



Beyond the sub-millimeter Band at wavelengths between 0.1 millimeter (100 microns) and 0.001 millimeter (1 micron) we are in a complicated electromagnetic band in which warm bodies emit most of their heat energy. The 'IR' band is also the band in which many common molecules emit specific frequencies of light as their constituent atoms rotate and vibrate.

**Problem 1** - What is the frequency range, in teraHertz, that is spanned by the IR band from 0.1 millimeters to 0.001 millimeters?

**Problem 2** - The energy of a quantum of electromagnetic energy (called a photon) is given by the formula  $E(\text{Joules}) = 6.63 \times 10^{-34} f$  where  $f$  is the frequency of the EM wave in Hertz. How much energy, in eV, do these infrared photons carry at the ends of the infrared band? (Note: The amounts of energy are so small, physicists use the 'electron-Volt' (eV) instead of the Joule.  $1 \text{ eV} = 1.6 \times 10^{-19}$  Joules)

**Problem 3** - At these wavelengths, warm bodies produce infrared light across the IR band. The temperature of a body can be determined by the wavelength at which the maximum brightness occurs according to the formula  $T = 2897/L$  where  $L$  is the wavelength in microns, and  $T$  is the temperature in Kelvin degrees. For example, a human with a temperature of 98 F (309 K) will have a 'black body' curve that peaks at a wavelength of 9.4 microns.

A) The above graph shows the brightness of the infrared light from two bodies at two different temperatures. What are the two wavelengths for which the combined spectrum has its two maximum intensities?

B) From the formula, what are the temperatures for each of the two bodies?

**Problem 1** - Answer:

A) Frequency = (300,000,000 meters/sec)/wavelength. so at 0.1 millimeters (0.0001 meters) the frequency is  $300,000,000/0.0001 = 3 \times 10^{12}$  **Hertz or 3 teraHertz.**

B) Frequency = (300,000,000 meters/sec)/wavelength. so at 0.001 millimeters (0.000001 meters) the frequency is  $300,000,000/0.000001 = 300 \times 10^{12}$  **Hertz or 300 teraHertz.**

**Problem 2** - Answer: At 3 teraHertz the energy of a photon is

$$E = 6.63 \times 10^{-34} (3 \times 10^{12}) = 2.0 \times 10^{-21} \text{ Joules or } 0.01 \text{ eV} .$$

At 300 teraHertz the energy of a photon is

$$E = 6.63 \times 10^{-34} (3 \times 10^{14}) = 2.0 \times 10^{-19} \text{ Joules or } 1.0 \text{ eV} .$$

**Problem 3** - At these wavelengths, warm bodies produce infrared light across the IR band. The temperature of a body can be determined by the wavelength at which the maximum brightness occurs according to the formula  $T = 2897/L$  where L is the wavelength in microns, and T is the temperature in Kelvin degrees. For example, a human with a temperature of 98 F (309 K) will have a 'black body' curve that peaks at a wavelength of 9.4 microns.

A) The above graph shows the brightness of the infrared light from two bodies at two different temperatures. What are the two wavelengths for which the combined spectrum has its two maximum intensities? Answer: **The peaks are at 20 microns and 80 microns.** Students may use estimates for the peak locations between 20-25 K and 80-100K.

B) From the formula, what are the temperatures for each of the two bodies?

Answer; For the 20-micron peak, and peak wavelength of 20 microns, the temperature is  $T = 2897/20 = 144 \text{ K}$ . For the 80 micron peak, the temperature is  $T = 2897/80 = 36 \text{ K}$ .