DISTRIBUTION FUNCTIONS

Before moving to the practical lets see the basic terms and definition for proper understanding:

Fermi-Dirac Distribution:

Fermi-Dirac statistics is used to describe the behaviour of fermions, which are the particles that obey the Pauli exclusion principle, meaning no two fermions can occupy the same quantum state simultaneously. The probability distribution function for the occupation of different energy states by fermions at a given temperature T is given by:

$$n_i = \frac{1}{e^{\frac{\varepsilon_i - \mu}{k_B T}} + 1}$$

Where:
- n_i is the average number of particles in the i^{th} energy state.
- ε_i is the energy of the i^{th} state.
- μ is the chemical potential.
- k_B is the Boltzmann constant.
- T is the temperature.

Bose-Einstein Distribution:

Bose-Einstein statistics is used to describe the behaviour of bosons, which are the particles that follow Bose-Einstein distribution. Bosons do not obey Pauli's Exclusion principle, meaning any number of bosons can occupy the same quantum state. The probability distribution function for the occupation of different energy states by bosons at a given temperature (T) is given by:

$$n_i = \frac{1}{e^{\frac{\varepsilon_i - \mu}{k_B T}} - 1}$$

Where:
- n_i is the average number of particles in the i^{th} energy state.
- ε_i is the energy of the i^{th} state.
- μ is the chemical potential.
- k_B is the Boltzmann constant.
- T is the temperature

Maxwell Boltzmann Distribution:

Maxwell-Boltzmann statistics describe the behaviour of classical particles, such as non-interacting gas particles. In this case, there is no restriction on the number of particles occupying a particular energy state. The probability distribution function for the occupation of different energy states by classical particles at a given temperature T is given by the Boltzmann distribution:

$$n_i = \frac{1}{e^{\frac{\varepsilon_i}{k_B T}}}$$

Where:
- n_i is the average number of particles in the i^{th} energy state.
- ε_i is the energy of the i^{th} state.
- k_B is the Boltzmann constant.
- T is the temperature

For the code we have defined a constant a as shown:
The Maxwell-Boltzmann distribution function is given by:

$$n_i = \frac{1}{e^{\frac{\epsilon_i - \mu}{k_B T}} + a}$$

Here a is a variable whose value is as follows:
a = 0 (Maxwell Boltzmann Statistics)
a = 1 (Bose EInstein Statistics)
a = -1 (Fermi DIrac Statistics)

EXPERIMENT 7

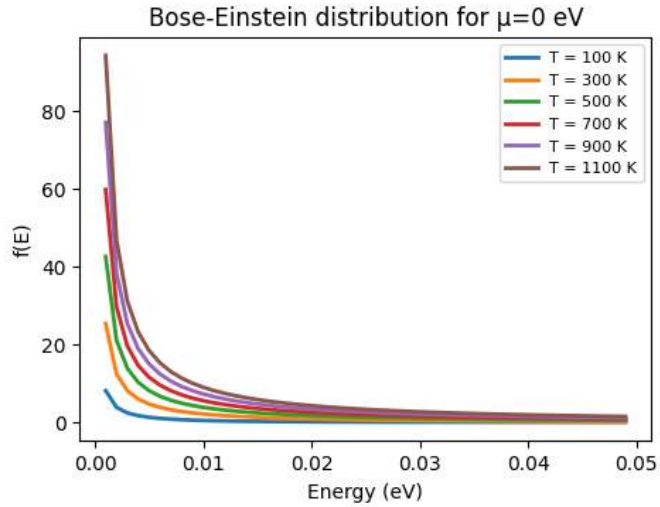
AIM: Plot the Maxwell-Boltzmann distribution, Fermi-Dirac distribution, Bose-Einstein distribution functions with energy at different temperatures and compare them.

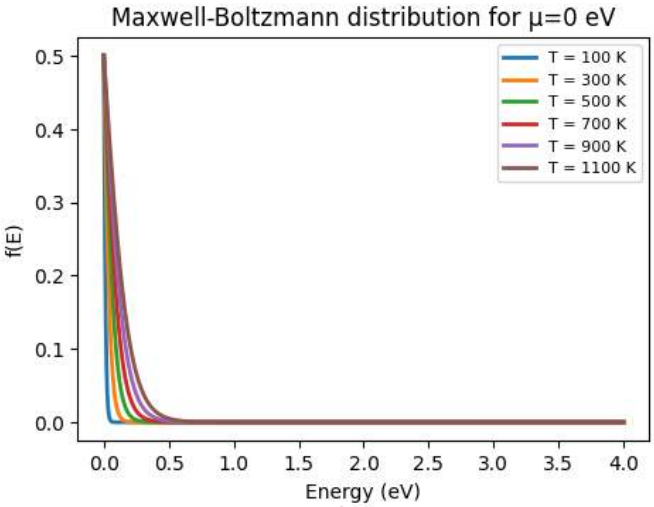
CODE:

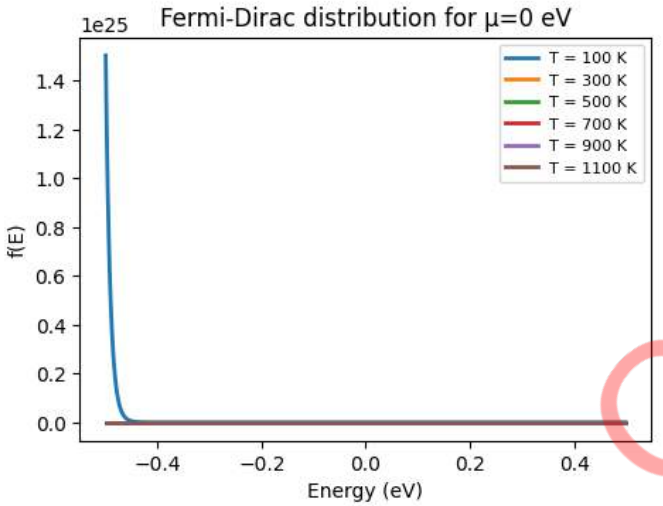
```
import numpy as np
import matplotlib.pyplot as plt

e = 1.6e-19  # Electron charge (C)
k = 1.38e-23  # Boltzmann's constant (J/K)
u = 0  # Chemical potential (eV)

T = np.arange(100, 1101, 200) # Temperature range in K
distributions = ['Bose-Einstein', 'Maxwell-Boltzmann', 'Fermi-Dirac']
a_values = [-1, 1, 0]  # a values for BE, MB, FD distributions
# Set up the figure and axis
fig, axes = plt.subplots(2, 2, figsize=(10, 8))
```

```
axes = axes.flatten()

# Plotting the distributions
for n, distribution in enumerate(distributions):
    a = a_values[n]
    if distribution == 'Maxwell-Boltzmann':
        E = np.arange(0, 4, 0.001)  # for MB
    elif distribution == 'Bose-Einstein':
        E = np.arange(0, 0.05, 0.001)  # for BE
    else:
        E = np.arange(-0.5, 0.5, 0.001)  # for FD

    f = np.zeros((len(T), len(E)))
    for j in range(len(T)):
        for i in range(len(E)):
            if distribution == 'Bose-Einstein' and (np.exp(((E[i] - u) * e) / (k *
T[j])) - 1) == 0:
                f[j, i] = np.inf  # Handle division by zero for Bose-Einstein
            else:
                f[j, i] = 1 / (np.exp(((E[i] - u) * e) / (k * T[j])) + a)

    ax = axes[n]
    for j in range(len(T)):
        ax.plot(E, f[j, :], label=f'T = {T[j]} K', linewidth=2)

    ax.set_ylabel('f(E)', fontsize=10)
    ax.set_xlabel('Energy (eV)', fontsize=10)
    ax.legend(fontsize=8)
    ax.set_title(f'{distribution} distribution for μ={u} eV', fontsize=12)

fig.delaxes(axes[3])
plt.tight_layout(pad=2.0)
plt.show()
```


OUTPUT:


Bose-Einstein distribution for μ=0 eV
T = 100 K
T = 300 K
T = 500 K
T = 700 K
T = 900 K
T = 1100 K
f(E)
Energy (eV)


Maxwell-Boltzmann distribution for μ=0 eV
T = 100 K
T = 300 K
T = 500 K
T = 700 K
T = 900 K
T = 1100 K
f(E)
Energy (eV)


Fermi-Dirac distribution for μ=0 eV
1e25
T = 100 K
T = 300 K
T = 500 K
T = 700 K
T = 900 K
T = 1100 K
f(E)
Energy (eV)