Planck Radiation Formula

From the assumption that the electromagnetic modes in a cavity were quantized in energy with the quantum energy equal to Planck's constant times the frequency, Planck derived a radiation formula. The average energy per "mode" or "quantum" is the energy of the quantum times the probability that it will be occupied (the Einstein-Bose distribution function):

$$\langle E \rangle = \frac{h\upsilon}{e^{h\upsilon/kT} - 1}$$

This average energy times the density of such states, expressed in terms of either frequency or wavelength

$$\rho(\nu) = \frac{dn_s}{d\nu} = \frac{8\pi}{c^3}\nu^2 \qquad \rho(\lambda) = \frac{dn_s}{d\lambda} = \frac{8\pi}{\lambda^4}$$

gives the energy density, the Planck radiation formula.

Energy per unit volume per unit frequency	$S_\upsilon = \frac{8\pi h}{c^3}\frac{\upsilon^3}{e^{h\upsilon/kT} - 1}$	**Example**
Energy per unit volume per unit wavelength	$S_\lambda = \frac{8\pi hc}{\lambda^5}\frac{1}{e^{hc/\lambda kT} - 1}$	**Example**

The Planck radiation formula is an example of the distribution of energy according to Bose-Einstein statistics. The above expressions are obtained by multiplying the density of states in terms of frequency or wavelength times the photon energy times the Bose-Einstein distribution function with normalization constant A=1.

To find the radiated power per unit area from a surface at this temperature, multiply the energy density by c/4. The density above is for thermal equilibrium, so setting inward=outward gives a factor of 1/2 for the radiated power outward. Then one must average over all angles, which gives another factor of 1/2 for the angular dependence which is the square of the cosine.

Major applications of the Planck formula

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