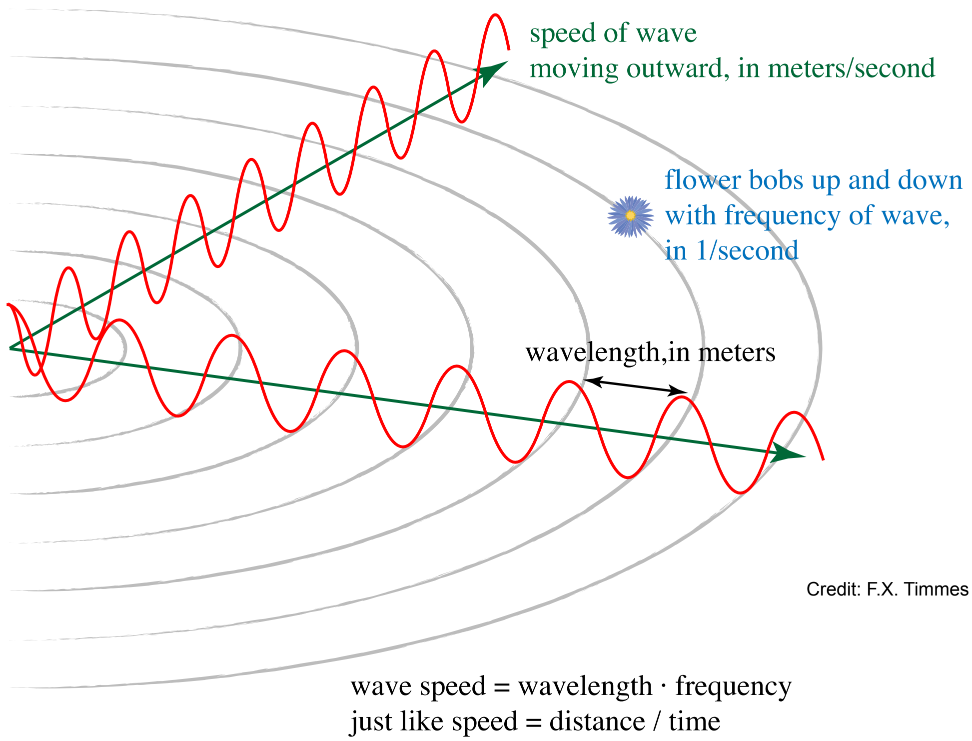
If you want to find the secrets of the universe, think in terms of energy, frequency and vibration.
Nikola Tesla

What's The Frequency Kenneth?

Hi. So what is light? Light is two things. Light can be treated as a wave or as a particle, which we call a photons. Which representation one chooses to use is a matter of convenience.



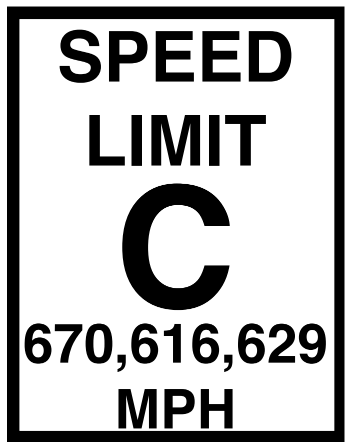
We will start off with waves. Light is an electromagnetic wave. I'll use the terms electromagnetic wave and light interchangeably. I don't necessarily mean visible light. I mean any kind of light whether it's radio, x-rays, gamma rays, infrared, ultraviolet, etc. I mean all of these when I say light.

The image above is an example of a wave. The wave is going outwards. The distance between two peaks in that wave is referred to as the wavelength. It doesn't mean you have to use peak-to-peak. You could go trough-to-trough, or you could go middle-to-middle. Any convenient location where the wave repeats itself. The wavelength of the wave is a distance, measured in meters.

You could also just stand at a fixed location and count how many waves go by you, as though you were a flower bobbing up and down on a ripple wave of water as it spread outward. You count the number of waves that go by as you stand in any one location. 1, 2, 3, 4, 5, 6, 7 … That number divided by the period of time that you are counting those waves is referred to as the frequency of the wave. It is measured in the units one over seconds, per second, as in how many waves went past you per second. One over seconds is more commonly referred to as Hz (hertz).

$$1/\text{second} = 1\ \text{Hz}$$

The neat relationship between the wavelength and the frequency is that if you multiply the wavelength and the frequency together, you get the speed of the wave! So the speed is equal to the wavelength times the frequency. This is really just your old friend in disguise, a distance divided by a time is equal to a speed. The distance here is the wavelength. The “divided by a time” is the frequency. And the product is equal to the speed.



Credit: F.X. Timmes

Now light is kind of a special wave, because it doesn't need a medium to propagate. How weird! All other kinds of waves — for example, sound waves, the reason you're hearing my voice, generally must have some sort of medium to propagate in — water, air, rock, whatever it may be. But light will travel in a vacuum, all by itself. And it always travels at the same speed of about 300,000 kilometers per second in a vacuum. Always.

The relationship between wavelength, frequency, and speed for light is:

$$c = \text{wavelength} \times \text{frequency}$$

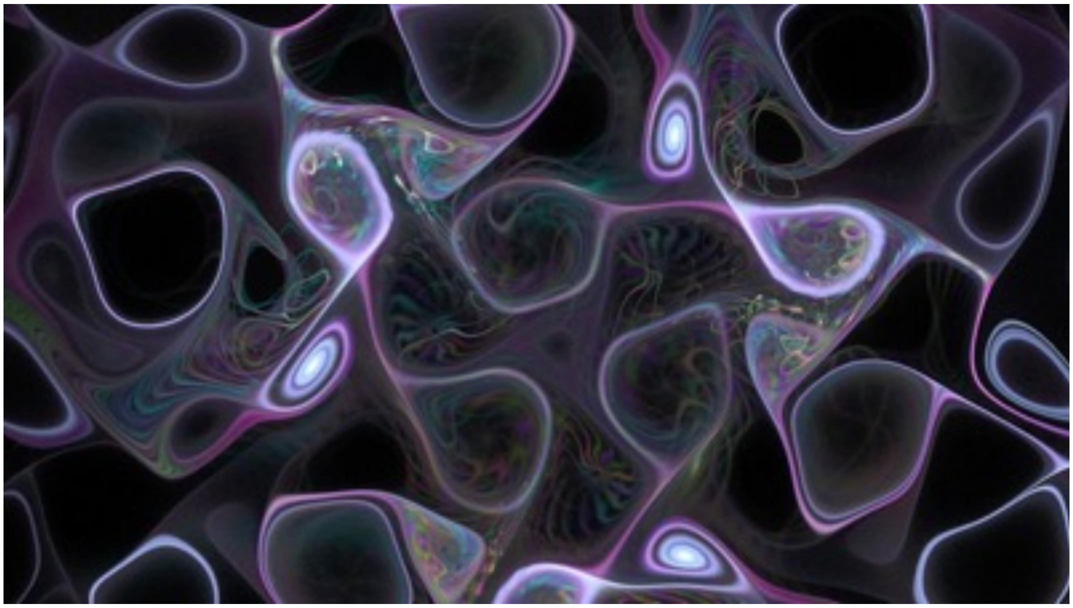
where c is the speed of light. And it is given by some crazy number in miles per hour shown in the above image.

Light is also a particle. We call these particles of light photons — and each photon’s energy is determined by its frequency:

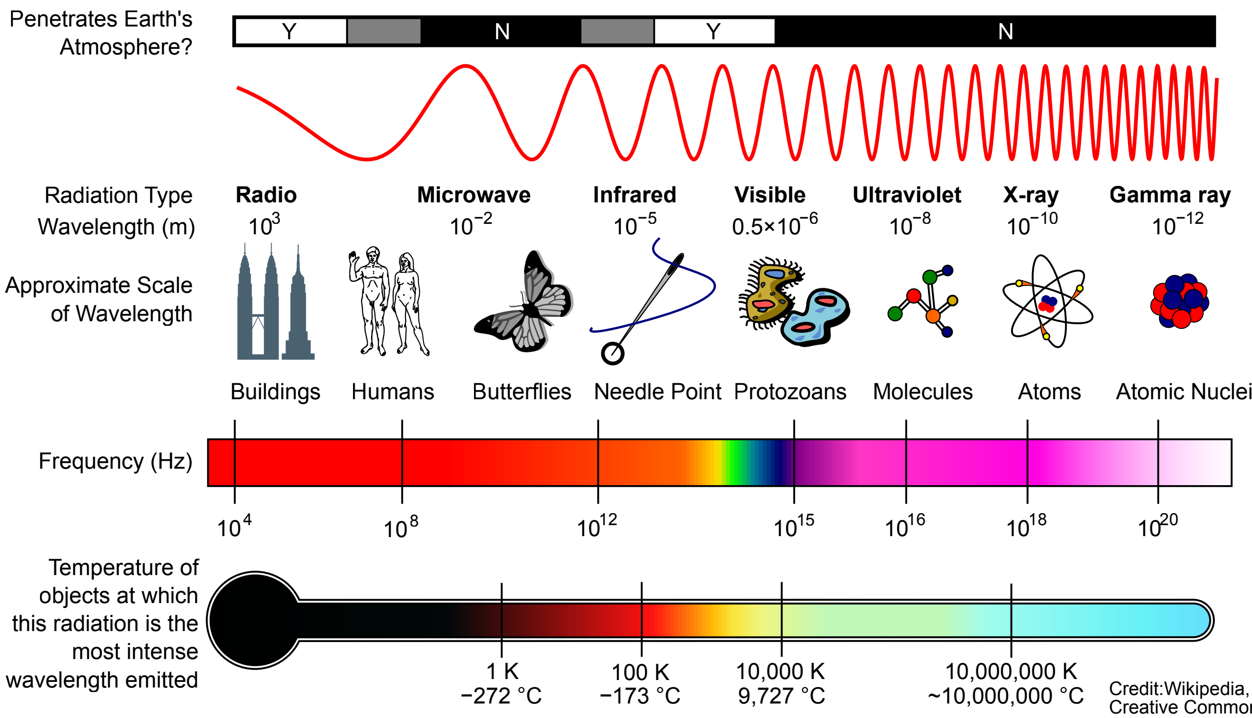
$$\text{Energy} = \text{Planck's constant} \times \text{frequency} = h \times f$$

Planck’s constant, usually given the symbol h, is a constant of nature, like the speed of light c or the gravitational constant G. One interpretation of Planck's constant is that it sort of sets the pixel size of the universe. If you start blowing a picture up — like you’re familiar with on a typical jpg image or a png image — it starts to pixelate, you start to see the individual pixels in the picture.

Same thing with nature. If you start zooming in and zooming in, at some point, it starts to get fuzzy. And that scale at which it starts to get fuzzy is set by Planck's constant. The image below is just sort of a fun artistic rendition of what that “quantum foam” may look like.



Credit: Alex Sukontsev, Creative Commons



Credit:Wikipedia, Creative Commons

Our last point in this module is the electromagnetic spectrum:

We give different names to different parts of the electromagnetic spectrum. It's all continuous of course, but we give different names for convenience. At the very longest wavelengths, we have radio waves. As the wavelength gets shorter, we go to infrared. Then we have visible light. Then we have the ultraviolet. At ever shorter wavelengths we have x-rays and then finally, we have gamma rays.

Each wavelength corresponds to a length scale where that light interacts more strongly with matter. Look at the illustration above carefully, to get a sense of when wavelengths correspond to what size objects. In general, we'll just say that gamma rays correspond to nuclear phenomena. Visible light corresponds to basically kind of dust particle-size stuff. And radio waves correspond to larger building-type objects.

So, visible light. We only see in that little tiny sliver of the electromagnetic spectrum that we call visible light, the familiar colors of the rainbow from red to blue. Why is that? How come we don't see in infrared? Why don't we see in ultraviolet? And why is yellow the color our eyes are most sensitive to?

Well, it's because over several million years of evolution, our eyes have gravitated toward where the Sun puts out most of its energy! The Sun puts most of its energy out in the visible light. So our eyes, as energy-seeking and energy-hungry devices, have evolved to see best and absorb the most energy where the Sun is putting out most of its energy.

If our Sun happened to be a smaller, cooler, red star, we would probably see in the infrared. If our star was a hot, massive, blue star, we would probably see better in the ultraviolet. So it's really a product of our star and evolution as to why we happen to see in the visible wavelengths.

But with technology we can “see” in any of the wavelengths, from radio all the way to gamma rays. And this multi-wavelength capability gives us more complete information of what's happening with something, rather than just the sliver of visible light.

Thanks! Bye Bye.