Pali-English Dictionary by T. W. Rhys Davids and William Stede and The Graphical Law

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Abstract

We study the head words of the Pali-English Dictionary by T. W. Rhys Davids and William Stede, the 5th reprint, Delhi, 2018. 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 BW(c=0.01), the magnetisation curve of the Ising Model in the Bragg-Williams approximation in the presence of external magnetic field, H. $c = \frac{H}{\gamma\epsilon} = 0.01$ with ϵ being the strength of coupling between two neighbouring spins in the Ising Model, γ representing the number of nearest neighbours of a spin, which very large.

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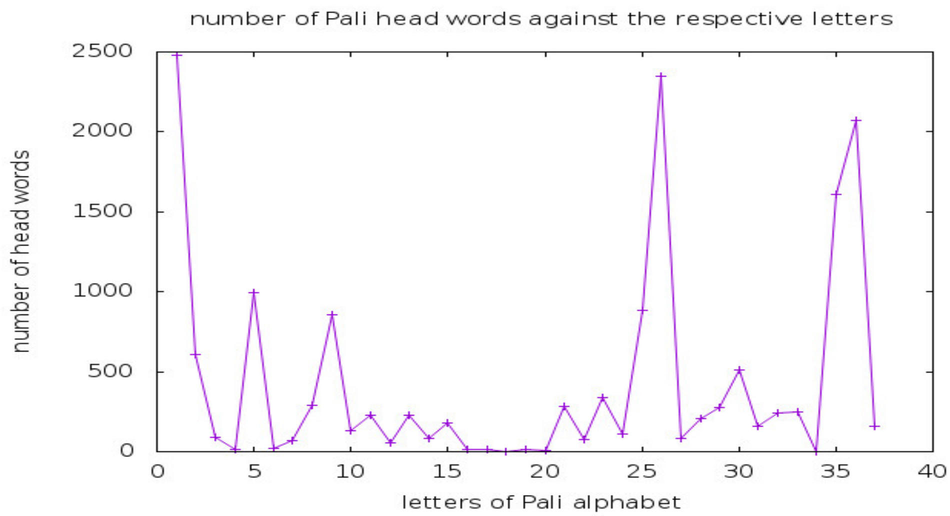

FIG. 1. The vertical axis is the number of head words of the Pali-English Dictionary , [1]. The horizontal axis is the letters of the Pali alphabet. Letters are represented by the sequence number in the alphabet as it appears in the dictionary, [1].

A	Ā	I	Ī	U	Ū	E	O	K	Kh	G	Gh	C	Ch	J	Jh	Ñ	Ṭ	Ṭh
2478	609	88	15	992	24	71	290	853	133	230	52	227	84	183	15	11	0	16
Ḍ	T	Th	D	Dh	N	P	Ph	B	Bh	M	Y	R	L	Ḷ	V	S	H	
7	281	76	341	110	881	2348	85	206	279	512	160	240	249	0	1610	2070	161	

TABLE I. Head words of Pali-English Dictionary by T. W. Rhys Davids and William Stede: the odd rows represent letters of the Pali alphabet, in the serial order, [1], the even rows represent the numbers of corresponding head words.

I. INTRODUCTION

To know whether Pali carries any imprint of magnetic field, we look forward to Pali-English Dictionary by T. W. Rhys Davids and William Stede, [1]. We count all the head words one by one and probe for the magnetic field pattern. The result is the figure, fig.1, the table, tableI. To visualise we plot the number of head words against the respective letters in the dictionary sequence,[1], in the adjoining figure, fig.1. 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 the 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 [86].

The planning of the paper is as follows. In the next section, we describe the Graphical Law analysis of head words of the Pali-English 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, [87], denoted by k. k is a positive integer starting from one. Moreover, the minimum non-zero number of head words is seven. Hence we attach a limiting number of head words, equal to one. The limiting rank is maximum rank plus one, here it is thirty five. As a result both $\frac{lnf}{lnf_{max}}$ and $\frac{lnk}{lnk_{lim}}$ varies from zero to one. Then we tabulate in the adjoining table,II, and plot $\frac{lnf}{lnf_{max}}$ against $\frac{lnk}{lnk_{lim}}$ 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 lnfs with lnf_{n-max}, and starting from $k=2$ in the figure fig.3. Normalising the lnfs with lnf_{2n-max}, we tabulate in the adjoining table,II, and starting from $k=3$ we draw in the figure fig.6. Normalising the lnfs with lnf_{3n-max} we record in the adjoining table,II, and plot starting from $k=4$ in the figure fig.4. 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	2478	7.815	1	Blank	Blank	Blank	Blank	Blank
2	0.69	0.194	2348	7.761	0.993	1	Blank	Blank	Blank	Blank
3	1.10	0.309	2070	7.635	0.977	0.984	1	Blank	Blank	Blank
4	1.39	0.390	1610	7.384	0.945	0.951	0.967	1	Blank	Blank
5	1.61	0.452	992	6.900	0.883	0.889	0.904	0.934	1	Blank
6	1.79	0.503	881	6.781	0.868	0.874	0.888	0.918	0.983	1
7	1.95	0.548	853	6.749	0.864	0.870	0.884	0.914	0.978	0.995
8	2.08	0.584	609	6.412	0.820	0.826	0.840	0.868	0.929	0.946
9	2.20	0.618	512	6.238	0.798	0.804	0.817	0.845	0.904	0.920
10	2.30	0.646	341	5.832	0.746	0.751	0.764	0.790	0.845	0.860
11	2.40	0.674	290	5.670	0.726	0.731	0.743	0.768	0.822	0.836
12	2.48	0.697	281	5.638	0.721	0.726	0.738	0.764	0.817	0.831
13	2.56	0.719	279	5.631	0.721	0.726	0.738	0.763	0.816	0.830
14	2.64	0.742	249	5.517	0.706	0.711	0.723	0.747	0.800	0.814
15	2.71	0.761	240	5.481	0.701	0.706	0.718	0.742	0.794	0.808
16	2.77	0.778	230	5.438	0.696	0.701	0.712	0.736	0.788	0.802
17	2.83	0.795	227	5.425	0.694	0.699	0.711	0.735	0.786	0.800
18	2.89	0.812	206	5.328	0.682	0.687	0.698	0.722	0.772	0.786
19	2.94	0.826	183	5.209	0.667	0.671	0.682	0.705	0.755	0.768
20	3.00	0.843	161	5.081	0.650	0.655	0.665	0.688	0.736	0.749
21	3.04	0.854	160	5.075	0.649	0.654	0.665	0.687	0.736	0.748
22	3.09	0.868	133	4.890	0.626	0.630	0.640	0.662	0.709	0.721
23	3.14	0.882	110	4.700	0.601	0.606	0.616	0.637	0.681	0.693
24	3.18	0.893	88	4.477	0.573	0.577	0.586	0.606	0.649	0.660
25	3.22	0.904	85	4.443	0.569	0.572	0.582	0.602	0.644	0.655
26	3.26	0.916	84	4.431	0.567	0.571	0.580	0.600	0.642	0.653
27	3.30	0.927	76	4.331	0.554	0.558	0.567	0.587	0.628	0.639
28	3.33	0.935	71	4.263	0.545	0.549	0.558	0.577	0.618	0.629
29	3.37	0.947	52	3.951	0.506	0.509	0.517	0.535	0.573	0.583
30	3.40	0.955	24	3.178	0.407	0.409	0.416	0.430	0.461	0.469
31	3.43	0.963	16	2.773	0.355	0.357	0.363	0.376	0.402	0.409
32	3.47	0.975	15	2.708	0.347	0.349	0.355	0.367	0.392	0.399
33	3.50	0.983	11	2.398	0.307	0.309	0.314	0.325	0.348	0.354
34	3.53	0.992	7	1.946	0.249	0.251	0.255	0.264	0.282	0.287
35	3.56	1	1	0	0	0	0	0	0	0

TABLE II. Pali-English Dictionary by T. W. Rhys Davids and William Stede, Head Words: ranking,natural logarithm, normalisations

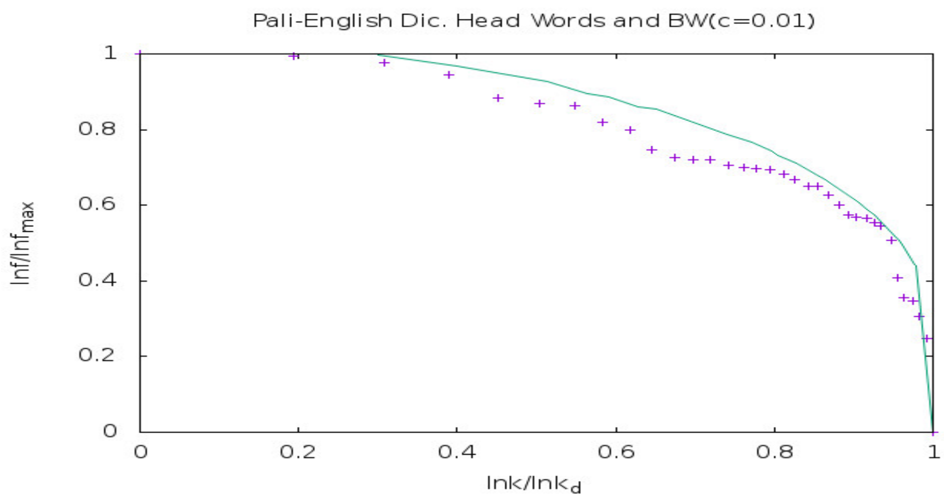

FIG. 2. The vertical axis is $\frac{lnf}{lnf_{max}}$ and the horizontal axis is $\frac{lnk}{lnk_{lim}}$. The + points represent the head words of the Pali-English Dictionary, with the fit curve being the Bragg-Williams curve, BW(c=0.01), in the presence of external magnetic field, $c = \frac{H}{\gamma\epsilon} = 0.01$.

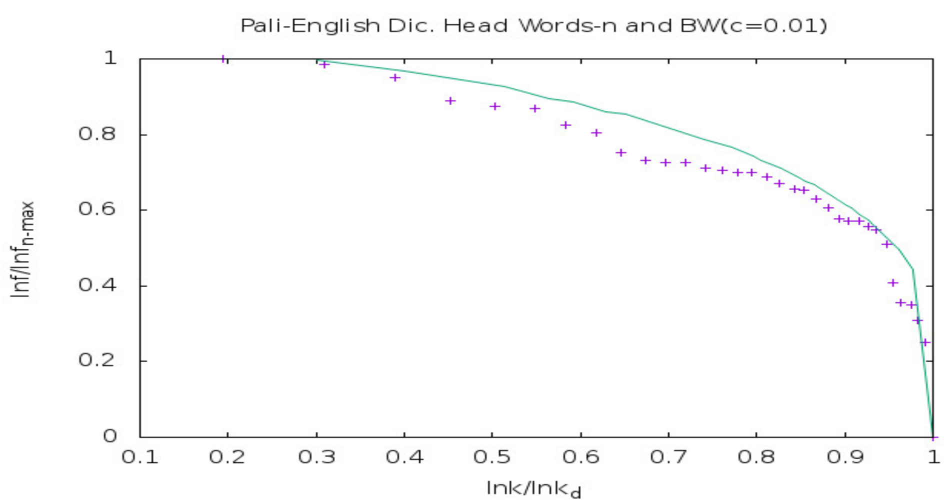

FIG. 3. The vertical axis is $\frac{lnf}{lnf_{n-max}}$ and the horizontal axis is $\frac{lnk}{lnk_{lim}}$. The + points represent the head words of the Pali-English Dictionary, with the fit curve being the Bragg-Williams curve, BW(c=0.01), in the presence of external magnetic field, $c = \frac{H}{\gamma\epsilon} = 0.01$.

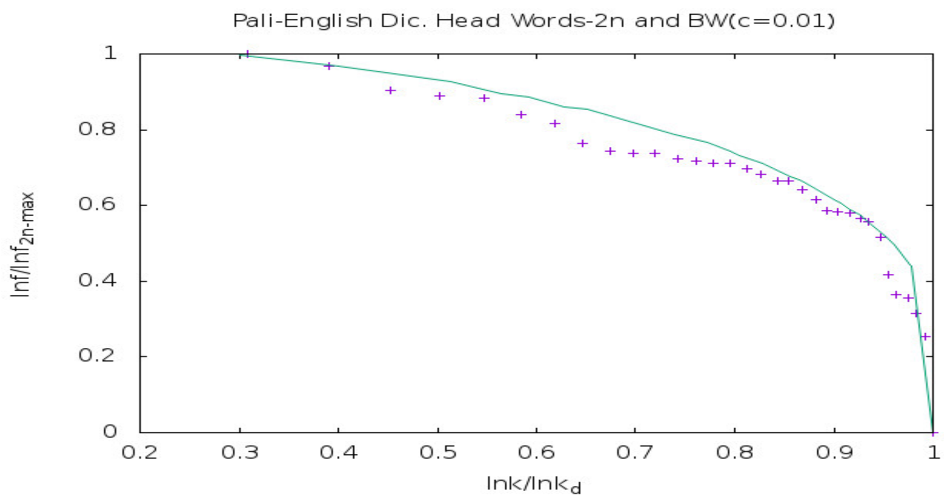

FIG. 4. The vertical axis is $\frac{lnf}{lnf_{2n-max}}$ and the horizontal axis is $\frac{lnk}{lnk_{lim}}$. The + points represent the head words of the Pali-English Dictionary, with the fit curve being the Bragg-Williams curve, BW(c=0.01), in the presence of external magnetic field, $c = \frac{H}{\gamma\epsilon} = 0.01$.

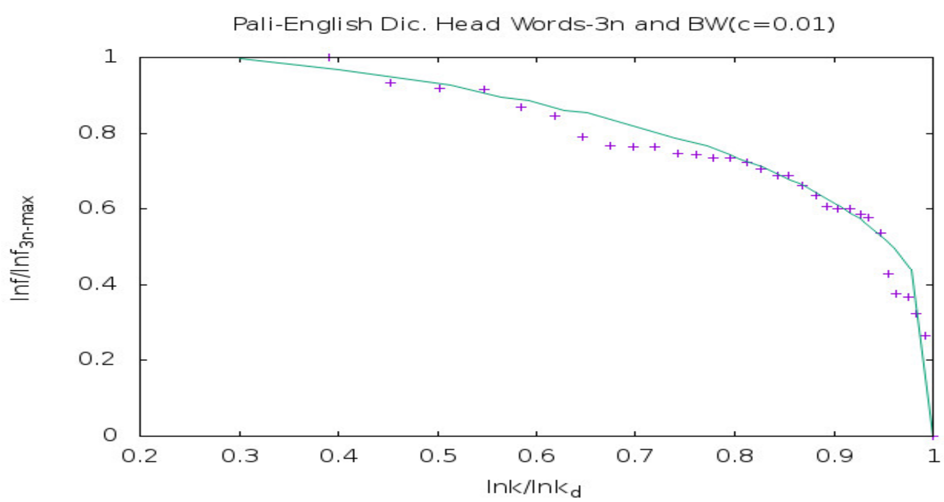

FIG. 5. The vertical axis is $\frac{lnf}{lnf_{3n-max}}$ and the horizontal axis is $\frac{lnk}{lnk_{lim}}$. The + points represent the head words of the Pali-English Dictionary, with the fit curve being the Bragg-Williams curve, BW(c=0.01), in the presence of external magnetic field, $c = \frac{H}{\gamma\epsilon} = 0.01$.

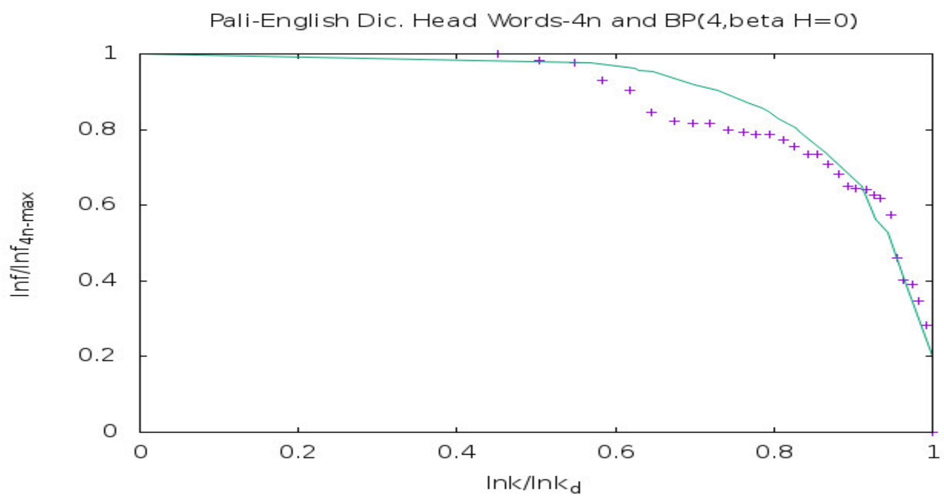

FIG. 6. The vertical axis is $\frac{lnf}{lnf_{4n-max}}$ and the horizontal axis is $\frac{lnk}{lnk_{lim}}$. The + points represent the head words of the Pali-English Dictionary, with the reference curve being BP(4,$\beta H = 0$), the Bethe-Peierls curve in the presence of four nearest neighbours and in the absence of external magnetic field, $m = 0$ or, $\beta H = 0$.

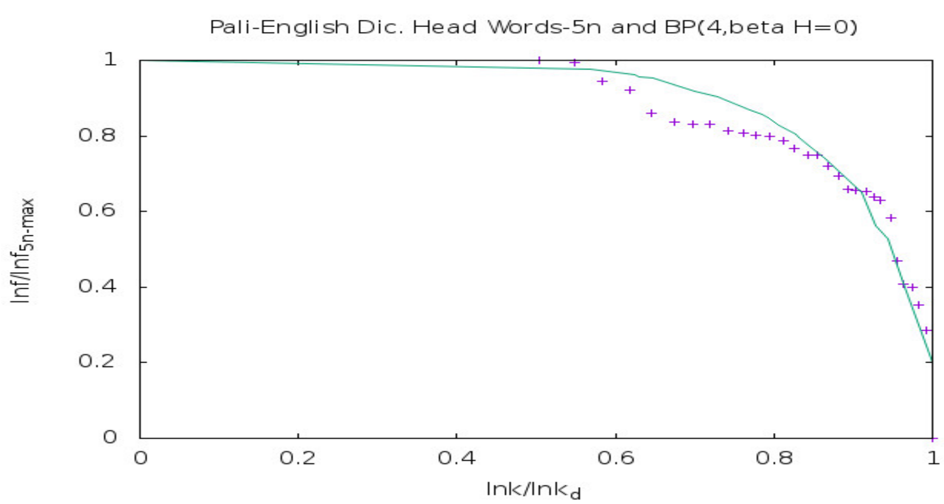

FIG. 7. The vertical axis is $\frac{lnf}{lnf_{5n-max}}$ and the horizontal axis is $\frac{lnk}{lnk_{lim}}$. The + points represent the head words of the Pali-English Dictionary, with the reference curve being BP(4,$\beta H = 0$), the Bethe-Peierls curve in the presence of four nearest neighbours and in the absence of external magnetic field, $m = 0$ or, $\beta H = 0$.

A. conclusion

From the figures (fig.2-fig.7), we observe that there is a curve of magnetisation, behind the head words of the Pali-English Dictionary by T. W. Rhys Davids and William Stede, [1]. This is the magnetisation curve, BW(c=0.01), in the Bragg-Williams approximation of the Ising model, in the presence of external magnetic field, $c = \frac{H}{\gamma\epsilon} = 0.01$.
Moreover, the associated correspondence is,

$$\frac{lnf}{lnf_{3n-max}} \longleftrightarrow \frac{M}{M_{max}},$$

$$lnk \longleftrightarrow T.$$

k corresponds to temperature in an exponential scale, [94].

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 $L = \frac{1}{N}\Sigma_i \sigma_i$, where σ_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 $\mu\Sigma_i\sigma_i$ or, $\mu(N_+ - N_-)$ or, $\mu N L$, $M_{max} = \mu N$. $\frac{M}{M_{max}} = L$. $\frac{M}{M_{max}}$ is referred to as reduced magnetisation. Moreover, the Ising Hamiltonian,[88], for the lattice of spins, setting μ to one, is $-\epsilon\Sigma_{n.n}\sigma_i\sigma_j - H\Sigma_i\sigma_i$, where n.n refers to nearest neighbour pairs. The difference $\triangle E$ of energy if we flip an up spin to down spin is, [89], $2\epsilon\gamma\bar{\sigma} + 2H$, where γ is the number of nearest neighbours of a spin. According to Boltzmann principle, $\frac{N_-}{N_+}$ equals $exp(-\frac{\triangle E}{k_B T})$, [90]. In the Bragg-Williams approximation,[91], $\bar{\sigma} = L$, considered in the thermal average sense. Consequently,

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

where, $c = \frac{H}{\gamma\epsilon}$, $T_c = \gamma\epsilon/k_B$, [92]. $\frac{T}{T_c}$ is referred to as reduced temperature.
Plot of L vs $\frac{T}{T_c}$ or, reduced magentisation 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 [89]. 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, [88],[89],[90],[91],[92], due to Bethe-Peierls, [93], reduced magnetisation varies with reduced temperature, for γ neighbours, in absence of external magnetic field, as

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

$ln\frac{\gamma}{\gamma-2}$ 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.

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.

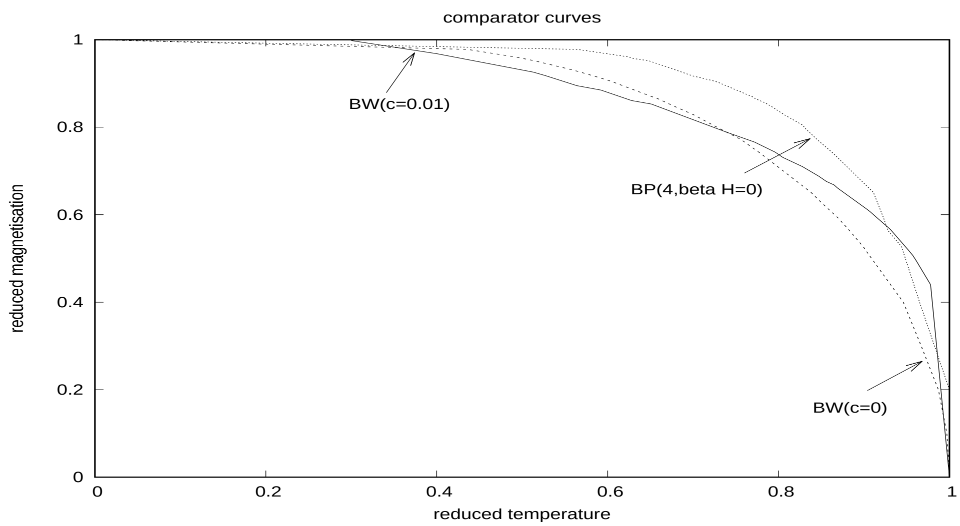

FIG. 8. Reduced magnetisation vs reduced temperature curves for Bragg-Williams approximation, in absence(dark) of and presence(inner in the top) of external magnetic field, $c = \frac{H}{\gamma\epsilon} = 0.01$, and Bethe-Peierls approximation in absence of external magnetic field, for four nearest neighbours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

IV. ACKNOWLEDGMENT

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

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