Homework 4

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Light Bulb and Photons

(a) The energy of the photons may be calculated using $E = hf$

$$E = \frac{hc}{\lambda} = \frac{(6.626 \cdot 10^{-34})(3 \cdot 10^{8})}{550 \cdot 10^{-9}} = 3.614 \cdot 10^{-19}[\text{J}]$$

- The total amount of energy in 55 watts can be found as:

$$\frac{55}{E} = 15.27 \cdot 10^{19}[\text{photons per second}]$$

- With 75% efficiency, this becomes

$$.75 \cdot 15.27 \cdot 10^{19} = 11.45 \cdot 10^{19}[\text{photons per second}]$$

- Converting to hours, we finally get:

$$11.45 \cdot 10^{19} \cdot 3600 = 4.122 \cdot 10^{23}[\text{photons per hour}]$$

(b)

- The area of the plate is:

$$(.01)^2 = .0001[\text{m}^2]$$

- The area of the emitted light within the radius of the plate is:

$$4\pi r^2 = 4\pi(1)^2 = 12.566[\text{m}^2]$$

- Using area proportions and the number calculated in (a), we get:

$$\left(11.45 \cdot 10^{19}\right)\frac{.0001}{12.566} = 9.11 \cdot 10^{14}[\text{photons}]$$

Compton Scattering

- The formula for energy difference of a scattered electron is:

$$\frac{1}{E'} - \frac{1}{E} = \frac{1}{m_e c^2}(1 - \cos(\theta))$$

- The maximum kinetic energy given to the electron occurs when the subsequent energy of the photon is minimal, or when $\theta = 180$. Thus, we obtain:

$$\frac{1}{E'} = \frac{2}{m_e c^2} + \frac{1}{E}$$

$$E' = \left(\frac{2}{m_e c^2} + \frac{1}{E}\right)^{-1}$$

Thermal Radiation

(a) • Using Wien's displacement:

$$\lambda_{max} = \frac{2.9 \cdot 10^{-3}}{T}$$
$$\lambda_{max} = \frac{2.9 \cdot 10^{-3}}{273 + 34}$$
$$\lambda_{max} = 9.45[\mu\text{m}]$$

• Per the EM spectrum below, this is in the infrared range

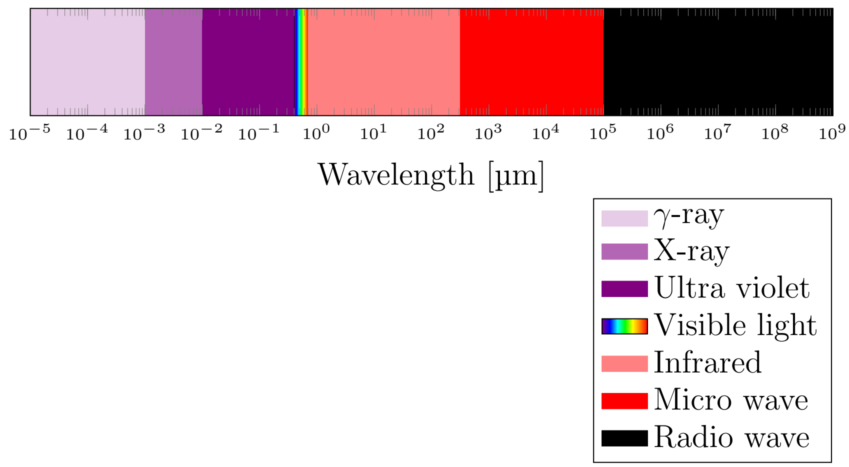

Figure 1: Electromagnetic Spectrum

(b) • Assuming a human body to be roughly $2[\text{m}^2]$ in surface area, Stefan's law may be used:

$$P = \sigma A T^4$$
$$\left(5.67 \cdot 10^{-8}\right)(2)(273 + 34)^4 = 1007.3[\text{W}]$$

Photoelectric Effect

• The formula relation for voltage and work function is:

$$e^- V = hf - \phi$$

• With copper, this means:

$$V = \frac{\frac{hc}{\lambda} - \phi_1}{e^-}$$

- With sodium, V would be:

$$V_s = \frac{\frac{hc}{\lambda} - \phi_2}{e^-}$$

- This means:

$$V_s = V - \frac{\phi_2 - \phi_1}{e^-}$$