TN2624 MATLAB Session 4

March 7, 2013

Heat capacity of the Einstein solid – numerical calculations (50 pts)

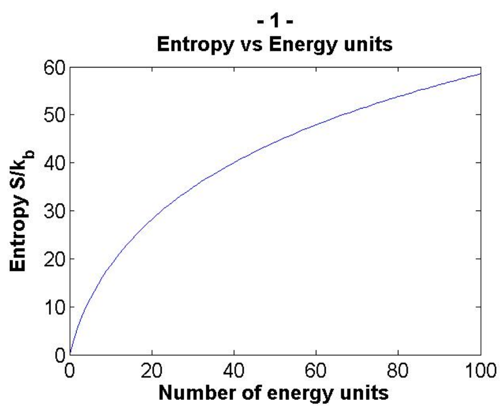
1. **(10 pts)**

$$\Omega(N,q) = \frac{(q+n-1)!}{q!(N-1)!}$$

(2points)

```
clear all
clc
N=25;
q=0:100;
sok=gammaln(q+N)-gammaln(q+1)-ones(1,length(q)).*gammaln(N)
```

(4points)



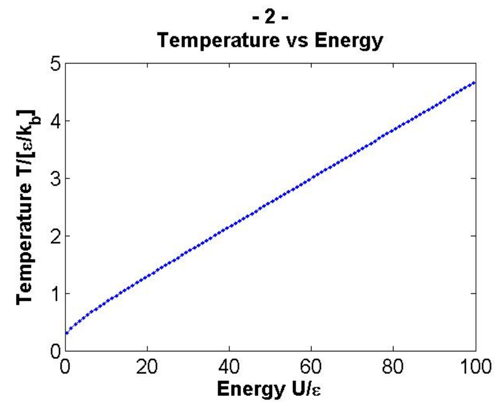
(4points), no labels: **(2points)**

2. **(10 pts)**

The resulting temperature has units ϵ/k_b **(2points)**

```
U=q; %Energy in units of epsilon
T=diff(U)./diff(sok)
%Interpolate the vector U
Uint=(diff(U)*0.5+U(1:(end-1)))
```

(4points)

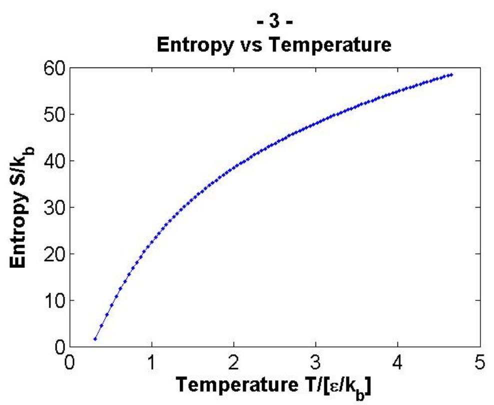


(4points), no labels: **(-2points)**

3. **(10 pts)**

```
%Interpolate the vector sok
sokint=(diff(sok)*0.5+sok(1:(end-1)))
```

(0points)



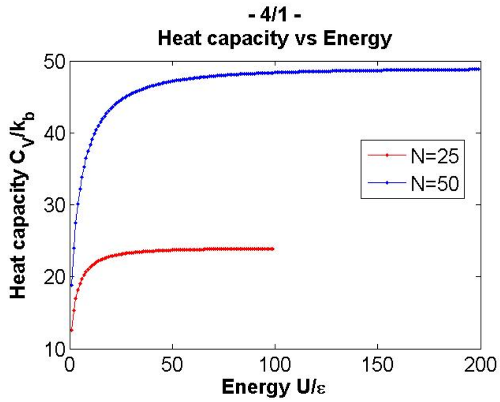
(10points), no labels: **(-2 points)**

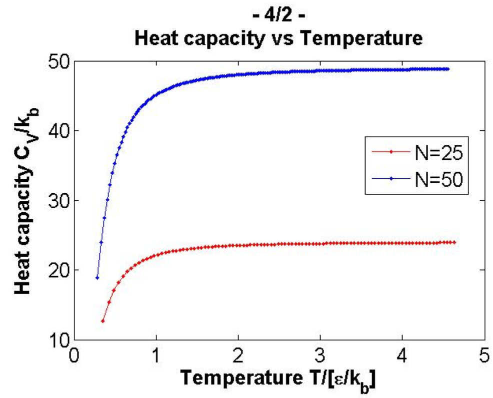
4. **(20 pts)**

The units of the heat capacity is just k_b.**(2 points)**

```
C=diff(Uint)./diff(T)
Tint=(diff(T)*0.5+T(1:(end-1)))
Uint2=(diff(Uint)*0.5+Uint(1:(end-1)))
```

(6 points)





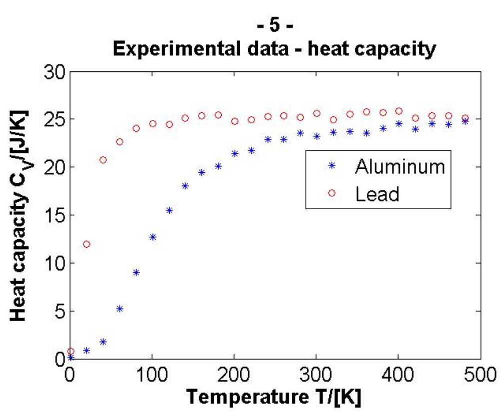
(6points per plot); no labels (-2 points per plot); no legend (-2 points per plot)

A larger number of oscillators leads to a higher heat capacity. **(3points)** Larger number of oscillators → higher multiplicity and entropy → larger slope of the function S(U) → lower maximum temperature for a given energy range OR higher heat capacity → lower temperature for given internal energy OR any other explanation **(3points)**

Heat capacity of the Einstein solid – comparison to real examples (50 pts)

5. **(15 pts)**

```
clear all
clc

A_Pb=importdata('lead.dat');
C_Pb=A_Pb(:,2);
T_Pb=A_Pb(:,1);

A_Al=importdata('aluminum.dat');
C_Al=A_Al(:,2);
T_Al=A_Al(:,1);
```



(15points), no legend: **(-4points)**, no labels: **(-4points)**

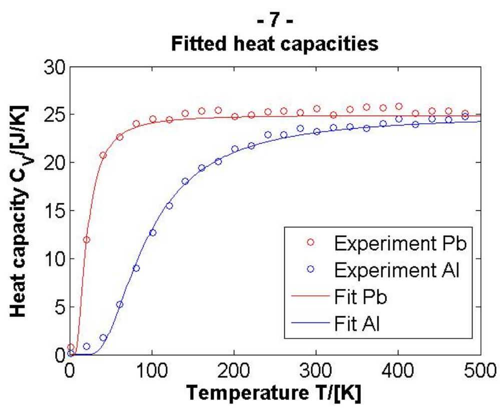
6. **(20 pts)**

```
T_exp=T_Pb;
C_exp=C_Pb;
%T_exp=T_Al;
%C_exp=C_Al;

Na=6.022*10^23;
kb=1.38*10^-23; %J/K
ev=1.6*10^-19;
C_func=@(eps) sum((C_exp-3*Na*kb.*(eps./(kb.*T_exp)).^2.*...
       exp(eps./(kb.*T_exp))./(exp(eps./(kb.*T_exp))-1).^2).^2)

epsf=fminsearch(C_func,0.01*ev)/ev
```

(14points)

$\epsilon_{Pb} = 0.0055\,\mathrm{eV}$ **(3points)**
$\epsilon_{Al} = 0.0248\,\mathrm{eV}$ **(3points)**

7. **(10 pts)**



(10points), no legend: **(-2points)**, no labels: **(-2points)**

8. **(5 pts)**

The distance between the energy levels is proportional to the frequency f of the oscillator $\epsilon = hf$. h is Planck's constant. Therefore, higher values of ϵ are an indication for higher frequencies, higher spring constants, and therefore for stiffer/harder materials/higher speed of sound. **(5points)**