BLACK BODY RADIATION

Before moving to the practical let's see the basic terms and definition for proper understanding:

Blackbody Radiation:

Blackbody radiation refers to the electromagnetic radiation emitted by a perfectly black object that absorbs all incident radiation and emits radiation according to its temperature. Several laws describe the distribution of this radiation with respect to wavelength or frequency.

Planck's Law:

Planck's law of blackbody radiation gives the spectral radiance $u(\lambda)$ (radiant energy per unit wavelength interval) of a blackbody at temperature (T):

$$u(\lambda, T) = \frac{8\pi hc}{\lambda^5}\frac{1}{e^{hc/(\lambda k_B T)} - 1}$$

or equivalently for frequency ν:

$$u(\nu, T) = \frac{8\pi h\nu^3}{c^3}\frac{1}{e^{h\nu/(k_B T)} - 1}$$

where:
- h is Planck's constant,
- c is the speed of light,
- k_B is the Boltzmann constant,
- T is the temperature in Kelvin,
- λ is the wavelength of light,
- ν is the frequency of light.

Planck's law accurately describes the spectrum of radiation emitted by blackbodies across all wavelengths and temperatures

Rayleigh-Jeans Law:

The Rayleigh-Jeans law is an approximation valid at long wavelengths (low frequencies) compared to the temperature of the emitting body:

$$u(\lambda, T) = \frac{8\pi k_B T}{\lambda^4}$$

or

$$u(\nu, T) = \frac{8\pi\nu^2 k_B T}{c^3}$$

This law fails at shorter wavelengths due to the ultraviolet catastrophe, where it predicts infinite energy density.

Wien's Distribution Law:

Wien's displacement law gives the wavelength $(\lambda_{\max})$ at which the spectral radiance of a blackbody is maximum:

$$\lambda_{\max} T = b$$

where $(b \approx 2.898 \times 10^{-3} mK)$ (Wien's displacement constant)
It indicates the peak wavelength shifts inversely with temperature.

The plot shows how Planck's law accurately describes blackbody radiation across all wavelengths and temperatures, while Rayleigh-Jeans law diverges at shorter wavelengths, and Wien's law gives the peak wavelength where radiation intensity is highest.

EXPERIMENT 12

AIM: Plot Planck’s law of Black body radiation w.r.t. wavelength/frequency at different temperatures. Compare it with Rayleigh-Jeans Law and Wien’s distribution law for a given temperature

CODE:

```
import numpy as np
import matplotlib.pyplot as plt

# Initializing the constants
k = 0.01; mu = -1; n = 10000
E = [i * 1 - 1000 for i in range(n)] # Energy range
T = [1000, 5222, 10333] # Temperature range
Fmb_values = []
Ffd_values = []
Fbe_values = []
```

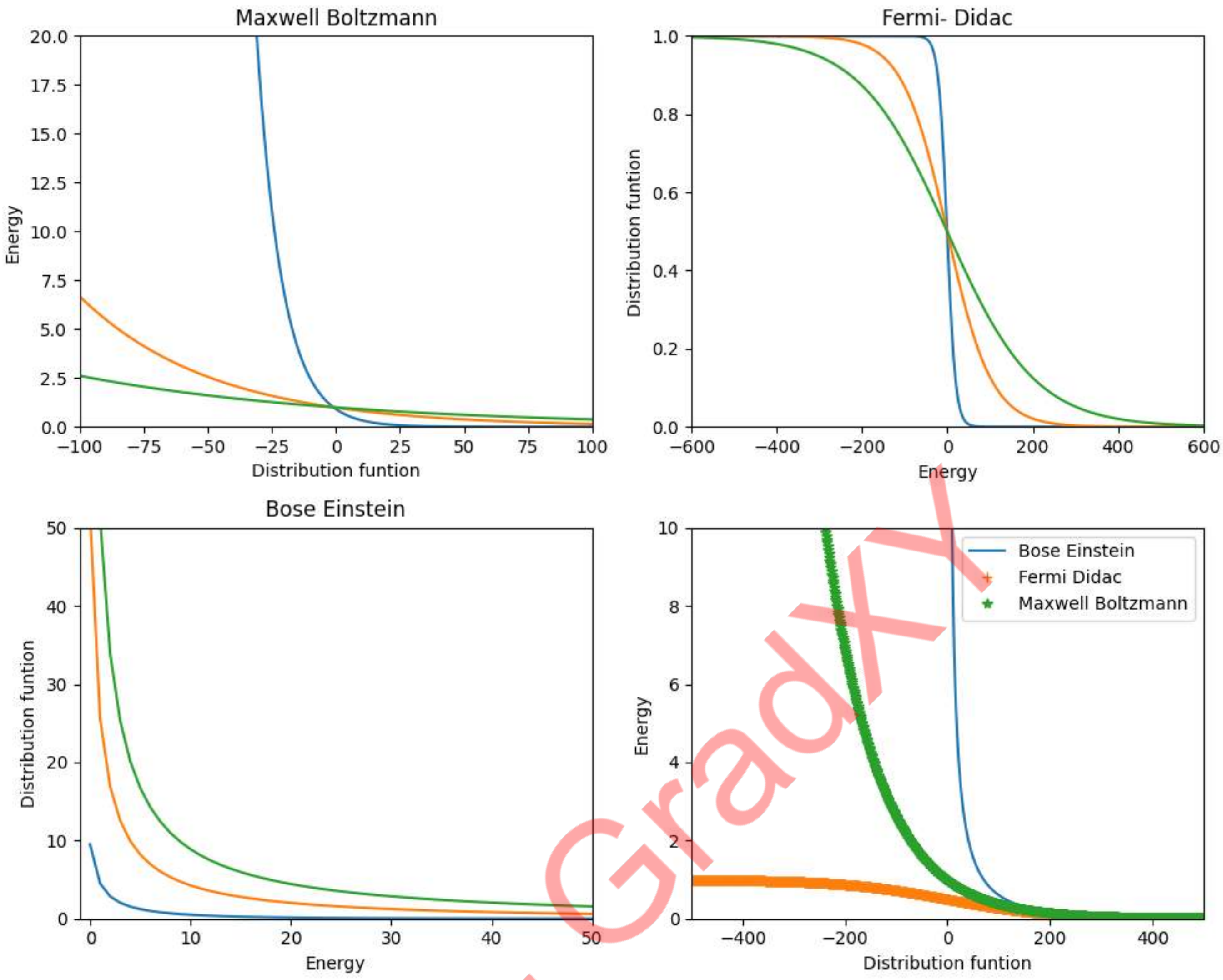
```
# Plotting the graphs
plt.figure(figsize=(10, 8))
for t in T:
    Fmb = [1 / np.exp((E[j] - mu) / (k * t)) for j in range(n)]
    Fmb_values.append(Fmb)
    plt.subplot(2, 2, 1)
    plt.ylim(0,20)
    plt.xlim(-100,100)
    plt.plot(E, Fmb)
    plt.title('Maxwell Boltzmann')
    plt.xlabel('Distribution funtion')
    plt.ylabel('Energy')

    Ffd = [1 / ((np.exp((E[j] - mu) / (k * t)))+1) for j in range(n)]
    Ffd_values.append(Ffd)
    plt.subplot(2, 2, 2)
    plt.ylim(0,1)
    plt.xlim(-600,600)
    plt.plot(E, Ffd)
    plt.title('Fermi- Didac')
    plt.ylabel('Distribution funtion')
    plt.xlabel('Energy')

    Fbe = [1 /((np.exp((E[j] - mu) / (k * t)))-1) for j in range(n)]
    Fbe_values.append(Fbe)
    plt.subplot(2, 2, 3)
    plt.ylim(-10,10)
    plt.xlim(-50,50)
    plt.plot(E, Fbe)
    plt.xlim(-1,50)
    plt.ylim(0,50)
    plt.title('Bose Einstein')
    plt.ylabel('Distribution funtion')
    plt.xlabel('Energy')


plt.subplot(2, 2, 4)
plt.ylim(0,10)
plt.xlim(-500,500)
plt.plot(E,Fbe, label='Bose Einstein')
plt.plot(E,Ffd,'+', label='Fermi Didac')
plt.plot(E,Fmb,'*', label='Maxwell Boltzmann')
plt.xlabel('Distribution funtion')
plt.ylabel('Energy')
plt.legend()
plt.tight_layout()
plt.show()
```

OUTPUT:


Maxwell Boltzmann
Energy
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
−100
−75
−50
−25
0
25
50
75
100
Distribution funtion
Fermi- Didac
Distribution funtion
1.0
0.8
0.6
0.4
0.2
0.0
−600
−400
−200
0
200
400
600
Energy
Bose Einstein
Distribution funtion
50
40
30
20
10
0
0
10
20
30
40
50
Energy
Bose Einstein
Fermi Didac
Maxwell Boltzmann
Energy
10
8
6
4
2
0
−400
−200
0
200
400
Distribution funtion