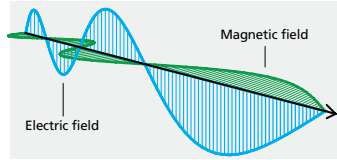


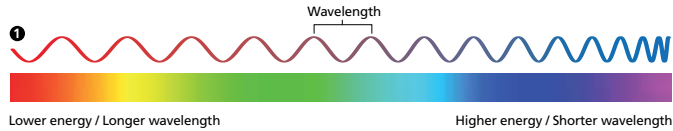
CRIBSHEET #13

LIGHT

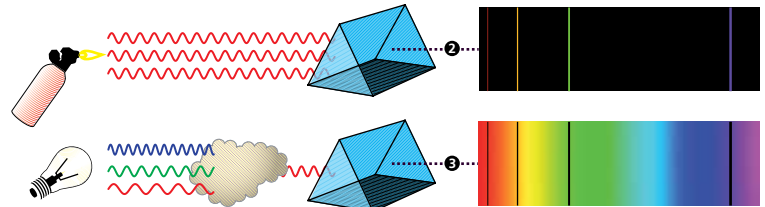
*What is light and where does it come from?
How can light be used to investigate the world around us?*



Light is energy that travels as a wave through space. Most of the light we encounter in everyday life is produced by nuclear fusion in stars or the energetic excitation of electrons in atoms. A wave of light actually has two components: an **electric field**, and a **magnetic field**. Consequently light is also called **electromagnetic radiation**. Electricity and magnetism are interdependent: One can produce the other. Similar to how passing a magnet over a coil of copper wire briefly generates electricity, or how a constant electric current can magnetize iron, a light wave's oscillating electric and magnetic fields reinforce each other and propagate through empty space at nearly **300,000 kilometers per second**. This value is known as the **speed of light**, and appears to be the universe's ultimate speed limit—nothing travels through space faster.



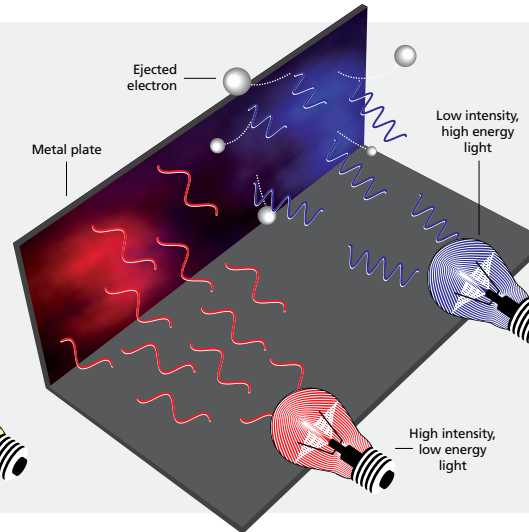
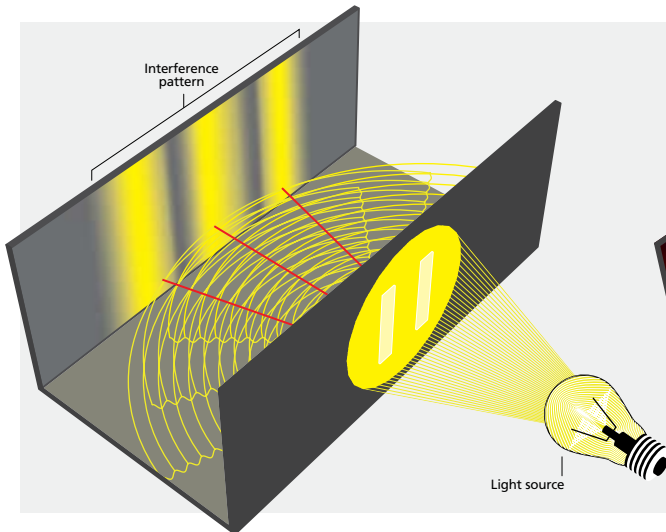
All forms of light—radio waves, microwaves, infrared, visible, ultraviolet, x-rays, and gamma rays—are identical except for their **wavelength**. Light's wavelength determines its energy; the **shorter** wavelengths have **higher** energy. Light from most natural sources contains multiple wavelengths. White light contains all visible wavelengths. Refracting it through a prism separates them into a **continuous spectrum** ❶.



LIGHT AND MATTER

Each kind of atom in a substance **absorbs** characteristic wavelengths of light; all other wavelengths are **reflected** back or **transmitted** through. Different mixtures of atoms reflect different wavelengths, creating the diversity of colors we perceive in the world around us.

Because light can originate from the excitation of electrons in atoms, and each element of the periodic table has a unique atomic configuration of electrons, the elemental composition of any substance can be discovered through observing the spectrum it produces when its electrons are energized. For instance, burning a sample of hydrogen gas creates light. Running that light through a prism produces a distinct **emission spectrum** ❷. Conversely, light passing through a cool cloud of hydrogen gas and then a prism produces a unique **absorption spectrum** ❸. By studying spectra like these, we can measure the chemical composition of practically anything on Earth, as well as the atmospheres of other planets, the Sun, and even the distant stars.



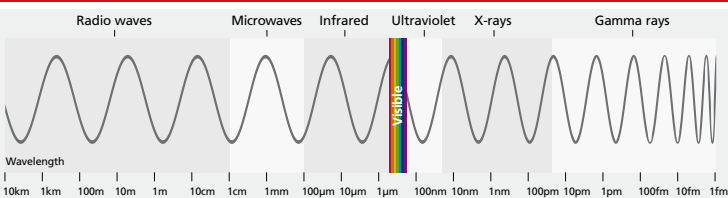
WAVE-PARTICLE DUALITY

Light usually behaves like a **continuous wave**, but it can also act as if it is composed of discrete **particles** of energy called **photons**.

Light's wave-like nature can be revealed when light diffracts through two slits and shines onto another surface. Light passing through the slits acts as two waves that disrupt and interfere with each other. Where the waves' peaks and troughs overlap, they combine to produce a characteristic **interference pattern** of light and dark bands.

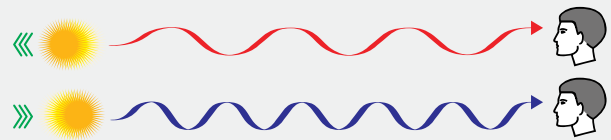
But when light of **different wavelengths** shines on a metal surface, the existence of individual photons becomes clear. If an electron in the metal absorbs more than a threshold amount of energy, it breaks free and zips away. Since shorter wavelengths contain more energy, a very **bright** but **long-wavelength** light will have no effect on the metal, while a very **dim** but **short-wavelength** light will release electrons. The energy of ejected electrons increases not with greater amounts of light, but with more energetic wavelengths. This means each electron ejection depends on the energy of an individual photon.

THE ELECTROMAGNETIC SPECTRUM



In theory, light's shortest possible wavelength is trillions of times smaller than the diameter of a proton, and light may have no upper limit on its wavelength. In practice, we can detect light with wavelengths ranging from thousands of kilometers down to less than the size of an atomic nucleus. The electromagnetic spectrum is the continuum of wavelengths between these extremes. Our eyes can only see light between 400 and 700 nanometers in wavelength—a minuscule portion of the entire electromagnetic spectrum.

REDSHIFT/BLUESHIFT



Like the sound of a passing siren that rises and then falls in pitch as it approaches and recedes, light waves from a source moving in relation to an observer exhibit similar shifts. As a light source approaches an observer its light is compressed to shorter wavelengths—this is a **blueshift**. As a light source recedes, its light is stretched—this is a **redshift**. The redshifts and blueshifts for most slow-moving, earthbound objects are too small to be easily noticed. But on astronomical scales, we can measure the motions of planets, stars, and galaxies using this effect.

THE ISSUE: HARNESSING LIGHT

Many of the past century's major scientific and technological advances came from studying the physics of light, and this trend is certain to extend well into the future. Our understanding of light has allowed us to study the universe on the smallest and largest of scales. It has given us applications like radio, television, radar, medical x-rays, microwave ovens, and wireless computer networking, to name but a few. Now, emerging technologies like quantum computing, efficient solar power, and light-based spacecraft propulsion are poised to further transform science and our society.

SOUNDBITE

Light is electromagnetic radiation that moves through space at 300,000 kilometers per second and acts as both a wave and a particle.