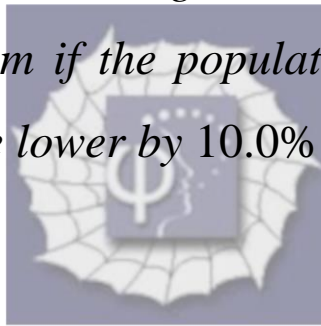


780.

**Problem 52.30 (RHK)**

*A population inversion for two levels is often described by assigning a negative Kelvin temperature to the system. We have to show that such a negative temperature would indeed correspond to an inversion. A three-level laser emits laser light at a wavelength of 550 nm. We have to find the negative temperature that would describe the system if the population of the upper level exceeds that of the lower by 10.0%.*



**Solution:**

The energy difference between the upper and the lower levels is determined by the energy of the photon, which corresponds to a wavelength of 550 nm. We have

$$E_2 - E_1 = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{550 \times 10^{-9}} \text{ J} = 3.62 \times 10^{-19} \text{ J} .$$

Let the population of the lower level be  $n(E_1)$ . As the population of the upper level  $n(E_2)$  exceeds that of the lower level by 10%, we have

$$\frac{n(E_2)}{n(E_1)} = 1.10 .$$

Let the system be described by temperature  $-|T|$  K.

From the Boltzmann distribution, we have

$$\frac{n(E_2)}{n(E_1)} = \exp(-(E_2 - E_1)/kT) = 1.10,$$

or

$$\exp(3.62 \times 10^{-19} / 1.38 \times 10^{-23} |T|) = 1.10,$$

or

$$T = -\frac{2.62 \times 10^4}{\ln 1.10} \text{ K} = -\frac{2.62 \times 10^4}{9.53 \times 10^{-2}} \text{ K} = -2.75 \times 10^5 \text{ K}.$$

