Database System

ASSN - 03

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1. Problem cognition

This problem is to compute some physical properties in the 2D Ising Model. They are the followings:

- 1. Total energy configuration
- 2. Total magnetization configuration
- 3. Capacity (or Specific heat)
- 4. Spontaneous magnetization
- 5. Susceptibility
- 6. Critical temperature using Binder formula

Simulated annealing and Metropoil-Hasting algorithm are used to a stable state of 2D Ising system.

2. Code (Programming Language: R)

```
nr = 4; nc = 4; # Number of rows and columns
A = matrix(nrow = nr, ncol = nc)
npass = 2e5 # Number of passes for each temperature
neguil = 1e5 # Number of equilibration steps for each T
T_hi = 5 \# Temperature to start scan at
T_{lo} = 0.5 # Temperature to finish scan at
dT = 0.1 # Temperature scanning interval
nscans = as.integer((T_hi - T_lo)/dT) + 1
# Initialize results table
M = matrix(nrow = nscans, ncol = 6, byrow=TRUE,
dimnames=list(rep("",nscans),c("T","E_av","Cv","Mag_av","Mag_sus", "Binder")))
npass_conf = matrix(nrow = npass - nequil, ncol = 3)
Ann = function(A, m, n) {
 if (m == nr) Ann1 = A[1,n] else Ann1 = A[m+1,n] # bottom
 if (n == 1) Ann2 = A[m,nc] else Ann2 = A[m,n-1] # left
 if (m == 1) Ann3 = A[nr,n] else Ann3 = A[m-1,n] # top
 if (n == nc) Ann4 = A[m,1] else Ann4 = A[m,n+1] # right
 return(Ann1 + Ann2 + Ann3 + Ann4)
for (isc in 1:nscans) { # T scan loop
  temp = T_hi - dT*(isc - 1)
  # Initialize variables
 beta = 1/temp
 oc = 0 # output count
  E_av = 0
 E2_av = 0
 mag_av = 0
 mag2_av = 0
 mag4_av = 0
  # Set up initial checkerboard spin configuration
  A[1,1] = 1
 for (i in 1:(nr - 1)) A[i+1,1] = -A[i,1]
 for (j in 1:(nc - 1)) A[,j+1] = -A[,j]
```

for (ipass in 0:npass) { # Monte Carlo passes at T

```
if (ipass > nequil) {
     oc = oc + 1 # output count
     mag = sum(A)/(nr*nc)
     mag_av = mag_av + mag
     mag2_av = mag2_av + mag^2
     mag4_av = mag4_av + mag^4
     E = 0
     for (m in 1:nr) {
       for (n in 1:nc) {
         E = E - A[m,n]*Ann(A,m,n)
         }
       }
     E = E/(2*nr*nc)
     E_av = E_av + E
     E2_av = E2_av + E^2
     if(temp == 5.0){}
       npass\_conf[oc,1] = oc
       npass\_conf[oc,2] = E_av/oc
       npass_conf[oc,3] = abs(mag_av/oc)
   # Choose a random spin to change
   m = sample(nr,1,replace=TRUE)
   n = sample(nc,1,replace=TRUE)
   ts = -A[m,n] \# Flip sign of spin
   dU = -2*ts*Ann(A,m,n)
   log_eta = log(runif(1))
   if(-beta*dU > log_eta) A[m,n] = ts
 } # end MC passes at T
  M[isc,1] = temp
 M[isc,2] = E_av/oc
 M[isc,3] = beta^2*(E2_av/oc - (E_av/oc)^2)
  M[isc,4] = abs(mag_av/oc)
  M[isc,5] = beta*(mag2_av/oc - (mag_av/oc)^2)
 M[isc,6] = 1-(mag4_av/oc - (3*mag2_av/oc))
  print (isc) # print result (deleted from output)
 if(temp == 5.0){
   plot(npass_conf[,1], npass_conf[,2], xlab="N", ylab="<E>")
   plot(npass_conf[,1], npass_conf[,3], xlab="N", ylab="<M>")
   dev.new()
} # end T scans
nr = 8; nc = 8; # Number of rows and columns
A = matrix(nrow = nr, ncol = nc)
# Initialize results table
N = matrix(nrow = nscans, ncol = 6, byrow=TRUE,
dimnames=list(rep("",nscans),c("T","E_av","Cv","Mag_av","Mag_sus", "Binder")))
for (isc in 1:nscans) { # T scan loop
 temp = T_hi - dT*(isc - 1)
  # Initialize variables
```

}

```
beta = 1/temp
 oc = 0 # output count
 E_{av} = 0
  E2_av = 0
 mag_av = 0
 mag2_av = 0
  mag4_av = mag4_av + mag^4
  # Set up initial checkerboard spin configuration
 A[1,1] = 1
 for (i in 1:(nr - 1)) A[i+1,1] = -A[i,1]
 for (j in 1:(nc - 1)) A[,j+1] = -A[,j]
 for (ipass in 0:npass) { # Monte Carlo passes at T
   if (ipass > nequil) {
     oc = oc + 1 # output count
     mag = sum(A)/(nr*nc)
     mag_av = mag_av + mag
     mag2_av = mag2_av + mag^2
     mag4_av = mag4_av + mag^4
     E = 0
     for (m in 1:nr) {
       for (n in 1:nc) {
         E = E - A[m,n]*Ann(A,m,n)
     }
     E = E/(2*nr*nc)
     E_av = E_av + E
     E2_av = E2_av + E^2
   # Choose a random spin to change
   m = sample(nr,1,replace=TRUE)
   n = sample(nc,1,replace=TRUE)
   ts = -A[m,n] \# Flip sign of spin
   dU = -2*ts*Ann(A,m,n)
   log_eta = log(runif(1))
   if(-beta*dU > log_eta) A[m,n] = ts
 } # end MC passes at T
 N[isc,1] = temp
 N[isc,2] = E_av/oc
 N[isc,3] = beta^2*(E2_av/oc - (E_av/oc)^2)
 N[isc,4] = abs(mag_av/oc)
 N[isc,5] = beta*(mag2_av/oc - (mag_av/oc)^2)
 N[isc,6] = 1-(mag4_av/oc - (3*mag2_av/oc))
  print (isc) # print result (deleted from output)
} # end T scans
nr = 12; nc = 12; # Number of rows and columns
A = matrix(nrow = nr, ncol = nc)
# Initialize results table
O = matrix(nrow = nscans, ncol = 6, byrow=TRUE,
dimnames=list(rep("",nscans),c("T","E_av","Cv","Mag_av","Mag_sus", "Binder")))\\
for (isc in 1:nscans) { # T scan loop
 temp = T_hi - dT*(isc - 1)
```

```
# Initialize variables
 beta = 1/temp
 oc = 0 # output count
 E_av = 0
 E2_av = 0
 mag_av = 0
  mag2_av = 0
 mag4_av = 0
  # Set up initial checkerboard spin configuration
 A[1,1] = 1
 for (i in 1:(nr - 1)) A[i+1,1] = -A[i,1]
 for (j in 1:(nc - 1)) A[,j+1] = -A[,j]
 for (ipass in 0:npass) { # Monte Carlo passes at T
   if (ipass > nequil) {
     oc = oc + 1 # output count
     mag = sum(A)/(nr*nc)
     mag_av = mag_av + mag
     mag2_av = mag2_av + mag^2
     E = 0
     for (m in 1:nr) {
       for (n in 1:nc) {
         E = E - A[m,n]*Ann(A,m,n)
     }
     E = E/(2*nr*nc)
     E_av = E_av + E
     E2_av = E2_av + E^2
   # Choose a random spin to change
   m = sample(nr,1,replace=TRUE)
   n = sample(nc,1,replace=TRUE)
   ts = -A[m,n] # Flip sign of spin
   dU = -2*ts*Ann(A,m,n)
   log_eta = log(runif(1))
   if(-beta*dU > log_eta) A[m,n] = ts
 } # end MC passes at T
 O[isc,1] = temp
 O[isc,2] = E_av/oc
  O[isc,3] = beta^2*(E2_av/oc - (E_av/oc)^2)
 O[isc,4] = abs(mag_av/oc)
 O[isc,5] = beta*(mag2_av/oc - (mag_av/oc)^2)
 O[isc,6] = 1-(mag4_av/oc - (3*mag2_av/oc))
  print (isc) # print result (deleted from output)
} # end T scans
```

3. Result of implementation

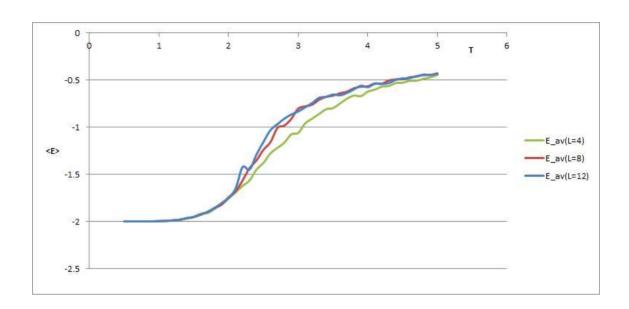
> source('~/R/two_dim_ising_model.R')

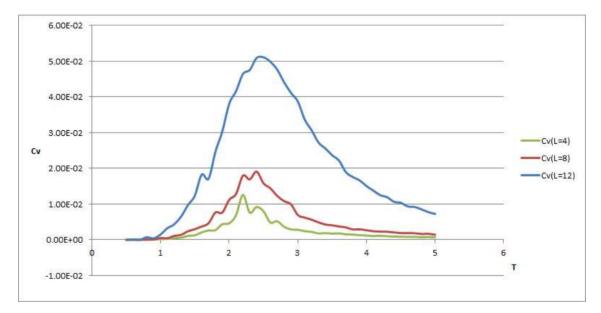
Т	$E_av(L=4)$	Cv(L=4)	Mag_av(L=4)	Mag_sus(L=4)
5	-0.44343	6.92E-04	0.009519	3.91E-03
4.9	-0.46848	7.51E-04	0.011528	4.09E-03
4.8	-0.48589	6.98E-04	0.01853	4.51E-03
4.7	-0.50548	8.30E-04	0.012769	4.76E-03
4.6	-0.50692	8.18E-04	0.006968	4.53E-03

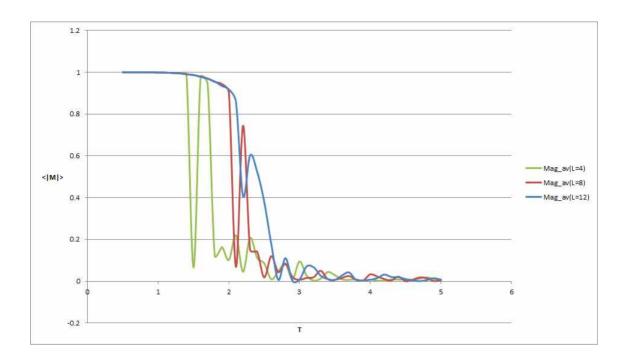
4.5	-0.52636	8.80E-04	0.007041	5.28E-03
	-0.53072			
4.4		9.04E-04	0.00805	5.54E-03
4.3	-0.56162	1.01E-03	0.007989	7.14E-03
4.2	-0.56839	1.14E-03	0.00221	6.68E-03
4.1	-0.60046	1.07E-03	0.002625	5.84E-03
4	-0.62114	1.20E-03	0.008059	7.56E-03
3.9	-0.66845	1.30E-03	0.001844	7.98E-03
3.8	-0.66274	1.47E-03	0.008706	9.79E-03
3.7	-0.69607	1.55E-03	0.006584	1.18E-02
	-0.74754	1.78E-03	0.009036	1.40E-02
3.6				
3.5	-0.79609	1.72E-03	0.029178	1.05E-02
3.4	-0.80834	1.90E-03	0.044006	1.10E-02
3.3	-0.85806	1.80E-03	0.012681	1.39E-02
3.2	-0.90807	2.24E-03	0.003445	1.52E-02
3.1	-0.95809	2.42E-03	0.026564	2.11E-02
3	-1.0591	2.82E-03	0.094496	2.48E-02
2.9	-1.07539	2.92E-03	0.009826	2.91E-02
2.8	-1.16304	3.63E-03	0.082743	3.76E-02
2.7	-1.21881	5.20E-03	0.048236	5.24E-02
2.6	-1.27702	4.86E-03	0.009428	5.29E-02
2.5			0.085851	
	-1.37789	7.99E-03		5.69E-02
2.4	-1.44882	9.20E-03	0.111759	6.24E-02
2.3	-1.56476	7.62E-03	0.207349	9.24E-02
2.2	-1.62151	1.26E-02	0.045146	1.50E-01
2.1	-1.6899	6.88E-03	0.219605	5.92E-03
2	-1.75665	4.64E-03	0.10183	1.61E-03
1.9	-1.81893	4.38E-03	0.163558	2.13E-03
1.8	-1.86516	2.72E-03	0.122435	7.46E-04
1.7	-1.9102	2.62E-03	0.943585	5.64E-04
1.6	-1.91709	2.09E-03	0.975954	3.44E-04
1.5	-1.94921	1.29E-03	0.065176	1.72E-04
1.4	-1.96662	1.11E-03	0.990774	1.36E-04
1.3	-1.97902	6.11E-04	0.994501	5.89E-05
1.2				
	-1.98808	4.75E-04	0.996923	4.46E-05
1.1	-1.9928	2.66E-04	0.998088	1.90E-05
1	-1 99709	2 26F-04	0 999265	1 56F-05
1	-1.99709	2.26E-04	0.999265	1.56E-05
1 0.9	-1.99709 -1.99934	2.26E-04 5.30E-05	0.999265 0.999835	1.56E-05 2.98E-06
		5.30E-05		2.98E-06
0.9 0.8	-1.99934 -1.99908	5.30E-05 2.35E-05	0.999835 0.99977	2.98E-06 1.17E-06
0.9 0.8 0.7	-1.99934 -1.99908 -2	5.30E-05 2.35E-05 2.39E-06	0.999835 0.99977 1	2.98E-06 1.17E-06 1.05E-07
0.9 0.8	-1.99934 -1.99908 -2 -1.99992	5.30E-05 2.35E-05 2.39E-06 0.00E+00	0.999835 0.99977	2.98E-06 1.17E-06 1.05E-07 0.00E+00
0.9 0.8 0.7	-1.99934 -1.99908 -2	5.30E-05 2.35E-05 2.39E-06	0.999835 0.99977 1	2.98E-06 1.17E-06 1.05E-07
0.9 0.8 0.7 0.6	-1.99934 -1.99908 -2 -1.99992	5.30E-05 2.35E-05 2.39E-06 0.00E+00	0.999835 0.99977 1 0.999979	2.98E-06 1.17E-06 1.05E-07 0.00E+00
0.9 0.8 0.7 0.6 0.5	-1.99934 -1.99908 -2 -1.99992 -2	5.30E-05 2.35E-05 2.39E-06 0.00E+00 0.00E+00	0.999835 0.99977 1 0.999979	2.98E-06 1.17E-06 1.05E-07 0.00E+00 0.00E+00
0.9 0.8 0.7 0.6 0.5	-1.99934 -1.99908 -2 -1.99992 -2 E_av(L=8)	5.30E-05 2.35E-05 2.39E-06 0.00E+00 0.00E+00	0.999835 0.99977 1 0.999979 1 Mag_av(L=8)	2.98E-06 1.17E-06 1.05E-07 0.00E+00 0.00E+00 Mag_sus(L=8)
0.9 0.8 0.7 0.6 0.5	-1.99934 -1.99908 -2 -1.99992 -2 E_av(L=8) -0.42657	5.30E-05 2.35E-05 2.39E-06 0.00E+00 0.00E+00 Cv(L=8) 1.45E-03	0.999835 0.99977 1 0.999979 1 Mag_av(L=8) 0.004542	2.98E-06 1.17E-06 1.05E-07 0.00E+00 0.00E+00 Mag_sus(L=8) 8.52E-03
0.9 0.8 0.7 0.6 0.5	-1.99934 -1.99908 -2 -1.99992 -2 E_av(L=8)	5.30E-05 2.35E-05 2.39E-06 0.00E+00 0.00E+00	0.999835 0.99977 1 0.999979 1 Mag_av(L=8)	2.98E-06 1.17E-06 1.05E-07 0.00E+00 0.00E+00 Mag_sus(L=8)
0.9 0.8 0.7 0.6 0.5	-1.99934 -1.99908 -2 -1.99992 -2 E_av(L=8) -0.42657	5.30E-05 2.35E-05 2.39E-06 0.00E+00 0.00E+00 Cv(L=8) 1.45E-03	0.999835 0.99977 1 0.999979 1 Mag_av(L=8) 0.004542	2.98E-06 1.17E-06 1.05E-07 0.00E+00 0.00E+00 Mag_sus(L=8) 8.52E-03
0.9 0.8 0.7 0.6 0.5 T 5 4.9	-1.99934 -1.99908 -2 -1.99992 -2 E_av(L=8) -0.42657 -0.44505 -0.44104	5.30E-05 2.35E-05 2.39E-06 0.00E+00 0.00E+00 Cv(L=8) 1.45E-03 1.67E-03 1.64E-03	0.999835 0.99977 1 0.999979 1 Mag_av(L=8) 0.004542 0.001037 0.014287	2.98E-06 1.17E-06 1.05E-07 0.00E+00 0.00E+00 Mag_sus(L=8) 8.52E-03 9.93E-03 9.36E-03
0.9 0.8 0.7 0.6 0.5 T 5 4.9 4.8 4.7	-1.99934 -1.99908 -2 -1.99992 -2 E_av(L=8) -0.42657 -0.44505 -0.44104 -0.46097	5.30E-05 2.35E-05 2.39E-06 0.00E+00 0.00E+00 Cv(L=8) 1.45E-03 1.67E-03 1.64E-03 1.84E-03	0.999835 0.99977 1 0.999979 1 Mag_av(L=8) 0.004542 0.001037 0.014287 0.018158	2.98E-06 1.17E-06 1.05E-07 0.00E+00 0.00E+00 Mag_sus(L=8) 8.52E-03 9.93E-03 9.36E-03 9.85E-03
0.9 0.8 0.7 0.6 0.5 T 5 4.9 4.8 4.7 4.6	-1.99934 -1.99908 -2 -1.99992 -2 E_av(L=8) -0.42657 -0.44505 -0.44104 -0.46097 -0.46873	5.30E-05 2.35E-05 2.39E-06 0.00E+00 0.00E+00 Cv(L=8) 1.45E-03 1.67E-03 1.64E-03 1.84E-03 1.86E-03	0.999835 0.99977 1 0.999979 1 Mag_av(L=8) 0.004542 0.001037 0.014287 0.018158 0.007112	2.98E-06 1.17E-06 1.05E-07 0.00E+00 0.00E+00 Mag_sus(L=8) 8.52E-03 9.93E-03 9.36E-03 9.85E-03 1.10E-02
0.9 0.8 0.7 0.6 0.5 T 5 4.9 4.8 4.7	-1.99934 -1.99908 -2 -1.99992 -2 E_av(L=8) -0.42657 -0.44505 -0.44104 -0.46097	5.30E-05 2.35E-05 2.39E-06 0.00E+00 0.00E+00 Cv(L=8) 1.45E-03 1.67E-03 1.64E-03 1.84E-03	0.999835 0.99977 1 0.999979 1 Mag_av(L=8) 0.004542 0.001037 0.014287 0.018158	2.98E-06 1.17E-06 1.05E-07 0.00E+00 0.00E+00 Mag_sus(L=8) 8.52E-03 9.93E-03 9.36E-03 9.85E-03
0.9 0.8 0.7 0.6 0.5 T 5 4.9 4.8 4.7 4.6 4.5	-1.99934 -1.99908 -2 -1.99992 -2 E_av(L=8) -0.42657 -0.44505 -0.44104 -0.46097 -0.46873 -0.49037	5.30E-05 2.35E-05 2.39E-06 0.00E+00 0.00E+00 Cv(L=8) 1.45E-03 1.67E-03 1.64E-03 1.84E-03 1.90E-03	0.999835 0.99977 1 0.999979 1 Mag_av(L=8) 0.004542 0.001037 0.014287 0.018158 0.007112 0.0004	2.98E-06 1.17E-06 1.05E-07 0.00E+00 0.00E+00 Mag_sus(L=8) 8.52E-03 9.93E-03 9.36E-03 9.85E-03 1.10E-02 1.28E-02
0.9 0.8 0.7 0.6 0.5 T 5 4.9 4.8 4.7 4.6 4.5 4.4	-1.99934 -1.99908 -2 -1.99992 -2 E_av(L=8) -0.42657 -0.44505 -0.44505 -0.44104 -0.46097 -0.46873 -0.49037 -0.49174	5.30E-05 2.35E-05 2.39E-06 0.00E+00 0.00E+00 Cv(L=8) 1.45E-03 1.67E-03 1.64E-03 1.84E-03 1.86E-03 1.90E-03 2.06E-03	0.999835 0.99977 1 0.999979 1 Mag_av(L=8) 0.004542 0.001037 0.014287 0.018158 0.007112 0.0004 0.022005	2.98E-06 1.17E-06 1.05E-07 0.00E+00 0.00E+00 Mag_sus(L=8) 8.52E-03 9.93E-03 9.36E-03 9.85E-03 1.10E-02 1.28E-02 1.21E-02
0.9 0.8 0.7 0.6 0.5 T 5 4.9 4.8 4.7 4.6 4.5 4.4	-1.99934 -1.99908 -2 -1.99992 -2 E_av(L=8) -0.42657 -0.44505 -0.44104 -0.46097 -0.46873 -0.49037 -0.49174 -0.50324	5.30E-05 2.35E-05 2.39E-06 0.00E+00 0.00E+00 Cv(L=8) 1.45E-03 1.67E-03 1.64E-03 1.84E-03 1.90E-03 2.06E-03 2.26E-03	0.999835 0.99977 1 0.999979 1 Mag_av(L=8) 0.004542 0.001037 0.014287 0.018158 0.007112 0.0004 0.022005 0.004421	2.98E-06 1.17E-06 1.05E-07 0.00E+00 0.00E+00 Mag_sus(L=8) 8.52E-03 9.93E-03 9.36E-03 9.85E-03 1.10E-02 1.28E-02 1.21E-02 1.27E-02
0.9 0.8 0.7 0.6 0.5 T 5 4.9 4.8 4.7 4.6 4.5 4.4	-1.99934 -1.99908 -2 -1.99992 -2 E_av(L=8) -0.42657 -0.44505 -0.44505 -0.44104 -0.46097 -0.46873 -0.49037 -0.49174	5.30E-05 2.35E-05 2.39E-06 0.00E+00 0.00E+00 Cv(L=8) 1.45E-03 1.67E-03 1.64E-03 1.84E-03 1.86E-03 1.90E-03 2.06E-03	0.999835 0.99977 1 0.999979 1 Mag_av(L=8) 0.004542 0.001037 0.014287 0.018158 0.007112 0.0004 0.022005	2.98E-06 1.17E-06 1.05E-07 0.00E+00 0.00E+00 Mag_sus(L=8) 8.52E-03 9.93E-03 9.36E-03 9.85E-03 1.10E-02 1.28E-02 1.21E-02
0.9 0.8 0.7 0.6 0.5 T 5 4.9 4.8 4.7 4.6 4.5 4.4	-1.99934 -1.99908 -2 -1.99992 -2 E_av(L=8) -0.42657 -0.44505 -0.44505 -0.44104 -0.46097 -0.46873 -0.49037 -0.49174 -0.50324 -0.53794	5.30E-05 2.35E-05 2.39E-06 0.00E+00 0.00E+00 Cv(L=8) 1.45E-03 1.67E-03 1.64E-03 1.84E-03 1.90E-03 2.06E-03 2.26E-03 2.29E-03	0.999835 0.99977 1 0.999979 1 Mag_av(L=8) 0.004542 0.001037 0.014287 0.018158 0.007112 0.0004 0.022005 0.004421	2.98E-06 1.17E-06 1.05E-07 0.00E+00 0.00E+00 Mag_sus(L=8) 8.52E-03 9.93E-03 9.36E-03 9.85E-03 1.10E-02 1.28E-02 1.21E-02 1.27E-02 1.36E-02
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0.9 0.8 0.7 0.6 0.5 T 5 4.9 4.8 4.7 4.6 4.5 4.4 4.3 4.2 4.1 4 3.9 3.8 3.7 3.6 3.5 3.4 3.3 3.2 3.1 3 2.9	-1.99934 -1.99908 -2 -1.99992 -2 E_av(L=8) -0.42657 -0.44505 -0.44104 -0.46097 -0.46873 -0.49037 -0.49174 -0.50324 -0.53794 -0.53461 -0.56458 -0.56937 -0.58569 -0.62161 -0.63823 -0.66392 -0.67682 -0.70712 -0.75893 -0.77785 -0.80149 -0.91068	5.30E-05 2.35E-05 2.39E-06 0.00E+00 0.00E+00 Cv(L=8) 1.45E-03 1.67E-03 1.64E-03 1.84E-03 1.90E-03 2.06E-03 2.26E-03 2.29E-03 2.41E-03 2.68E-03 2.95E-03 2.95E-03 2.95E-03 2.95E-03 3.77E-03 3.74E-03 4.08E-03 4.29E-03 4.29E-03 6.23E-03 6.95E-03 9.93E-03	0.999835 0.99977 1 0.999979 1 Mag_av(L=8) 0.004542 0.001037 0.014287 0.018158 0.007112 0.0004 0.022005 0.004421 0.010166 0.022519 0.032714 0.003748 0.007557 0.024781 0.015936 0.007065 0.009413 0.050199 0.01892 0.015894 0.00713 0.020023	2.98E-06 1.17E-06 1.05E-07 0.00E+00 0.00E+00 Mag_sus(L=8) 8.52E-03 9.93E-03 9.36E-03 1.10E-02 1.28E-02 1.21E-02 1.27E-02 1.36E-02 1.47E-02 1.67E-02 1.71E-02 1.85E-02 2.28E-02 2.34E-02 2.34E-02 2.16F-02 2.92E-02 3.16E-02 4.03E-02 4.75E-02 7.53E-02
0.9 0.8 0.7 0.6 0.5 T 5 4.9 4.8 4.7 4.6 4.5 4.4 4.3 4.2 4.1 4 3.9 3.8 3.7 3.6 3.5 3.4 3.3 3.2 3.1 3 2.9 2.8	-1.99934 -1.99908 -2 -1.99992 -2 E_av(L=8) -0.42657 -0.44505 -0.44104 -0.46097 -0.46873 -0.49037 -0.49174 -0.50324 -0.53794 -0.53461 -0.56458 -0.56458 -0.56937 -0.62161 -0.63823 -0.66392 -0.67682 -0.70712 -0.75893 -0.77785 -0.80149 -0.91068 -0.98198	5.30E-05 2.35E-05 2.39E-06 0.00E+00 0.00E+00 Cv(L=8) 1.45E-03 1.67E-03 1.64E-03 1.84E-03 1.90E-03 2.26E-03 2.29E-03 2.41E-03 2.68E-03 2.95E-03 2.95E-03 2.95E-03 4.90E-03 5.64E-03 6.23E-03 6.95E-03 9.93E-03 1.08E-02	0.999835 0.99977 1 0.999979 1 Mag_av(L=8) 0.004542 0.001037 0.014287 0.018158 0.007112 0.0004 0.022005 0.004421 0.010166 0.022519 0.032714 0.003748 0.007557 0.024781 0.015936 0.007065 0.009413 0.050199 0.01892 0.015894 0.00713 0.020023 0.083819	2.98E-06 1.17E-06 1.05E-07 0.00E+00 0.00E+00 Mag_sus(L=8) 8.52E-03 9.93E-03 9.36E-03 1.10E-02 1.28E-02 1.21E-02 1.27E-02 1.36E-02 1.47E-02 1.47E-02 1.67E-02 2.28E-02 2.34E-02 2.34E-02 2.67E-02 4.03E-02 4.03E-02 4.76E-02 7.53E-02 9.03E-02
0.9 0.8 0.7 0.6 0.5 T 5 4.9 4.8 4.7 4.6 4.5 4.4 4.3 4.2 4.1 4 3.9 3.8 3.7 3.6 3.5 3.4 3.3 3.2 3.1 3 2.9	-1.99934 -1.99908 -2 -1.99992 -2 E_av(L=8) -0.42657 -0.44505 -0.44104 -0.46097 -0.46873 -0.49037 -0.49174 -0.50324 -0.53794 -0.53461 -0.56458 -0.56937 -0.58569 -0.62161 -0.63823 -0.66392 -0.67682 -0.70712 -0.75893 -0.77785 -0.80149 -0.91068	5.30E-05 2.35E-05 2.39E-06 0.00E+00 0.00E+00 Cv(L=8) 1.45E-03 1.67E-03 1.64E-03 1.84E-03 1.90E-03 2.06E-03 2.26E-03 2.29E-03 2.41E-03 2.68E-03 2.95E-03 2.95E-03 2.95E-03 2.95E-03 3.77E-03 3.74E-03 4.08E-03 4.29E-03 4.29E-03 6.23E-03 6.95E-03 9.93E-03	0.999835 0.99977 1 0.999979 1 Mag_av(L=8) 0.004542 0.001037 0.014287 0.018158 0.007112 0.0004 0.022005 0.004421 0.010166 0.022519 0.032714 0.003748 0.007557 0.024781 0.015936 0.007065 0.009413 0.050199 0.01892 0.015894 0.00713 0.020023	2.98E-06 1.17E-06 1.05E-07 0.00E+00 0.00E+00 Mag_sus(L=8) 8.52E-03 9.93E-03 9.36E-03 1.10E-02 1.28E-02 1.21E-02 1.27E-02 1.36E-02 1.47E-02 1.67E-02 1.71E-02 1.85E-02 2.28E-02 2.34E-02 2.34E-02 2.16F-02 2.92E-02 3.16E-02 4.03E-02 4.75E-02 7.53E-02

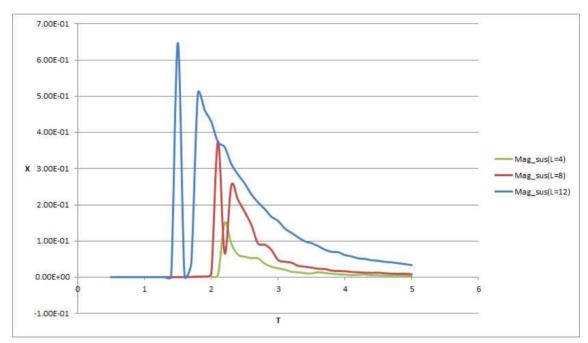
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2.5	-1.23813	1.58E-02	0.018352	1.81E-01
2.4	-1.35174	1.91E-02	0.141834	2.14E-01
2.3	-1.43373	1.69E-02	0.150927	2.54E-01
2.2	-1.56402	1.79E-02	0.744076	6.68E-02
2.1	1 60002			3.75E-01
	-1.68083	1.28E-02	0.068822	
2	-1.74188	1.12E-02	0.903907	9.55E-03
1.9	-1.8194	7.64E-03	0.944011	1.95E-03
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1 /		2.39E-03	0.991262	2.60E-04
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1.3	-1.98143	1.40E-03	0.995091	1.38E-04
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0.7	-1.99995	1.37E-05	0.999987	6.00E-07
			0.999967	
0.6	-2	0.00E + 00	1	0.00E + 00
0.5	-2	0.00E+00	1	0.00E+00
0.5	-2	0.00L+00	1	0.00L+00
_	F = (L 12)	C (L 12)	Man - (1 12)	Mag sus(L=12
Т	E_av(L=12)	Cv(L=12)	Mag_av(L=12))
_	0.42244	7.255.02	0.006307	,
5	-0.43244	7.25E-03	0.006307	3.37E-02
4.9	-0.44313	7.76E-03	0.014061	3.63E-02
			0.005411	
4.8	-0.44672	8.53E-03		3.88E-02
4.7	-0.45707	9.21E-03	0.000291	4.12E-02
4.6	-0.47871	9.35E-03	0.004563	4.25E-02
4.5	-0.48103	1.04E-02	0.010181	4.56E-02
4.4	-0.49678	1.06E-02	0.019348	4.69E-02
4.3	-0.53064	1.19E-02	0.020268	5.09E-02
4.2	-0.53952	1.25E-02	0.031988	5.20E-02
4.1	-0.53811	1.38E-02	0.015041	5.77E-02
4	-0.57434	1.51E-02	0.006987	6.15E-02
3.9	-0.55849	1.66E-02	0.004058	6.91E-02
3.8	-0.5973	1.76E-02	0.005856	7.03E-02
3.7	-0.63529	1.89E-02	0.042172	7.62E-02
			0.02742	
3.6	-0.66037	2.22E-02	0.02743	8.64E-02
3.5	-0.65297	2.37E-02	0.00585	9.42E-02
3.4	-0.67641	2.56E-02	0.010603	9.92E-02
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3.1	-0.78771		0.070721	
		3.37E-02		1.35E-01
3	-0.83207	3.87E-02	0.007957	1.56E-01
2.9	-0.86424	4.11E-02	0.001656	1.67E-01
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	-0.96842	4.76E-02	0.006162	2.07E-01
2.6			0.006162	2.07E-01
2.6	-1.03098	4.99E-02	0.178177	2.29E-01
2.6 2.5				
2.5	-1.03098 -1.1547	4.99E-02 5.11E-02	0.178177 0.380736	2.29E-01 2.59E-01
2.5 2.4	-1.03098 -1.1547 -1.28973	4.99E-02 5.11E-02 5.09E-02	0.178177 0.380736 0.524438	2.29E-01 2.59E-01 2.84E-01
2.5	-1.03098 -1.1547	4.99E-02 5.11E-02	0.178177 0.380736	2.29E-01 2.59E-01
2.5 2.4 2.3	-1.03098 -1.1547 -1.28973 -1.44893	4.99E-02 5.11E-02 5.09E-02 4.76E-02	0.178177 0.380736 0.524438 0.602312	2.29E-01 2.59E-01 2.84E-01 3.13E-01
2.5 2.4 2.3 2.2	-1.03098 -1.1547 -1.28973 -1.44893 -1.42216	4.99E-02 5.11E-02 5.09E-02 4.76E-02 4.64E-02	0.178177 0.380736 0.524438 0.602312 0.408223	2.29E-01 2.59E-01 2.84E-01 3.13E-01 3.59E-01
2.5 2.4 2.3 2.2 2.1	-1.03098 -1.1547 -1.28973 -1.44893 -1.42216 -1.64977	4.99E-02 5.11E-02 5.09E-02 4.76E-02 4.64E-02 4.16E-02	0.178177 0.380736 0.524438 0.602312 0.408223 0.859387	2.29E-01 2.59E-01 2.84E-01 3.13E-01 3.59E-01 3.74E-01
2.5 2.4 2.3 2.2	-1.03098 -1.1547 -1.28973 -1.44893 -1.42216	4.99E-02 5.11E-02 5.09E-02 4.76E-02 4.64E-02	0.178177 0.380736 0.524438 0.602312 0.408223	2.29E-01 2.59E-01 2.84E-01 3.13E-01 3.59E-01
2.5 2.4 2.3 2.2 2.1	-1.03098 -1.1547 -1.28973 -1.44893 -1.42216 -1.64977 -1.74677	4.99E-02 5.11E-02 5.09E-02 4.76E-02 4.64E-02 4.16E-02 3.81E-02	0.178177 0.380736 0.524438 0.602312 0.408223 0.859387 0.917868	2.29E-01 2.59E-01 2.84E-01 3.13E-01 3.59E-01 3.74E-01 4.29E-01
2.5 2.4 2.3 2.2 2.1 2	-1.03098 -1.1547 -1.28973 -1.44893 -1.42216 -1.64977 -1.74677 -1.80379	4.99E-02 5.11E-02 5.09E-02 4.76E-02 4.64E-02 4.16E-02 3.81E-02 3.03E-02	0.178177 0.380736 0.524438 0.602312 0.408223 0.859387 0.917868 0.934869	2.29E-01 2.59E-01 2.84E-01 3.13E-01 3.59E-01 3.74E-01 4.29E-01 4.62E-01
2.5 2.4 2.3 2.2 2.1	-1.03098 -1.1547 -1.28973 -1.44893 -1.42216 -1.64977 -1.74677	4.99E-02 5.11E-02 5.09E-02 4.76E-02 4.64E-02 4.16E-02 3.81E-02	0.178177 0.380736 0.524438 0.602312 0.408223 0.859387 0.917868	2.29E-01 2.59E-01 2.84E-01 3.13E-01 3.59E-01 3.74E-01 4.29E-01
2.5 2.4 2.3 2.2 2.1 2 1.9	-1.03098 -1.1547 -1.28973 -1.44893 -1.42216 -1.64977 -1.74677 -1.80379 -1.85673	4.99E-02 5.11E-02 5.09E-02 4.76E-02 4.64E-02 4.16E-02 3.81E-02 3.03E-02 2.47E-02	0.178177 0.380736 0.524438 0.602312 0.408223 0.859387 0.917868 0.934869 0.956093	2.29E-01 2.59E-01 2.84E-01 3.13E-01 3.59E-01 3.74E-01 4.29E-01 4.62E-01 5.08E-01
2.5 2.4 2.3 2.2 2.1 2 1.9 1.8	-1.03098 -1.1547 -1.28973 -1.44893 -1.42216 -1.64977 -1.74677 -1.80379 -1.85673 -1.89753	4.99E-02 5.11E-02 5.09E-02 4.76E-02 4.64E-02 4.16E-02 3.81E-02 3.03E-02 2.47E-02 1.71E-02	0.178177 0.380736 0.524438 0.602312 0.408223 0.859387 0.917868 0.934869 0.956093 0.969191	2.29E-01 2.59E-01 2.84E-01 3.13E-01 3.59E-01 3.74E-01 4.29E-01 4.62E-01 5.08E-01 3.81E-02
2.5 2.4 2.3 2.2 2.1 2 1.9 1.8 1.7	-1.03098 -1.1547 -1.28973 -1.44893 -1.42216 -1.64977 -1.74677 -1.80379 -1.85673	4.99E-02 5.11E-02 5.09E-02 4.76E-02 4.64E-02 4.16E-02 3.81E-02 3.03E-02 2.47E-02 1.71E-02 1.83E-02	0.178177 0.380736 0.524438 0.602312 0.408223 0.859387 0.917868 0.934869 0.956093 0.969191 0.978189	2.29E-01 2.59E-01 2.84E-01 3.13E-01 3.59E-01 3.74E-01 4.29E-01 4.62E-01 5.08E-01 3.81E-02 3.36E-03
2.5 2.4 2.3 2.2 2.1 2 1.9 1.8	-1.03098 -1.1547 -1.28973 -1.44893 -1.42216 -1.64977 -1.74677 -1.80379 -1.85673 -1.89753	4.99E-02 5.11E-02 5.09E-02 4.76E-02 4.64E-02 4.16E-02 3.81E-02 3.03E-02 2.47E-02 1.71E-02	0.178177 0.380736 0.524438 0.602312 0.408223 0.859387 0.917868 0.934869 0.956093 0.969191	2.29E-01 2.59E-01 2.84E-01 3.13E-01 3.59E-01 3.74E-01 4.29E-01 4.62E-01 5.08E-01 3.81E-02
2.5 2.4 2.3 2.2 2.1 2 1.9 1.8 1.7 1.6	-1.03098 -1.1547 -1.28973 -1.44893 -1.42216 -1.64977 -1.74677 -1.80379 -1.85673 -1.89753 -1.92366 -1.95284	4.99E-02 5.11E-02 5.09E-02 4.76E-02 4.64E-02 4.16E-02 3.81E-02 3.03E-02 2.47E-02 1.71E-02 1.83E-02 1.24E-02	0.178177 0.380736 0.524438 0.602312 0.408223 0.859387 0.917868 0.934869 0.956093 0.969191 0.978189 0.98697	2.29E-01 2.59E-01 2.84E-01 3.13E-01 3.59E-01 3.74E-01 4.29E-01 4.62E-01 5.08E-01 3.81E-02 3.36E-03 6.47E-01
2.5 2.4 2.3 2.2 2.1 2 1.9 1.8 1.7 1.6 1.5	-1.03098 -1.1547 -1.28973 -1.44893 -1.42216 -1.64977 -1.74677 -1.80379 -1.85673 -1.89753 -1.92366 -1.95284 -1.96223	4.99E-02 5.11E-02 5.09E-02 4.76E-02 4.64E-02 4.16E-02 3.81E-02 3.03E-02 2.47E-02 1.71E-02 1.83E-02 1.24E-02 9.74E-03	0.178177 0.380736 0.524438 0.602312 0.408223 0.859387 0.917868 0.934869 0.956093 0.969191 0.978189 0.98697 0.989704	2.29E-01 2.59E-01 2.84E-01 3.13E-01 3.59E-01 3.74E-01 4.29E-01 4.62E-01 5.08E-01 3.81E-02 3.36E-03 6.47E-01 1.27E-03
2.5 2.4 2.3 2.2 2.1 2 1.9 1.8 1.7 1.6	-1.03098 -1.1547 -1.28973 -1.44893 -1.42216 -1.64977 -1.74677 -1.80379 -1.85673 -1.89753 -1.92366 -1.95284	4.99E-02 5.11E-02 5.09E-02 4.76E-02 4.64E-02 4.16E-02 3.81E-02 3.03E-02 2.47E-02 1.71E-02 1.83E-02 1.24E-02	0.178177 0.380736 0.524438 0.602312 0.408223 0.859387 0.917868 0.934869 0.956093 0.969191 0.978189 0.98697	2.29E-01 2.59E-01 2.84E-01 3.13E-01 3.59E-01 3.74E-01 4.29E-01 4.62E-01 5.08E-01 3.81E-02 3.36E-03 6.47E-01
2.5 2.4 2.3 2.2 2.1 2 1.9 1.8 1.7 1.6 1.5 1.4 1.3	-1.03098 -1.1547 -1.28973 -1.44893 -1.42216 -1.64977 -1.74677 -1.80379 -1.85673 -1.89753 -1.92366 -1.95284 -1.96223 -1.98247	4.99E-02 5.11E-02 5.09E-02 4.76E-02 4.64E-02 4.16E-02 3.81E-02 3.03E-02 2.47E-02 1.71E-02 1.83E-02 1.24E-02 9.74E-03 6.49E-03	0.178177 0.380736 0.524438 0.602312 0.408223 0.859387 0.917868 0.934869 0.956093 0.969191 0.978189 0.98697 0.989704 0.995408	2.29E-01 2.59E-01 2.84E-01 3.13E-01 3.59E-01 3.74E-01 4.29E-01 4.62E-01 5.08E-01 3.81E-02 3.36E-03 6.47E-01 1.27E-03 6.19E-04
2.5 2.4 2.3 2.2 2.1 2 1.9 1.8 1.7 1.6 1.5 1.4 1.3 1.2	-1.03098 -1.1547 -1.28973 -1.44893 -1.42216 -1.64977 -1.74677 -1.80379 -1.85673 -1.89753 -1.92366 -1.95284 -1.96223 -1.98247 -1.98876	4.99E-02 5.11E-02 5.09E-02 4.76E-02 4.64E-02 4.16E-02 3.81E-02 3.03E-02 2.47E-02 1.71E-02 1.83E-02 1.24E-02 9.74E-03 6.49E-03 4.34E-03	0.178177 0.380736 0.524438 0.602312 0.408223 0.859387 0.917868 0.934869 0.956093 0.969191 0.978189 0.98697 0.989704 0.995408	2.29E-01 2.59E-01 2.84E-01 3.13E-01 3.59E-01 3.74E-01 4.29E-01 5.08E-01 3.81E-02 3.36E-03 6.47E-01 1.27E-03 6.19E-04 3.61E-04
2.5 2.4 2.3 2.2 2.1 2 1.9 1.8 1.7 1.6 1.5 1.4 1.3	-1.03098 -1.1547 -1.28973 -1.44893 -1.42216 -1.64977 -1.74677 -1.80379 -1.85673 -1.89753 -1.92366 -1.95284 -1.96223 -1.98247	4.99E-02 5.11E-02 5.09E-02 4.76E-02 4.64E-02 4.16E-02 3.81E-02 3.03E-02 2.47E-02 1.71E-02 1.83E-02 1.24E-02 9.74E-03 6.49E-03	0.178177 0.380736 0.524438 0.602312 0.408223 0.859387 0.917868 0.934869 0.956093 0.969191 0.978189 0.98697 0.989704 0.995408	2.29E-01 2.59E-01 2.84E-01 3.13E-01 3.59E-01 3.74E-01 4.29E-01 5.08E-01 3.81E-02 3.36E-03 6.47E-01 1.27E-03 6.19E-04
2.5 2.4 2.3 2.2 2.1 2 1.9 1.8 1.7 1.6 1.5 1.4 1.3 1.2 1.1	-1.03098 -1.1547 -1.28973 -1.44893 -1.42216 -1.64977 -1.74677 -1.80379 -1.85673 -1.89753 -1.92366 -1.95284 -1.96223 -1.98247 -1.98876 -1.99381	4.99E-02 5.11E-02 5.09E-02 4.76E-02 4.64E-02 4.16E-02 3.81E-02 3.03E-02 2.47E-02 1.71E-02 1.83E-02 1.24E-02 9.74E-03 6.49E-03 4.34E-03 3.26E-03	0.178177 0.380736 0.524438 0.602312 0.408223 0.859387 0.917868 0.934869 0.956093 0.969191 0.978189 0.98697 0.989704 0.995408 0.997008	2.29E-01 2.59E-01 2.84E-01 3.13E-01 3.59E-01 3.74E-01 4.29E-01 4.62E-01 5.08E-01 3.81E-02 3.36E-03 6.47E-01 1.27E-03 6.19E-04 3.61E-04 2.84E-04
2.5 2.4 2.3 2.2 2.1 2 1.9 1.8 1.7 1.6 1.5 1.4 1.3 1.2 1.1	-1.03098 -1.1547 -1.28973 -1.44893 -1.42216 -1.64977 -1.74677 -1.80379 -1.85673 -1.89753 -1.92366 -1.95284 -1.96223 -1.98247 -1.98876 -1.99381 -1.99595	4.99E-02 5.11E-02 5.09E-02 4.76E-02 4.64E-02 4.16E-02 3.81E-02 3.03E-02 2.47E-02 1.71E-02 1.83E-02 1.24E-02 9.74E-03 6.49E-03 4.34E-03 3.26E-03 1.47E-03	0.178177 0.380736 0.524438 0.602312 0.408223 0.859387 0.917868 0.934869 0.956093 0.969191 0.978189 0.98697 0.989704 0.995408 0.997008	2.29E-01 2.59E-01 2.84E-01 3.13E-01 3.59E-01 3.74E-01 4.29E-01 4.62E-01 5.08E-01 3.81E-02 3.36E-03 6.47E-01 1.27E-03 6.19E-04 3.61E-04 2.84E-04 9.51E-05
2.5 2.4 2.3 2.2 2.1 2 1.9 1.8 1.7 1.6 1.5 1.4 1.3 1.2 1.1 1	-1.03098 -1.1547 -1.28973 -1.44893 -1.42216 -1.64977 -1.74677 -1.80379 -1.85673 -1.89753 -1.92366 -1.95284 -1.96223 -1.98247 -1.98876 -1.99381 -1.99595 -1.99922	4.99E-02 5.11E-02 5.09E-02 4.76E-02 4.64E-02 4.16E-02 3.81E-02 3.03E-02 2.47E-02 1.71E-02 1.83E-02 1.24E-02 9.74E-03 6.49E-03 4.34E-03 3.26E-03 1.47E-03 4.08E-04	0.178177 0.380736 0.524438 0.602312 0.408223 0.859387 0.917868 0.934869 0.956093 0.969191 0.978189 0.98697 0.989704 0.995408 0.997008 0.997008	2.29E-01 2.59E-01 2.84E-01 3.13E-01 3.59E-01 3.74E-01 4.29E-01 4.62E-01 5.08E-01 3.81E-02 3.36E-03 6.47E-01 1.27E-03 6.19E-04 3.61E-04 2.84E-04 9.51E-05 2.32E-05
2.5 2.4 2.3 2.2 2.1 2 1.9 1.8 1.7 1.6 1.5 1.4 1.3 1.2 1.1	-1.03098 -1.1547 -1.28973 -1.44893 -1.42216 -1.64977 -1.74677 -1.80379 -1.85673 -1.89753 -1.92366 -1.95284 -1.96223 -1.98247 -1.98876 -1.99381 -1.99595	4.99E-02 5.11E-02 5.09E-02 4.76E-02 4.64E-02 4.16E-02 3.81E-02 3.03E-02 2.47E-02 1.71E-02 1.83E-02 1.24E-02 9.74E-03 6.49E-03 4.34E-03 3.26E-03 1.47E-03	0.178177 0.380736 0.524438 0.602312 0.408223 0.859387 0.917868 0.934869 0.956093 0.969191 0.978189 0.98697 0.989704 0.995408 0.997008	2.29E-01 2.59E-01 2.84E-01 3.13E-01 3.59E-01 3.74E-01 4.29E-01 4.62E-01 5.08E-01 3.81E-02 3.36E-03 6.47E-01 1.27E-03 6.19E-04 3.61E-04 2.84E-04 9.51E-05

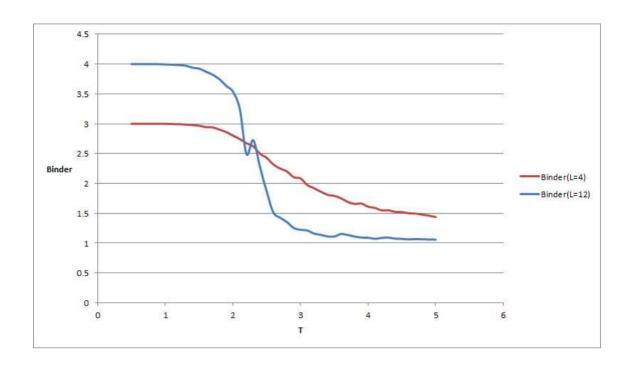
0.7	-1.99998	0.00E + 00	0.999995	0.00E + 00
0.6	-2	1.18E-04	1	4.43E-06
0.5	-2	0.00E + 00	1	0.00E + 00











4. Conclusion

- 1) Along each Monte Carlo Step, the total magnetization and total energy converges to the point at which the system has the maximized entropy(the minimized energy).
- 2) The spontaneous magnetization configuration increases and the energy configuration decreases while the temperature decreases.
- 3) Been known well, it is certain that there is a critical temperature at which susceptibility and heat capacity of the system jump. Around T = $2.2 \sim 2.4$ is it under the simulation condition.
- 4) The more lattice the system has, the larger height of peak of susceptibility and heat capacity of system is at the critical temperature.