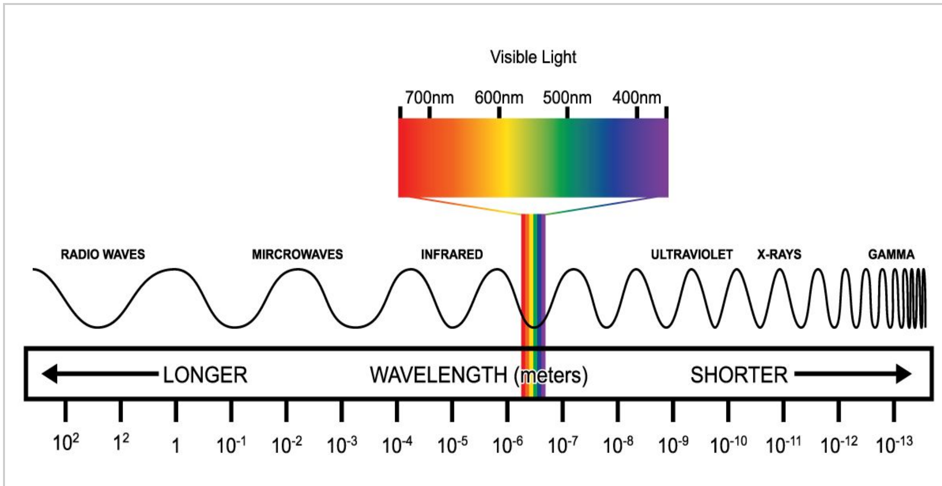
How to Perform UV Monitoring with the Adafruit Si1145

This article will help you understand why the amount of harmful Ultraviolet energy changes over time and show you how you can measure it at your location.

Humans have photoreceptors in our eyes that detect photons in a very narrow range: between ~400 nm and 700 nm (~750-430 THz). When the frequency (energy) of the photons is lower than the range we have evolved to see, the photons are termed infrared. When the frequency is above the range we have evolved to see, the photons have enough energy to burn our skin. These photons are called ultraviolet.



Florida Center for Environmental Studies.

The Si1145 is a low power I²C interfaced sensor capable of detecting photons of visible, infrared, and ultraviolet light. The chip and its 8 pins sit within a 2mm x 2mm footprint. This size is too small for hand soldering, so if you're going to play with it, you'll need a breakout-board with an on-board voltage regulator like the Si1145 from Adafruit. Adafruit has also been kind enough to create an Arduino-compatible library which makes it very easy to use the sensor.

Parts Required

Part	Price
Si1145	$14
Arduino Uno R3	$17
I2C LCD	$13
Male/Female or Male/Male Jumpers	$9
Solderless Breadboard	$10

You will have to purchase Adafruit's Si1145 and the I²C LCD. If you're a tinkerer, you'll likely have the other parts already on hand.

Datasheets LCD (PDF) sensor (PDF).

Libraries**:** Si1145 Library I2C Liquid Crystal Libraries Project Code

Code

After you have made the connections, upload and execute the following code:

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <Adafruit_SI1145.h>
Adafruit_SI1145 uv = Adafruit_SI1145();
LiquidCrystal_I2C lcd(0x27,20,4);
void setup() {
  lcd.init();
  lcd.backlight();
  uv.begin();
```

```
}
void loop() {
  float UVindex = uv.readUV();
  UVindex /= 100.0;
  lcd.setCursor(8,0);
  lcd.print("  ");
  lcd.setCursor(17,0);
  lcd.print("  ");
  lcd.setCursor(19,1);
  lcd.print(" ");
  lcd.setCursor(2,0);
  lcd.print("Vis:");
  lcd.print(uv.readVisible());
  lcd.setCursor(11, 0);
  lcd.print("IR:");
  lcd.print(uv.readIR());
  lcd.setCursor(0,1);
  lcd.print("UV Index: ");
  lcd.print(" ");
  lcd.print(round(UVindex));
  lcd.print(" (");
  lcd.print(UVindex);
  lcd.print(")");
  lcd.setCursor(0,2);
  lcd.print("                    ");
  lcd.setCursor(0,3);
  lcd.print(" 1 2 3 4 5 6 7 8 9 +");
  lcd.setCursor(UVindex*2,2);
  lcd.print("Θ");
  delay(1000);
}
```

On your LCD, you should see readings for visible and infrared light, as well as a calculated UV Index and a visual index of readings 1-9+.

When the readings go beyond 9, the cursor should move down to the next line indicating measurements from 10 to 19.

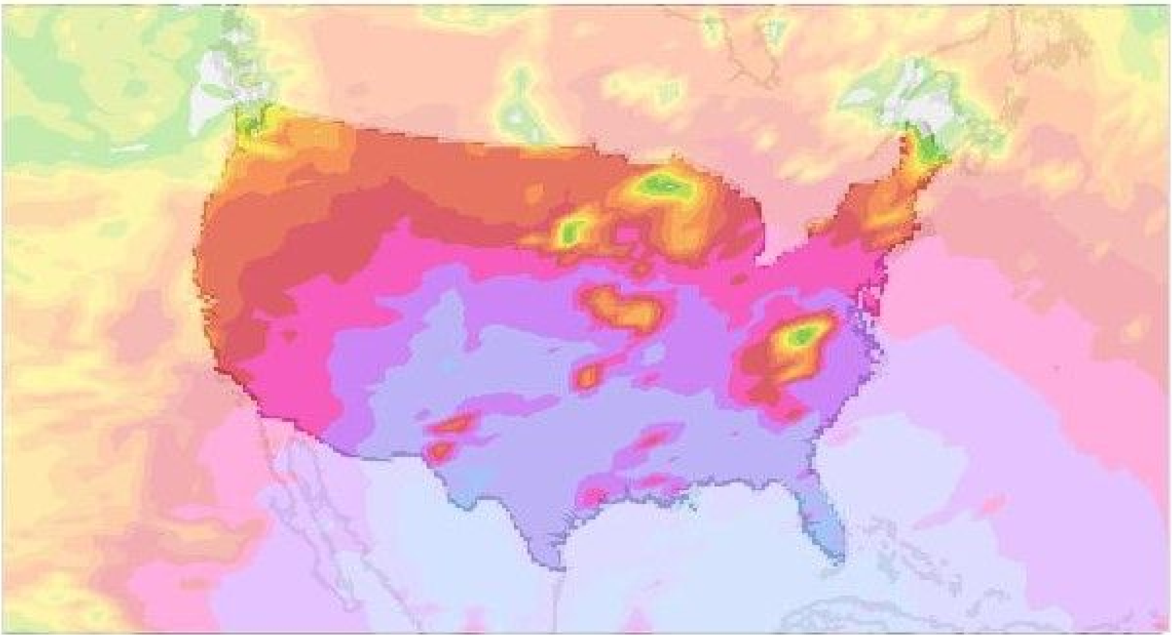
Skin type influences the length of time before a person experiences sunburn. Perhaps create an equation or lookup table that provides a user with a time-to-burn countdown timer.

	no sunscreen	SPF 15	SPF 30	SPF 45
skin type I	2 h	33.5 h	66.5 h	100 h
skin type II	3 h	41.5 h	83.5 h	125 h
skin type III	4 h	58.5 h	116.5 h	175 h
skin type IV	5 h	75 h	150 h	225 h
skin type V	6.5 h	100 h	200 h	300 h
skin type VI	11 h	166.5 h	333.5 h	500 h

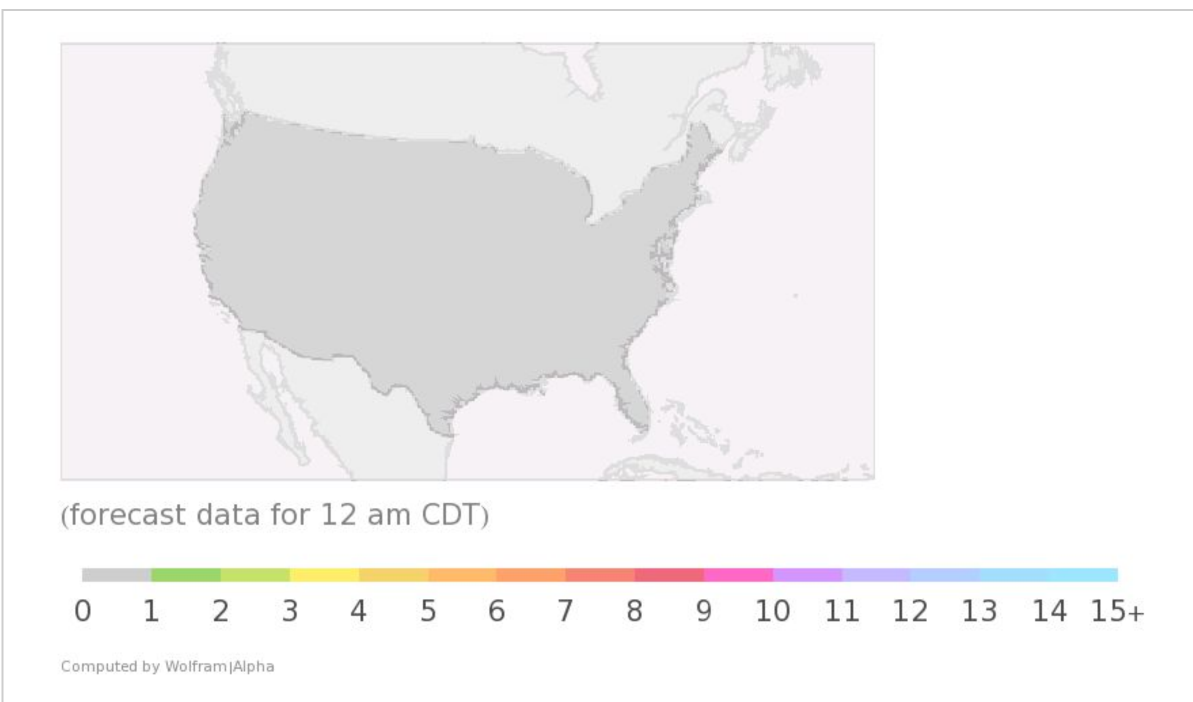
UV Index 1

More Information About Why the UV Index Changes

The weather forecast gives a UV Index for your forecast region, usually during the local solar noon. However, the amount of UV radiation that reaches the Earth's surface is dynamic. If you need up-to-date information, you have to measure it at the location.



UV forecast map for the United States on July 10th, 2016 from Wolfram Alpha



Timelapse hourly UV forecast map for the United States on July 10th, 2016 from Wolfram Alpha

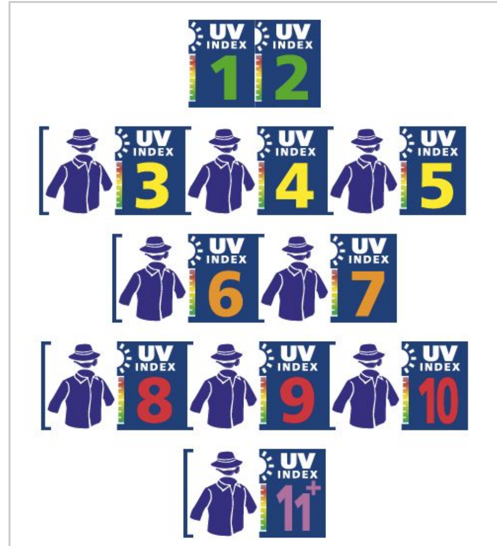
Daily UV Index

The National Weather Service measures the atmospheric Ozone, the cloud-cover, the angle of the sunlight, and a few other variables. Rather than bombard the public with a great many numbers and data points that they may or may not understand, information is aggregated, a UV Index is calculated, and a number is presented to the public.

They also provide a tool to give you a UV Index forecast for a given location.

The EPA UV Index tool. It's interactive! Give it a try.

A number less than 3 on this Index indicates that a moderate amount of sun exposure is okay. Any number greater than 3 and the World Health Organization recommends applying sunscreen and wearing a hat, sunglasses, and pants.



Graphic of the UV index. Image courtesy of the World Health Organization.

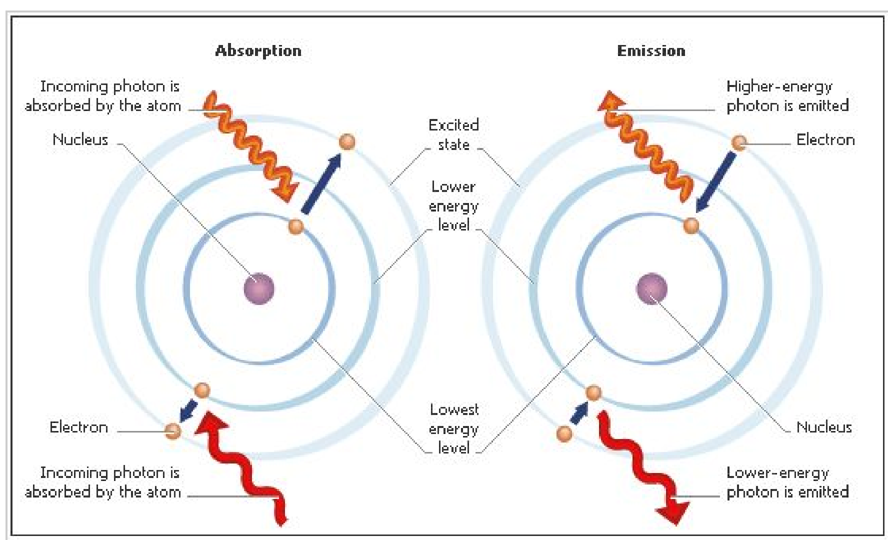
The amount of the Sun's energy that makes it to the surface of the earth to give you a sunburn depends on two primary factors—the angle of cast shadows and the atmospheric molecules that get in the way.

Understanding why the amount of ultraviolet radiation changes over the course of the day, over the course of the year, and with the weather requires a bit more physics. If you're interested, please read on.

A Quantum Theory of Electromagnetic Radiation and Atmospheric Absorption

When electrons moving around the nuclei of atoms transition from higher-energy orbitals to lower-energy orbitals, they emit a photon—electromagnetic energy of specific frequency. That photon travels through space until it is absorbed by another atom and causes an electron to move from a lower-energy orbital to a higher-energy orbital or leave the atom/molecule altogether.

If the travelling photon's energy doesn't exactly match a transition energy for the atom/molecule, the photon will not be absorbed by the atom. These orbital transitions are nature's tuning forks—they only occur at very specific frequencies (although each frequency can be Doppler-shifted a bit higher or lower through relative motion).

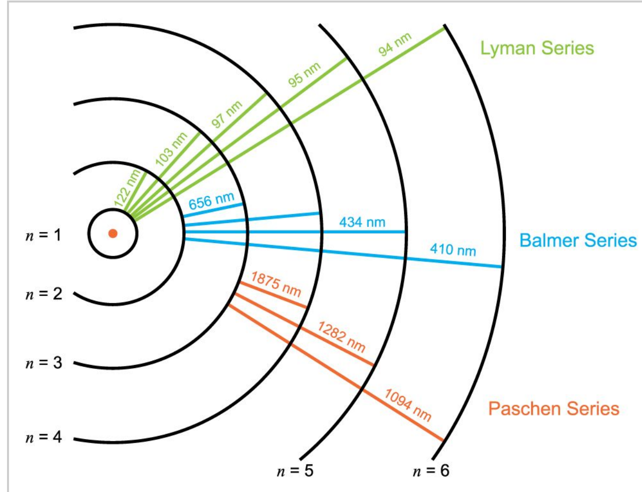


Depiction of electron absorption and emission. Image courtesy of StackExchange.

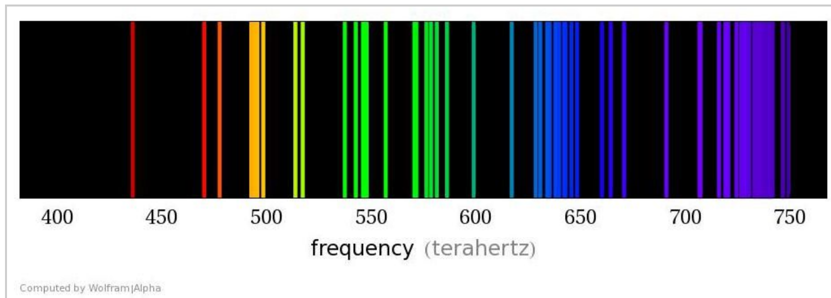
Every electron orbital has a specific energy associated with it, and the frequency (energy) of the photons that are emitted or absorbed must exactly equal the difference in orbital energies.

As atoms gain electrons, the orbitals gain complexity and the frequencies of photons that are produced become more varied. And with complexity comes uniqueness: Each element of the periodic table has a unique fingerprint (or barcode) we can use to identify it. This is the same science that lets us know what distant stars and planets are made of.

Atoms can absorb a photon of one frequency (energy) and emit photons of a different frequency that correspond to different orbital transitions. Atoms can absorb higher-energy photons and emit lower-energy photons, as illustrated below where Uranium Oxide infused in glass is used to convert ultraviolet light to bright green.



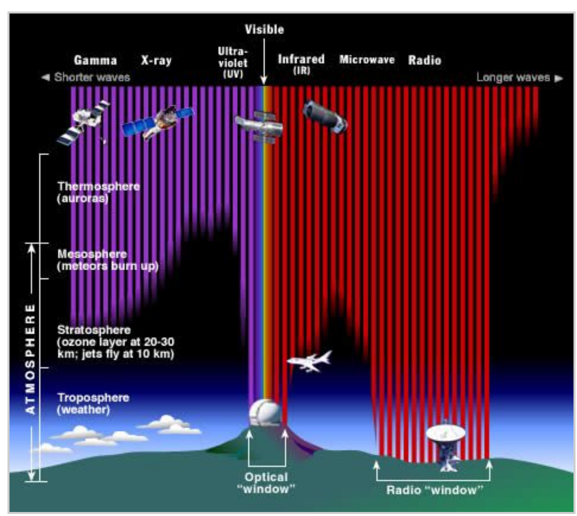
Transitions of the Bohr model of atomic Hydrogen. Image designed by WikiMedia.



Compare the color of the spectral lines around 550 THz of the oxidative state of uranium above to the color of the glass below. Image courtesy of Wolfram Alpha.

Shining ultraviolet LEDs on Uranium-infused glass causes it to glow neon green. Photo by Mark Hughes.

Our atmosphere is full of atoms and molecules that can absorb photons at one frequency (high-energy) and then re-emit the energy as a series of photons at another frequency (lower-energy). The more atmospheric molecules the ultraviolet photons pass through, the better the chance they will be absorbed and reemitted at lower-frequency, thereby changing much of the harmful ultraviolet radiation to visible or infrared radiation.

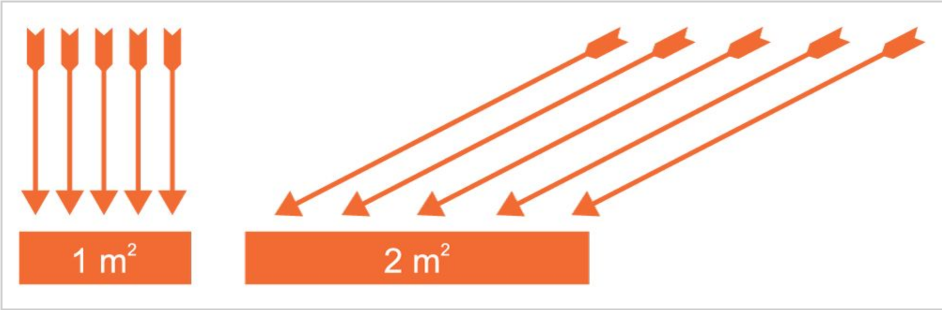


Graphic of how far portions of the EM spectrum can make it through the Earth's atmosphere. Image courtesy of NASA.

Understanding the Angle of Incident Light

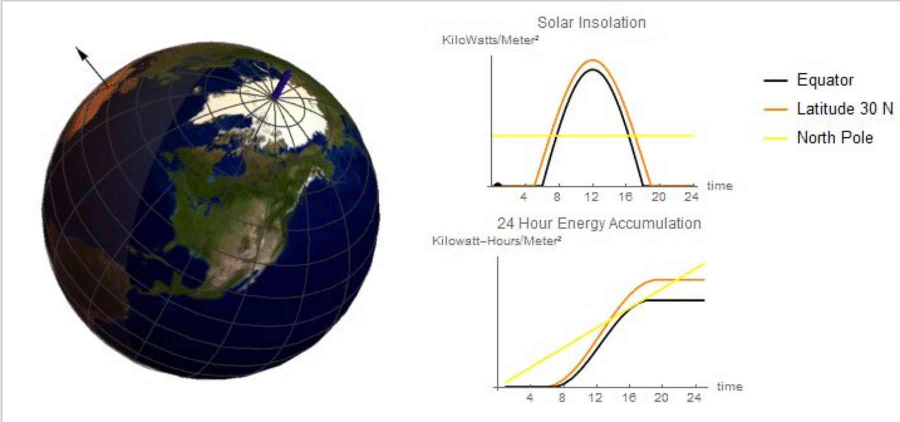
The angle of incidence for light changes with the seasons and throughout the daylight hours. It is measured from an imaginary line that is perpendicular to a point on the surface of the Earth to a line that points towards the sun. When the shadows are longest, the intensity of the sunlight is at its lowest as light from the sun spreads out to cover large areas. When shadows are shortest, the intensity of the sunlight is greatest and you are at greatest risk of a sunburn.

As the angle of incidence deviates from the normal, the intensity decreases.



Insolation & the UV Index

These two ideas—the angle of incoming light and the amount of atmospheric absorption—combine to determine the amount of INcoming SOLar radiATION that reaches the earth's surface. We accordingly call this insolation (and from the Latin word *insolare*).



Animation made with Wolfram's Mathematica based on this graphic.

Since the frequency of radiation affects how harmful it is for our skin, the National Weather Service creates a weighted average over a series of frequencies. It combines the weighted average with the altitude and weather at a given location to determine the UV Index for a location.

For more information on how the UV Index is calculated, visit the EPA webpage or jump straight to their Guide to the UV Index.

To learn more about the International Agency for Research on Cancer, which discusses how UV radiation can lead to cancer, read this article (PDF).

Lastly, if you'd like to use Wolfram's Mathematica (available free on the Raspbian operating system) to create your own graphics, I've included the code I used to create the animations below:

Mathematica Notebook to Create Your Own Graphics