Homework 1

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ECE 542: Semiconductor Development Fundamentals

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1 A SEMICONDUCTOR HAS A BANDGAP OF 0.5 EV. WHAT IS THE BANDGAP IN JOULES?

0.5 Ev = 8.0109e-20 J

2 A SEMICONDUCTOR HAS A BANDGAP OF 2 × 10^−19 J. WHAT IS THE BANDGAP IN EV?

2e−19 J = 1.2484 eV

3 FIND THE COST PER TRANSISTOR FOR:

3.1 A SINGLE TRANSISTOR

FQP13N10

$0.98

3.1.1 Source: Mouser

3.1.2 Part Number:

3.1.2.1 Mouser #: 512-FQP13N10

3.1.2.2 Manufacturer #: FQP13N10

3.2 A REPRESENTATIVE IC

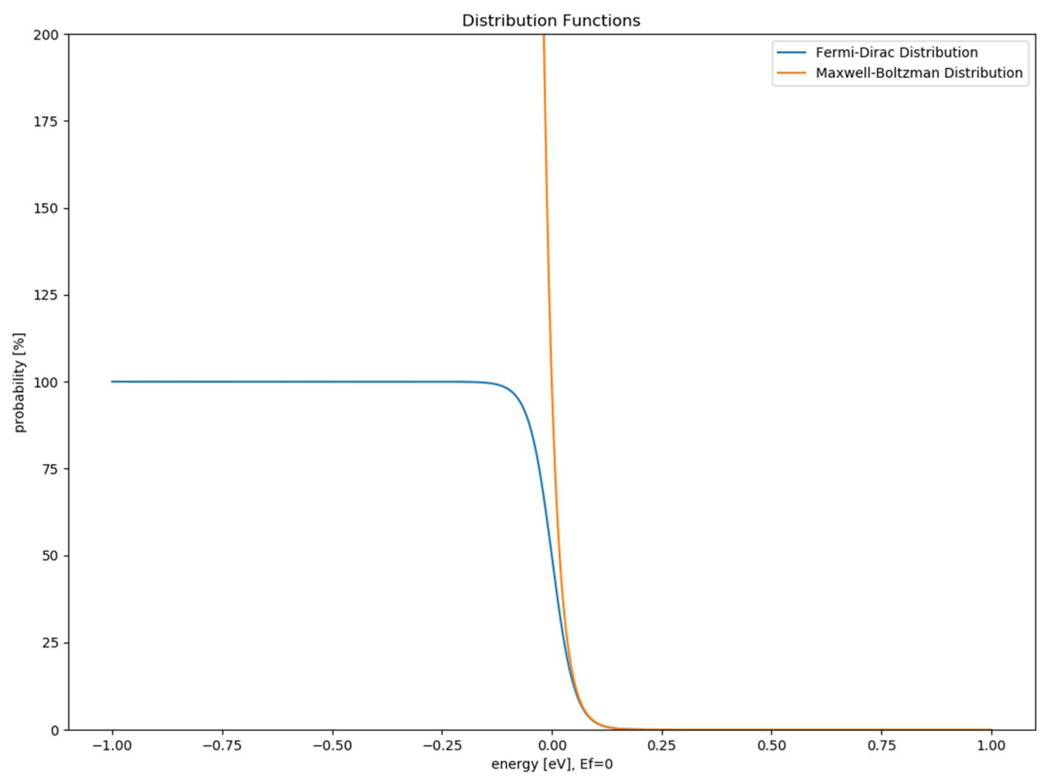
AMD Ryzen™ 9 3900X

$0.0499e-8

3.2.1 Source: AMD

3.2.2 Part Number: 100-000000023

4 Using a computer and your favorite math program, plot the Fermi-Dirac distribution function as a function of energy. On the same plot, show the Maxwell-Boltzmann distribution function. The y-axis should range from 0 to 2. The x-axis should range from Ef – 1 eV to Ef + 1 eV. Do this at a temperature of 300 K.



Note: The y-axis range is 0-200 because the entire y-axis is multiplied by 100 to ensure it represents a probability value.

4.1 Over what range does the Maxwell-Boltzmann distribution function approximate the Fermi-Dirac distribution function?

The Maxwell-Boltzmann distribution approximates the Fermi-Dirac equation well when E-Ef is 0.1 or greater.

5 APPENDIX

5.1 CALCULATIONS.PY

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

def convert_ev_to_joules(electron_volts):
    return electron_volts * 1.60218e-19

def convert_joule_to_ev(joules):
    return joules * 6.242e18

def fermi_dirac_distribution(E, Ef=0, T=300, boltzmann_constant = 1.38064852e-23):
    """
        boltzmann_constant units are expected to be m^2*kg*s^-2*K^-1 or J*K^-1
        # E and Ef units are expected to be in eV
    """
    exp_value = convert_ev_to_joules(E - Ef) / (boltzmann_constant * T)
    return 1 / ( 1 + np.exp(exp_value))

def maxwell_boltzmann_distribution(E, Ef=0, T=300, boltzmann_constant = 1.38064852e-23):
    """
        boltzmann_constant units are expected to be m^2*kg*s^-2*K^-1 or J*K^-1
        # E and Ef units are expected to be in eV
    """
    # E and Ef are expected to be in eV
    exp_value = convert_ev_to_joules(E - Ef) / (boltzmann_constant * T)
    return np.exp(-exp_value)


if __name__ == "__main__":
    print("A SEMICONDUCTOR HAS A BANDGAP OF 0.5 EV.  WHAT IS THE BANDGAP IN JOULES?")
    print("0.5 eV = ", convert_ev_to_joules(0.5), "J")

    print("A SEMICONDUCTOR HAS A BANDGAP OF 2e-19 J.  WHAT IS THE BANDGAP IN EV?")
    print("2e-19 J = ", convert_joule_to_ev(2e-19), "eV")

    energies = np.linspace(-1, 1, 10000)
    fermi_dirac_distributions = np.array(list(map(fermi_dirac_distribution, energies))) * 100
    maxwell_boltzmann_distributions = np.array(list(map(maxwell_boltzmann_distribution, energies))) * 100

    plt.plot(energies, fermi_dirac_distributions, label="Fermi-Dirac Distribution")
    plt.plot(energies, maxwell_boltzmann_distributions, label="Maxwell-Boltzman Distribution")
    plt.legend()
    plt.title("Distribution Functions")
    plt.xlabel("energy [eV], Ef=0")
    plt.ylabel("probability [%]")
    plt.ylim((0, 200))
    plt.show()
```