

# The Thai-English Student's Dictionary compiled by Mary R. Haas and The Graphical Law

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(Dated: October 16, 2024)

## Abstract

We study the head words of the Thai-English Student's Dictionary compiled by Mary R. Haas, way back in 1964. We draw the natural logarithm of the number of head words, normalised, starting with a letter vs the natural logarithm of the rank of the letter, normalised. We conclude that the Dictionary can be characterised by  $BP(4, \beta H = 0)$ , the magnetisation curve for the Bethe-Peierls approximation of the Ising model with four nearest neighbours in the absence of external magnetic field.  $\beta$  is  $\frac{1}{k_B T}$  where, T is temperature, H is external magnetic field and  $k_B$  is the tiny Boltzmann constant.

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k	kh	kh	kh	ng	c	ch	ch	s	ch	j	d	t	th	th	th	n	d	t	th	th	th	n
623	217	276	8	85	231	109	190	99	3	7	2	1	3	1	2	2	132	243	81	214	23	132
b	p	ph	f	ph	f	ph	m	j	r	ry	ryy	l	ly	lyy	w	s	s	s	h	l	?	h
223	418	98	35	308	69	31	210	155	296	6	2	236	1	1	158	45	2	456	399	3	492	38

TABLE I. The Thai-English Student’s Dictionary head words: the odd rows represent letters(English equivalent) of the Thai alphabet,[1], in the serial order; the even rows represent the number of head words of the Thai-English Student’s Dictionary[1].

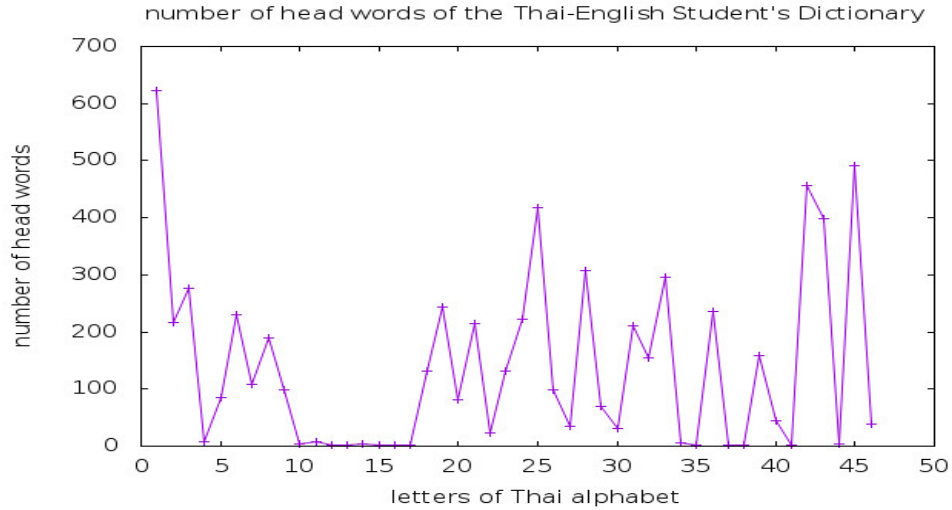


FIG. 1. The vertical axis is the number of head words of the Thai-English Student’s Dictionary[1]. The horizontal axis is the letters of the Thai alphabet. Letters are represented by the sequence number in the alphabet as it appears in the dictionary, [1].

## I. INTRODUCTION

In this paper we go over to the language of Thailand. The language of Thailand is called Thai. We study a dictionary of Thai. This is the Thai-English Student’s Dictionary compiled by Mary R. Haas, [1]. We count one by one all the head words, in this Dictionary,[1]. The result is the table, I. To visualise we plot the number of head words against the respective letters in the dictionary sequence,[1], in the adjoining figure, fig.1.

Looking for the Graphical Law in this dictionary, we proceed narrating the development. We have started considering magnetic field pattern in [2], in the languages we converse with. We have studied there, a set of natural languages, [2] and have found existence of a magnetisation curve under each language. We have termed this phenomenon as the Graphical Law. Then,

we moved on to investigate, [3], into dictionaries of five disciplines of knowledge and found the existence of a curve of magnetisation under each discipline. This was followed by finding of the graphical law in references from [4] to [82].

The planning of the paper is as follows. In the next section, section II, we describe the Graphical Law analysis of the head words of the Thai-English Student's Dictionary[1]. The section III, we give an introduction to the standard curves of magnetisation of Ising model. The section IV is Acknowledgment. The last section is Bibliography.

## II. THE GRAPHICAL LAW ANALYSIS

For the purpose of exploring graphical law, we assort the letters according to the number of head words, in the descending order, denoted by  $f$  and the respective rank, [83], denoted by  $k$ .  $k$  is a positive integer starting from one. Moreover, the minimum non-zero number of head words is one. The limiting rank is maximum rank, here it is thirty six. As a result both  $\frac{\ln f}{\ln f_{max}}$  and  $\frac{\ln k}{\ln k_{lim}}$  varies from zero to one. Then we tabulate in the adjoining table, II, and plot  $\frac{\ln f}{\ln f_{max}}$  against  $\frac{\ln k}{\ln k_{lim}}$  in the figure fig.2. We then ignore the letter with the highest number of head words, tabulate in the adjoining table, II, and redo the plot, normalising the  $\ln f$ s with  $\ln f_{n-max}$ , and starting from  $k = 2$  in the figure fig.3. Normalising the  $\ln f$ s with  $\ln f_{2n-max}$ , we tabulate in the adjoining table, II, and starting from  $k = 3$  we draw in the figure fig.4. Normalising the  $\ln f$ s with  $\ln f_{3n-max}$  we record in the adjoining table, II, and plot starting from  $k = 4$  in the figure fig.5. In this way we obtain up to the figure fig.7.

k	lnk	lnk/ $lnk_{lim}$	f	lnf	lnf/ $lnf_{max}$	lnf/ $lnf_{n-max}$	lnf/ $lnf_{2n-max}$	lnf/ $lnf_{3n-max}$	lnf/ $lnf_{4n-max}$	lnf/ $lnf_{5n-max}$
1	0	0	623	6.435	1	Blank	Blank	Blank	Blank	Blank
2	0.69	0.193	492	6.198	0.963	1	Blank	Blank	Blank	Blank
3	1.10	0.307	456	6.122	0.951	0.988	1	Blank	Blank	Blank
4	1.39	0.388	418	6.035	0.938	0.974	0.986	1	Blank	Blank
5	1.61	0.450	399	5.989	0.931	0.966	0.978	0.992	1	Blank
6	1.79	0.500	308	5.730	0.890	0.924	0.936	0.949	0.957	1
7	1.95	0.545	296	5.690	0.884	0.918	0.929	0.943	0.950	0.993
8	2.08	0.581	276	5.620	0.873	0.907	0.918	0.931	0.938	0.981
9	2.20	0.615	243	5.493	0.854	0.886	0.897	0.910	0.917	0.959
10	2.30	0.642	236	5.464	0.849	0.882	0.893	0.905	0.912	0.954
11	2.40	0.670	231	5.442	0.846	0.878	0.889	0.902	0.909	0.950
12	2.48	0.693	223	5.407	0.840	0.872	0.883	0.896	0.903	0.944
13	2.56	0.715	217	5.380	0.836	0.868	0.879	0.891	0.898	0.939
14	2.64	0.737	214	5.366	0.834	0.866	0.877	0.889	0.896	0.936
15	2.71	0.757	210	5.347	0.831	0.863	0.873	0.886	0.893	0.933
16	2.77	0.774	190	5.247	0.815	0.847	0.857	0.869	0.876	0.916
17	2.83	0.791	158	5.063	0.787	0.817	0.827	0.839	0.845	0.884
18	2.89	0.807	155	5.043	0.784	0.814	0.824	0.836	0.842	0.880
19	2.94	0.821	132	4.883	0.759	0.788	0.798	0.809	0.815	0.852
20	3.00	0.838	109	4.691	0.729	0.757	0.766	0.777	0.783	0.819
21	3.04	0.849	99	4.595	0.714	0.741	0.751	0.761	0.767	0.802
22	3.09	0.863	98	4.585	0.713	0.740	0.749	0.760	0.766	0.800
23	3.14	0.877	85	4.443	0.690	0.717	0.726	0.736	0.742	0.775
24	3.18	0.888	81	4.394	0.683	0.709	0.718	0.728	0.734	0.767
25	3.22	0.899	69	4.234	0.658	0.683	0.692	0.702	0.707	0.739
26	3.26	0.911	45	3.807	0.592	0.614	0.622	0.631	0.636	0.664
27	3.30	0.922	38	3.638	0.565	0.587	0.594	0.603	0.607	0.635
28	3.33	0.930	35	3.555	0.552	0.574	0.581	0.589	0.594	0.620
29	3.37	0.941	31	3.434	0.534	0.554	0.561	0.569	0.573	0.599
30	3.40	0.950	23	3.135	0.487	0.506	0.512	0.519	0.523	0.547
31	3.43	0.958	8	2.079	0.323	0.335	0.340	0.344	0.347	0.363
32	3.47	0.969	7	1.946	0.302	0.314	0.318	0.322	0.325	0.340
33	3.50	0.978	6	1.792	0.278	0.289	0.293	0.297	0.299	0.313
34	3.53	0.986	3	1.099	0.171	0.177	0.180	0.182	0.184	0.192
35	3.56	0.994	2	0.693	0.108	0.112	0.113	0.115	0.116	0.121
36	3.58	1	1	0	0	0	0	0	0	0

TABLE II. The Thai-English Student's Dictionary compiled by Mary R. Haas, head words: ranking, natural logarithm, normalisations

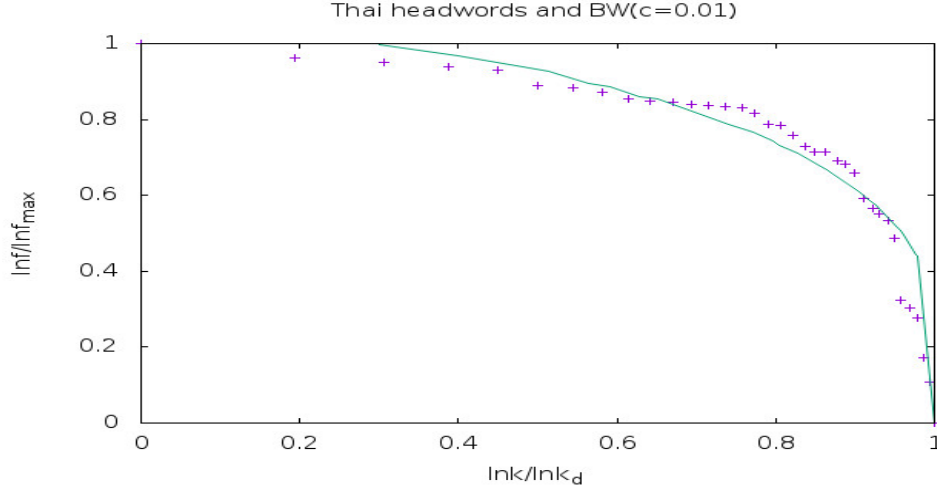


FIG. 2. The vertical axis is  $\frac{\ln f}{\ln f_{max}}$  and the horizontal axis is  $\frac{\ln k}{\ln k_{lim}}$ . The + points represent the head words of the Thai-English Student's Dictionary, [1], with the fit curve, BW( $c=0.01$ ), being the Bragg-Williams curve in the presence of external magnetic field,  $c = \frac{H}{\gamma\epsilon} = 0.01$ .

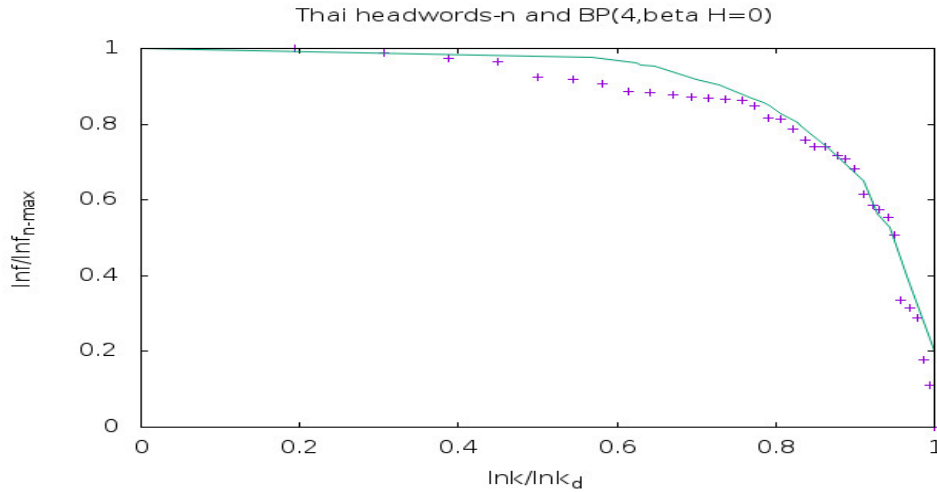


FIG. 3. The vertical axis is  $\frac{\ln f}{\ln f_{n-max}}$  and the horizontal axis is  $\frac{\ln k}{\ln k_{lim}}$ . The + points represent the head words of the Thai-English Student's Dictionary, [1], with the fit curve, BP( $4, \beta H = 0$ ), being the Bethe-Peierls curve in the presence of four nearest neighbours and in the absence of external magnetic field,  $m = 0$  or,  $\beta H = 0$ .

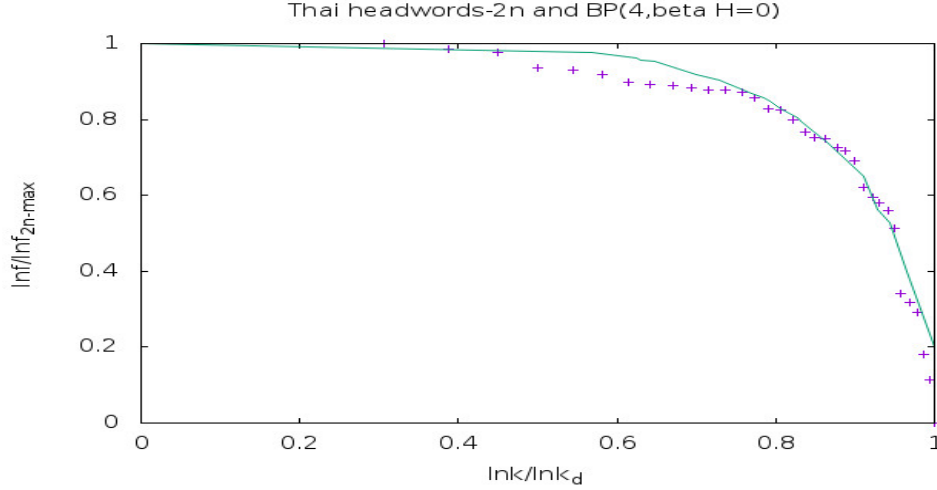


FIG. 4. The vertical axis is  $\frac{\ln f}{\ln f_{2n-max}}$  and the horizontal axis is  $\frac{\ln k}{\ln k_{lim}}$ . The + points represent the head words of the Thai-English Student's Dictionary, [1], with the fit curve,  $BP(4, \beta H = 0)$ , being the Bethe-Peierls curve in the presence of four nearest neighbours and in the absence of external magnetic field,  $m = 0$  or,  $\beta H = 0$ .

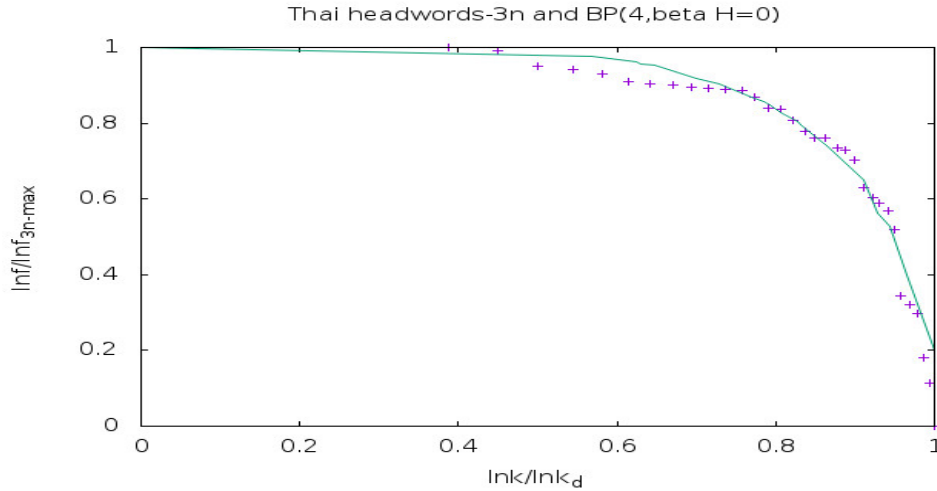


FIG. 5. The vertical axis is  $\frac{\ln f}{\ln f_{3n-max}}$  and the horizontal axis is  $\frac{\ln k}{\ln k_{lim}}$ . The + points represent the head words of the Thai-English Student's Dictionary, [1], with the fit curve,  $BP(4, \beta H = 0)$ , being the Bethe-Peierls curve in the presence of four nearest neighbours and in the absence of external magnetic field,  $m = 0$  or,  $\beta H = 0$ .

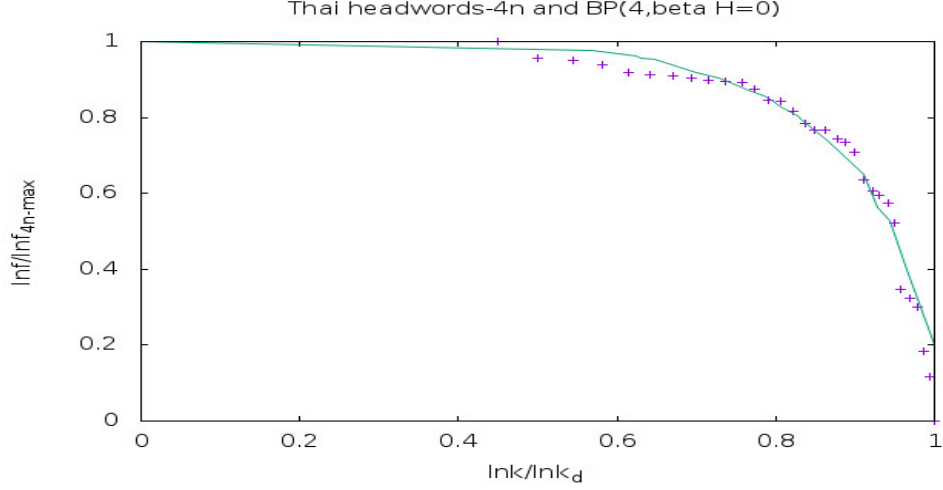


FIG. 6. The vertical axis is  $\frac{\ln f}{\ln f_{4n-max}}$  and the horizontal axis is  $\frac{\ln k}{\ln k_{lim}}$ . The + points represent the head words of the Thai-English Student's Dictionary, [1], with the fit curve,  $BP(4, \beta H = 0)$ , being the Bethe-Peierls curve in the presence of four nearest neighbours and in the absence of external magnetic field,  $m = 0$  or,  $\beta H = 0$ .

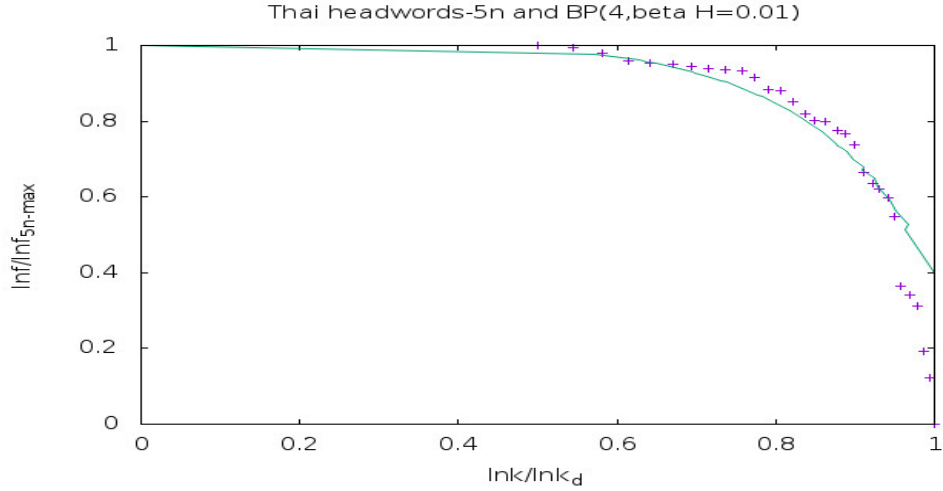


FIG. 7. The vertical axis is  $\frac{\ln f}{\ln f_{5n-max}}$  and the horizontal axis is  $\frac{\ln k}{\ln k_{lim}}$ . The + points represent the head words of the Thai-English Student's Dictionary, [1], with the fit curve,  $BP(4, \beta H = 0.04)$ , being the Bethe-Peierls curve in the presence of four nearest neighbours and external magnetic field,  $m = 0.005$  or,  $\beta H = 0.01$ .

## A. conclusion

From the figures (fig.2-fig.7), we observe that there is a curve of magnetisation, behind the head words of the Thai-English Dictionary,[1]. This is the magnetisation curve, BP(4, $\beta H = 0$ ), in the Bethe-Peierls approximation of the Ising model, in the presence of four nearest neighbours and in the absence of external magnetic field.

Moreover, the associated correspondence is,

$$\frac{\ln f}{\ln f_{4n-max}} \longleftrightarrow \frac{M}{M_{max}},$$
$$\ln k \longleftrightarrow T.$$

$k$  corresponds to temperature in an exponential scale, [84].



### III. APENDIX: MAGNETISATION

#### A. Bragg-Williams approximation

Let us consider a coin. Let us toss it many times. Probability of getting head or, tale is half i.e. we will get head and tale equal number of times. If we attach value one to head, minus one to tale, the average value we obtain, after many tossing is zero. Instead let us consider a one-sided loaded coin, say on the head side. The probability of getting head is more than one half, getting tale is less than one-half. Average value, in this case, after many tossing we obtain is non-zero, the precise number depends on the loading. The loaded coin is like ferromagnet, the unloaded coin is like para magnet, at zero external magnetic field. Average value we obtain is like magnetisation, loading is like coupling among the spins of the ferromagnetic units. Outcome of single coin toss is random, but average value we get after long sequence of tossing is fixed. This is long-range order. But if we take a small sequence of tossing, say, three consecutive tossing, the average value we obtain is not fixed, can be anything. There is no short-range order.

Let us consider a row of spins, one can imagine them as spears which can be vertically up or, down. Assume there is a long-range order with probability to get a spin up is two third. That would mean when we consider a long sequence of spins, two third of those are with spin up. Moreover, assign with each up spin a value one and a down spin a value minus one. Then total spin we obtain is one third. This value is referred to as the value of long-range order parameter. Now consider a short-range order existing which is identical with the long-range order. That would mean if we pick up any three consecutive spins, two will be up, one down. Bragg-Williams approximation means short-range order is identical with long-range order, applied to a lattice of spins, in general. Row of spins is a lattice of one dimension.

Now let us imagine an arbitrary lattice, with each up spin assigned a value one and a down spin a value minus one, with an unspecified long-range order parameter defined as above by  $L = \frac{1}{N}\sum_i\sigma_i$ , where  $\sigma_i$  is i-th spin, N being total number of spins. L can vary from minus one to one.  $N = N_+ + N_-$ , where  $N_+$  is the number of up spins,  $N_-$  is the number of down spins.  $L = \frac{1}{N}(N_+ - N_-)$ . As a result,  $N_+ = \frac{N}{2}(1 + L)$  and  $N_- = \frac{N}{2}(1 - L)$ . Magnetisation or, net magnetic moment ,  $M$  is  $\mu\sum_i\sigma_i$  or,  $\mu(N_+ - N_-)$  or,  $\mu NL$ ,  $M_{max} = \mu N$ .  $\frac{M}{M_{max}} = L$ .  $\frac{M}{M_{max}}$  is

referred to as reduced magnetisation. Moreover, the Ising Hamiltonian,[85], for the lattice of spins, setting  $\mu$  to one, is  $-\epsilon \sum_{n.n} \sigma_i \sigma_j - H \sum_i \sigma_i$ , where n.n refers to nearest neighbour pairs. The difference  $\Delta E$  of energy if we flip an up spin to down spin is, [86],  $2\epsilon\gamma\bar{\sigma} + 2H$ , where  $\gamma$  is the number of nearest neighbours of a spin. According to Boltzmann principle,  $\frac{N_-}{N_+}$  equals  $exp(-\frac{\Delta E}{k_B T})$ , [87]. In the Bragg-Williams approximation,[88],  $\bar{\sigma} = L$ , considered in the thermal average sense. Consequently,

$$\ln \frac{1+L}{1-L} = 2 \frac{\gamma\epsilon L + H}{k_B T} = 2 \frac{L + \frac{H}{\gamma\epsilon}}{\frac{T}{\gamma\epsilon/k_B}} = 2 \frac{L + c}{\frac{T}{T_c}} \quad (1)$$

where,  $c = \frac{H}{\gamma\epsilon}$ ,  $T_c = \gamma\epsilon/k_B$ , [89].  $\frac{T}{T_c}$  is referred to as reduced temperature.

Plot of  $L$  vs  $\frac{T}{T_c}$  or, reduced magnetisation vs. reduced temperature is used as reference curve. In the presence of magnetic field,  $c \neq 0$ , the curve bulges outward. Bragg-Williams is a Mean Field approximation. This approximation holds when number of neighbours interacting with a site is very large, reducing the importance of local fluctuation or, local order, making the long-range order or, average degree of freedom as the only degree of freedom of the lattice. To have a feeling how this approximation leads to matching between experimental and Ising model prediction one can refer to FIG.12.12 of [86]. W. L. Bragg was a professor of Hans Bethe. Rudolf Peierls was a friend of Hans Bethe. At the suggestion of W. L. Bragg, Rudolf Peierls following Hans Bethe improved the approximation scheme, applying quasi-chemical method.

## B. Bethe-peierls approximation in presence of four nearest neighbours, in absence of external magnetic field

In the approximation scheme which is improvement over the Bragg-Williams, [85],[86],[87],[88],[89], due to Bethe-Peierls, [90], reduced magnetisation varies with reduced temperature, for  $\gamma$  neighbours, in absence of external magnetic field, as

$$\frac{\ln \frac{\gamma}{\gamma-2}}{\ln \frac{factor-1}{factor^{\frac{\gamma-1}{\gamma}} - factor^{\frac{1}{\gamma}}}} = \frac{T}{T_c}; factor = \frac{\frac{M}{M_{max}} + 1}{1 - \frac{M}{M_{max}}} \quad (2)$$

$\ln \frac{\gamma}{\gamma-2}$  for four nearest neighbours i.e. for  $\gamma = 4$  is 0.693. For a snapshot of different kind of magnetisation curves for magnetic materials the reader is urged to give a google search "reduced magnetisation vs reduced temperature curve". In the following, we describe

BW	BW(c=0.01)	BP(4,βH = 0)	reduced magnetisation
0	0	0	1
0.435	0.439	0.563	0.978
0.439	0.443	0.568	0.977
0.491	0.495	0.624	0.961
0.501	0.507	0.630	0.957
0.514	0.519	0.648	0.952
0.559	0.566	0.654	0.931
0.566	0.573	0.7	0.927
0.584	0.590	0.7	0.917
0.601	0.607	0.722	0.907
0.607	0.613	0.729	0.903
0.653	0.661	0.770	0.869
0.659	0.668	0.773	0.865
0.669	0.676	0.784	0.856
0.679	0.688	0.792	0.847
0.701	0.710	0.807	0.828
0.723	0.731	0.828	0.805
0.732	0.743	0.832	0.796
0.756	0.766	0.845	0.772
0.779	0.788	0.864	0.740
0.838	0.853	0.911	0.651
0.850	0.861	0.911	0.628
0.870	0.885	0.923	0.592
0.883	0.895	0.928	0.564
0.899	0.918		0.527
0.904	0.926	0.941	0.513
0.946	0.968	0.965	0.400
0.967	0.998	0.965	0.300
0.987		1	0.200
0.997		1	0.100
1	1	1	0

TABLE III. Reduced magnetisation vs reduced temperature data s for Bragg-Williams approximation, in absence of and in presence of magnetic field,  $c = \frac{H}{\gamma\epsilon} = 0.01$ , and Bethe-Peierls approximation in absence of magnetic field, for four nearest neighbours.

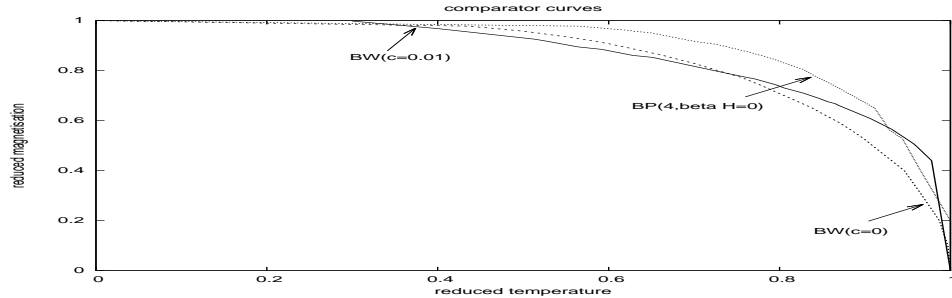


FIG. 8. Reduced magnetisation vs reduced temperature curves for Bragg-Williams approximation, in absence(dark) of and presence(inner in the top) of magnetic field,  $c = \frac{H}{\gamma\epsilon} = 0.01$ , and Bethe-Peierls approximation in absence of magnetic field, for four nearest neighbours (outer in the top).

data s generated from the equation(1) and the equation(2) in the table, III, and curves of magnetisation plotted on the basis of those data s. BW stands for reduced temperature in Bragg-Williams approximation, calculated from the equation(1). BP(4) represents reduced temperature in the Bethe-Peierls approximation, for four nearest neighbours, computed from the equation(2). The data set is used to plot fig.8. Empty spaces in the table, III, mean corresponding point pairs were not used for plotting a line.

### C. Bethe-peierls approximation in presence of four nearest neighbours, in the presence of external magnetic field

In the Bethe-Peierls approximation scheme , [90], reduced magnetisation varies with reduced temperature, for  $\gamma$  neighbours, in presence of external magnetic field, as

$$\frac{\ln \frac{\gamma}{\gamma-2}}{\ln \frac{e^{-\frac{2\beta H}{\gamma}} \text{factor}^{\frac{\gamma-1}{\gamma}} - e^{-\frac{2\beta H}{\gamma}} \text{factor}^{\frac{1}{\gamma}}}{\text{factor} - 1}} = \frac{T}{T_c}; \text{factor} = \frac{\frac{M}{M_{max}} + 1}{1 - \frac{M}{M_{max}}}. \quad (3)$$

Derivation of this formula ala [90] is given in the appendix of [7].

$\ln \frac{\gamma}{\gamma-2}$  for four nearest neighbours i.e. for  $\gamma = 4$  is 0.693. For four neighbours,

$$\frac{0.693}{\ln \frac{e^{-\frac{2\beta H}{\gamma}} \text{factor}^{\frac{\gamma-1}{\gamma}} - e^{-\frac{2\beta H}{\gamma}} \text{factor}^{\frac{1}{\gamma}}}{\text{factor} - 1}} = \frac{T}{T_c}; \text{factor} = \frac{\frac{M}{M_{max}} + 1}{1 - \frac{M}{M_{max}}}. \quad (4)$$

In the following, we describe datas in the table, IV, generated from the equation(4) and curves of magnetisation plotted on the basis of those datas. BP(m=0.03) stands for reduced temperature in Bethe-Peierls approximation, for four nearest neighbours, in presence of a variable external magnetic field, H, such that  $\beta H = 0.06$ . calculated from the equation(4). BP(m=0.025) stands for reduced temperature in Bethe-Peierls approximation, for four nearest neighbours, in presence of a variable external magnetic field, H, such that  $\beta H = 0.05$ . calculated from the equation(4). BP(m=0.02) stands for reduced temperature in Bethe-Peierls approximation, for four nearest neighbours, in presence of a variable external magnetic field, H, such that  $\beta H = 0.04$ . calculated from the equation(4). BP(m=0.01) stands for reduced temperature in Bethe-Peierls approximation, for four nearest neighbours, in presence of a variable external magnetic field, H, such that  $\beta H = 0.02$ . calculated from the equation(4). BP(m=0.005) stands for reduced temperature in Bethe-Peierls approximation, for four nearest neighbours, in presence of a variable external magnetic field, H, such that  $\beta H = 0.01$ . calculated from the equation(4). The data set is used to plot fig.9. Empty spaces in the table, IV, mean corresponding point pairs were not used for plotting a line.

BP(m=0.03)	BP(m=0.025)	BP(m=0.02)	BP(m=0.01)	BP(m=0.005)	reduced magnetisation
0	0	0	0	0	1
0.583	0.580	0.577	0.572	0.569	0.978
0.587	0.584	0.581	0.575	0.572	0.977
0.647	0.643	0.639	0.632	0.628	0.961
0.657	0.653	0.649	0.641	0.637	0.957
0.671	0.667		0.654	0.650	0.952
	0.716			0.696	0.931
0.723	0.718	0.713	0.702	0.697	0.927
0.743	0.737	0.731	0.720	0.714	0.917
0.762	0.756	0.749	0.737	0.731	0.907
0.770	0.764	0.757	0.745	0.738	0.903
0.816	0.808	0.800	0.785	0.778	0.869
0.821	0.813	0.805	0.789	0.782	0.865
0.832	0.823	0.815	0.799	0.791	0.856
0.841	0.833	0.824	0.807	0.799	0.847
0.863	0.853	0.844	0.826	0.817	0.828
0.887	0.876	0.866	0.846	0.836	0.805
0.895	0.884	0.873	0.852	0.842	0.796
0.916	0.904	0.892	0.869	0.858	0.772
0.940	0.926	0.914	0.888	0.876	0.740
	0.929			0.877	0.735
	0.936			0.883	0.730
	0.944			0.889	0.720
	0.945				0.710
	0.955			0.897	0.700
	0.963			0.903	0.690
	0.973			0.910	0.680
				0.909	0.670
	0.993			0.925	0.650
		0.976	0.942		0.651
	1.00				0.640
		0.983	0.946	0.928	0.628
		1.00	0.963	0.943	0.592
			0.972	0.951	0.564
			0.990	0.967	0.527
			1.00	0.964	0.513
				1.00	0.500
					0.400
					0.300
					0.200
					0.100
					0

TABLE IV. Bethe-Peierls approx. in presence of little external magnetic fields

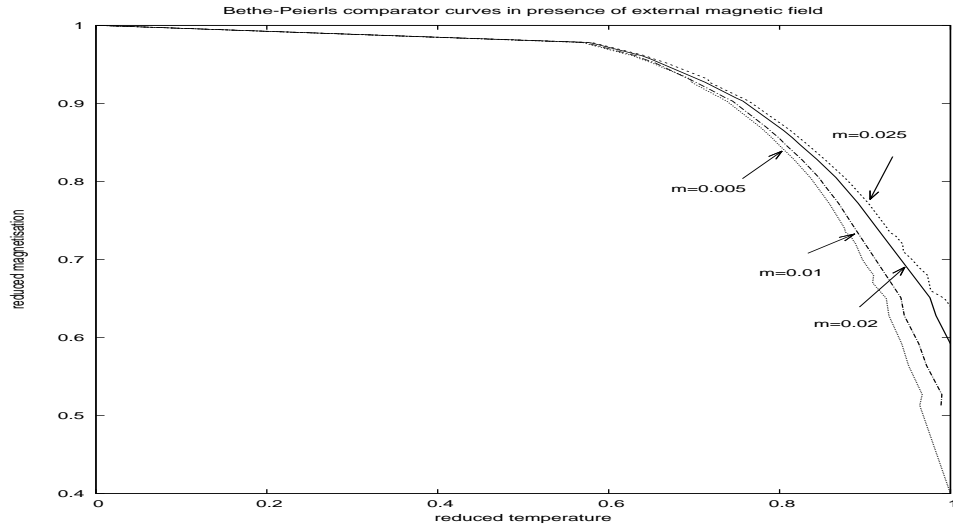


FIG. 9. Reduced magnetisation vs reduced temperature curves for Bethe-Peierls approximation in presence of little external magnetic fields, for four nearest neighbours, with  $\beta H = 2m$ .

#### IV. ACKNOWLEDGMENT

We have used gnuplot for plotting the figures in this paper.

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