PHYS 325 Assignment 1:
Classical and Quantum Models for Blackbody Radiation

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Date: February 15th, 2015
PHYS 325 Computational Physics

1 Background

Blackbody radiation is emitted by an object that is at complete thermal equilibrium and comes from the oscillating material of the blackbody generating electromagnetic waves. This happens for temperatures above absolute zero. Some examples of black body radiation include the light emitted from iron when it is heated and also lava. Both materials are radiating light due to their jiggling atoms.[1]

The phenomenon of blackbody radiation and its radiation spectrum could not be explained by the classical laws of thermodynamics and electromagnetism. Why was it that when gas was heated, it exhibited specific bands of radiation, whereas thermal radiation from solid objects was continuous? It wasn't until Max Planck introduced the concept of *quantized* energy that a model which fit the phenomenon of thermal radiation was found.[2]

The thermodynamic model for the spectrum of radiation given by equation 1 (Rayleigh-Jean Law) shows that as the frequency of the light increases, its radiated intensity goes to infinity. The major problem with this, even if the intensity could infinity, was that this would not be experimentally measurable. Equation 2 introduces Plancks model for the radiation spectrum of a blackbody, using his assumption of the quantized nature of energy distributed between mass and electromagnetic waves. The results of both models can be summarized in figure 1, which plots equation 1 and 2 together.

$$u(v,T) = \frac{8\pi v^2}{c^3} kT \tag{1}$$

$$u(v,T) = \frac{8\pi v^2}{c^3} \frac{hv}{e^{\frac{hv}{kT}} - 1} \tag{2}$$

As can be seen, 1 can be expected to give a graph with a continually rising slope. 2, however, has a function which will increase until the exponential term in the denominator becomes greater than the term in the numerator. Plotting these functions in MATLAB while simplifying the constants to 1 gives an idea of how these functions compare.

[1] Wikipedia
[2] "Quantum Mechanics: Concepts and Applications", Nouredine Zettili

2 Computational Results

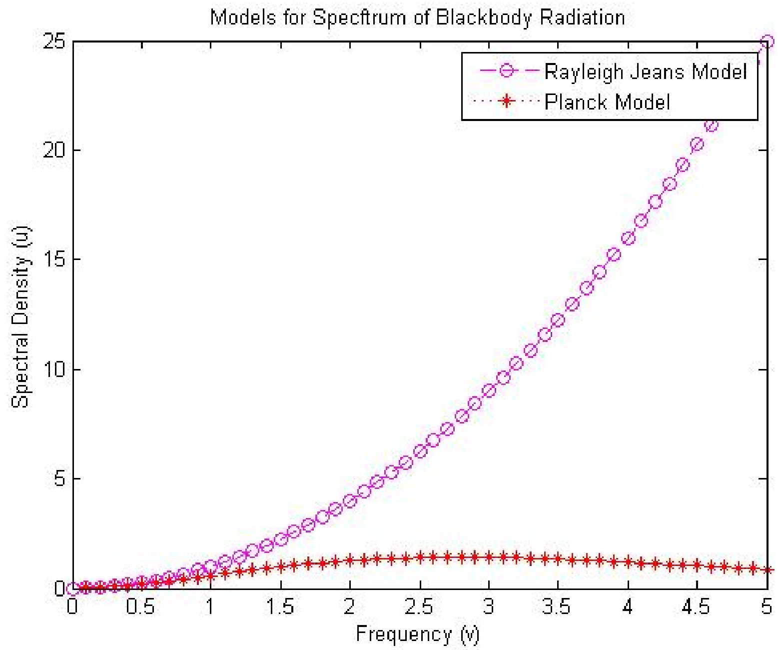

Figure 1: The Rayleigh-Jeans and Planck equations for the spectrum of radiation emitted by a blackbody are significantly different past about 1Hz in the figure. The Rayleigh-Jeans model increases towards infinity, whereas the Planck model does not. This was the major failure of the Rayleigh-Jeans model, and ushered in the era of Quantum Physics.

As can be seen from figure 1, the Rayleigh Jeans model continues to rise in spectral density as the frequency increases. This was the ultraviolet catastrophe, and did not conform to experimental observations. Planck's model, which utilizes quantized amounts of energy, reduces to essentially 0 as the frequency increases due to the limiting exponential in the denominator of 2.

3 MATLAB Code

```
clear
%PHYS 385 Assignment #1

%generate array, set value of kT
v = [0.0:0.1:5];
kT = 200;

%constants used in the equation
%c = speed of light
c = 1; %299792458;
%k = Boltzman's constant.
k = 1.3806488e-23;
%planck's constant
h = 1; %6.62606957e-34;

%The equation for the Rayleigh-Jeans model
u_RJ = v.^2;  %((v.^2)*((8*pi)/(c^3))*kT);

%The equation for the Planck model
p_term1 = (v.^2)*(1); %1 should actually be (8*pi)/(c^3)
exp_term = ((h*v))/(kT);
p_term2 = ((h*v)/(exp(exp_term)-1));
u_P = (v.^3)./(exp(v)-1);

%plot the functions together
plot(v,u_RJ,'--mo',v,u_P,':r*')
title('Models for Specftrum of Blackbody Radiation')
xlabel('Frequency (v)') % x-axis label
ylabel('Spectral Density (u)') % y-axis label
legend('Rayleigh Jeans Model','Planck Model')
```