Electromagnetic spectrum

EM waves can exist w/ any wavelength λ

[from millions of km, to < fm (size of nucleus)]

All EM waves travel (in vacuum) w/ speed $c = 3 \times 10^8 \frac{m}{s}$

Exact: $c = 299,792,458 \frac{m}{s}$ (by definition)

Recall $c = \frac{\lambda}{T}$

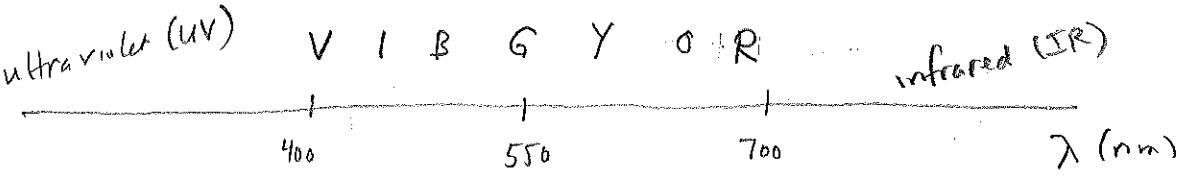
Since frequency $f = \frac{1}{T} \Rightarrow \boxed{f = \frac{c}{\lambda}}$ [smaller $\lambda \Rightarrow$ higher f]

POSSIBLE DEMO: Travelling wave: f vs λ

Visible light: $\lambda \simeq 400 - 700$ nm [size of small cell]

$(1 \text{ nm} = 10^{-9} \text{m})$

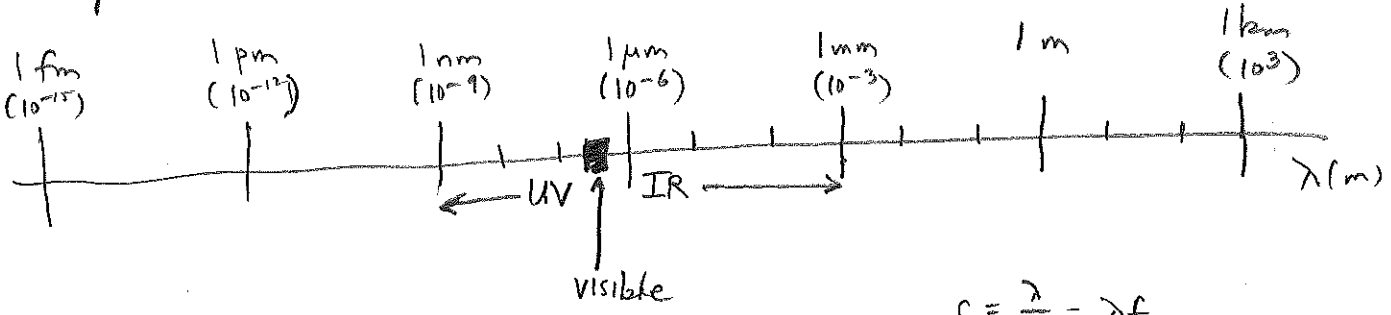
POSSIBLE DEMO: OH projector w/ slit from sheet of paper + prism/grating



monochromatic $\Rightarrow$ single wavelength ("one color")

White = mixture of wavelengths

spectrum (log scale!)



$c = \frac{\lambda}{T} = \lambda f$

radio waves — AM — $f \approx 1000\ kHz = 10^6 \frac{cyc}{sec}$ [generated by oscillating charges in transmission antennas]

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8 \frac{m}{s}}{10^6 \frac{cyc}{sec}} = 300\ m$$ [put on diagram]

FM: $f \approx 100\ MHz = 10^8 \frac{cyc}{sec}$

$$\lambda = \frac{3 \times 10^8 \frac{m}{s}}{10^8 \frac{cyc}{s}} = 3\ m$$ [put on diagram]

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shortwave

[wireless $f \sim 1 - 60\ GHz$
$\lambda = 5\ mm - 30\ cm$ (microwaves)]

microwave oven $f \approx 2.5\ GHz$

$\Rightarrow \lambda = 12\ cm$

[standing wave. Try marshmallow on a plate. Why rotating plate?]

[XM radio 2332.5 – 2345.0 MHz]

Infrared: $700\text{nm} < \lambda < 1\text{ mm}$ [warmth on skin, night vision goggles, remote control]

Visible: $400\text{ nm} < \lambda < 700\text{ nm}$

$f = \frac{c}{\lambda} \sim 5 \times 10^{14}\text{ Hz}$

Ultraviolet: $100\text{ nm} < \lambda < 400\text{ nm}$ [Sun burns, skin cancer; absorbed by O_2, N_2 + by ozone in atmosphere]

- UVA 320 - 400
- UVB 290 - 320
- UVC 100 - 290

[but actually down to ~10 nm]

X-rays: $0.01\text{ nm} \leq \lambda < 10\text{ nm}$ [deceleration of electrons]

[~size of atoms used for determining molecular structure, DNA]

γ-rays: $\lambda < 10^{-11}\text{ m}$ [emitted by nuclei, radioactivity, cosmic rays, matter/anti-matter $e^+e^- \rightarrow \gamma\gamma$]