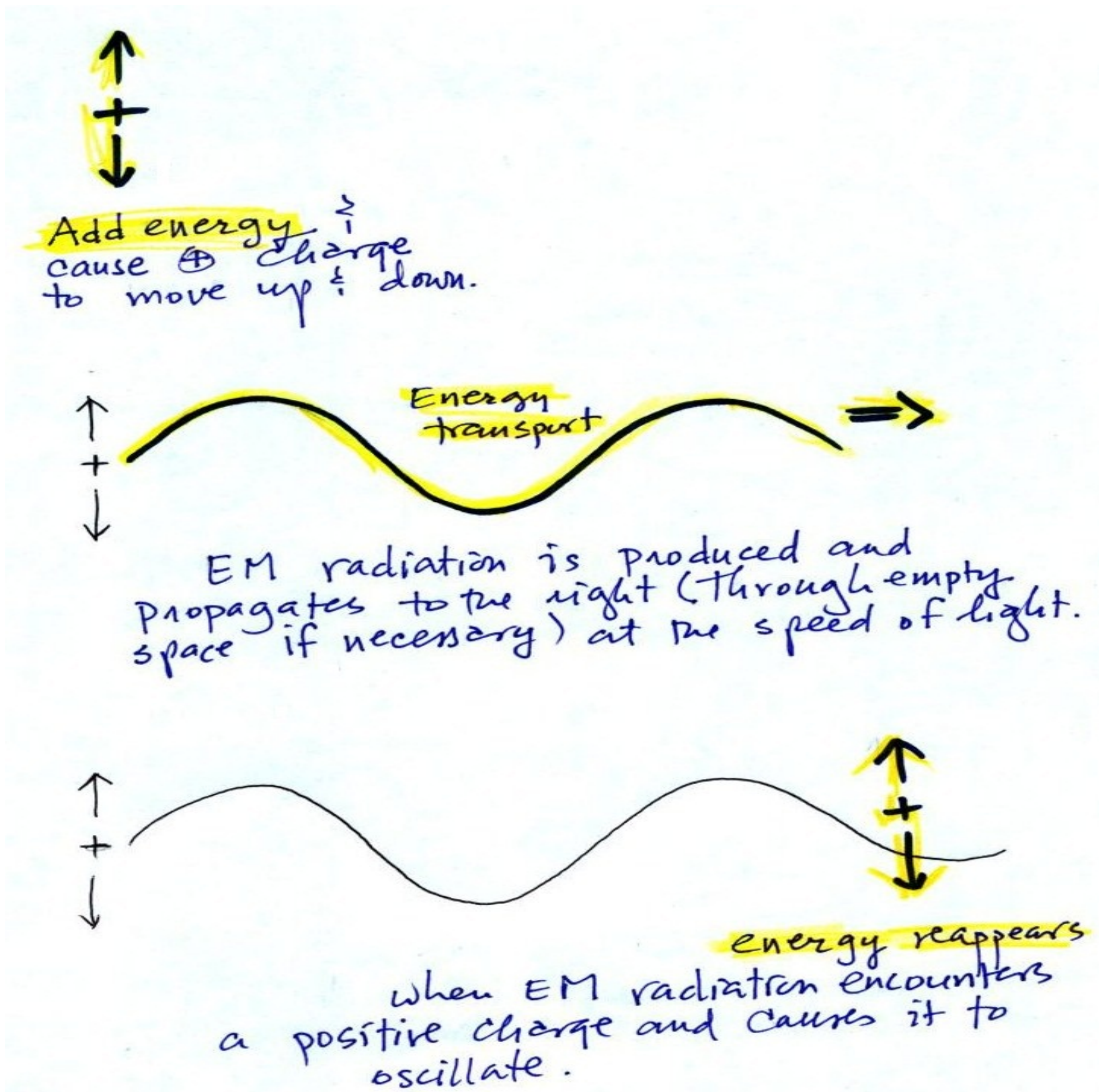


Or you can describe the radiation temporally using the frequency of oscillation (number of up and down cycles completed by an oscillating charge per second). By temporally we mean you at view one particular point for a certain period of time.



The following figure illustrates how energy can be transported from one place to another (even through empty space) in the form of electromagnetic (EM) radiation. You add energy when you cause an electrical charge to move up and down and create the EM radiation (top left). In the middle part of the figure, the EM radiation then travels out to the right (it could be through empty space or through the atmosphere). Once the EM radiation encounters an electrical charge at another location (bottom right), the energy reappears as the radiation causes the charge to move. Energy has been transported (propagated) from left to right.

The amount of energy propagated depends upon the frequency of the oscillation that is created. If a charge moves up and down slowly, lower energy long wave radiation is produced. If a charge is caused to oscillate quickly, high energy shortwave radiation is produced. EM radiation of all frequencies propagates at the same speed, which is the speed of light.



Below is a partial list of some of the different types of EM radiation. The energy of EM radiation is a function of its oscillation frequency. High energy radiation such as gamma rays and x-rays has a short frequency. Low energy radiation such as radio waves and microwaves has a long frequency. In studying the atmosphere, ultraviolet light (UV), visible light (VIS), and infrared light (IR) are the most important forms of radiation. Microwave radiation is used for satellite measurements of atmospheric constituents such as water vapor.

Note the micrometer (millionths of a meter) units used for wavelength for these kinds of light. <u>The visible portion of the spectrum falls between 0.4 and 0.7 micrometers. UV and IR light are both invisible to the eye.</u> All of the vivid colors in the visible range are EM radiation with slightly different wavelengths. When you see all of these colors mixed together, you see white light.