S. No.	Date	Name of Experiment	Exp. No.	Page No.	Signature/ Remarks
1	19-01-23	Plot the following fn^c with energy at diff. temp.- (a). Maxwell Boltzmann distribution (b). Fermi Dirac distribution (c). Bose- Einstein distribution	01		23/03/202
2		Plot the specific heat of solids (a). Dulong - Petit law (b). Einstein distribution fn^c (c). Debye's distribution fn^c for a temp. range	02		
3		Plot Planck's law for Black body radiation at diff. temp. Compare it with Rayleigh-Jeans law & wein's distribution law for a given temp.	03		
4.		Plot the probability of various macrostates in coin-tossing experiment (two level system) v/s no. of heads with 4,6,8 coins, etc.	04		20/4/
5.		Compute the velocity distribution of particles for the system and comparison with maxwell velocity distribution.	05		

Experiment : 01

Date ______

Page No. ______

Aim: Plot the following functions with energy at different temperatures
(a). Maxwell - Boltzmann distribution (MB)
(b). Fermi - Dirac distribution (BE)
(c). Bose - Einstein distribution (FD)

Formulae: The general expression for the three distribution function is given by -

$$f(E) = \frac{1}{\exp\left(\frac{E-u}{kT}\right)+a} \quad \begin{cases} \text{for MB, } a = 0 \\ BE, = -1 \\ FD, = +1 \end{cases}$$

→ E is the energy
→ u is the chemical potential
→ K is the Boltzmann constant
→ T is absolute temperature

Coding:

```
//20/6631 - AVICHAL LAMBA//
//Defining constants//
clc; clear; clf;
K= 1.38e-23;
//Temperature in Kelvin//
T1 = 100 ; T2 = 300 ; T3 = 500;
To = 1500;
EF = 1.6e-19;
mu = 1.6e-19;
Emin = 0;
```

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```
//Defining Constants//
clc;clear;clf;
k=1.38e-23;
//Temperature in kelvin//
T1=100;T2=300;T3=500;
To=1500;
EF=1.6e-19;
mu=1.6e-19;
Emin=0;
Emax=3e-20;
n=1000;
E=linspace(Emin,Emax,n);
Fmin=0;
Fmax=2e-23;
F=linspace(Fmin,Fmax,n);
Gmin=0;
Gmax=2e-19;
G=linspace(Gmin,Gmax,n);
Hmin=0;
Hmax=2e-18;
H=linspace(Hmin,Hmax,n);
// MAXWELL-BOLTZMANN //
for i=1:n
MB1(i)=exp(-E(i)/(k*T1))
end
for i=1:n
MB2(i)=exp(-E(i)/(k*T2))
end
for i=1:n
MB3(i)=exp(-E(i)/(k*T3))
end
subplot(2,2,1)
plot(E',MB1,'blue');
plot(E',MB2,'red');
plot(E',MB3,'green');
legend(['T1','T2','T3']);
title("M-B Statistics")
xlabel("Energy");
ylabel("Occupation index")
// BOSE-EINSTEIN //
for i=1:n
D1(i)=exp((F(i))/(k*T1))-1;
BE1(i)=1/D1(i);
end
for i=1:n
D2(i)=exp((F(i))/(k*T2))-1;
BE2(i)=1/D2(i);
end
for i=1:n
D3(i)=exp((F(i))/(k*T3))-1;
BE3(i)=1/D3(i);
end
subplot(2,2,2)
plot(F',BE1,'blue');
plot(F',BE2,'red');
plot(F',BE3,'green');
legend(['T1','T2','T3']);
title("B-E Statistics,mu=0")
xlabel("Energy");
ylabel("Occupation index")
// FERMI-DIRAC //
for i=1:n
D1(i)=exp((G(i)-mu)/(k*T1))+1;
FD1(i)=1/D1(i);
end
for i=1:n
```

Experiment :

Date

Page No.

```
Emax = 3e-20;
n =1000;
E= linspace (Emin, Emax,n);
Fmin=0;
Fmax = 2e-23;
F= linspace (Fmin, Fmax,n);
Gmin= 0;
Gmax= 2e-19;
G= linspace (Gmin, Gmax,n);
Hmin=0
Hmax= 2e-18;
H= linspace (Hmin, Hmax, n);
//MAXWELL - BOLTZMANN//
for i=1:n
    MB1(i)= exp(-E(i)/(K*T1))
end
for i=1:n
    MB2 (i)= exp (-E(i)/(K*T2))
end
for i=1:n
    MB3 (i)= exp (-E(i)/(K*T3))
end
Subplot (2,2,1)
Plot (E', MB1, 'blue');
Plot (E', MB2, 'red');
Plot (E', MB3, 'green');
legend ([ 'T1', 'T2', 'T3']);
```

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```
D2(i)=exp((G(i)-mu)/(k*T2))+1;
FD2(i)=1/D2(i);
end
for i=1:n
D3(i)=exp((G(i)-mu)/(k*T3))+1;
FD3(i)=1/D3(i);
end
subplot(2,2,3)
plot(G',FD1,'blue');
plot(G',FD2,'red');
plot(G',FD3,'green');
legend(['T1','T2','T3']);
title("F-D Statistics,mu=0")
xlabel("Energy");
ylabel("Occupation index")
// COMPARISION AT T=1500 //
for i=1:n
MB(i)=exp(-H(i)/(k*To))
end
for i=1:n
D(i)=exp((H(i))/(k*To))-1;
BE(i)=1/D(i);
end
for i=1:n
D(i)=exp((H(i)-EF)/(k*To))+1;
FD(i)=1/D(i);
end
subplot(2,2,4)
plot(H',MB,'blue');
plot(H',BE,'red');
plot(H',FD,'green');
legend(['MB','BE','FD']);
title("COMPARISION BETWEEN MB,BE & FD,mu=0")
xlabel("Energy");
ylabel("Occupation index")
```

```
D2(i)=exp((G(i)-mu)/(k*T2))+1;
FD2(i)=1/D2(i);
end
for i=1:n
D3(i)=exp((G(i)-mu)/(k*T3))+1;
FD3(i)=1/D3(i);
end
subplot(2,2,3)
plot(G',FD1,'blue');
plot(G',FD2,'red');
plot(G',FD3,'green');
legend(['T1','T2','T3']);
title("F-D Statistics,mu=0")
xlabel("Energy");
ylabel("Occupation index")
// COMPARISION AT T=1500 //
for i=1:n
MB(i)=exp(-H(i)/(k*To))
end
for i=1:n
D(i)=exp((H(i))/(k*To))-1;
BE(i)=1/D(i);
end
for i=1:n
D(i)=exp((H(i)-EF)/(k*To))+1;
FD(i)=1/D(i);
end
subplot(2,2,4)
plot(H',MB,'blue');
plot(H',BE,'red');
plot(H',FD,'green');
legend(['MB','BE','FD']);
title("COMPARISION BETWEEN MB,BE & FD,mu=0")
xlabel("Energy");
ylabel("Occupation index")
```

Experiment : Date Page No.

```
title ("M-B statistics")
xlabel ("Energy");
ylabel ("occupation index").
//BOSE - EINSTEIN//
for i=1:n
D1 (i) = exp ((F(i)) /(k*T1))-1;
BE (i) = 1/D1 (i);
end
for i=1:n
D2 (i) = exp((F(i) / k*T2))-1;
BE 2 (i)= 1/D2 (i);
end
for i=1:n
D3 (i) = exp ((F(i) / k*T3))-1;
BE3 (i)= 1/D3 (i);
end
Subplot (2,2,2)
plot (F', BE1, 'blue');
plot (F', BE2, 'red');
plot (F', BE3, 'green');
legend ([ 'T1', 'T2', 'T3']);
title ("B-E statistics, mu=0")
xlabel ("Energy")
ylabel (" Occupation index")
//FERMI- DIRAC//
for i=1:n
D1 (i)= exp ((G(i)-mu)/(k*T1))+1;
```

Experiment :

Date

Page No.

```
FD1 (i)= 1/D1(i);
end
for i=1:n
D2 (i) = exp((G(i)-mu)/(k*T2))+1;
FD2 (i)= 1/D2 (i);
end
for  i=1:n
D3 (i)= exp ((G(i)-mu)/(k* T3))+1;
FD3 (i)= 1/D3 (i);
end
Subplot (2,2,3)
Plot (G', FD1 , 'blue');
Plot (G', FD2 , 'red');
Plot (G', FD3, 'green');
legend (['T1', 'T2', 'T3']);
title ("F-D statistics, mu=0")
xlabel ("Energy");
ylabel ("Occupation index")
//COMPARISON AT T=1500//
for i=1:n
  MB(i) = exp (-H(i)/(k*To))
end
for  i=1:n
   D(i)= exp ((H(i))/(k* To))-1;
end
for i= 1:n
  D(i)= exp ((H(i)-EF)/(k* To))+1;
```

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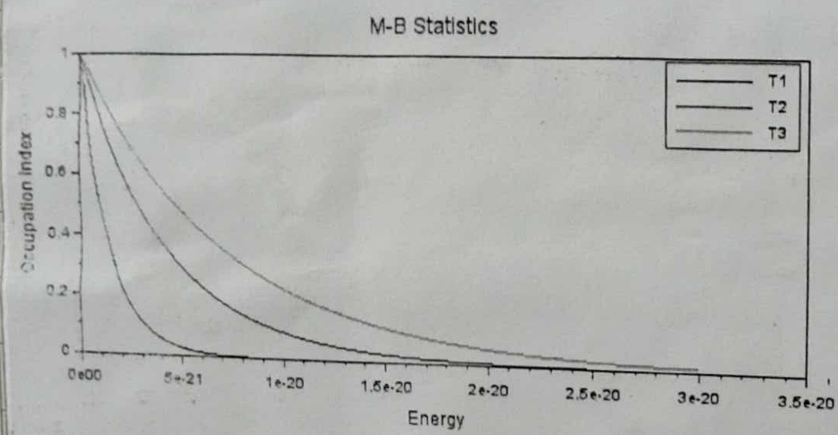
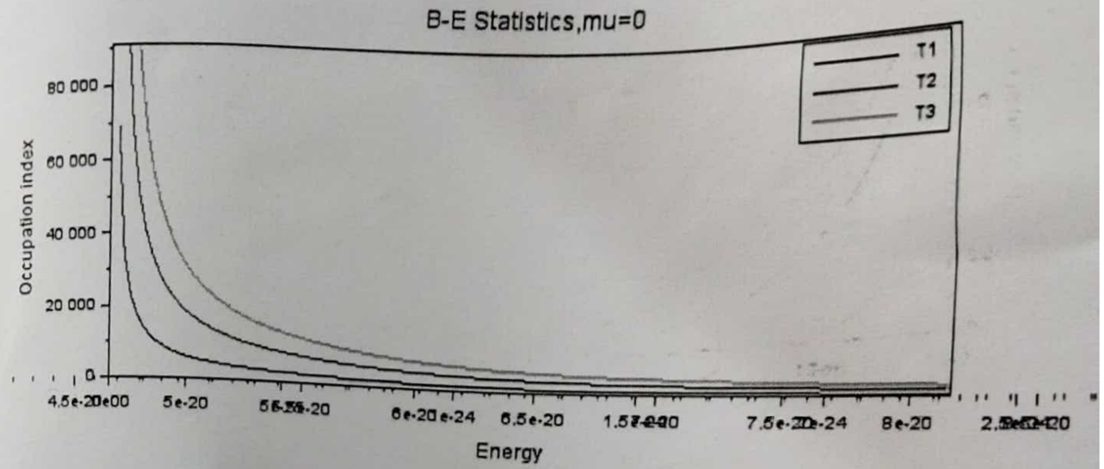
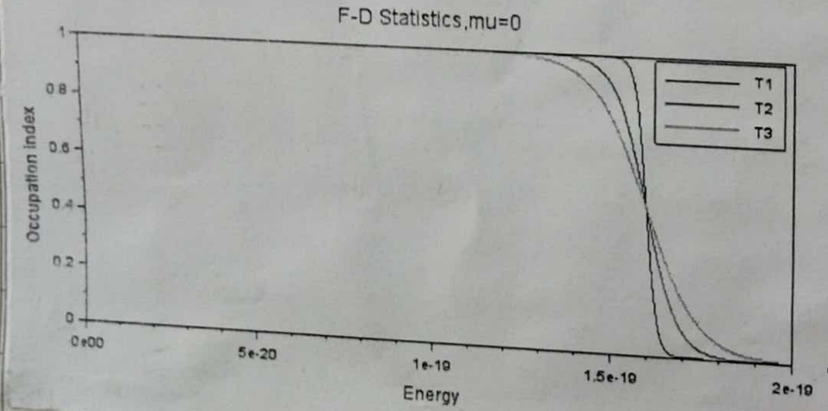
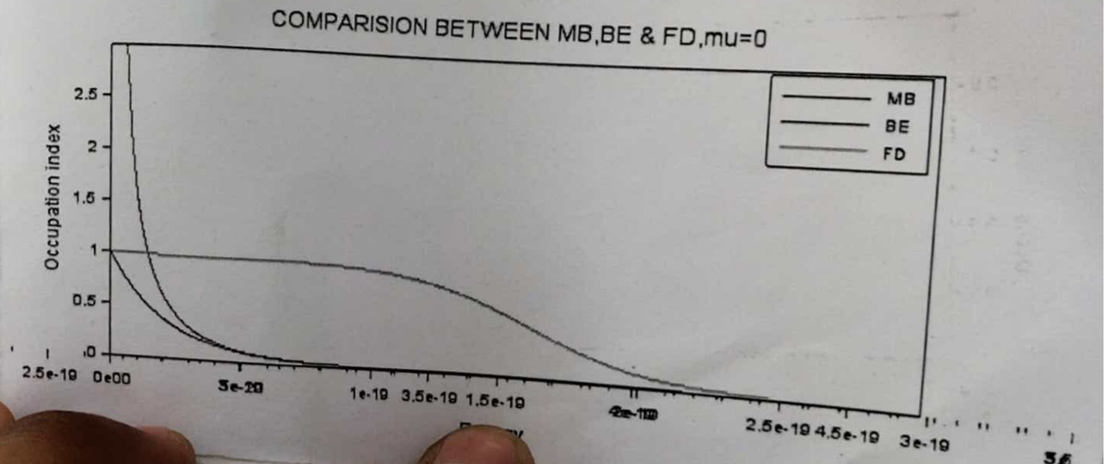

M-B Statistics
Occupation index
Energy
T1
T2
T3


B-E Statistics,mu=0
Occupation index
Energy
T1
T2
T3


F-D Statistics,mu=0
Occupation index
Energy
T1
T2
T3


COMPARISION BETWEEN MB,BE & FD,mu=0
Occupation index
MB
BE
FD

Experiment :

Date

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```
FD(i)= 1/D(i);
end
Subplot (2,2,4)
plot ('H', MB, 'blue');
plot ('H', BE, 'red');
plot ('H', FD, 'green');
legend (['MB', 'BE', 'FD']);
title ("COMPARISON BETWEEN MB, BE & FD, mu=0')
xlabel ("Energy");
ylabel ("Occupation index")
```

23/03/2023

Experiment: 02

Date ______

Page No. ______

Aim: Plot the specific heat of solids

(a) Dulong - petit law

(b) Einstein distribution function

(c) Debye's distribution function for a temp range

Theory:

Dulong - petit law: The average energy of atom per degree of freedom is KT so for N atoms with 3 DOF.

$$C_v = \left(\frac{\partial E}{\partial T}\right)_v = 3NK = 3R$$

N = No. of atoms
K = Boltzman's constant
R = Universal gas constant

$\boxed{C_v = 3R}$, Graph [C_v, T]

Einstein - distribution function: Quantum oscillator are considered having discrete energy values

$$E = \frac{h\nu}{\exp\left(\frac{h\nu}{KT}\right) - 1}$$

for N oscillation in 3D, $E = 3N\bar{E}$

$$C_v = \left(\frac{\partial E}{\partial T}\right)_v = 3NK\left(\frac{h\nu}{KT}\right)^2 \frac{\exp(h\nu/KT)}{(\exp[h\nu/KT]-1)^2}$$

$$\frac{h\nu}{K} = T_e = \text{Einstein Temp.}$$

$$\Rightarrow C_v = 3NK\left(\frac{T_e}{T}\right)^2 \frac{\exp(T_e/T)}{[\exp(T_e/T)-1]^2} \longrightarrow \text{Plot } C_v/T$$

DELTA

```
//Specific Heat of Solids using Dulong Petit Law,Einstien Mpodel and Debye Model
clc;
clear;
clf;
K=1.38e-23;//Boltzmann Constant
N=6e23;
name=input('Enter the name of the solid:','string');
Te=input('Enter the value of Einstein Temperature (K):');
Td=input('Enter the value of Debye Temperature (K):');
T=0:2*Td;//Temperature range in Kelvin
for i=1:length(T)
    Cvdp(i)=3*N*K; //Dulong Petit Law
    if T(i)==0 then
        Cve(i)=0;
        Cvd(i)=0;
    else
        x=(Te/T(i));
        Cve(i)=(3*N*K*(x^2)*exp(x))/((exp(x)-1)^2);//Einstein Theory
        I=integrate('((y^4)*exp(y))/((exp(y)-1)^2)','y',0,Td/T(i));
        Cvd(i)=9*N*K*I*((T(i)/Td)^3); //Debye Theory
        end
end
plot(T',[Cvdp,Cve,Cvd],'linewidth',5);
legend('Dulong Petit Law','Einstein Model','Debye Model',4);
title(string(name)+'(Td='+string(Td)+'K and Te='+string(Te)+'K)');
ylabel('Specific Heat,Cv(J/,(mol-K))','fontsize',6);
xlabel('Temperature (K)','fontscale',6);
```

Experiment :

Date

Page No.

Debye distribution function:

Coupled oscillator considered having normal mode = 2

T.E = no. of normal modes, average energy of one mode

Sol. we get

$$C_V = 9NK\left(\frac{T}{T_D}\right)^3 \int_0 \frac{y^4 e^y}{(e^y-1)^2}\,dy$$

$T_D = \frac{h\nu_D}{K}$ = Debye Temp.

for 3D : $C_V \propto T^3$; for 1D : $C_V \propto T$

for 2D : $C_V \propto T^3$

~~For Diamond~~
~~$T_d = 2250K$~~
~~$T_e = 1320K$~~

For copper
$T_d = 340K$
$T_e = 240K$

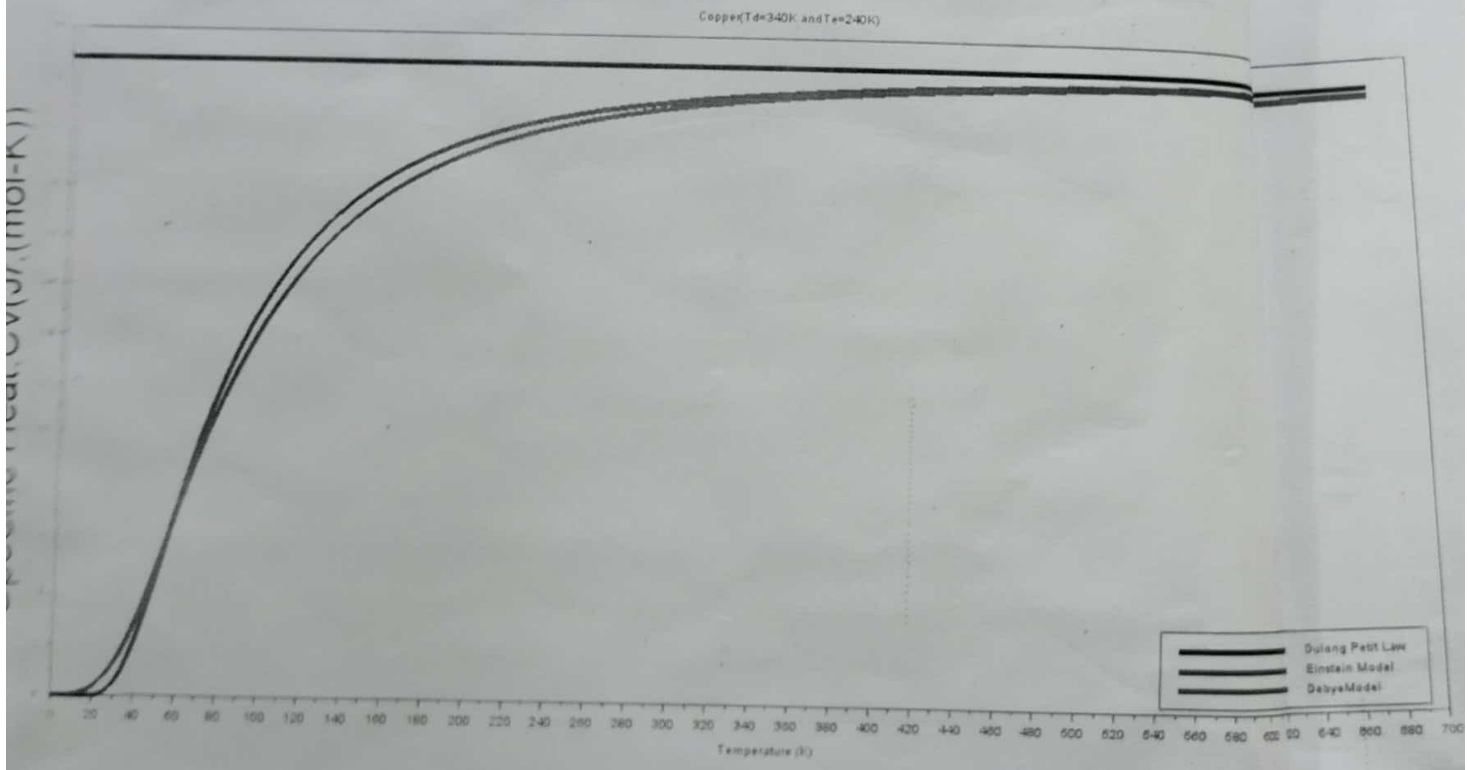
Algorithm :

- Define function 'F' to calculate Debye integration
- Define values of constants used ie h, K, R
- Define the name of solid in variable's 'name'

Compare the name with "Copper" 'diamond' in & provide specific values of Td, Te & Temp change in vector.

- Calculate the length of T in variable x.

```
Enter the name of the solid: Copper
Enter the value of Einstein Temperature(K): 240
Enter the value of Debye Temperature(K): 340
[illegible] Property specification : bad argument specified
```



Experiment :

Date

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- Run 3 separable loop & calculate dulong-petit Einstein & debye's function.
- In 3rd loop calculate debye's integration by function method in 1st step.
- Plot C_v V/S Temp. with proper labelling & title.

23/03/2023

```
//Plot Radiation Laws
clc;
clear;
clf;
h=6.626e-34;
kb=1.38e-23;
c=3e8;
T=500:100:1000;          //Temperature range in Kelvin
To=1000;          //Temperature for comparison of Planck with Rayleigh-Jeans/Weins
Wu=0.1:0.005:30;                    //wavlength in um
W=Wu.*10^-6;          //wavelength in meters
A=(8*3.14*h*c);
for j=1:length(T)
      for i=1:length(W)
up(j,i)=(A/W(i)^5)/(exp((h*c)/(kb*T(j)*W(i)))-1);      //Planck Law
            ur(j,i)=8*3.14*kb*T(j)/(W(i)^4);      //Rayleigh-Jeans Law
            uw(j,i)=(A/W(i)^5)*exp(-(h*c)/(kb*T(j)*W(i)));      //Weins Displacement Law
end
      if T(j)==To
   q=j;
end
      [p,k]=max(up(j,:));
      Wmax(j)=Wu(k);
      U(j)=(0.005*10^-6)*sum(up(j,:));          //calculate the area under the curve
end
//Plot Planck's Law
subplot(2,2,1)
plot(Wu',up','linewidth',5);
legend('T= '+string(T)+' K');
xlabel('$\lambda(\mu m)$','fontsize',6);
ylabel('$u(\lambda)$','fontsize',6);
title('Planck Radiation Law','fontsize',6);

//Comparison of Planck's Law, Rayleigh-Jeans Law and Weins Displacement Law
subplot(2,2,2)
plot(Wu',[up(q,:)' ur(q,:)' uw(q,:)'],'linewidth',5);
replot([0,0,20,200]);
```

Experiment : 03

Date

Page No.

Aim : Plot Plank's law for Black body radiation at diff. temp. Compare it with Rayleigh – Jeans law and wien's distribution law for a given temp.

Theory : wein's law –

$$U_\lambda = \frac{8\pi hc}{\lambda^5} e^{-hc/\lambda KT}$$

where λ = wavelength of radiation
U_λ = Energy flux corresponding to λ
K = Boltzmann's constant
T = Temperature

Planck's law –

$$U_\lambda = \frac{8\pi hc}{\lambda^5} \frac{1}{e^{(h\nu/KT)} - 1}$$

Rayleigh Jean's law

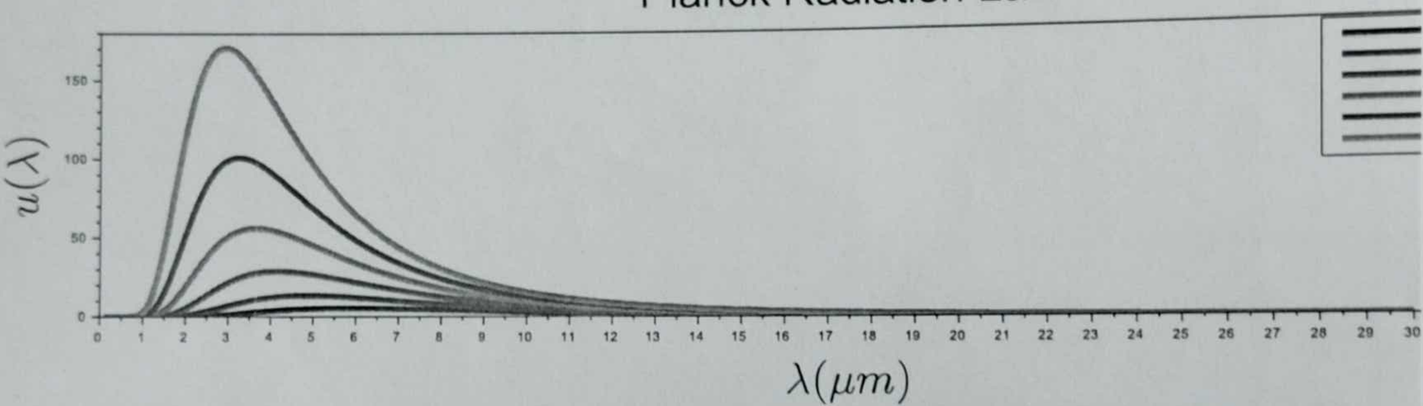
$$U_\lambda = \frac{8\pi KT}{\lambda^4}$$

Alogorithm :

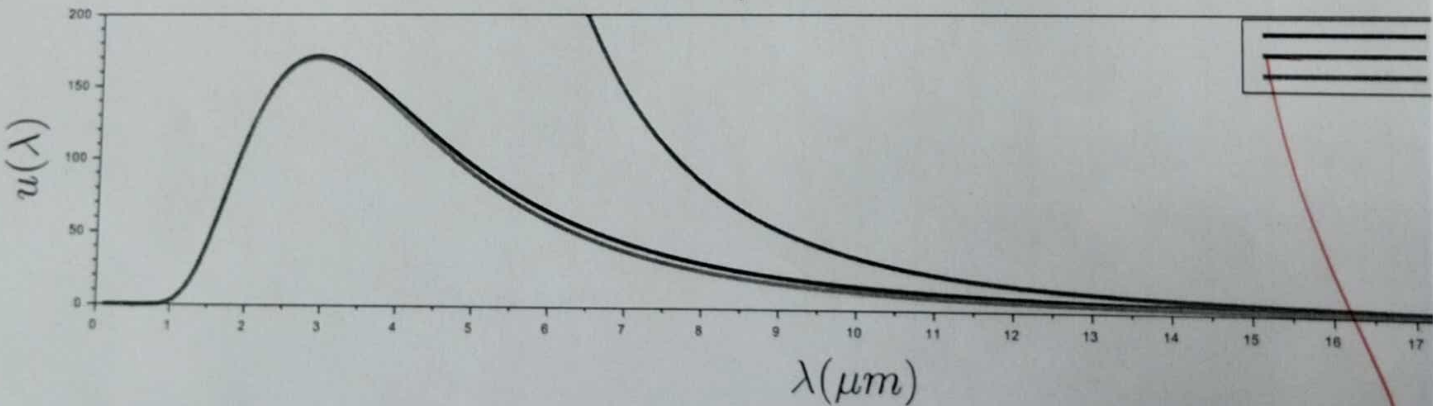
(a). For Plank's law at the diff. temperatures –
(i) Define constants used in Planks law.
(ii) Define temperature as vector with diff. values.
(iii) Define wavelength range in variable 'w'.
(iv). Calculate the number of value of wavelength in 'w'.
(v). Run first loop.
(vi). Run second loop inside first to calculate the Plank's values
(vii). End second loop and then the first loop.
(viii). Plot wavelength v/s Planck's energy flux.

```
legend('Planck Law', 'Rayleigh-Jeans Law', 'Wein Displacement Law');
title('Temperature: '+string(T(q))+' K','fontsize',6);
xlabel('$\lambda(\mu m)$','fontsize',6);
ylabel('$u(\lambda)$','fontsize',6);

//Weins Law
subplot(2,2,3)
TI=1./T;
plot(TI,Wmax','-o-','linewidth',5);
title('Weins Law','fontsize',6);
xlabel('$\frac1T(K^{-1})$','fontsize',6);
ylabel('$\lambda_{max}(\mu m)$','fontsize',6);
[b,a]=reglin(TI,Wmax');
disp('The value of Weins Constant is: '+string(b)+'um.K');

//Plot Stefan's Law
subplot(2,2,4)
T4=T.^4;
E=U.*(c/4);
plot(T4',E,'-o-','linewidth',5);
title('Stefan Law','fontsize',6);
xlabel('$\text T^4(K^4)$','fontsize',6);
ylabel('$E(W/m^2)$','fontsize',6);
[sigma,d]=reglin(T4,E');
disp('The value of Stefan constant is: '+string(sigma)+'W.m-2.K-4');
```

Planck Radiation Law



Temperature: 1000 K



Experiment :

Date

Page No.

(b). Rayleigh - Jean, wein's and Planck's Comparison at given time-

(i). Define constants used.

(ii). Define wavelength with specific range in variable 'w'.

(iii). Calculate length of values in wavelength.

(iv). Start the loop and calculate the energy density in each of three laws using corresponding formula and store them in Up, Ur and Uw respectively.

(v). End the loop.

(vi). Plot wavelength v/s Energy flux.

20/4/23

```
//6621_Rishant Singh
clc;clear;clf;
N=input("Enter the no. of separate experiments:");
for i=1:1:N
n=input("Enter the no. of coins:");
nom=2^n;
disp("n(h)   P(h)")
p=[]
h=[]
for j=0:1:n
    ns=factorial(n)/(factorial(j)*factorial(n-j));
    P(j+1)=ns/nom;
    h(j+1)=j;
    disp([h(j+1) P(j+1)]);
end
subplot(1,N,i)
plot(h,P,'o-')
title("No. of coins: "+string(n))
xlabel("No. of heads(H)")
ylabel("Probability")
end
```

Experiment : 04

Date 2/0

Page No.

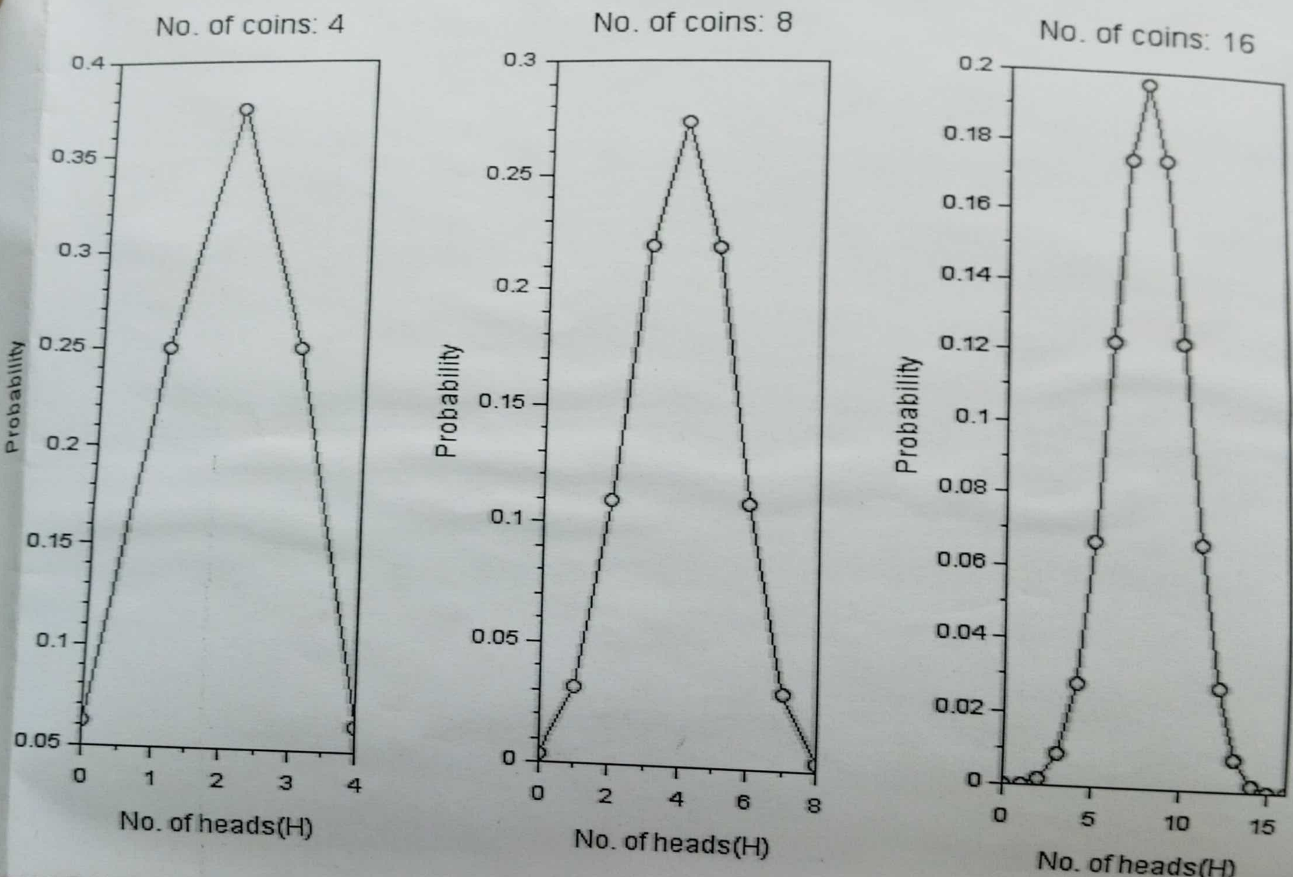
Aim: Plot the probability of various macrostates in coin-tossing experiment (two level system) v/s no. of heads with 4, 6, 8 coins, etc.

Theory: In general, if there are 'n' no. of coins, then the total no. of microstates will be 2^n.
No. of microstates associated with a particular macrostate (say p heads)

$$^nC_p = \frac{n!}{p!\,(n-p)!}$$

Alogrithm:

(i). Input the no. of seperate exp. in 'N'
(ii). Input the no. of coins in 'n'
(iii). Define the total no. of macrostates for the given no. of coins.
(iv). Define the no. of microstates corresponding to particular macrostates.
(v). Define the formula for probability & display it with appropriate no. of heads.
(vi). Plot the no. of heads v/s probability with proper labelling & appropriate title.



No. of coins: 4
No. of coins: 8
No. of coins: 16
Probability
No. of heads(H)

Experiment :

Date

Page No.

Console :

Enter the no. of separate exp. : 3

~~Enter the no. of coins:4~~ ~~Enter.~~

Enter the no. of coins:4

n(h)	p(h)
0	0.0625
1	0.26
2	0.375
3	0.25
4	0.0625

Enter the no. of coins: 8

n(h)	p(h)
0	0.0039062
1	0.03125
2	0.109375
3	0.21875
4	0.2734375
5	0.21875
6	0.109375
7	0.03125
8	0.0039062

Enter the no. of coins: 6

n(h)	p(h)
0	0.015625
1	0.09375
2	0.234375
3	0.3125
4	0.234375
5	0.09375
6	0.015625

20/4/22

```
//plot maxwell speed distribution
clc;clear;clf;
k=1.38e-23;
N=6e23;
pi=3.14;
v=0:1:2000;
T=300:300:900;
name=input("Enter the name of gas:","string");
M=input("Enter molar mass (g/mol) of "+string(name)+": ");
m=M/(N*1000)
disp('Temp(k)    vmp       vav       vrms')
for j=1:length(T)
    a=m/(2*k*T(j));
      for i=1:length(v)
           f(j,i)=(4*pi)*(a/pi)^1.5*(v(i)^2)*exp(-a*(v(i)^2));
      end
      [p,q]=max(f(j,:));
      vmp=v(q);
      vav=sqrt(4/pi)*vmp;
      vrms=sqrt(3/2)*vmp;
      disp([T(j) vmp vav vrms])
end
plot(v',f');
xlabel('v(m/s)');
ylabel('f(v)')
legend('T='+string(T)+'K');
title('Maxwellspeed distribution function for '+string(name),'fc
```

Experiment : 05

Date 8

Page No.

Aim: Compute the velocity distribution of particles for the system and comparison with maxwell velocity distribution.

Theory: Acc. to maxwell's velocity distribution law no. of molecules having speed v ~~to~~ to v+dv are given by -

$$dN = 4\pi N v^2 \left(\frac{m}{2\pi KT}\right)^{3/2} \exp\left(\frac{-mv^2}{2KT}\right) dv$$

K = Boltzmann constant

T = Temperature

N = Total no. of molecules or atoms

m = molecular /atomic mass

→ Expression for avg. speed = $V_{avg} = \sqrt{\frac{8KT}{\pi m}} = \sqrt{\frac{2.55KT}{m}}$

→ Expression for RMS speed = $V_{rms} = \sqrt{\frac{3KT}{m}}$

→ Expression for most probable speed = $V_{mp} = \sqrt{\frac{2KT}{m}}$

It is clear that

$$V_{rms} > V_{avg} > V_{mp}$$

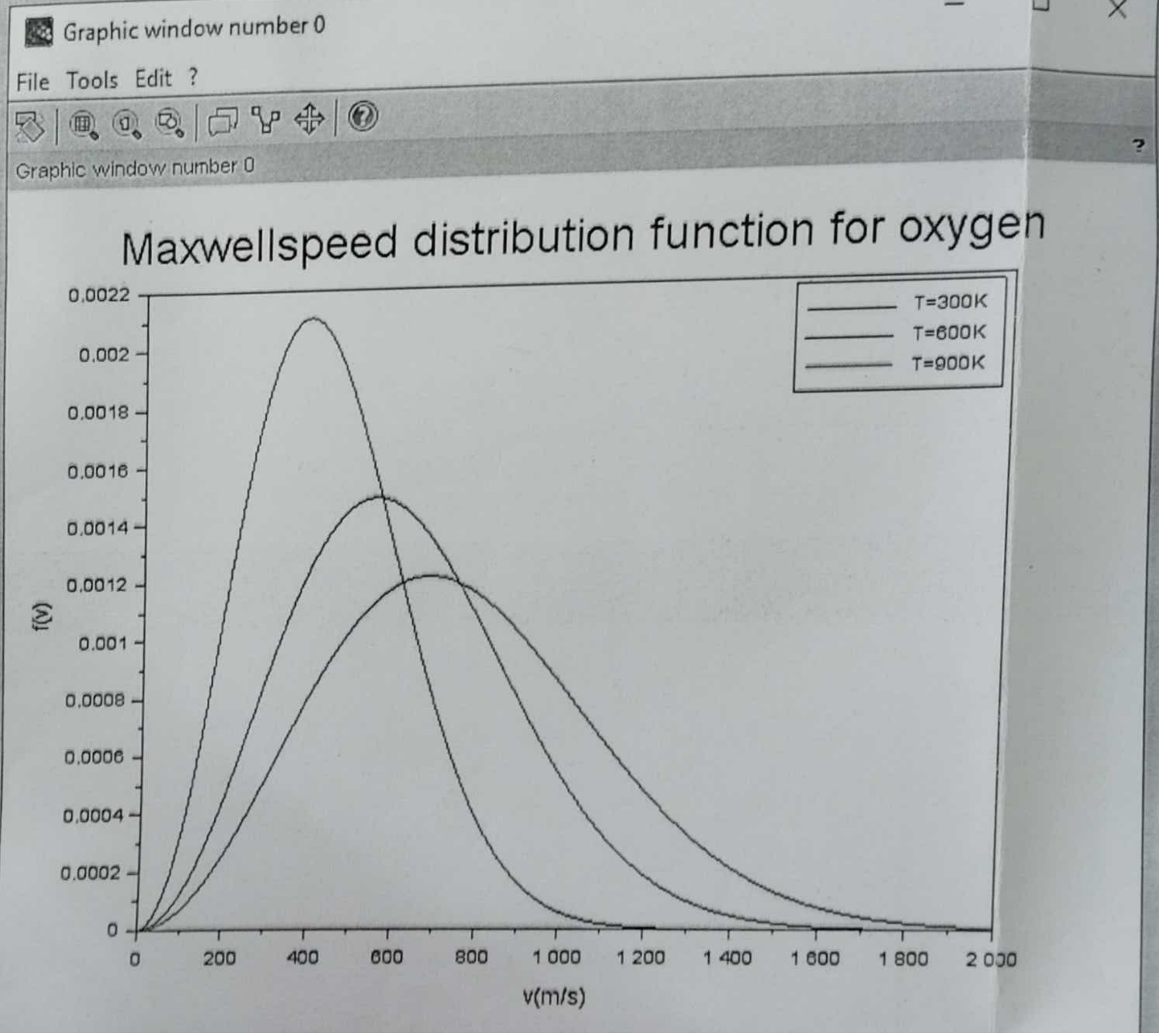
Alogrithm:

Define the constants appearing in the expressi[on] i.e M, K, N.

Probability

Scilab 6.1.1 Console

```
Enter the name of gas:oxygen

Enter molar mass (g/mol) of oxygen: 32


 "Temp(k)    vmp       vav        vrms"

  300.     394.    444.69413    482.54948

  600.     557.    628.66657    682.18289

  900.     682.    769.74973    835.276

-->
```



Experiment :

Date

Page No.

- Define 'T' as a vector with 3 values.
- Define velocity 'v' as vector with particular range of values.
- Find out no. of values assigned to 'v' in variable 'n'.
- Apply a for loop for calculation of distribution fn^c at every values of V using form
- Calculate the value of Vavg , Vrms, Vmp using formula.
- Display the velocities.
- End the loop
- Plot distribution function v/s V at diff. temp.

Coding :

//Maxwell boltzman's velocity distribution at temperature & calculation of V(rms), V(mp) V(avg) for system at that temp.

```
clc; clear; clf;
m = 5.31e-28 //mass of oxygen molecule
K = 1.38e-23 //Boltzmann's constant
N = 6.02 e23 //no. of oxygen molecul
T = [300, 500, 1000] // temp Kel
v=10:10:1500 //velocities m/s
n = length (v)
```

20/9/23

Experiment :

Date ______

Page No. ______

- Define 'T' as a vector with 3 values.
- Define velocity 'v' as vector with particular range of values.
- Find out no. of values assigned to 'v' in variable 'n'.
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Coding :

```
//Maxwell boltzman's velocity distribution at
temperature & calculation of V(rms), V(mp) &
V(avg) for system at that temp.
clc; clear; clf;
m = 5.31e-28   //mass of oxygen molecule in kg
K = 1.38e-23 //Boltzmann's constant
N = 6.02 e23 // no. of oxygen molecule (1mole)
T = [300, 500, 1000] // temp. in kelvins
v=10:10:1500 //velocities in m/s
n = length (v)
```

Incomplete

?

20/4/23