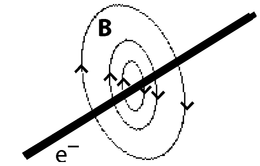
# PhyzGuide: Producing EM Waves

An electromagnetic (EM) wave consists of an oscillating electric field accompanied by an oscillating magnetic field. The fields oscillate at right angles to each other. So how in the heck do you "build" one? Sounds like you've got to shake a charged pith ball up and down while rattling a magnet side to side! As it turns out, it's not that complicated to make an EM wave; understanding EM wave production is, however, a bit taxing on one's mental faculties. So hang on tight!

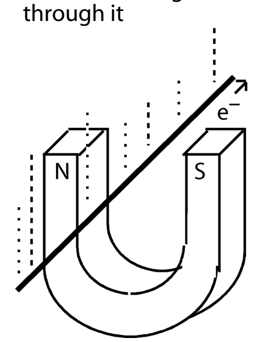


a magnetic field is induced around the wire as electric charges move through it

First we must recall two important symmetrical principles relating electricity and magnetism:

*1. A changing electric field induces a magnetic field perpendicular to the electric field. (A moving charge sets up a magnetic field—recall this is the principle upon which motors are based.)*

*2. A changing magnetic field induces an electric field perpendicular to the magnetic field. (Charged particles can be made to move through a wire by exposing them to a "changing" magnetic field—in a generator the field of the permanent magnet is constant, but the wire's motion relative to the field changes.)*

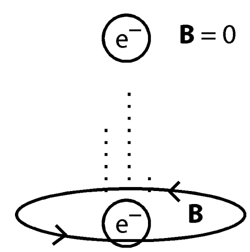


an electric field is induced in the wire as it moves through the magnetic field

So consider an electron in simple harmonic motion. As it moves, its electric field moves, and it sets up a magnetic field tangentially perpendicular to the motion of the motion of the charge. (What did he say?)

Since the magnetic field was zero before the electron moved and now has a particular strength, it qualifies as a changing magnetic field. Remember what changing magnetic fields do (check principle #2 above)? That's right—induce an electric field perpendicular to the magnetic field.

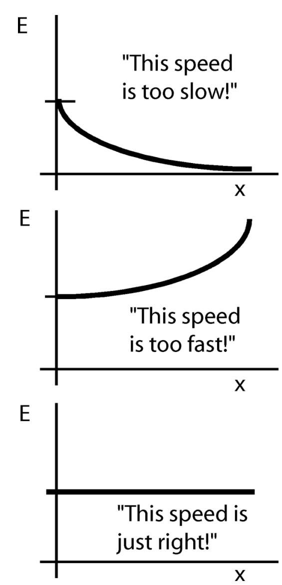
Surely you can see what this leads to—*electromagnetic proliferation!* Changing electric fields induce changing magnetic fields, which induce changing electric fields, which induce changing magnetic fields (and they told two friends, and *they* told two friends, and so on, and so on).




### GOLDIE-LOCKS AND THE SPEED OF LIGHT

One last question: how rapid is this "electromagnetic proliferation?" How long after an electric field changes does a magnetic field come into being? Is it instantaneous, or is there some "lag time?" In other words, how fast are these electromagnetic waves?

**James Clerk Maxwell**, a nineteenth-century Scottish mathematical genius, pondered this problem. His calculations showed that if the alternate fields were produced too *slowly,* the energy of the fields would die out. Unfortunately, there was no mechanism like "friction," or "air resistance" to explain the dissipation of electromagnetic energy. Maxwell's calculations also showed that if the fields induced each other too *quickly,* the energy associated with the fields would increase, again with no explanation. In either case, conservation of energy was violated. So Maxwell calculated the speed at which EM waves could propagate so that energy was conserved (no loss/no gain). The result was $v_{EM} = 3.0 \times 10^8$ m/s ( = 186,000 mi/s = 700,000,000 mph). "Aye," said Maxwell, "ahnnit makes goode since!" The speed of light had been measured prior to Maxwell's calculation. It was known to be about $v_{LIGHT} = 3.0 \times 10^8$ m/s. "OOT-RRREE-JUS!" he must have thought upon discovering that light behaved as an electromagnetic wave, "Am I awesome, oorrr whot?"




*NEWTON:MECHANICS::MAXWELL:ELECTROMAGNETISM*

# THE MANY FLAVORS OF ELECTROMAGNETIC WAVES

## The Electromagnetic Spectrum

**POWER FREQUENCIES**
60Hz US, 50Hz Europe; produced by generators and transmitted through power lines

**RADIO WAVES**
Encompass a broad range of communication wavelengths

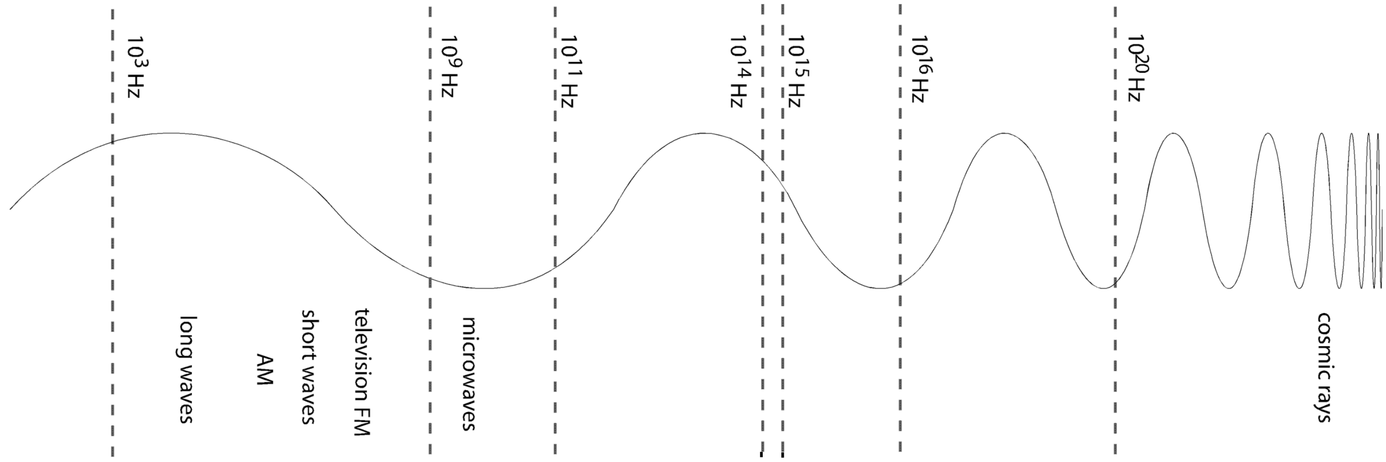
**INFRARED RADIATION**
Used for wireless remote controls in TV's, VCR's, etc.

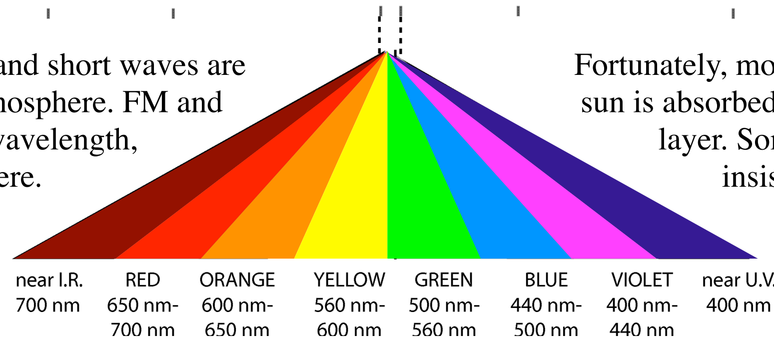
**OPTICAL SPECTRUM**
Includes all visible light and waves that can be caught on photographic film

**ULTRAVIOLET RADIATION**
Has photochemical, photoelectric, fluorescent effects

**X-RAYS**
High energy radiation with high penetrating power

**GAMMA RAYS**
Higher energy photons of very high penetrating power




Long waves, AM waves, and short waves are reflected by the earth's ionosphere. FM and TV waves are shorter in wavelength, and penetrate the ionosphere. The ionosphere becomes more highly reflective when sunlight is not hitting it. Therefore, AM signals can bounce many times over great distances. If all AM stations maintained normal power, nighttime reception would be a mishmash of signals from the dark half of the earth. Therefore, the FCC requires most AM stations to reduce power or go off the air at sunset.

The human eye is most sensitive to yellow-green light. This is because although the sun is a source of many EM wavelengths, the dominant wavelength emitted by the sun is 555 nm and through the course of evolution, our eyes developed sensitivity to the most prevalent wavelength we were exposed to!

Fortunately, most UV light from the sun is absorbed in the earth's ozone layer. Some people, however, insist on exposing themselves to these potentially deadly rays in an attempt to contract skin cancer. Another problem we face is the depletion of the ozone layer. As ***it*** goes, sun worshippers will rejoice as they are able to get that deep, dark, deadly tan in a matter of minutes, maybe seconds! We'll all die of skin cancer, but at least we'll look good!

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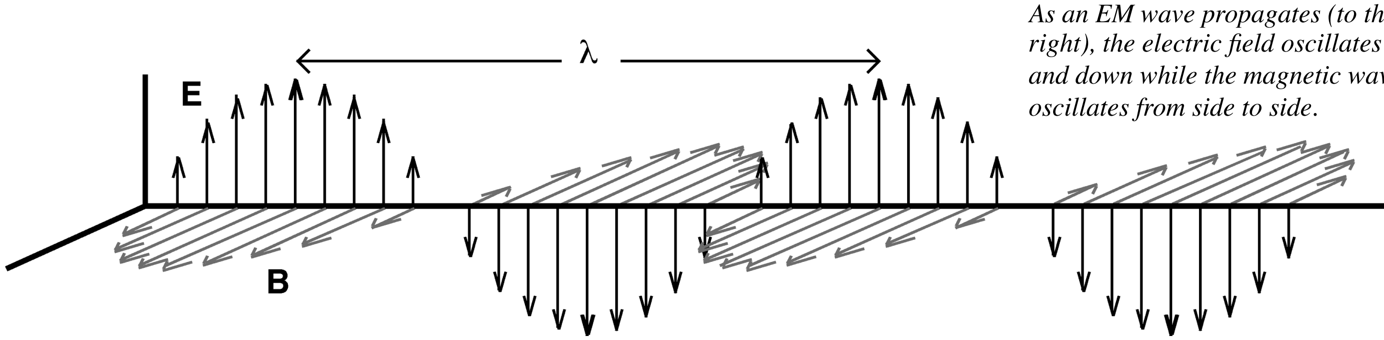


*As an EM wave propagates (to the right), the electric field oscillates up and down while the magnetic wave oscillates from side to side.*