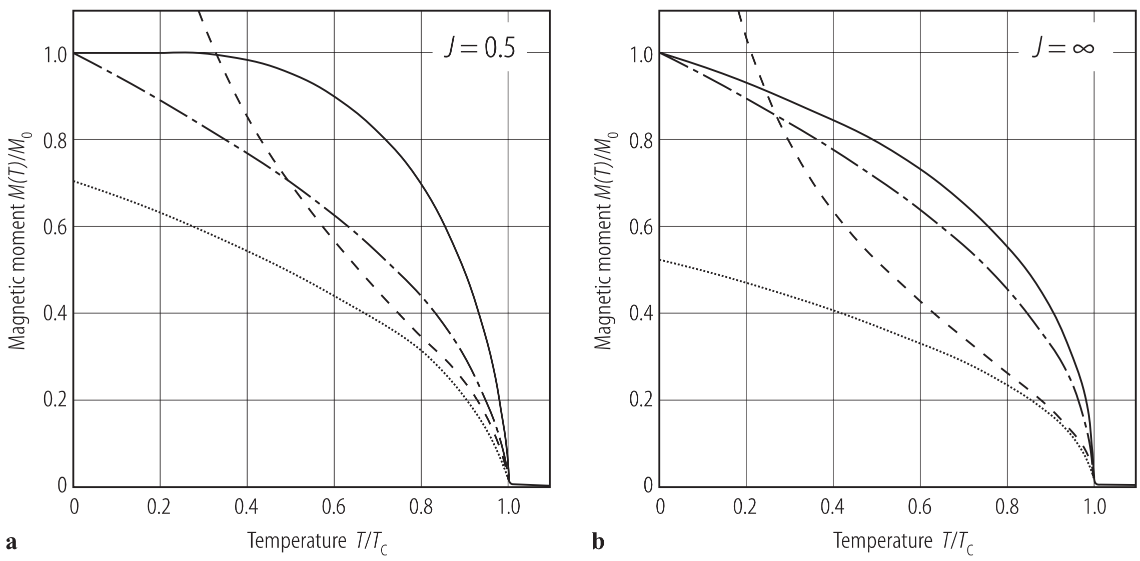

Fig. 62. Magnetisation for two values of J and for various approximations. Full line: mean field model, dashed line: high temperature series expansion with coefficients A and C temperature dependent, dotted line: high temperature expansion with C set equal to its value at T_C, dash-dotted line: high temperature expansion with C fixed such that the magnetisation at $T = 0$ is equal to the mean field value.

1.5.5.3.2.3 Magnetisation and Arrott plots

Using a temperature independent C coefficient, the magnetisation is obtained as shown in Fig. 63. The above analysis of the $\tilde{A}$ and C coefficients has shown that $\tilde{A}$ is related to the magnetic susceptibility (see eq. (24)) and that the coefficient C is determined by the higher order corrections. These corrections are connected with the deviation from linearity of the induced magnetic moment as a function of the external magnetic field. Thus the expansion coefficients of the free energy may be obtained from experiment by using the low and high field part of the magnetisation curve to extract the values of $\tilde{A}$ and C, respectively. An alternative means of analysis, which is both more direct and physically more transparent, has been proposed by Arrott [57A1]. He noticed that eq. (23) may be written in the form

$$M^2 = \frac{1}{C}\frac{(B_0)_{\text{ext}}}{M} - \frac{\tilde{A}}{C} \tag{44}$$

which resembles the equation for a straight line as given by y = mx + b. Thus, plotting the magnetisation for a given temperature as a function of field, and using as the unit on the x axis the ratio of applied magnetic field divided by the observed magnetic moment and on the y axis the square of the observed magnetic moment will yield straight lines. The graphical representation is given in Fig. 64. According to eq. (44) the lines have a slope proportional to $1/C$. They intersect the x axis at $\tilde{A}$. As temperature is varied (and $\tilde{A}(T)$ changes as a function of temperature) the lines are displaced parallel (for a temperature independent C coefficient) with respect to one another. The critical temperature is defined by the line which goes through the origin of the Arrott plot. For temperatures $T < T_C$ the lines cut the y axis at positive values of M^2, thus yielding the size of the spontaneous magnetic moment in zero external magnetic field. The intercept with the y axis is given by the ratio $-\tilde{A}/C = M^2$ (> 0 as A is negative for $T < T_C$). This result is consistent with the analysis of the free energy as given above and with the size of the magnetic moment as determined in eq. (42) or (43).

At this point some limitations of the approach should be mentioned and the shortcomings of Landau theory remarked upon. Firstly, as already seen in the discussion of the low temperature approximation of the free energy, the Landau theory does not include any fluctuations of the order parameter. For magnetic systems magnetic fluctuations (e.g. spin waves or Stoner excitations) are responsible for driving the ferromagnetic - paramagnetic phase transition. An extension of the free energy approach to include the effect of magnetic fluctuations has been given by Lonzarich and Taillefer [85L1]. In addition, for $T \approx T_C$ critical fluctuations become important and one has to expect deviations from the straight line Arrott plots (see Brommer and Franse [90B2] and [68B1] and references therein). Furthermore, for low external fields, deviations from a straight line will occur in the Arrott plot for a number of reasons. An underlying assumption of the analysis was the homogeneity of the sample. Any deviation from a homogeneous state as brought about by, for example, the magnetic domain structure of the sample, composition fluctuations or impurities will influence the magnetic moment and result in curvature of the low field parts in the Arrott plots. The curvature may be upwards or downwards depending on the physical origin of the deviations from homogeneity and temperature. A more complete discussion is given by Brommer and Franse [90B2].

In the next section an extension is given of the analysis of magnetic properties with the help of Arrott plots. The extension will be to substances which contain two magnetic subsystems. Within this group one may find two phased samples, compounds with more than either one magnetic sublattice or, alternatively, a magnetic sublattice with competing magnetic interactions. Each of these cases will be considered in turn and the effect on Arrott plots will be analysed.

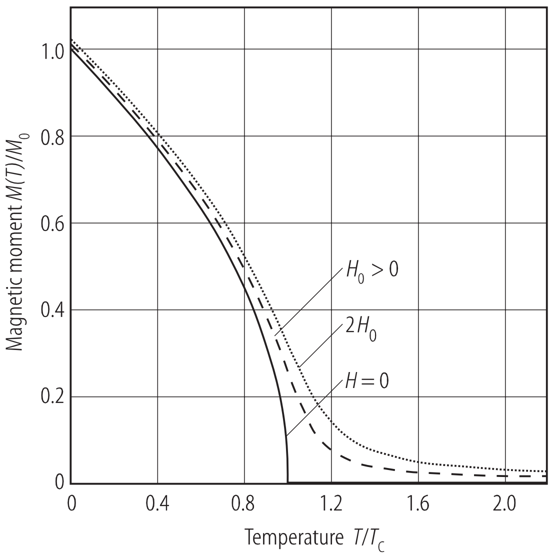

Fig. 63. Magnetic moment as a function of temperature for three different magnetic fields. Full line: the external magnetic field is zero. Dashed and dotted line: non-zero magnetic field and increasing by a factor of 2.

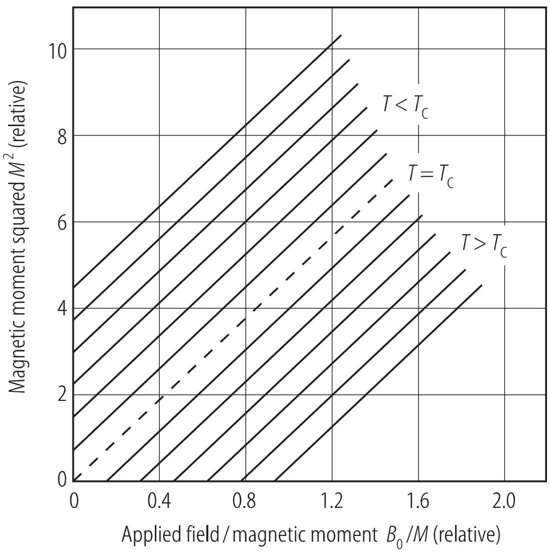

Fig. 64. Arrott plots as a function of temperature for a pure ferromagnet. The dashed line for $T = T_C$ passes through the origin and indicates the transition.