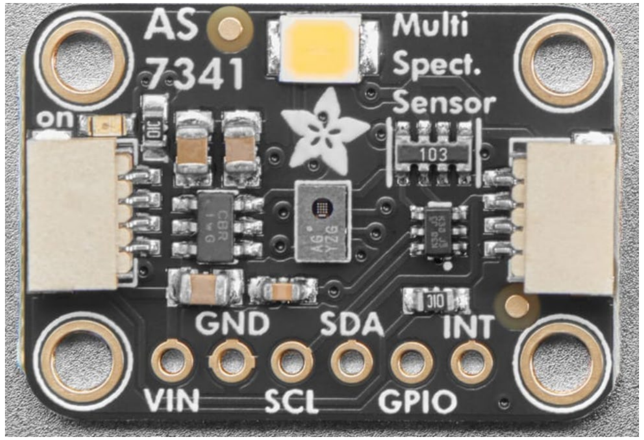
P524: Survey of Instrumentation and Laboratory Techniques
Week 11

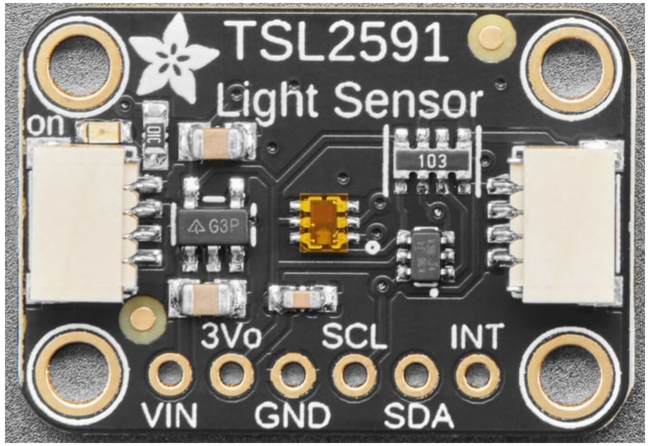
11/5/2024

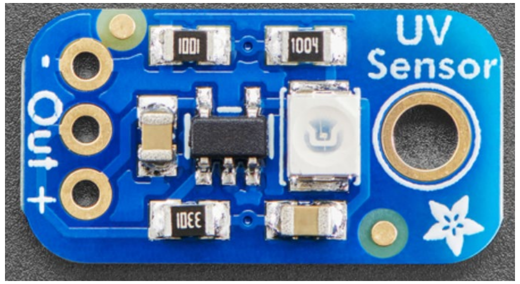
Week 11: sensors-7

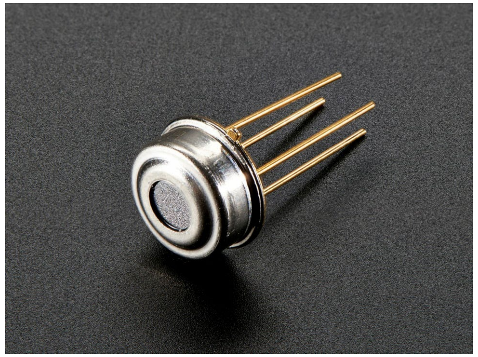
Light Sensors:

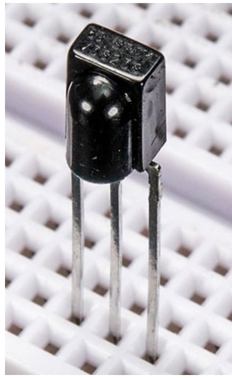
- Visible:
  - **AS7341** – Multi-spectrum light sensor
  - **TSL2591** – Light intensity meter (Has IR as well)
- UV:
  - Adafruit analog UV sensor (GUVA-S12SD)
- IR:
  - MLX90614 – IR Thermometer, comes in 3V and 5V
  - TSOP38238 – IR receiver



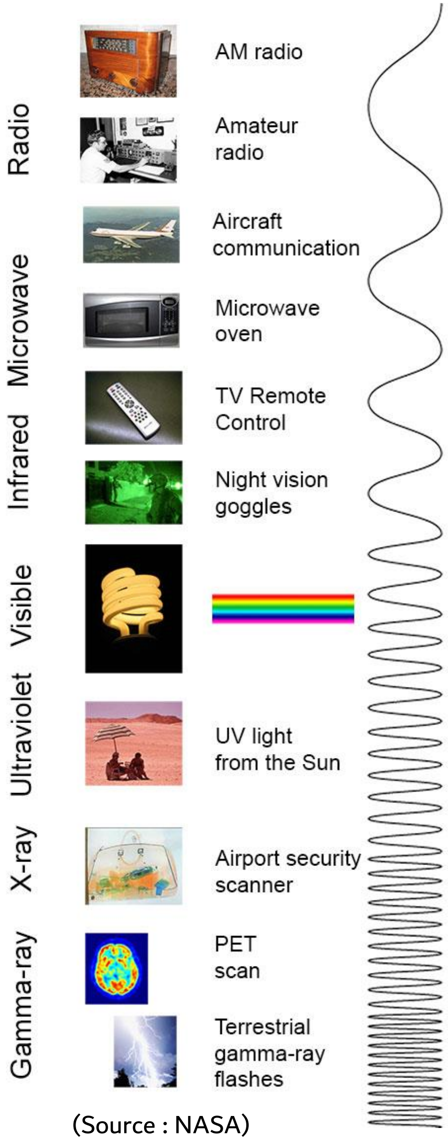








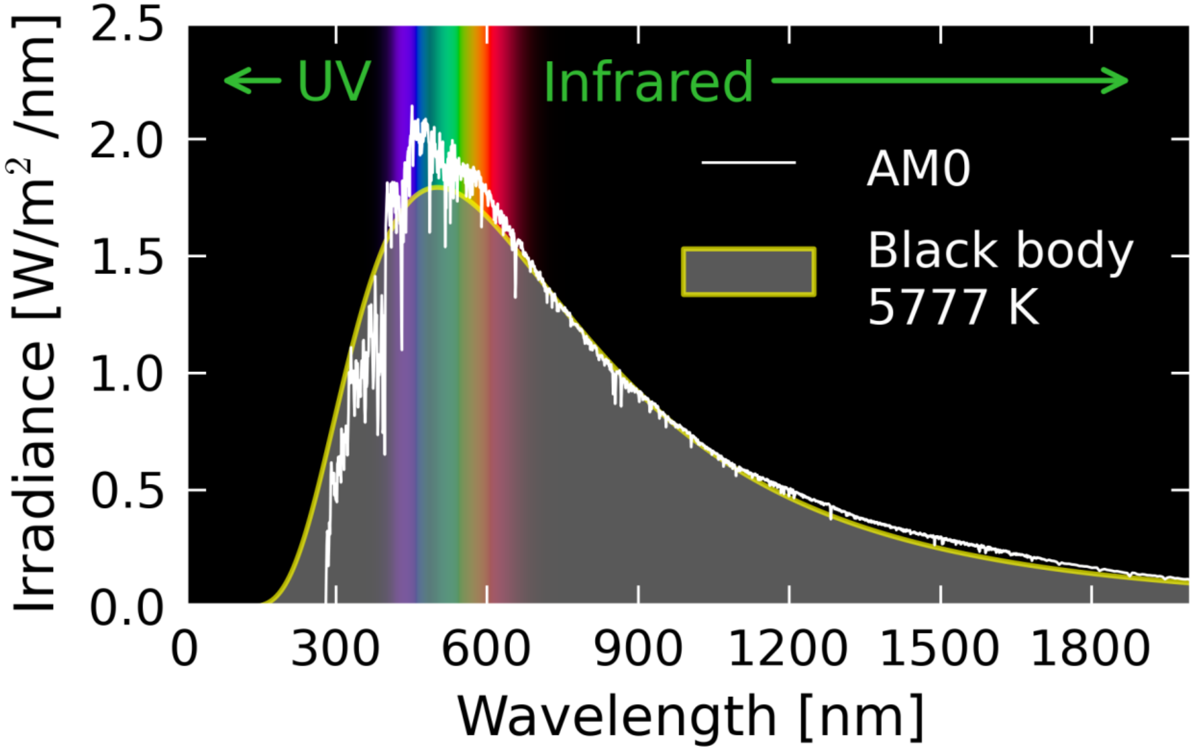
The Electromagnetic Spectrum



(Source : NASA)

- The EM spectrum encompasses all electromagnetic waves
- We split up the spectrum into different regions based on their energy
- Energy, frequency, and wavelength are all related
- We'll focus on IR, Visible, and UV

Visible light



(Source : Wikimedia, public domain)

- Wavelengths: ~750nm (Red) – 350 nm (violet)
- The light that we can see
- Highest intensity light from the Sun's black body spectrum
- Different wavelengths are perceived as color
  - Human eye has 3 color receptors
  - An object's color is determined by its reflected, scattered, and emitted light

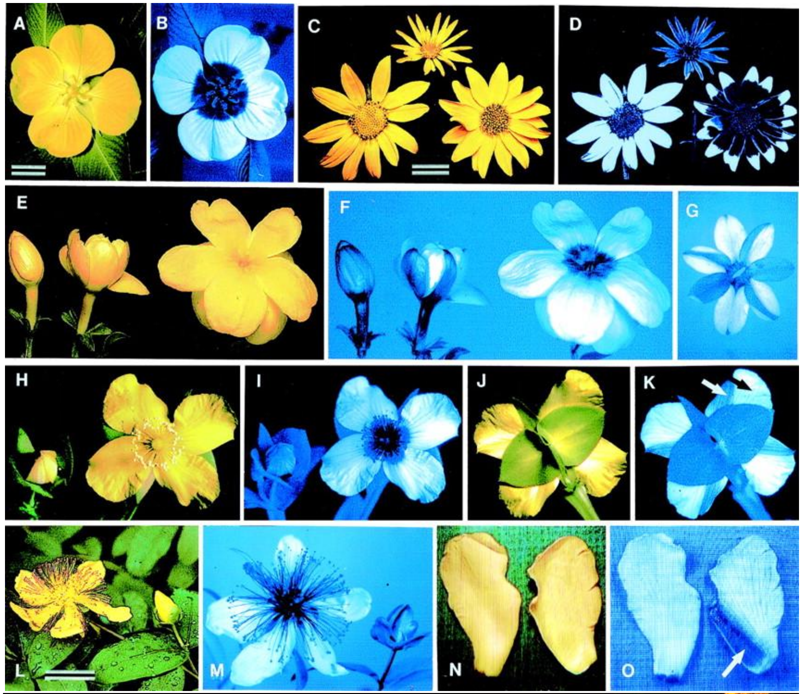
Infrared

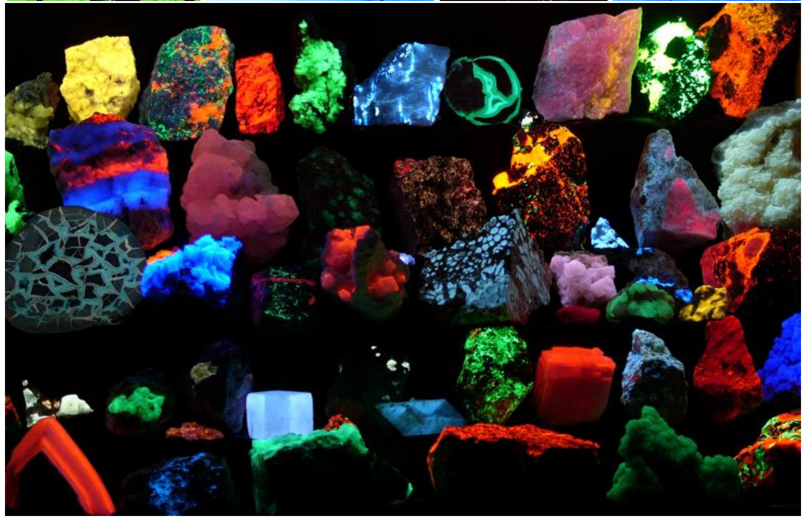
- Wavelengths ~1mm – 700nm
  - Some overlap between near-IR and visible i.e. in certain conditions people can see wavelengths up to 950nm
- Used in telecommunications
- Also useful for thermal sensing and imaging (black body radiation of living things is peaked in IR)

(Source : Wikimedia, public domain)

Objects that are opaque in the visible may be transparent in IR and vice-versa

(https://doi.org/10.1073/pnas.23147169)





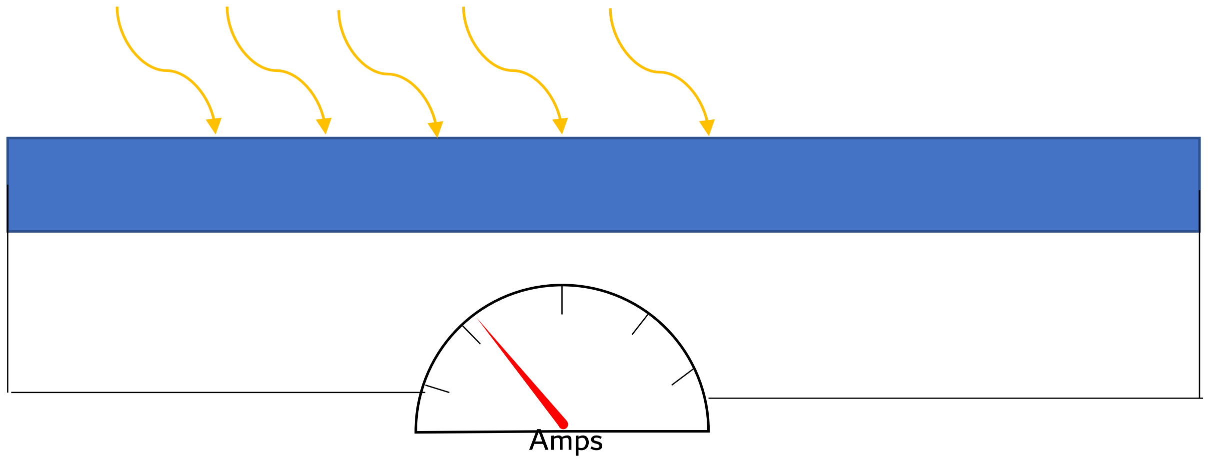
(Hannes Grobe/AWI)

Ultraviolet

- Wavelengths 400nm – 10nm
- Lowest energy ionizing radiation (light with enough energy to knock an electron off an atom) below 124 nm
- Causes many chemicals to fluoresce
    - Fluorescence – a phenomenon where a material re-emits absorbed light at a lower wavelength
- Vital for many biological processes; some animals and plants have markings visible in the UV

Photoelectric effect

- Light striking a material causes the emission of electrons
- Needs a certain minimum energy that is material-dependent (quantum mechanical effect! Einstein’s 1921 Nobel prize)
- Higher intensity -> more photocurrent

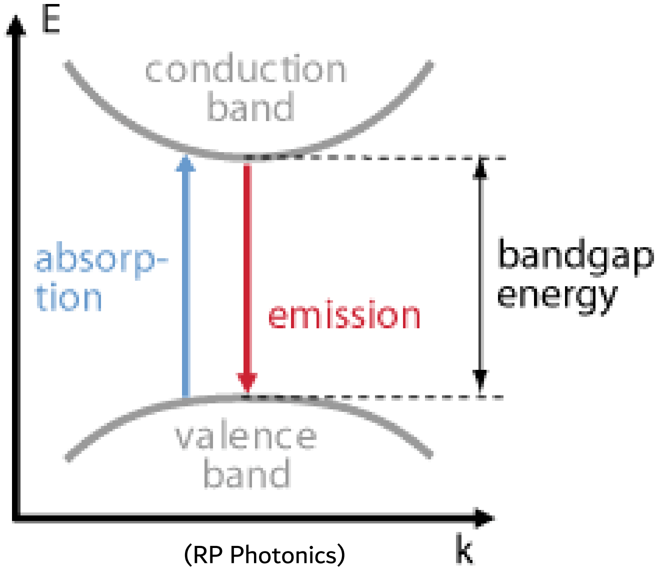


Application: Photodiodes

- Semiconductor device with a particular bandgap energy (energy gap between filled and unfilled electron states)

- Light with energy corresponding to bandgap excites electron into conduction band

- These electrons are free to flow as current

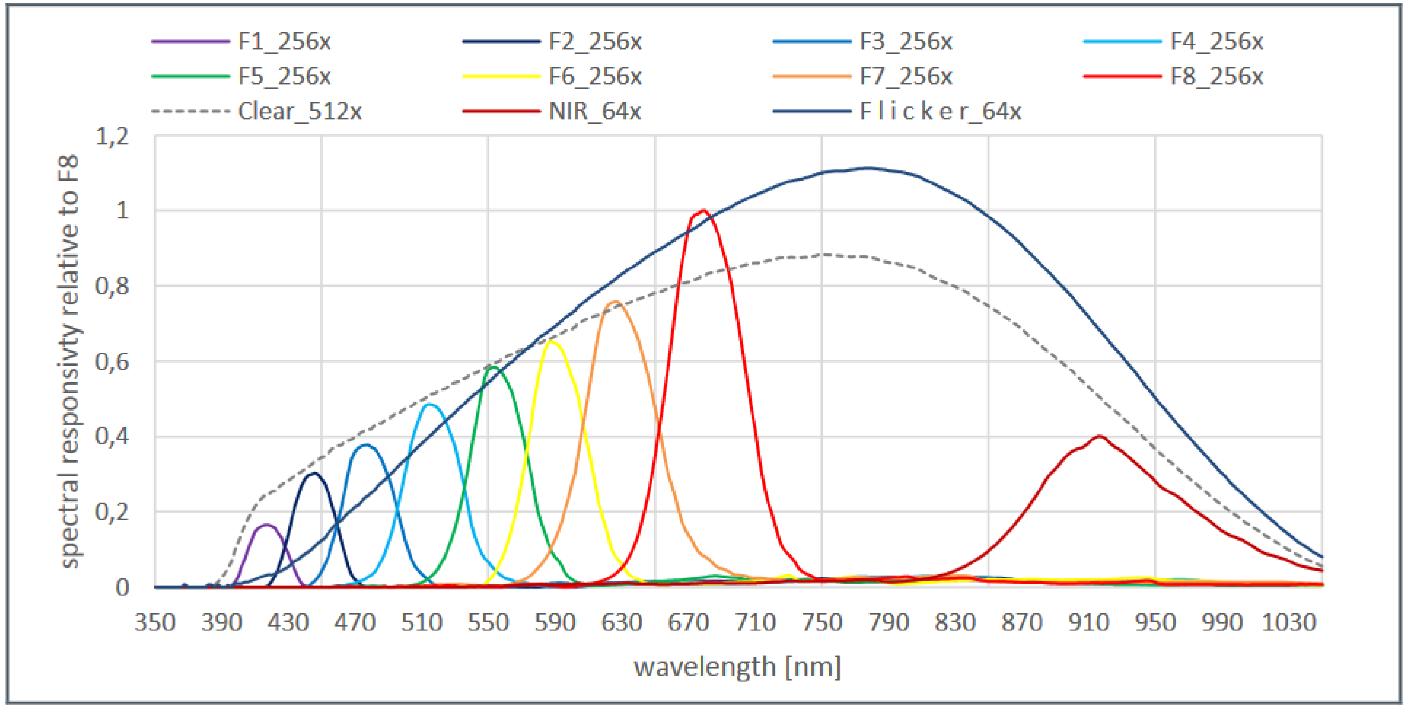


(RP Photonics)

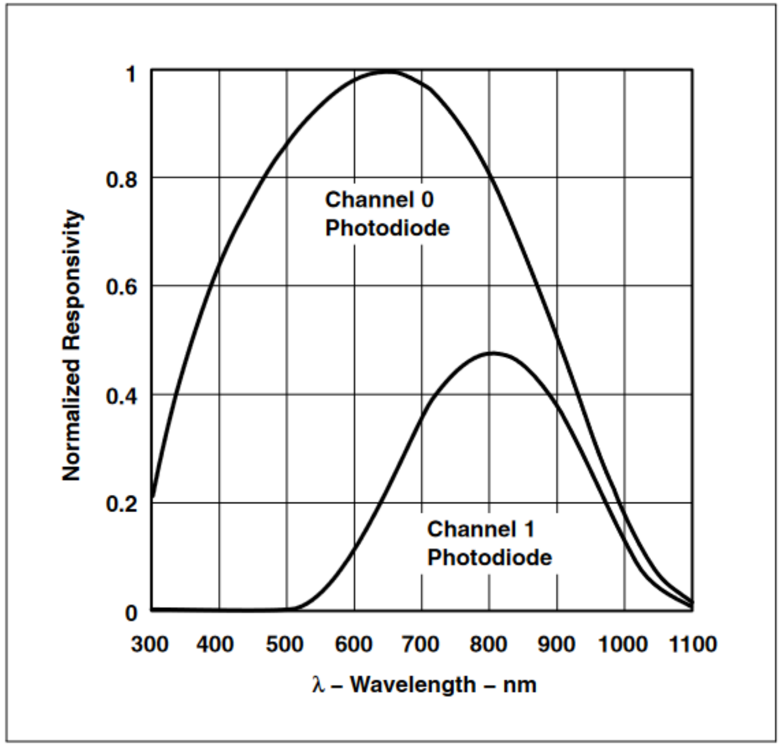
Visible sensors: AS7341 (Multichannel sensor)

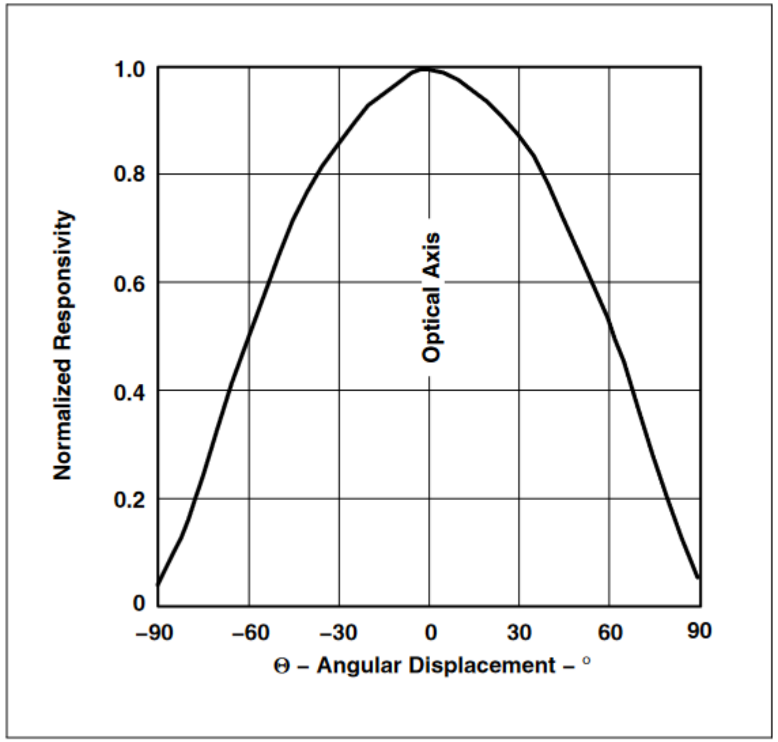
Channel	Center Wavelength [nm] typical	Full Width Half Maximum [nm] typical
F1	415	26
F2	445	30
F3	480	36
F4	515	39
F5	555	39
F6	590	40
F7	630	50
F8	680	52
NIR (Near IR)	910	n/a
Clear	Si response/non filtered	n/a
FD (Flicker Detection)	Si response/non filtered	n/a

Measured Spectral Responsivity Relative to F8[1]



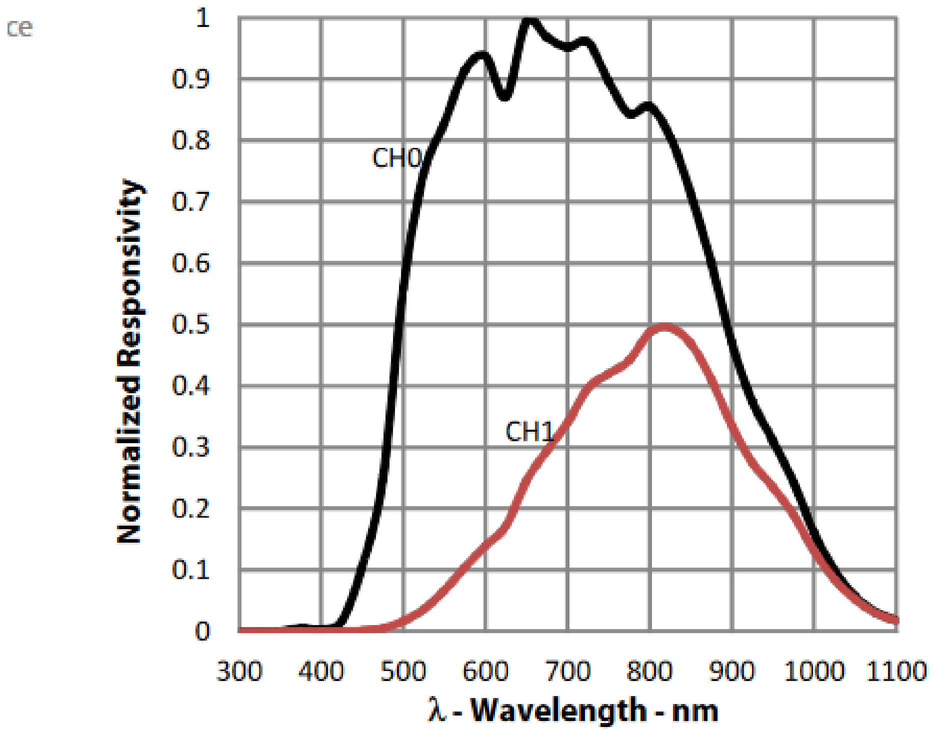
Visible sensors: TSL2561 (Intensity meter)

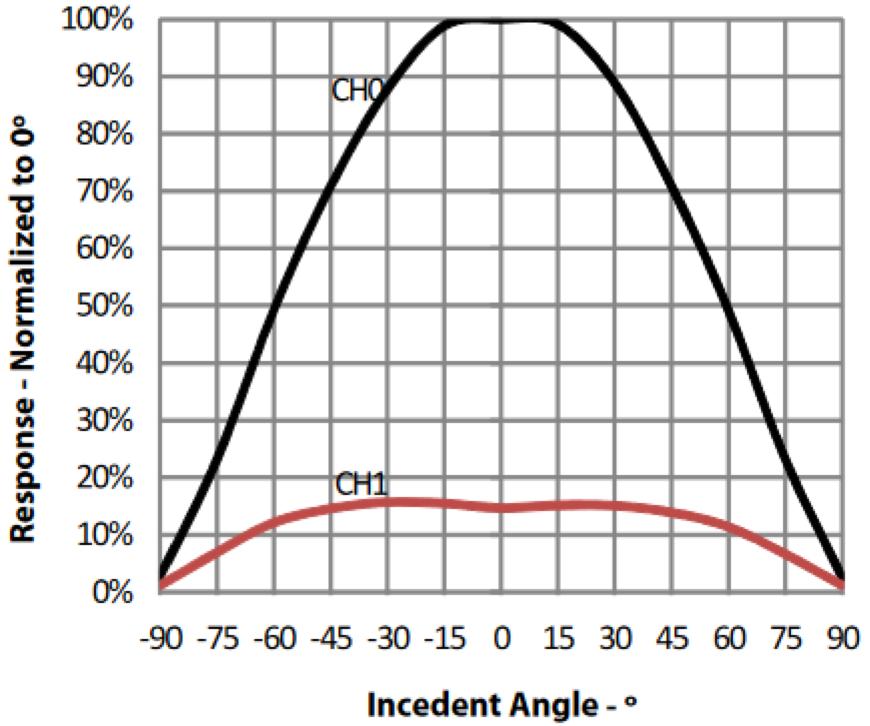




R_e	Irradiance responsivity	$\lambda_p = 640$nm, $T_{int} = 101$ms	Ch0		27.5		counts/ (μW/cm^2)
			Ch1		5.5		
		$\lambda_p = 940$nm, $T_{int} = 101$ms	Ch0		8.4		
			Ch1		6.9		

Visible sensors: TSL2591 (Intensity meter)





R_e Irradiance responsivity	White light [2] ATIME = 000b (100 ms)	CH0 CH1		264.1 34.9		counts/ ($\mu W/cm^2$)
	λ_p = 850 nm [3] ATIME = 000b (100 ms)	CH0 CH1		257.5 154.1		

Exercise

1. Interface with each of the sensors, **AS7341** and **TSL2591,** and make sure that they're functioning
2. Test the intensity meter **TSL2591** with your phone's flashlight.
3. Test the multi-spectrum meter **AS7341** with different colors of light (from the different light bulbs).
    1. What is the difference in the multi-spectrum measurements from LED light bulbs of different color temperature?
    2. What is the difference in the spectrum between the LED light bulb and the incandescent light bulb of the same color temperature?

Homework: The light flickers!

Many lights flicker (LCD screens, lightbulbs connected to AC power, LED light bulbs, etc.). Choose a light source and using the intensity meter (**TSL2591 or AS7341)** to determine if its output is flickering, and if so at what frequency.

a. First, you'll need to position the light sensor to your light source.

b. Sample the signal and look for patterns in the intensity vs time.

c. Do a Fast Fourier Transform to find the frequencies of the light flicker.

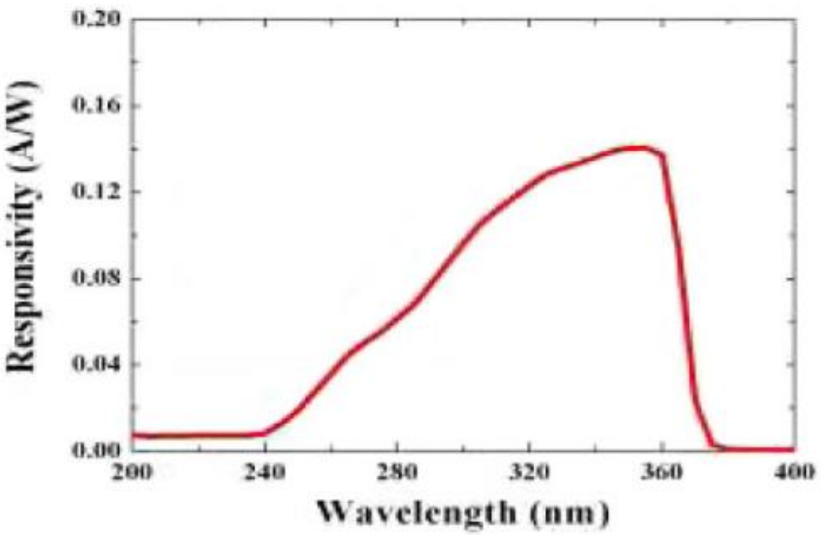
Light sensors we have available

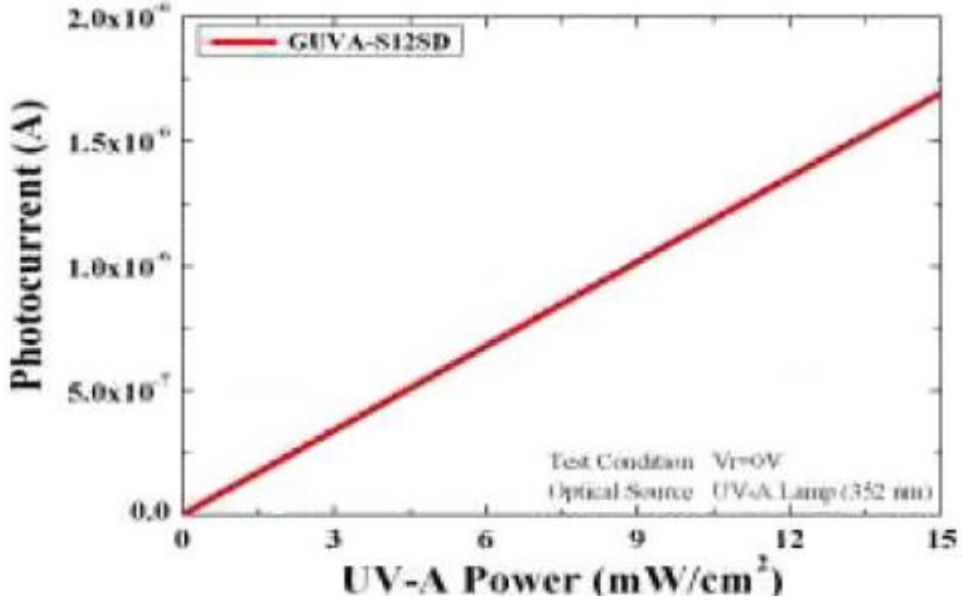
- Visible:
  - AS7341 – Multi-spectrum light sensor
  - TSL2591 – Light intensity meter (Has IR as well)
- UV:
  - Adafruit analog UV sensor (GUVA-S12SD)
- IR:
  - MLX90614 – IR Thermometer, comes in 3V and 5V
  - TSOP38238 – IR receiver

UV Sensor: GUVA-S12SD (Simple photodiode)

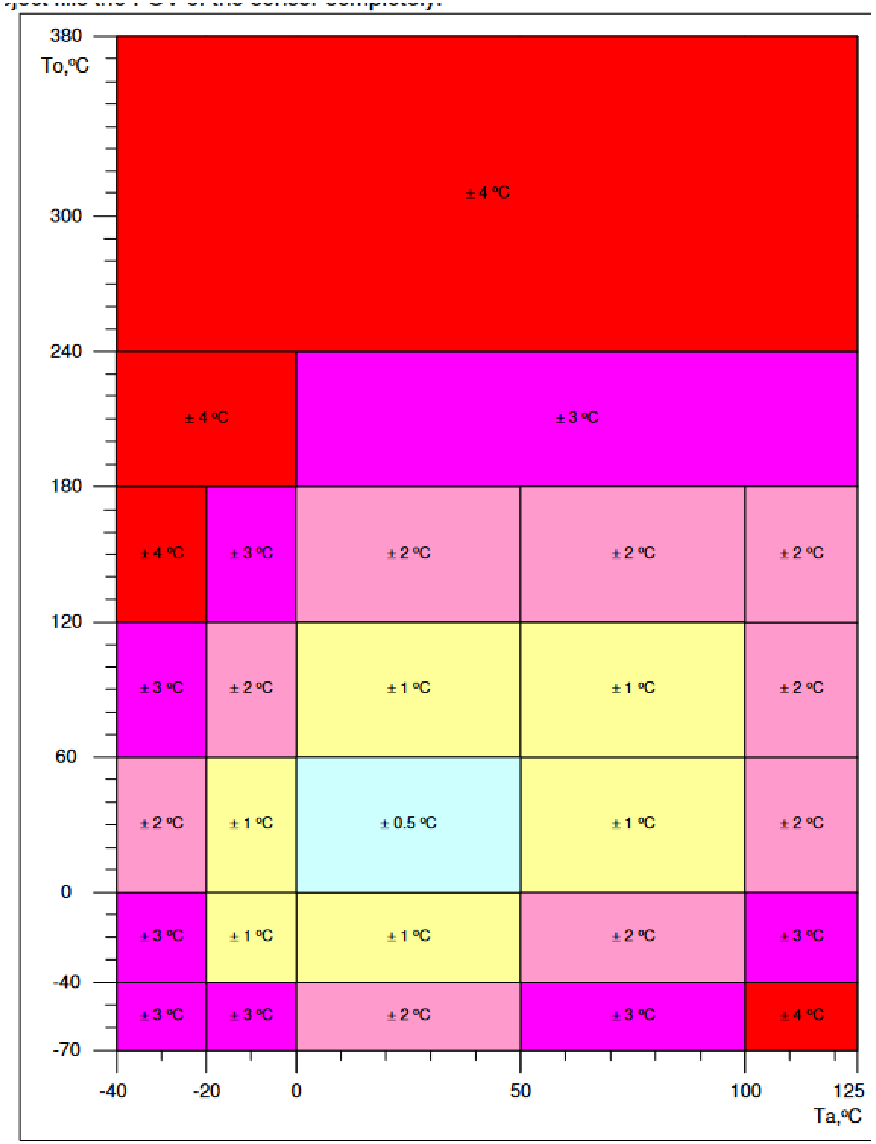
Characteristics (25°C)

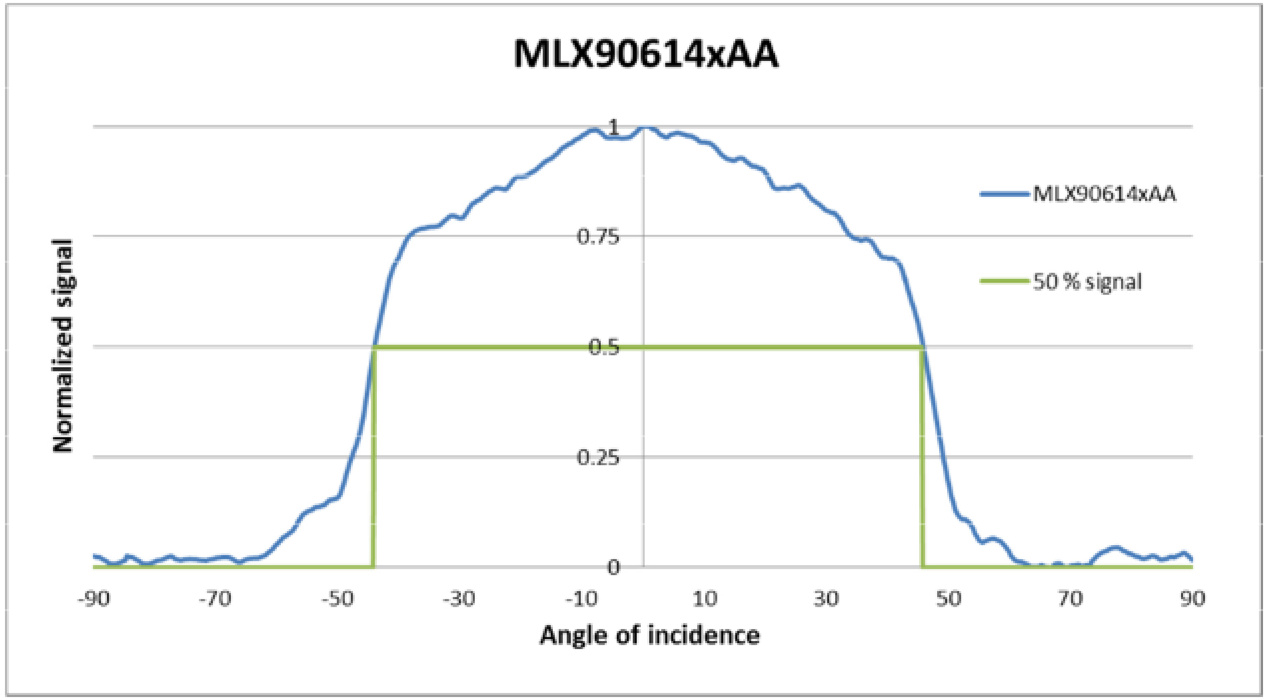
Item	Symbol	Test Conditions	Min.	Typ.	Max.	Unit
Dark Current	I_D	V_R = 0.1 V	-	-	1	nA
Photo Current	I_{PD}	UVA Lamp, 1 mW/cm²	-	113	-	nA
		1 UVI	-	26	-	nA
Temperature Coefficient	I_{TC}	UVA Lamp	-	0.08	-	% / °C
Responsivity	R	λ = 300 nm, V_R = 0 V	-	0.14	-	A/W
Spectral Detection Range	λ	10% of R	240	-	370	nm

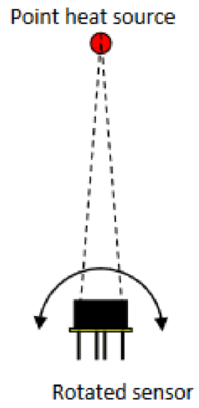


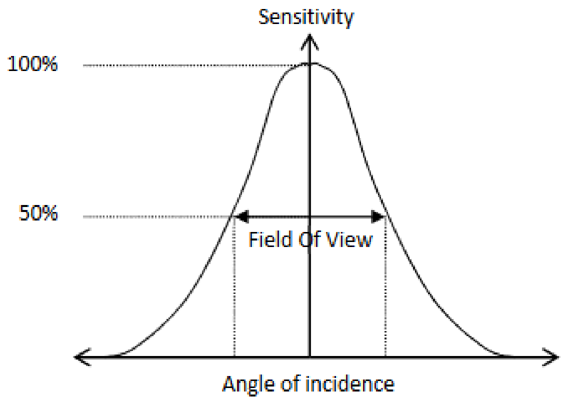


IR Sensors: MLX90614 (IR Thermometer)









IR Sensors: TSOP38238 (IR Receiver)

38 kHz	TSOP38238

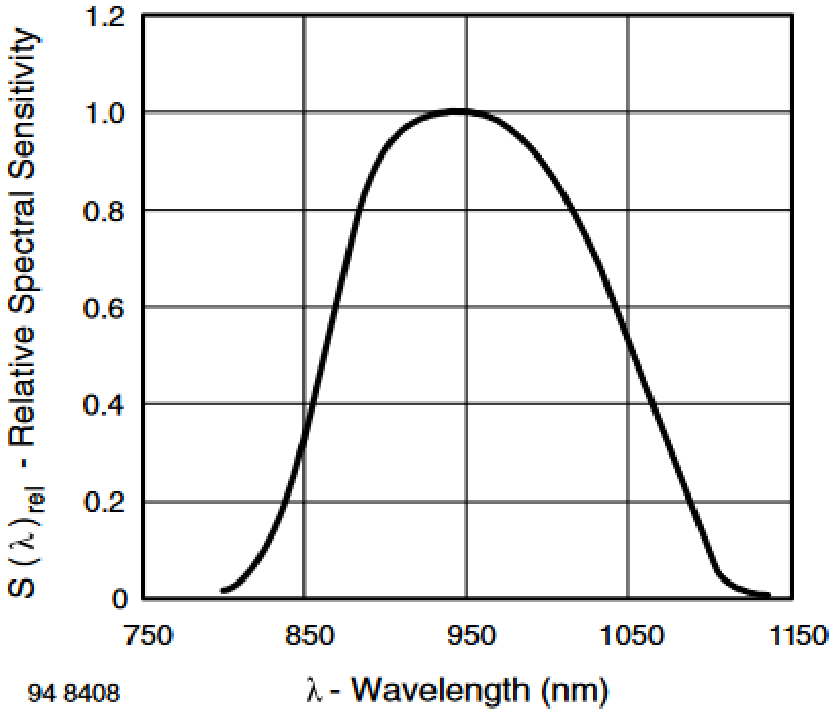


Fig. 11 - Relative Spectral Sensitivity vs. Wavelength

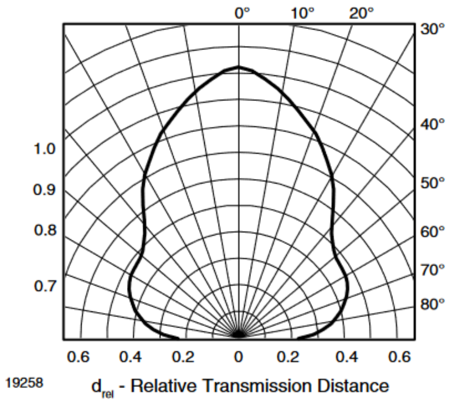


Fig. 12 - Horizontal Directivity

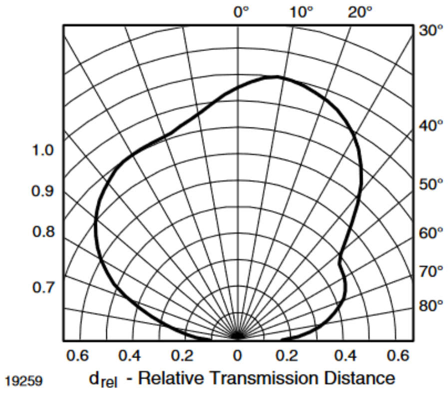


Fig. 13 - Vertical Directivity