PHYSICS AND CHEMISTRY

Chapter 1 – The Secret Language of Color

INTRODUCTION

- Plato, Newton, Da Vinci, Goethe, Einstein: All these great minds and many more grappled with the profound complexity of color. They sought to understand it, creating systems to explain its mysterious workings.
- Some fared better than other, and from the vantage point of our current scientific knowledge, any of their attempts now seem funny, bizarre, or downright fantastic.

INTRODUCTION

- In the 5th Century BC, Plato drew a causal relationship between color vision and the tears in our eyes. The eighteenth and nineteenth century philosopher Johan Wolfgang Von Goethe tried to impose order on color's chaos by arranging hues into three groups: powerful, gentle/soft, and radiant/splendid. Although we've come a long way in our understanding of color, much remains a mystery.

INTRODUCTION

- Color is everywhere, but most of us never think to ask about its origins. The average person has no idea why the sky is blue, the grass is green, the rose is red. We take such things for granted. But the sky is not blue, the grass is not green, the rose is not red. It has taken us centuries to figure this out.

NEWTON

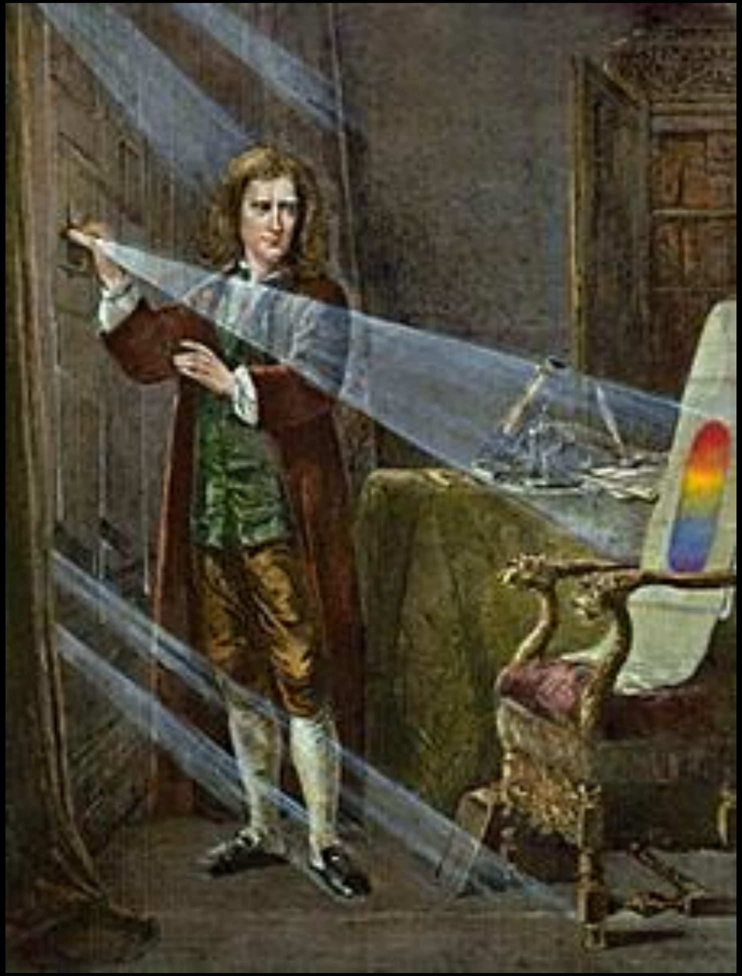
- It stands to reason that for thousands of years, many causal observers must have seen what Newton did: that light passing through a prism creates a rainbow on the surface where it lands; but Newton saw something no one else had seen. He deduced that the white light that appears to surround us actually contains all the different colors we find in a rainbow. Whit was not separate from these colors - or a color unto itself - but was the result of all colors being reflected at once. This counterintuitive and revolutionary theory did not take hold easily. Some of those greatest minds we mentioned simply wouldn't accept this theory. The idea that white light contained all color upset Goethe so that he refused - and demanded others refuse - even to attempt Newton's experiment.

NEWTON'S PRISM

- Although Newton's discovery was more than enough to upset his contemporaries' digestion, he didn't stop there; Newton also ascertained that colors refracted thought a prism could not be changed into other colors. Here's how he did it. He took a prism and placed it between a beam of light (coming from the hole in his window shutters) and a board with a small hole in it.

NEWTON'S PRISM

- The hole in the board was small enough that it only allowed one of the refracted colors to pass through it. He then placed all kinds of materials (including a second prism) in front of the beam passing through the small hole. Prior to the experiment, he had believed that if, for example, a blue piece of glass was placed in front of a red beam of light, the red would be transformed into another color.

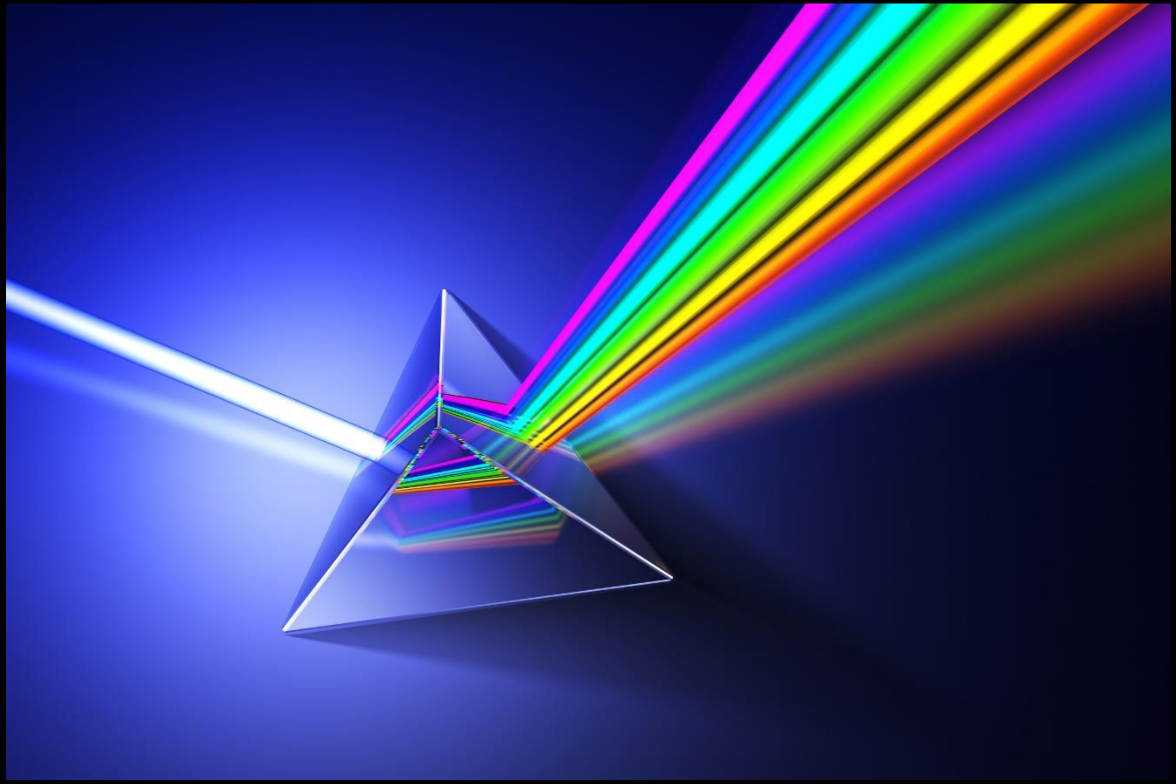


NEWTON'S PRISM

- But he found that this was not the case. No matter what color or type of material he placed in front of an individual beam of light, he couldn't get the refracted color to change. From this experiment, he deduced that there was a certain number of what he called "spectral" colors - color that cannot be broken down, colors that are fundamental.

NEWTON'S PRISM

- Once Newton confirmed that his spectral colors were unchangeable, he decided to name them - and here's where his method takes a left turn from the scientific to the fanciful. Taken with the idea that the rainbow should reflect the musical scale, Newton decided to name his colors in accordance with aesthetics.



NEWTON'S PRISM

- There are seven main tones in the musical scale, so Newton came up with seven corresponding colors. Hence the origin of ROYGBIV, the acronym by which we know Newton's spectral colors - red, orange, yellow, green, blue, indigo, and violet.

NEWTON'S PRISM

- Although the relationship to music was later set aside by scientists who questioned the basis for comparison, ROY G BIV is still used today as a teaching tool, even though indigo is not a color most people can even identify.

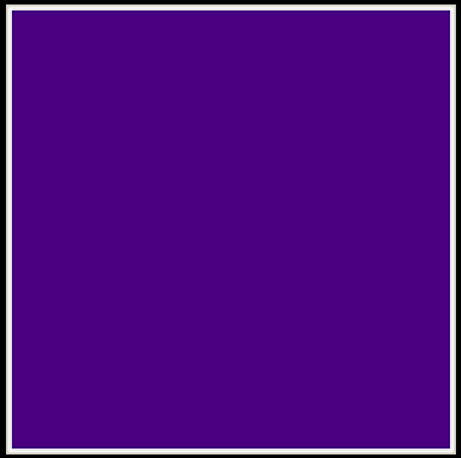
WHY 7 COLORS?

- The truth is, there's no perfect way to name the colors of the rainbow. Take a look at a real rainbow (as opposed to a kindergarten's rendition), and you'll see that its colors merge seamlessly from one to another. Any judgment on where one color ends and the other begins is arbitrary.

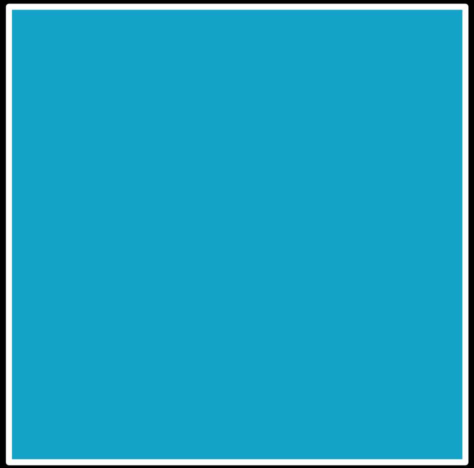
WHY 7 COLORS?

- Even Newton waffles on this point. At the beginning of his experimentation, his spectrum included eleven colors. Once he'd whittled the number down to seven, he still thought of orange and indigo as less important, calling them semitones in another nod to the musical scale.

WHY 7 COLORS?



Newton Indigo



Newton Blue

- There's another issue with naming the colors of the rainbow: The language of color is fluid, morphing over time across geographies in response to cultural forces that are sometimes too complex to pin down. For example, the color Newton called indigo is one the one most people would identify as plain old blue or a true blue that falls midway between green and violet. Newton's blue is what we now call cyan, more turquoise blue that falls between blue and green.

WHY 7 COLORS?

- As for the names of the last color in the rainbow, why is it violet as opposed to purple? Violet refers to the spectral color that looks bluish purple. Purple refers not to a spectral color but to a color created by a mix of light.

COLOR SYSTEMS

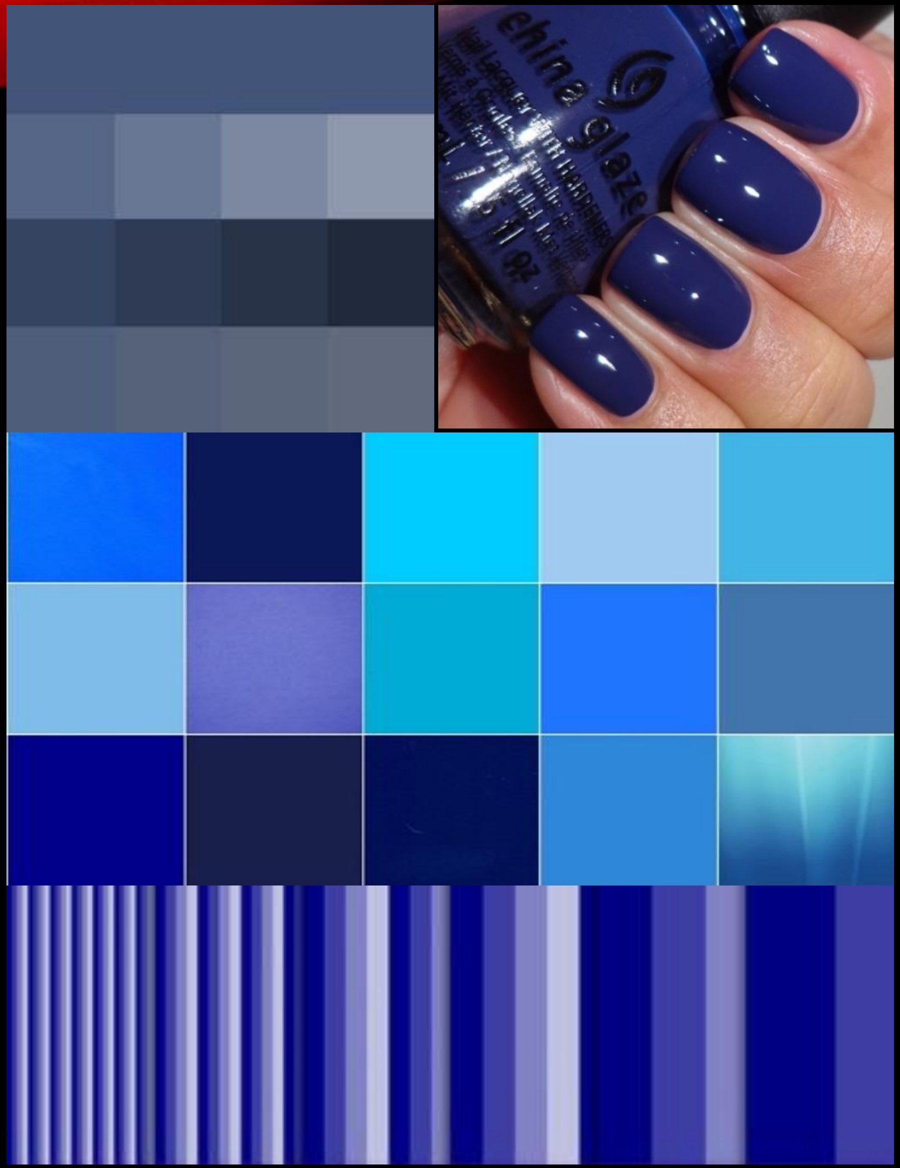
- Color systems pre-and post-Newton have codified a whole host of fundamental colors. By fundamental, we mean colors that our linguistic or scientific models don't allow us to reduce any further.

COLOR SYSTEMS

- Categorize/Explain the following color:

  Navy Blue

COLOR SYSTEMS



- Categorize/Explain the following color:

Navy Blue

FUNDAMENTALS

- Today, we consider red, yellow, orange, green, blue, and violet as fundamentals. These fundamental colors are referred to as hues. Although color's value (put simply, how dark or light it is) and its chroma (put simply, how dull or bright it is) can chance, its hues is essential to its identification.

FUNDAMENTALS

- Regardless of their number, the colors Newton called spectral should not be confused with the colors we've been taught are the primary colors that cannot be mixed and are therefore fundamental (i.e. red, blue, and yellow) or the class of shades known as secondary colors (i.e. orange, green, and purple).

FUNDAMENTALS

- These secondary colors, we've been taught, result from the mixing of the primary colors - red and yellow make orange, red and blue make purple, and blue and yellow make green - and therefore are not fundamental. But what Newton found was that orange, green, and violet (which, to repeat differs from purple) can be spectral and just as fundamental as the colors we call primary.

FUNDAMENTALS

- Orange, for example, can results from a mix of light, but it can also be pure. The same is trust for red, blue, and yellow, even thought we call them "primaries." You can tell a color that is a mixture of light from a spectral color by passing the light through a prism. The orange light that is a mix will break into its components when passed through a prism, but pure orange light will not.

FUNDAMENTALS

- Another major "aha!" moments would soon follow for Newton: the discovery that when red light was passed through a prism, it bent only slight, whereas violet light bent much more. This intriguing observation led Newton to believe that each color was made up of unique essential components. What made red red is different from what made violet violet. Although he was on the right track, Newton incorrectly hypothesized that light is composed of particles that travel in a straight line through some kind of ether. What he called his "particle theory" was eventually widely accepted

FUNDAMENTALS

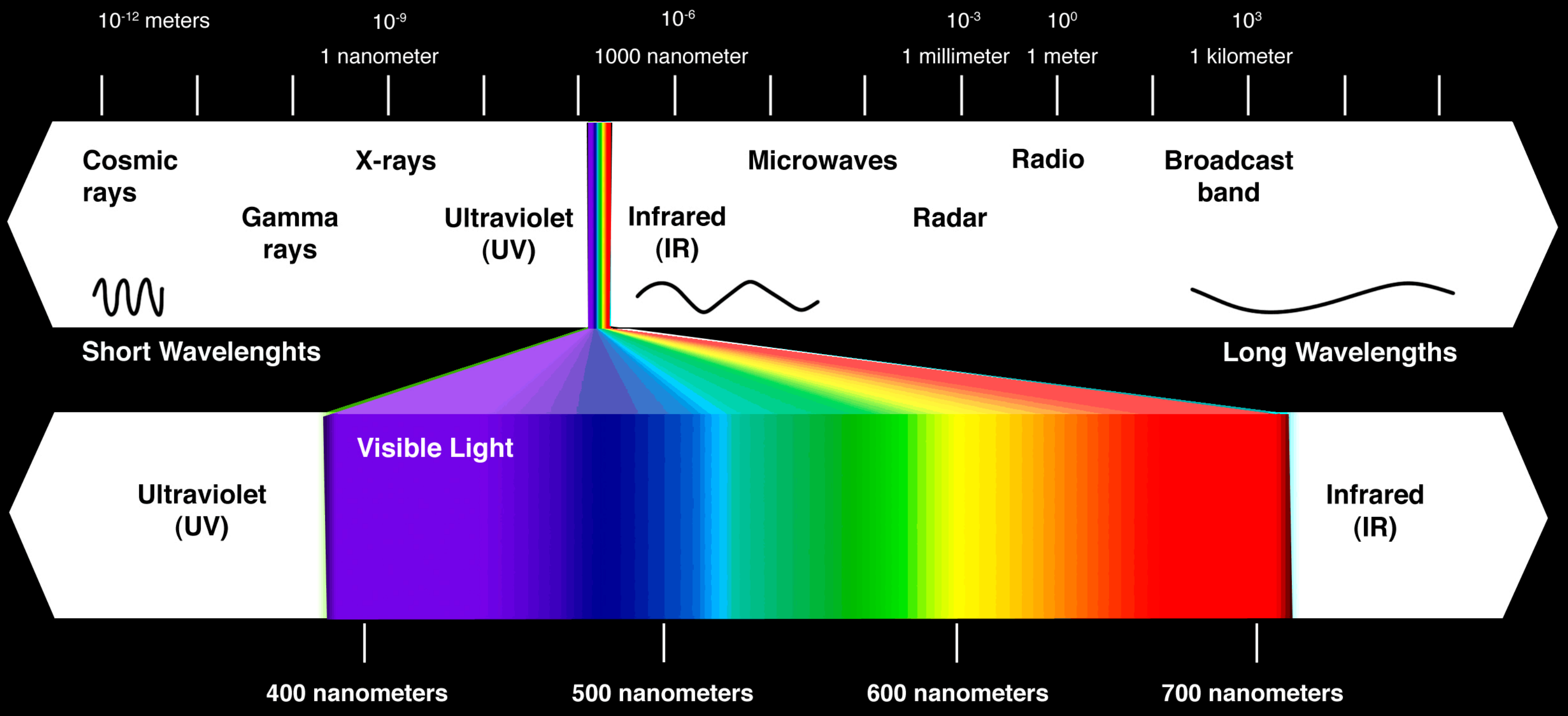
- Fast forward to the beginning of the 19th century, when an English scientist Thomas Young returned to a notion put forth by some of Newton's contemporaries. Although Newton was convinced that light is a particle, Young's experiments led him to believe light- like sound - is a wave. Another half century later, the venerable James Clerk Maxwell took Young's work and made a giant leap.

ELECTROMAGNETISM

- Before James Clerk Maxwell's work, electricity and magnetism were believed to be two separate forces, but Maxwell found the forced to be connected, and he called this interconnection electromagnetism. Maxwell showed how charged particles repel or attract one another, as well as how these charged particles act like waves when they travel through space.

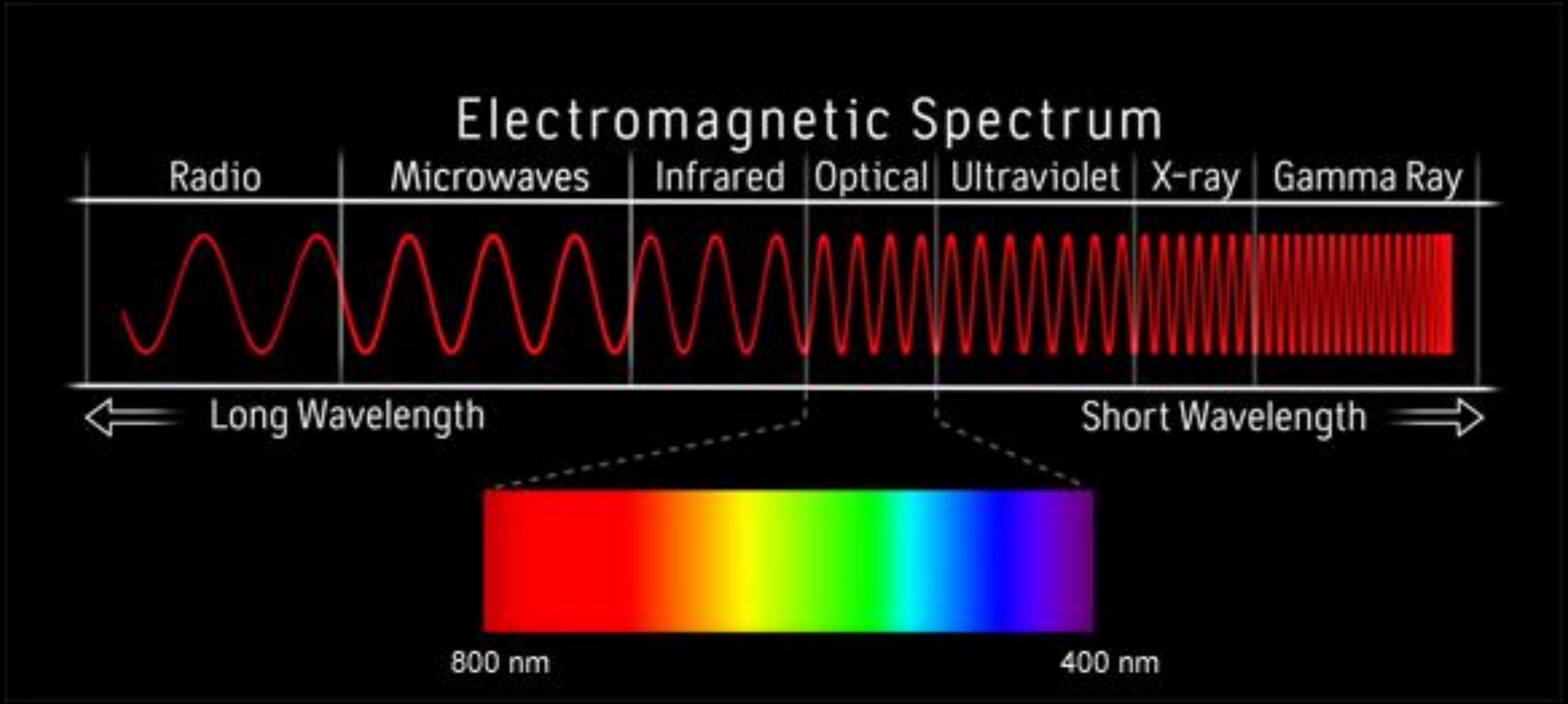
ELECTROMAGNETISM

- A particularly exciting part of Maxwell's treatise on the subject showed that a specific group of electromagnetic waves is the cause of visible light - in other words, the case of color. He identified other groups of electromagnetic waves, too, group we now recognize as ultraviolet light, radio waves, X-rays, and microwaves, to name a few



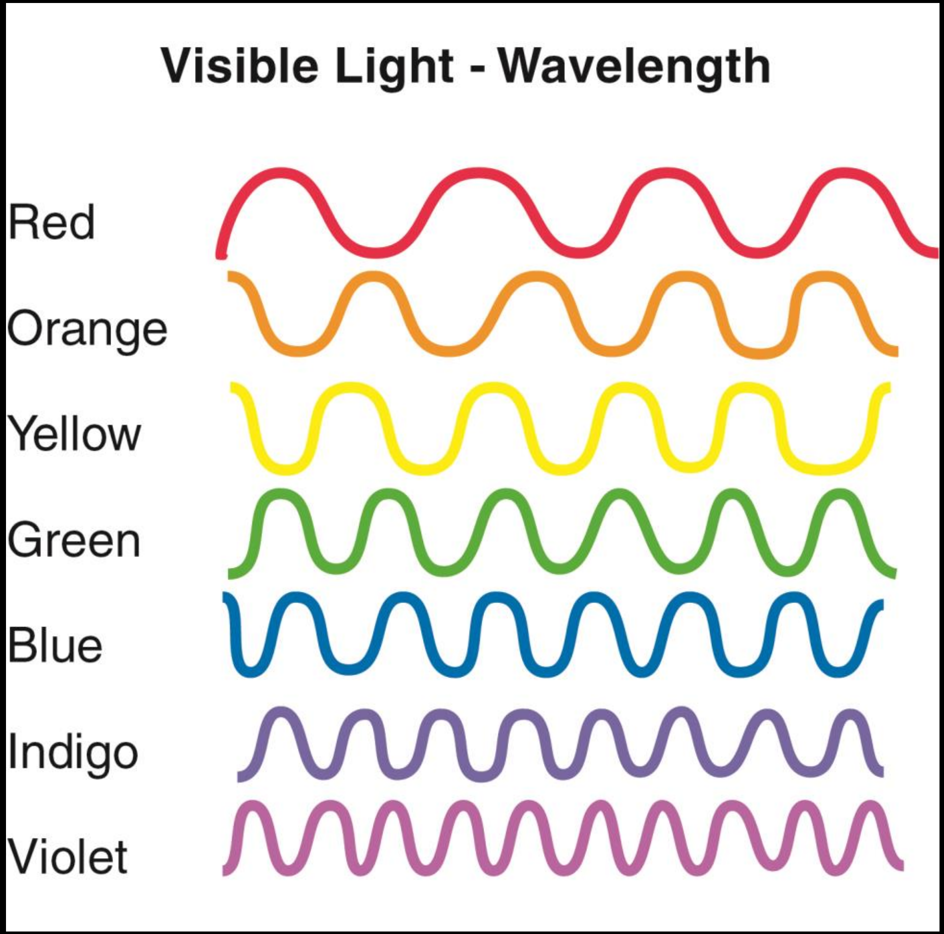
ELECTROMAGNETISM

- All of these fall on the electromagnetic spectrum, and each is measured and defined by its length and frequency, as does every microwave, radio wave, or other wavelength on the electromagnetic spectrum; but there is no essential quality separating visible light from these other kinds of waves - except that our eyes (or to be more precise, our brains) can perceive them as color.



ELECTROMAGNETISM

- Violet is the color with the shortest wavelength of visible light, at 380 to 450 nanometers (one nanometer is equal to one-billionth of a meter), but the highest frequency is equal to 789-668 THz (or terahertz, which is the unit for frequency). On the spectrum of electromagnetic radiation, it is the wave that is closed to ultra violet and x-rays.



ELECTROMAGNETISM

- Red has the longest wavelength, at 620 to 740 nanometers, but the lowest frequency of visible light is at 480 to 400 THz, closest to the infrared and microwaves.