Chapter 25 part 4

25.6: The Photon Model of Electromagnetic Waves

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- Low frequency (long wavelength) photons have lower energy.
- High frequency (short wavelength) photons have higher energy.

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- $$E_{\mathrm{photon}} = \frac{hc}{\lambda} = \frac{(6.63 \times 10^{-34}\,\mathrm{Js}) \times (3.00 \times 10^{8}\,\mathrm{m/s})}{655\,\mathrm{nm}} = 3.03 \times 10^{-19}\,\mathrm{J}$$

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- This is a small amount of energy. It is useful to convert it to electron volts:
- $$E_{\mathrm{photon}} = E \times \frac{1\,\mathrm{eV}}{1.602 \times 10^{-19}\,\mathrm{J}} = 1.89\,\mathrm{eV}$$

Example: Red laser pointer.

Revisit our laser pointer example. Let $P = 0.240\,\text{mW} = 0.000\,240\,\text{W}$. How many photons per second is that? Let $R = \text{photon rate} = \#\text{photons/second}$.

$$R = 0.000\,240\,\text{W} \times \frac{1\ \text{photon}}{3.03 \times 10^{-19}\,\text{J}} = 7.91 \times 10^{14}\,\text{photons/second}$$

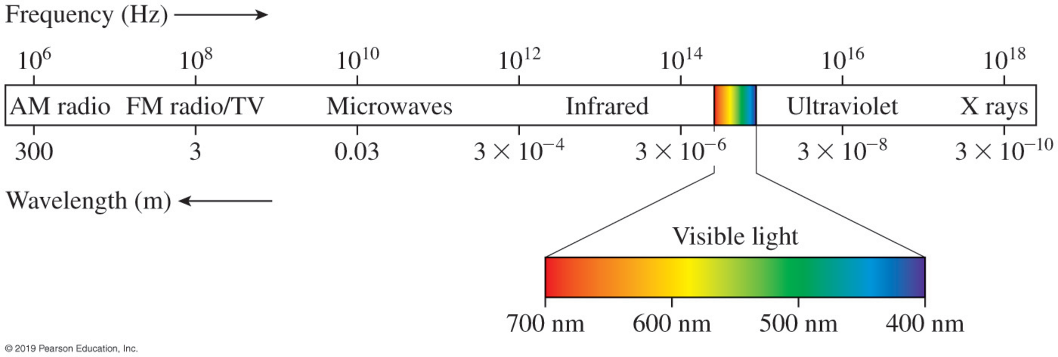
Even from a small battery-powered device, the number of photons is so large that it looks like a continuous stream. We will see much more in Ch. 28.

Handy unit combination:

$$hc = 1240\,\mathrm{eVnm}$$

$$E_{\mathrm{red}} = \frac{hc}{\lambda} = \frac{1240\,\mathrm{eVnm}}{655\,\mathrm{nm}} = 1.89\,\mathrm{eV}$$

Recall $c = \lambda f$. λ and f can span *huge* ranges. Recall too that $E = hf = \frac{hc}{\lambda}$.



The text gives good examples of phenomena associated with different wavelengths.

- **Cell phone**:

  $f = 1.90\,\text{GHz}$ (typical 4G LTE frequency). Then

$$\lambda = \frac{c}{f} = 0.158\,\text{m}$$

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- **Visible Light**:
  - $\lambda = 400\,\text{nm}$ to $700\,\text{nm}$. (Violet to red)
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- **X-rays**:
  - $\lambda \sim 0.3\,\text{nm}$, $f \sim 1.0 \times 10^{18}\,\text{Hz}$
  - $E_{\text{photon}} \sim 4100\,\text{eV}$

What's Next

- See Example 25.13 in text.
- Interaction with matter: Chs. 28, 29, and 30.
- Integrated Example 25.14 in text is a good review of many ideas.