1. Light rays consist of _________.

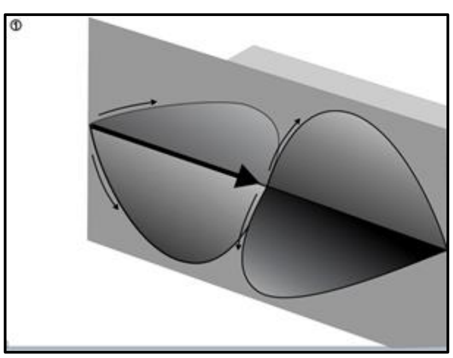
(A) magnetic waves alone
(B) electrical waves alone
(C) magnetic and electrical waves
(D) microwaves
(E) an electron in motion

All electromagnetic radiation, from radio waves to microwaves to visible rays to x-rays, consists of photons of electromagnetic energy.

The energy is in two planes. In one plane is the electrical wave, and in a plane perpendicular to the electrical wave is the magnetic wave.

When the electrical wave dips, it gives up its energy to the magnetic wave and the magnetic wave rises. When the magnetic wave dips and gives up its energy, and the electrical wave rises.

As the electrical and magnetic waves vibrate back and forth perpendicular to each other, they move forward in the direction of travel.



2. Electromagnetic rays that are not in the visible range include gamma rays, radio waves, ultraviolet rays, and infrared rays. Arrange these rays from lowest energy to highest energy.

(A) gamma rays, radio waves, ultraviolet rays, infrared rays
(B) radio waves , infrared rays, ultraviolet rays, gamma rays
(C) ultraviolet rays, infrared rays, radio rays, gamma rays
(D) gamma rays, ultraviolet rays, infrared rays, radio rays
(E) radio waves, ultraviolet rays, infrared rays, gamma rays

Radio waves are the longest electromagnetic waves, with lengths ranging up to miles long.

Somewhat shorter are the electromagnetic waves for TV and cell phones, and radar. Radar waves are about 10 cm long. Microwaves are about a centimeter long.

As electromagnetic waves get shorter in length, their frequency increases, because length times frequency equals the speed of an electromagnetic wave, and in a vacuum, all electromagnetic radiation travels at the same speed, c, 3 times $10^8 \frac{m}{sec}$.

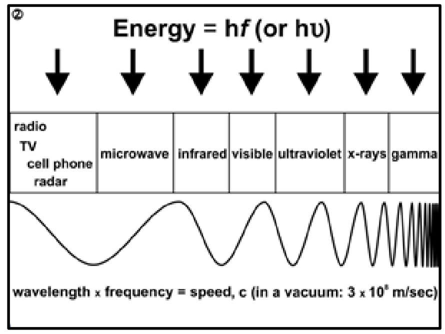
The energy of an electromagnetic wave is h, Planck's constant, times the electromagnetic wave's frequency: h times f, or h times v. For this reason, infrared light is slightly higher energy than microwaves, and visible red light is lower energy than blue light.

As we move out of the visible spectrum of light into ultraviolet light, we move into sunburn territory. X-rays are high enough energy to penetrate the soft tissues of the human body but not the bones.

The highest energy, and thus the highest frequency, electromagnetic radiation are gamma rays which possess enough energy to penetrate all the way through the human body.

X-rays generally have lower energy than gamma rays, but some high energy x-rays possess the same energy as gamma rays. In that case, the only thing that sets x-rays apart from gamma rays is the way they're made.

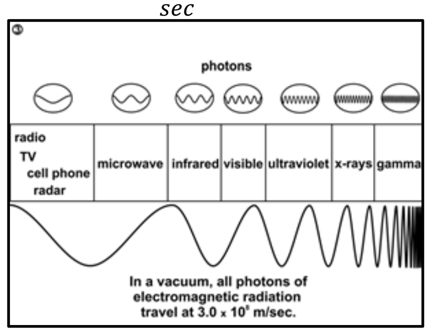
An x-ray is made when an electron in an outer shell falls to an inner shell and emits a high energy x-ray. Gamma rays result when a proton or neutron inside a nucleus decays.



3. Arrange gamma rays, radio waves, ultraviolet rays, and infrared rays in order of speed through a vacuum.

(A) gamma rays, ultraviolet waves, infrared rays, radio rays
(B) gamma rays, infrared rays, ultraviolet rays, radio rays
(C) gamma rays, radio rays, ultraviolet rays, infrared rays
(D) ultraviolet rays, gamma rays, infrared rays, radio rays
(E) all of their speeds through a vacuum are equal

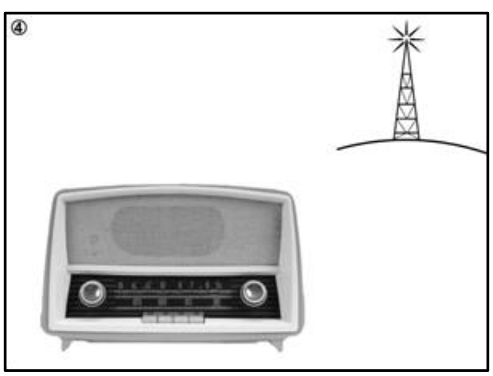
The speed of an electromagnetic wave traveling through a vacuum is the same as any other electromagnetic wave, regardless of its energy, wavelength, or frequency. That speed is the speed of light in a vacuum: 3 times $10^8 \frac{m}{sec}$.



4. Radio waves at 90 Mhz (mega hertz) ___________.

(A) cause air molecules to move back and forth at 90 Mhz
(B) cause electrons in the antennas to move back and forth at 90 Mhz
(C) cause the magnetic field inside an antenna to vibrate at 90 Mhz
(D) cause the bias current in the antenna to alternate at 90 Mhz
(E) cause electromagnetic waves in the antenna to alternate at 90 Mhz

Radio waves are electromagnetic radiation broadcast from a radio tower. The radio waves cause freely moving electrons in a metal antenna inside the radio to move back and forth at the same frequency as the radio waves being emitted from the tower. The movement of the electrons is detected by circuits inside the radio and converted into an electrical current that is amplified and sent to a speaker

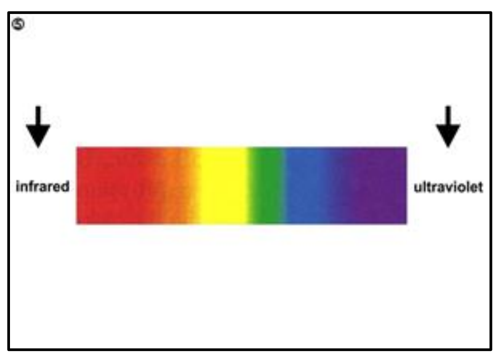


5. Which statement about ultraviolet and infrared electromagnetic waves is true?

(A) They travel at different speeds through outer space.
(B) They are both invisible to the human eye.
(C) Ultraviolet rays have longer wavelengths than infrared light rays.
(D) Infrared light rays have a higher frequency than ultraviolet light rays.
(E) Infrared light rays are higher energy than ultraviolet light rays.

All electromagnetic radiation travels at the same speed in a vacuum. Infrared light is low frequency, low energy light below the red end of the spectrum. Ultraviolet light is high frequency, high energy light above the blue end of the spectrum.

Being outside the range of visible light, infrared and ultraviolet light are invisible.



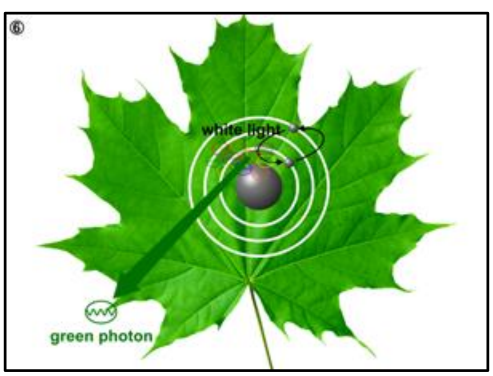
6. When white light strikes a green object __________.

(A) the green photons in the white light bounce off the object without being absorbed.
(B) all the photons in the white light are absorbed and the green photons are re-emitted.
(C) the green photons are absorbed and all the other photons are reflected away.
(D) green photons in the object are activated and released.

White light contains photons of every color.

A green object absorbs every photon but does not use the green photons.

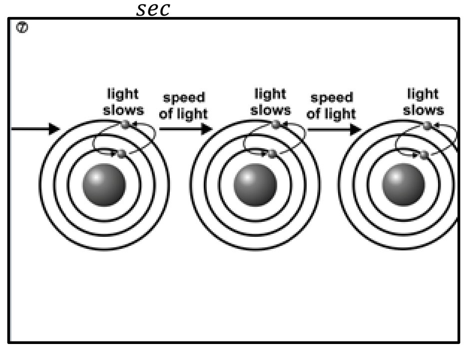
After the green photons elevate an electron to a higher orbit, the electron falls back to its original orbit, giving off a green photon in the process. Thus, green photons don't bounce off green objects; their energy is absorbed and then re-emitted.



7. When light traveling through a vacuum enters a transparent medium, the light slows down. Why does it slow down?

(A) The magnetic field within the medium opposes the movement of electromagnetic waves through the medium.
(B) The electrical field around electrons in the transparent medium causes light rays to slow down.
(C) A light ray strikes an atom and boosts the atoms' electron to a higher orbit. The re-emitted light ray continues on at a speed slower than the speed of light in a vacuum.
(D) A light ray strikes an atom and boosts the atom's electron to a higher orbit. The re-emitted light ray continues on at the speed of light in a vacuum until it strikes another atom.

A photon of light passing through a transparent medium slows because it spends time repeatedly boosting an atom's electron to a higher orbit and then waiting for the electron to drop back down to a lower orbit so that the photon can be reemitted. Between atoms, the photon travels at the speed of light in a vacuum, 3.0 times $10^8 \frac{m}{sec}$.



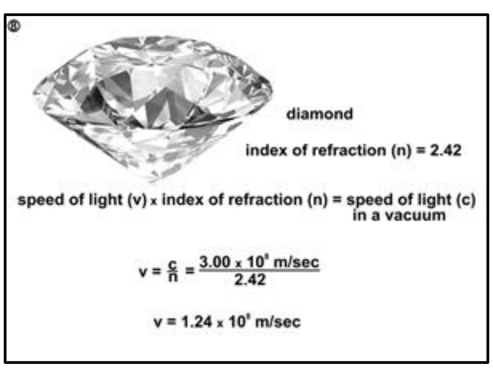
8. The index of refraction for a diamond is 2.42. The speed of light in a vacuum is 3 times ten to the 8 $\frac{m}{sec}$.
What is the speed of light through a diamond?

(A) $1.72 \text{ x } 10^7 \frac{m}{sec}$
(B) $3.45 \text{ x } 10^7 \frac{m}{sec}$
(C) $6.71 \text{ x } 10^7 \frac{m}{sec}$
(D) $9.57 \text{ x } 10^7 \frac{m}{sec}$
(E) $1.24 \text{ x } 10^8 \frac{m}{sec}$

The speed of light through a transparent medium times the transparent medium's index of refraction equals the speed of light though a vacuum.

Thus, the speed of light through a vacuum divided by the transparent medium's index of refraction equals the speed of light through the transparent medium.

For a diamond, 3 times ten to the 8 $\frac{m}{sec}$ divided by the index of refraction for a diamond equals 1.24 times 10 to the 8 $\frac{m}{sec}$.



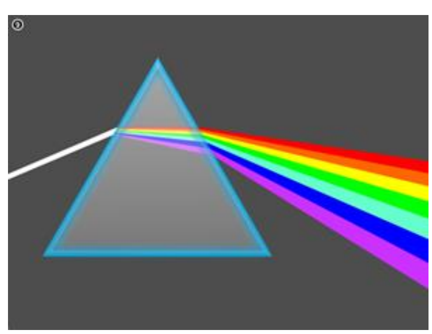
9. Higher energy blue light is better able to boost electrons to a higher orbit than lower energy red light. Because of this, _________.

(A) blue light passes through a transparent medium faster than red light
(B) blue light passes through a transparent medium slower that red light
(C) blue light and red light pass through a transparent medium at the same speed
(D) the transparent medium has a higher index of refraction for blue light than for red light
(E) B and D are both correct.

Blue light bends more than red light when going through a transparent medium. In other words, the same transparent medium has a higher index of refraction for blue light than for red light.

The reason blue light bends more than red light is that blue light slows more than red light when passing through a transparent medium.

The reason blue light slows more than red light is that it is better able to elevate electrons to a higher orbit than red light, so it spends more time elevating more electrons to higher orbits.



10. When a photon passes from the air into water, which property of the photon does not change?

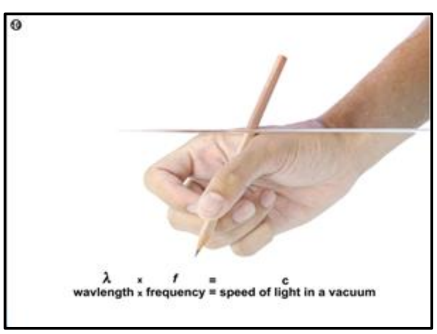
(A) speed
(B) direction
(C) wavelength
(D) frequency
(E) interference

Light passing through the air travels at the speed of light, c.

The speed of light is the light's wavelength times its frequency.

On entering a transparent medium, light slows. If the speed of light slows as it enters a transparent medium, it must do so either because the photon's wavelength shortens or its frequency slows. Which is it?

Color is determined by the frequency of a photon. The color of an object sticking halfway out of the water is the same above and below the water. This means that the frequency of photons does not change when passing through a transparent medium like water. What changes is the photon's wavelength.

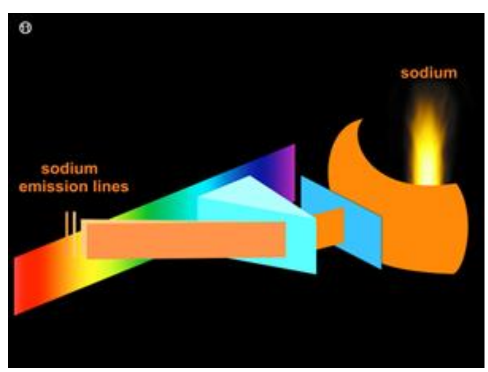


11. Heating a substance like sodium causes it to emit orange-yellow light. What happens when that light is passed through a prism?

(A) A single band of yellow light is seen.
(B) More than one band of yellow-orange light is seen.
(C) A single black band is seen in the yellow-orange end of the spectrum.
(D) More than one black band is seen in the yellow end of the spectrum.

Heating sodium, or any element, causes its electrons to jump to a higher orbit. When they fall back to a lower orbit, they emit two emission lines in the yellow-orange range. What does the fact that two emission lines were given off mean about sodium's electrons when heated?

It means that two of sodium's electrons jumped to two different orbits before falling back to a lower orbit, or that two electrons jumped to the same higher orbit and fell back to different orbits.



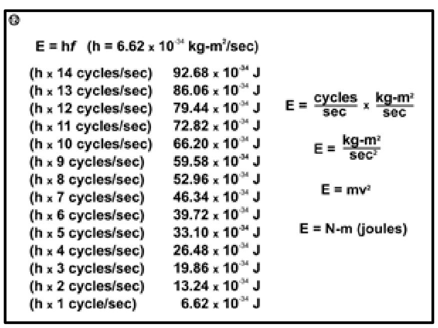
12. White light passing through a prism is made up of a continuous spectrum of colors.

(A) True
(B) False

The spectrum appears continuous, but only because the individual emission lines are so close together.

Individual spectral lines represent levels of energy. Two adjacent spectral lines are separated by only 1 cycle of Planck's constant. When 1 $\frac{cycle}{sec}$ is multiplied by Planck's constant, the difference is only 6.62 times 10^{-34} joules.

Notice that Planck's constant times frequency is the same units as mv^2, which has the same units as newton-meters, energy.



13. Sunlight passing through a hot gas, when seen through a spectrometer, produces specific black absorption bands.

(A) True
(B) False

A gas heated by the sun emits bands of light. The particular bands emitted depend on the atoms in the gas. The same gas, when cold, absorbs the same bands of sunlight, which appear as dark bands called absorption lines.