Oxford Hindi-English Dictionary and The Graphical Law

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Abstract

We study the head words of the dictionary, the Oxford Hindi-English Dictionary edited by R.S. McGregor, the 62^{nd} impression, 2023. 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 is very large.

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a	ā	i	ī	u	ū	ṛ	e	ai	o	au	ka	kha	ga	gha	ṅa	ca	cha	ja	jha	ña	ṭa
2604	676	248	59	742	73	15	91	52	81	79	2147	722	1002	304	0	1147	425	942	353	0	300
ṭha	ḍa	ḍha	ṇa	ta	tha	da	dha	na	pa	pha	ba	bha	ma	ya	ra	la	va	śa	ṣa	sa	ha
206	253	206	0	1132	119	1191	490	1448	2758	534	1774	732	1902	177	794	830	1180	539	5	2836	785

TABLE I. Oxford Hindi-English Dictionary head words: the odd rows represent letters of the Hindi alphabet,[1], in the serial order; the even rows represent the number of head words of the Oxford Hindi-English Dictionary, [1].

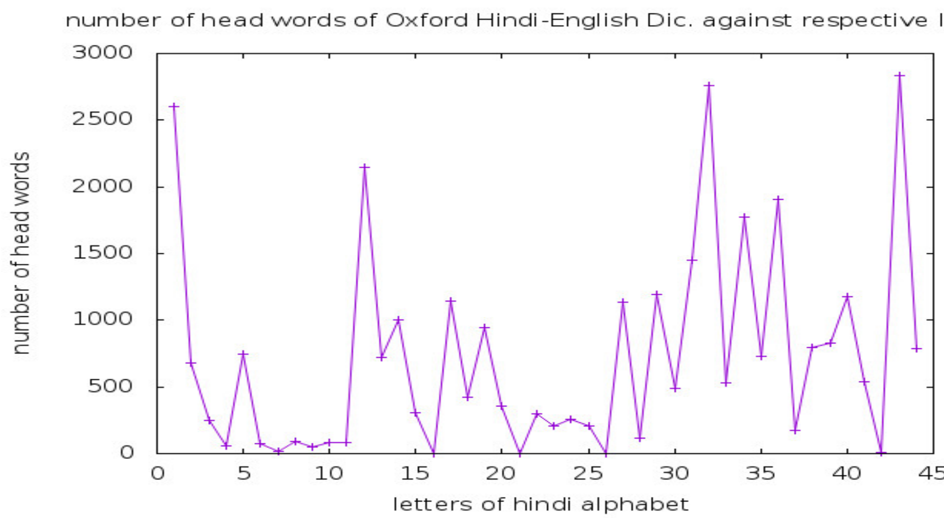

FIG. 1. The vertical axis is the number of head words of the Oxford Hindi-English Dictionary, [1]. The horizontal axis is the letters of the Hindi alphabet. Letters are represented by the sequence number in the alphabet as it appears in the dictionary, [1].

I. INTRODUCTION

Hindi is the official language of the Republic of India. English is the connecting language. We study a Hindi-English Dictionary. This is the Oxford Hindi-English Dictionary edited by R.S. McGregor, the 62^{nd} impression, 2023, [1]. We count one by one all the head words, used in the modern standardised Hindi language, 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 into, [3], dictionaries of five disciplines of knowledge and found existence of a curve magnetisation under each discipline. This was followed by finding of the graphical law in references from [4] to [70].

The planning of the paper is as follows. In the next section, we describe the Graphical Law analysis of the head words of the Oxford Hindi-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, [71], denoted by k. k is a positive integer starting from one. Moreover, the minimum non-zero number of head words is five. Hence, we attach a limiting entry number one. The limiting rank is maximum rank plus one, here it is forty one. 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 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.4. Normalising the lnfs with lnf_{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	2836	7.950	1	Blank	Blank	Blank	Blank	Blank
2	0.69	0.186	2758	7.922	0.996	1	Blank	Blank	Blank	Blank
3	1.10	0.296	2604	7.865	0.989	0.993	1	Blank	Blank	Blank
4	1.39	0.375	2147	7.672	0.965	0.968	0.975	1	Blank	Blank
5	1.61	0.434	1902	7.551	0.950	0.953	0.960	0.984	1	Blank
6	1.79	0.482	1774	7.481	0.941	0.944	0.951	0.975	0.991	1
7	1.95	0.526	1448	7.278	0.915	0.919	0.925	0.949	0.964	0.973
8	2.08	0.561	1191	7.083	0.891	0.894	0.901	0.923	0.938	0.947
9	2.20	0.593	1180	7.073	0.890	0.893	0.899	0.922	0.937	0.945
10	2.30	0.620	1147	7.045	0.886	0.889	0.896	0.918	0.933	0.942
11	2.40	0.647	1132	7.032	0.885	0.888	0.894	0.917	0.931	0.940
12	2.48	0.668	1002	6.910	0.869	0.872	0.879	0.901	0.915	0.924
13	2.56	0.690	942	6.848	0.861	0.864	0.871	0.893	0.907	0.915
14	2.64	0.712	830	6.721	0.845	0.848	0.855	0.876	0.890	0.898
15	2.71	0.730	794	6.677	0.840	0.843	0.849	0.870	0.884	0.893
16	2.77	0.747	785	6.666	0.838	0.841	0.848	0.869	0.883	0.891
17	2.83	0.763	742	6.609	0.831	0.834	0.840	0.861	0.875	0.883
18	2.89	0.779	732	6.596	0.830	0.833	0.839	0.860	0.874	0.882
19	2.94	0.792	722	6.582	0.828	0.831	0.837	0.858	0.872	0.880
20	3.00	0.809	676	6.516	0.820	0.823	0.828	0.849	0.863	0.871
21	3.04	0.819	539	6.290	0.791	0.794	0.800	0.820	0.833	0.841
22	3.09	0.833	534	6.280	0.790	0.793	0.798	0.819	0.832	0.839
23	3.14	0.846	490	6.194	0.779	0.782	0.788	0.807	0.820	0.830
24	3.18	0.857	425	6.052	0.761	0.764	0.769	0.789	0.801	0.809
25	3.22	0.868	353	5.866	0.738	0.740	0.746	0.765	0.777	0.784
26	3.26	0.879	304	5.717	0.719	0.722	0.727	0.745	0.757	0.764
27	3.30	0.889	300	5.704	0.717	0.720	0.725	0.743	0.755	0.762
28	3.33	0.898	253	5.533	0.696	0.698	0.703	0.721	0.733	0.740
29	3.37	0.908	248	5.513	0.693	0.696	0.701	0.719	0.730	0.737
30	3.40	0.916	206	5.328	0.670	0.673	0.677	0.694	0.706	0.712
31	3.43	0.925	177	5.176	0.651	0.653	0.658	0.675	0.685	0.692
32	3.47	0.935	119	4.779	0.601	0.603	0.608	0.623	0.633	0.639
33	3.50	0.943	91	4.511	0.567	0.569	0.574	0.588	0.597	0.603
34	3.53	0.951	81	4.394	0.553	0.555	0.559	0.573	0.582	0.587
35	3.56	0.960	79	4.369	0.550	0.552	0.555	0.569	0.579	0.584
36	3.58	0.965	73	4.290	0.540	0.542	0.545	0.559	0.568	0.573
37	3.61	0.973	59	4.078	0.513	0.515	0.518	0.532	0.540	0.545
38	3.64	0.981	52	3.951	0.497	0.499	0.502	0.515	0.523	0.528
39	3.66	0.987	15	2.708	0.341	0.342	0.344	0.353	0.359	0.362
40	3.69	0.995	5	1.609	0.202	0.203	0.205	0.210	0.213	0.215
41	3.74	1	1	0	0	0	0	0	0	0

TABLE II. Oxford Hindi-English Dictionary Head Words: ranking,natural logarithm, normalisations

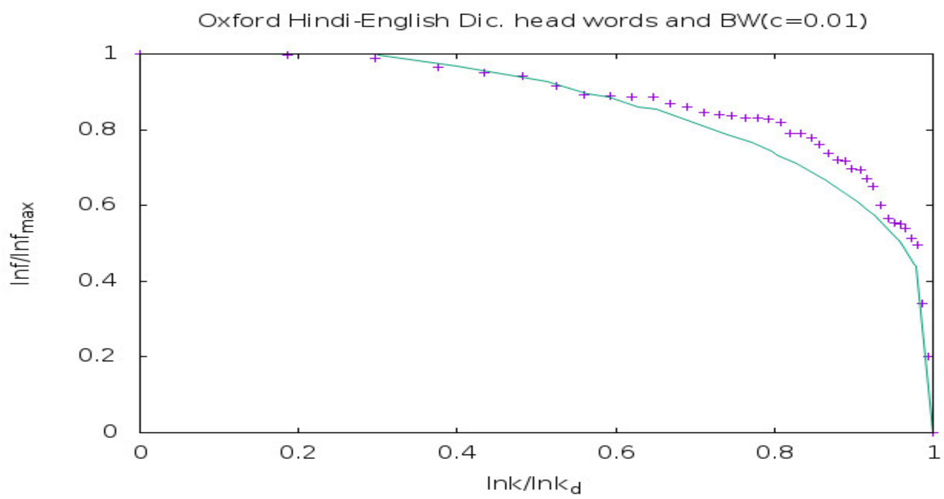

FIG. 2. The vertical axis is $\frac{lnf}{lnf_{max}}$ and the horizontal axis is $\frac{lnk}{lnk_{lim}}$. The + points represent the head words of the Oxford Hindi-English Dictionary, with the fit curve, BW(c=0.01), being the Bragg-Williams curve in the presence of external magnetic field, $c = \frac{H}{\gamma\epsilon}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

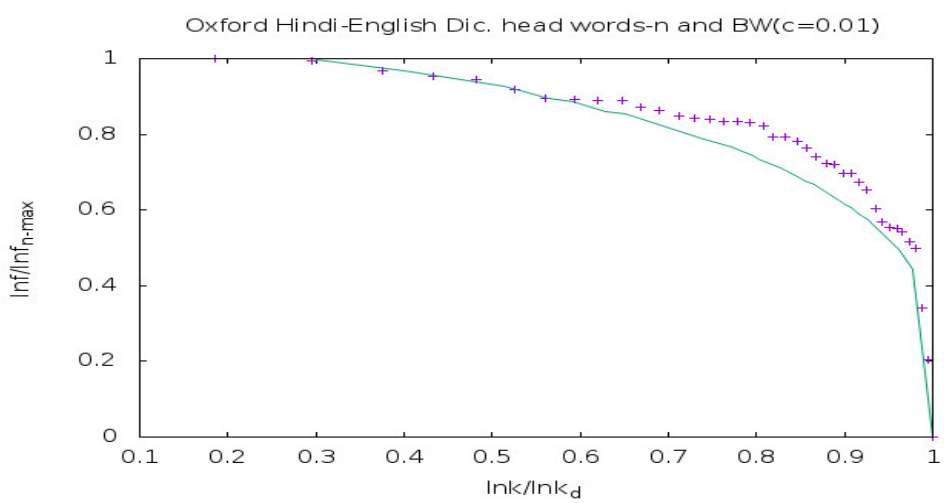

FIG. 3. The vertical axis is $\frac{lnf}{lnf_{n-max}}$ and the horizontal axis is $\frac{lnk}{lnk_{lim}}$. The + points represent the head words of the Oxford Hindi-English Dictionary, with the fit curve, BW(c=0.01), being the Bragg-Williams curve in the presence of external magnetic field, $c = \frac{H}{\gamma\epsilon}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

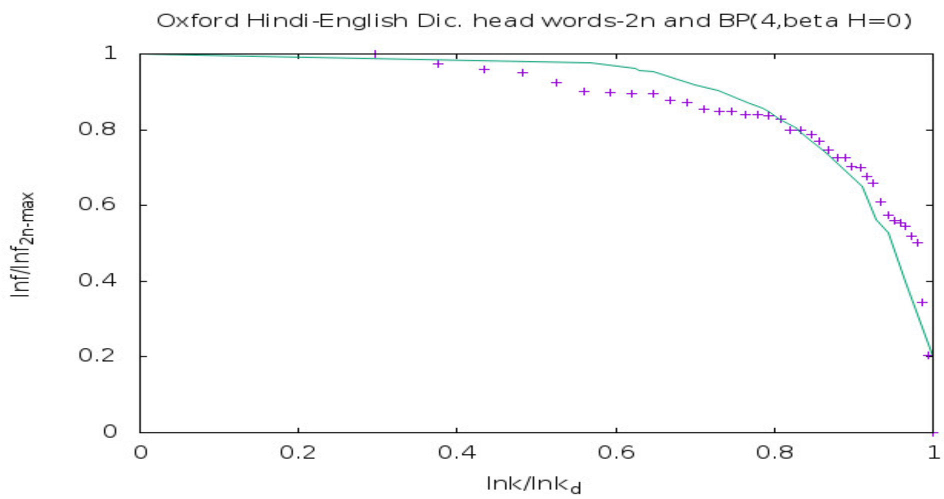

FIG. 4. The vertical axis is $\frac{lnf}{lnf_{2n-max}}$ and the horizontal axis is $\frac{lnk}{lnk_{lim}}$. The + points represent the head words of the Oxford Hindi-English Dictionary, with the fit curve, BP(4,$\beta H = 0$), being the Bethe-Peierls curve in the presence of four nearest neighbours and no external magnetic field, $m = 0$ or, $\beta H = 0$.

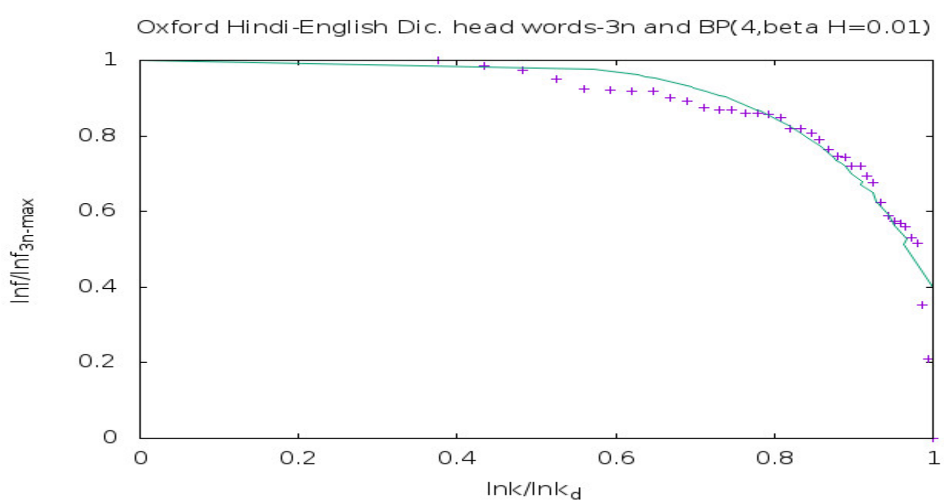

FIG. 5. The vertical axis is $\frac{lnf}{lnf_{3n-max}}$ and the horizontal axis is $\frac{lnk}{lnk_{lim}}$. The + points represent the head words of the Oxford Hindi-English Dictionary, with the fit curve, BP(4,$\beta H = 0.01$), being the Bethe-Peierls curve in the presence of four nearest neighbours and external magnetic field, $m = 0.005$ or, $\beta H = 0.01$.

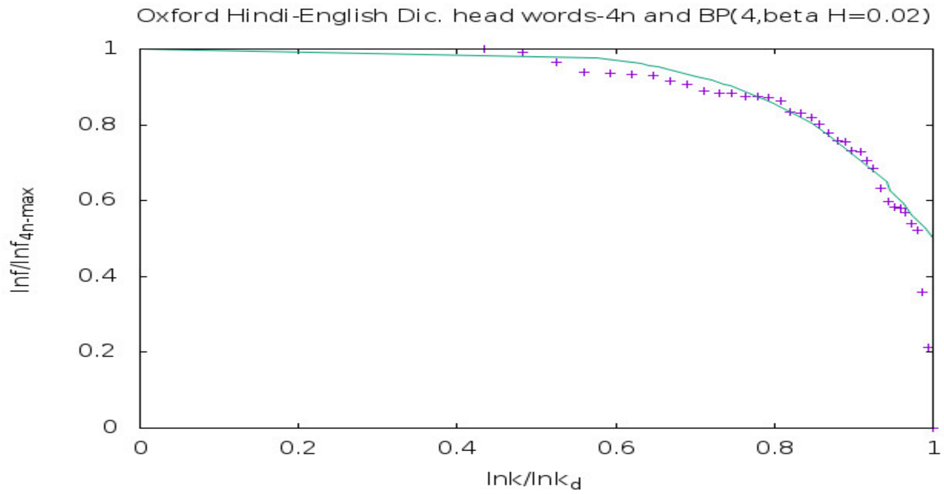

FIG. 6. The vertical axis is $\frac{lnf}{lnf_{4n-max}}$ and the horizontal axis is $\frac{lnk}{lnk_{lim}}$. The + points represent the head words of the Oxford Hindi-English Dictionary, with the fit curve, BP(4,$\beta H = 0.02$), being the Bethe-Peierls curve in the presence of four nearest neighbours and external magnetic field, $m = 0.01$ or, $\beta H = 0.02$.

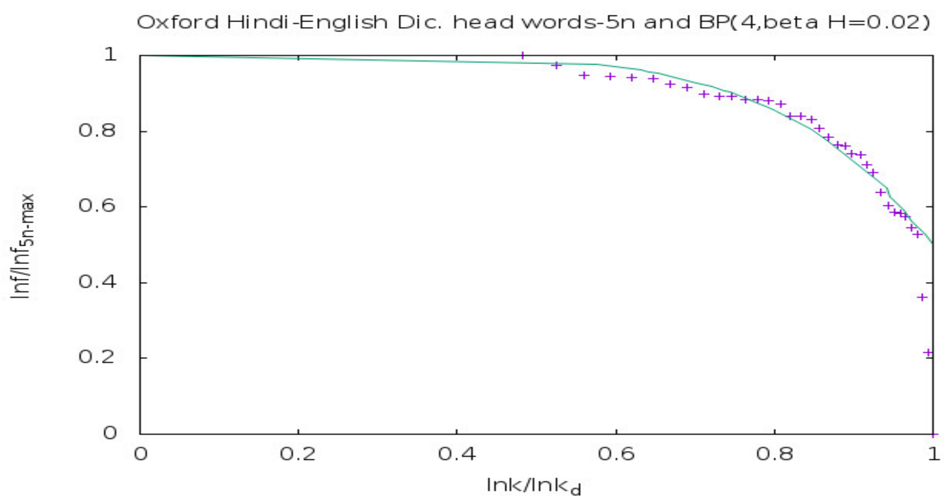

FIG. 7. The vertical axis is $\frac{lnf}{lnf_{5n-max}}$ and the horizontal axis is $\frac{lnk}{lnk_{lim}}$. The + points represent the head words of the Oxford Hindi-English Dictionary, with the fit curve, BP(4,$\beta H = 0.02$), being the Bethe-Peierls curve in the presence of four nearest neighbours and external magnetic field, $m = 0.01$ or, $\beta H = 0.02$.

A. conclusion

From the figures (fig.2-fig.7), we observe that there is a curve of magnetisation, behind the head words of the Oxford Hindi-English Dictionary,[1]. This is the magnetisation curve 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,

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

$$lnk \longleftrightarrow T.$$

k corresponds to temperature in an exponential scale, [78]. Nevertheless on successive normalisations, the head words of the Oxford Hindi-English Dictionary, go over to the magnetisation curve, BP(4,$\beta H = 0.02$). Hence, the head words of the Oxford Hindi-English Dictionary, [1], has a Bethe-Peierls core(in the presence of four nearest neighbours and in the presence of external magnetic field).

This work is to be seen in the light of our earlier set of works, [56], [57], [58].

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,[72], 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, [73], $2\epsilon\gamma\bar{\sigma} + 2H$, where γ is the number of nearest neighbours of a spin. According to Boltzmann principle, $\frac{N_-}{N_+}$ equals $exp(-\frac{\triangle E}{k_B T})$, [74]. In the Bragg-Williams approximation,[75], $\bar{\sigma} = L$, 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, $c = \frac{H}{\gamma\epsilon}$, $T_c = \gamma\epsilon/k_B$, [76]. $\frac{T}{T_c}$ 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 [73]. 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, [72],[73],[74],[75],[76], due to Bethe-Peierls, [77], 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.

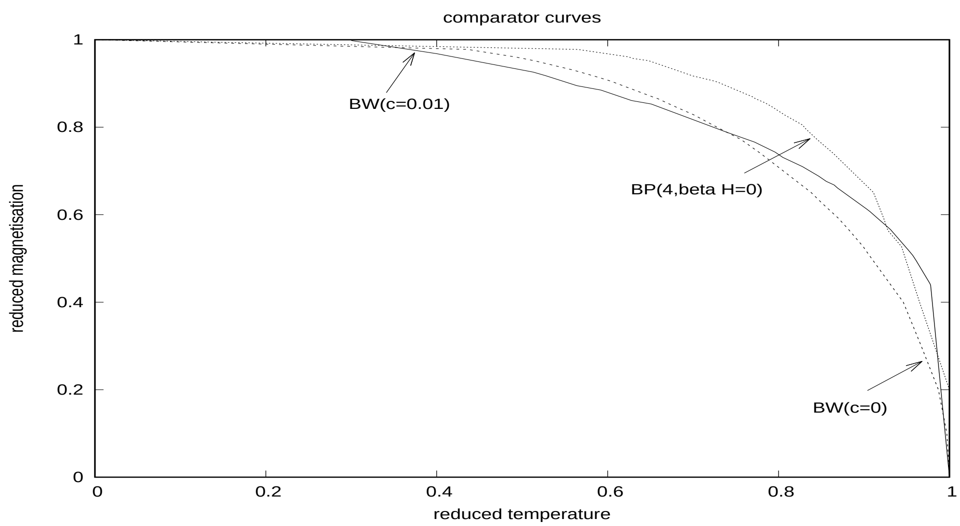

FIG. 8. Reduced magnetisation vs reduced temperature curves for Bragg-Williams approximation, in absence(dark) of and presence(inner in the top) of magnetic field, $c = \frac{H}{\gamma\epsilon} = 0.01$, and Bethe-Peierls approximation in absence of magnetic field, for four nearest neighbours (outer in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

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

In the Bethe-Peierls approximation scheme , [77], reduced magnetisation varies with reduced temperature, for γ neighbours, in presence of external magnetic field, as

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

Derivation of this formula ala [77] 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,

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

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
				0.964	0.513
			1.00		0.500
				1.00	0.400
					0.300
					0.200
					0.100
					0

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

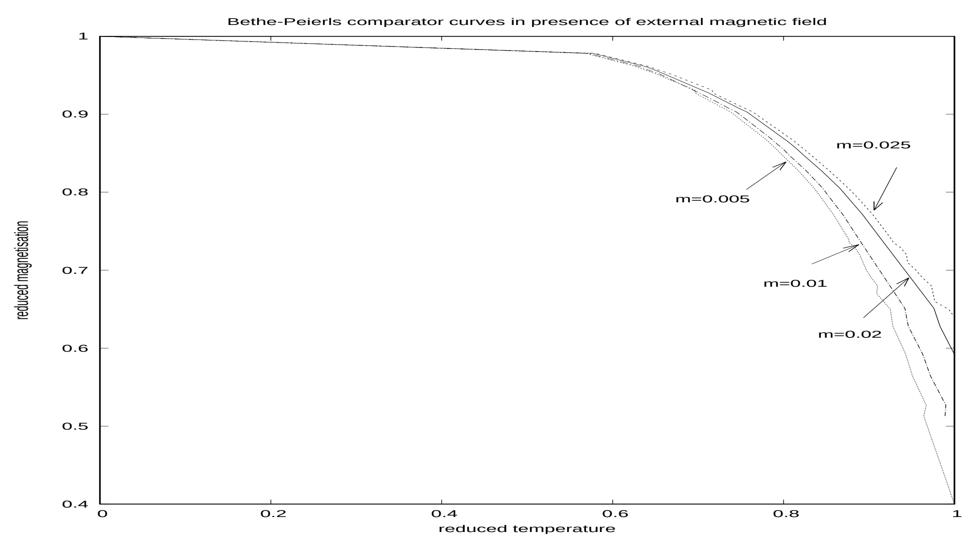

FIG. 9. Reduced magnetisation vs reduced temperature curves for Bethe-Peierls approximation in presence of little external magnetic fields, for four nearest neighbours, with $\beta H = 2m$.

IV. ACKNOWLEDGMENT

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

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