AIM

1. Plot Planck’s law & Rayleigh-Jean's Law of Black body radiation w.r.t. wavelength at different temperatures.

2. Compare both at high & low temperatures.

3. Verify Weins-Displacement Law

Breif about BlackBody Radiation

- "Blackbody radiation" or "Cavity radiation" refers to an object or system which absorbs all radiation incident upon it and re-radiates energy which is characteristic of this radiating system only, not dependent upon the type of radiation which is incident upon it.
- The radiated energy can be considered to be produced by standing wave or resonant modes of the cavity which is radiating.

Step-1 : Importing necessary libraries

In [140…

```
import numpy as np
from scipy.constants import h,c,k,pi
import matplotlib.pyplot as plt
```

Step-2 : Define an array for wavelength in micrometers & then convert it in meters

In [141…

```
L = (np.arange(0.1,30,0.005))*(1e-6) #0.1 um to 30 um with step size 0.005um
```

Step-3 : Define function planck_lamda for Plancks Law of Black Body Radiation

Plancks Radiation Formula in terms of Wavelength :

Energy per unit volume per unit wavelength

$$S_\lambda = \frac{8\pi hc}{\lambda^5}\frac{1}{e^{hc/\lambda kT}-1}$$

Image Source : BlackBody Radiation.

In [142…

```
def planck_lamda(L,T):
    a = (8*pi*h*c)/(L**5)
    b = (h*c)/(L*k*T)
    c1 = np.exp(b)-1
    d = a/c1
    return d
```

Step-4 : Find Intensity at 4 different temperatures (ex: 500K, 700K, 900K & 1100K)

In [143…

```
T500 = planck_lamda(L , 500)
T700 = planck_lamda(L , 700)
T900 = planck_lamda(L , 900)
T1100 = planck_lamda(L , 1100)
```

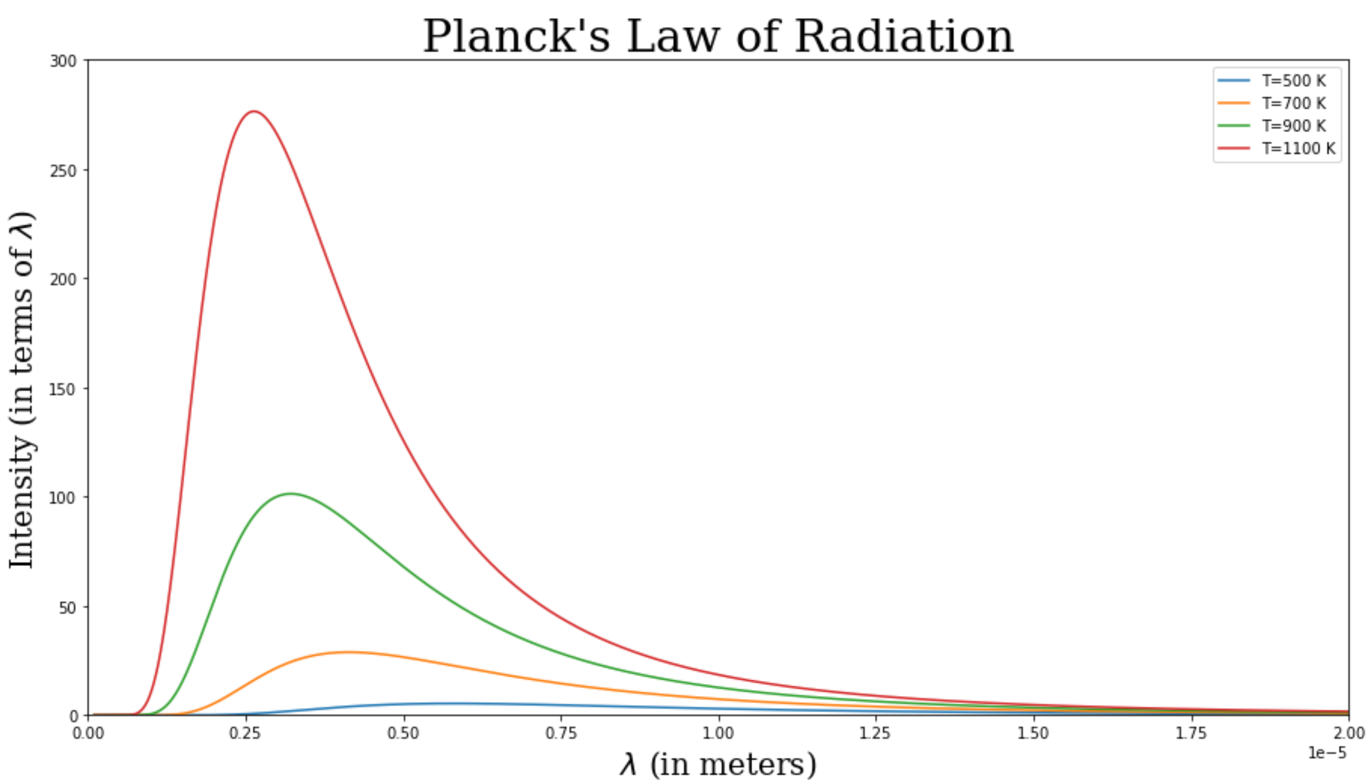
Step-5 : Plotting Planck's Law of Radiation at different temperatures

In [144…

```
plt.figure(figsize=(15, 8)) #Changing Figure Size
fontji = {'family':'serif','size':20}
fontji2 = {'family':'serif','size':30}

plt.plot(L, T500,label='T=500 K')
plt.plot(L, T700 ,label='T=700 K')
plt.plot(L, T900 ,label='T=900 K')
plt.plot(L, T1100 ,label='T=1100 K')
plt.legend()
plt.xlabel(r"$\lambda$ (in meters)",fontdict=fontji)
plt.ylabel(r"Intensity (in terms of $\lambda$)",fontdict=fontji)
plt.title("Planck's Law of Radiation",fontdict=fontji2)
plt.ylim(0,300)
plt.xlim(0,0.00002)
```

Out[144…

```
(0.0, 2e-05)
```



Step-6 : Define function rayleigh_lamda for Rayleigh Jeans Formula

In [145…

```
def r_lamda(L,T):
    i = 8*pi*k*T/(L**4)
    return i
```

Step-7 : Finding Intensity at different temperatures using r_lamda

In [146…

```
Tr500 = r_lamda(L , 500)
Tr700 = r_lamda(L , 700)
Tr900 = r_lamda(L , 900)
Tr1100 = r_lamda(L , 1100)
```

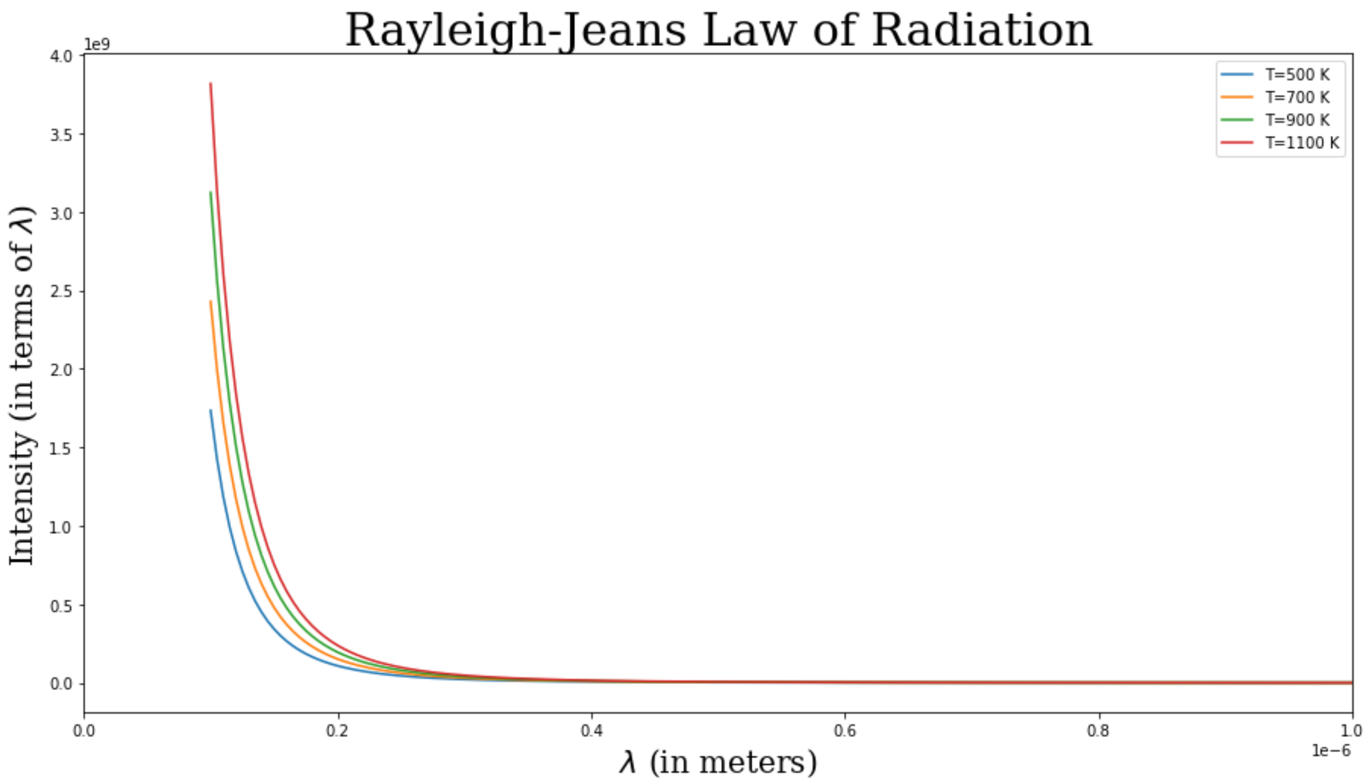
Step-8 : Plotting Rayleigh Jeans formula for different temperatures

In [147…

```
plt.figure(figsize=(15, 8)) #Changing Figure Size

plt.plot(L, Tr500,label='T=500 K')
plt.plot(L, Tr700 ,label='T=700 K')
plt.plot(L, Tr900 ,label='T=900 K')
plt.plot(L, Tr1100 ,label='T=1100 K')
plt.legend()
plt.xlabel(r"$\lambda$ (in meters)",fontdict=fontji)
plt.ylabel(r"Intensity (in terms of $\lambda$)",fontdict=fontji)
plt.title("Rayleigh-Jeans Law of Radiation",fontdict=fontji2)
#plt.ylim(0,1.2)
plt.xlim(0,0.000001)
```

Out[147…

```
(0.0, 1e-06)
```



Step-9 : Comparing Rayleigh Jeans & Plancks Formula at low & high temperatures

In [148…

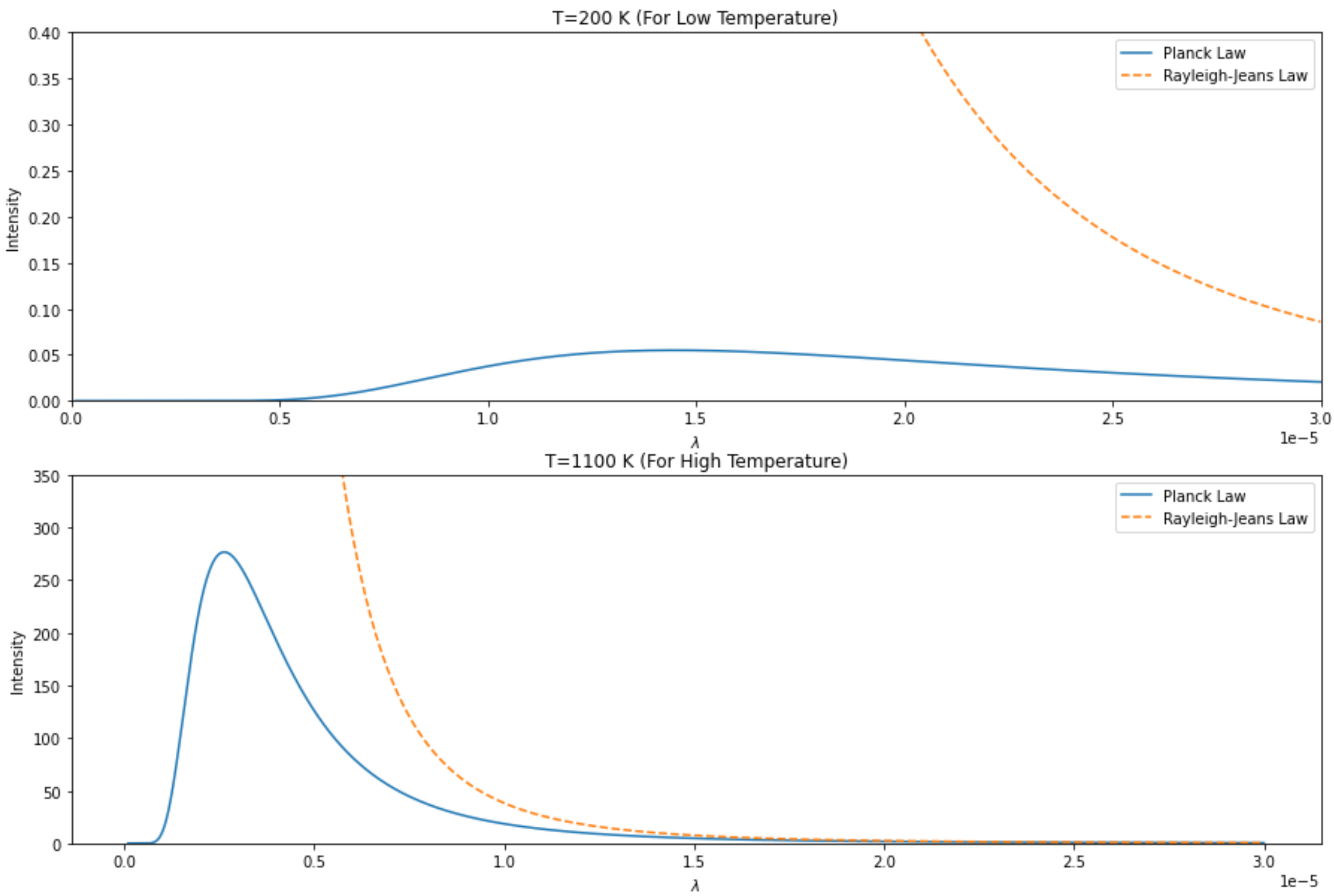
```python
plt.suptitle("Comparing Rayleigh-Jeans & Plancks Law for BBR at low & high temperatures
plt.figure(figsize=(15, 10)) #Changing Figure Size

plt.subplot(2,1,1)
plt.plot(L, (planck_lamda(L,200)),label='Planck Law')
plt.plot(L, (r_lamda(L,200)) , "--" , label="Rayleigh-Jeans Law")
plt.legend(loc="best")
plt.xlabel(r"$\lambda$ ")
plt.ylabel("Intensity")
plt.title("T=200 K (For Low Temperature)")
plt.ylim(0,0.4)
plt.xlim(0,0.00003)

plt.subplot(2,1,2)
plt.plot(L, T1100 ,label='Planck Law')
plt.plot(L, Tr1100 , "--" , label="Rayleigh-Jeans Law")
plt.legend(loc="best")
plt.xlabel(r"$\lambda$ ")
plt.ylabel("Intensity")
plt.title("T=1100 K (For High Temperature)")
plt.ylim(0,350)
```

```
/tmp/ipykernel_3710/3404406587.py:4: RuntimeWarning: overflow encountered in exp
  c1 = np.exp(b)-1
```

Out[148…

```
(0.0, 350.0)
```

```
<Figure size 432x288 with 0 Axes>
```



> **Conclusion** : The Rayleigh-Jeans curve agrees with the Planck radiation formula for long wavelengths or low frequencies.

Step-10 : Verifying Weins Displacement Law

- When the temperature of a blackbody radiator increases, the overall radiated energy increases and the peak of the radiation curve moves to shorter wavelengths.

- When the maximum is evaluated from the Planck radiation formula, the product of the peak wavelength and the temperature is found to be a constant.
- Formula : $\lambda_{peak} T = 2.898 \times 10^{-3}\ \mathrm{m \cdot K}$
- This relationship is called **Wien's displacement law**.

> **Note** : It should be noted that the peak of the radiation curve in the Wien relationship is the peak only because the intensity is plotted as a function of wavelength. If frequency or some other variable is used on the horizontal axis, the peak will be at a different wavelength.

- Source : Weins Displacement Law