University of Calcutta

Semester 5

PHYSICS

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CURIE WIESS LAW, WIESS THEORY OF FERROMAGNETISM AND FERROMAGNETIC DOMAIN

ASSIGNMENT

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CURIE LAW

The curie law states that in a paramagnetic material, the material’s magnetization is directly proportional to an applied magnetic field. But the case is not the same when the material is heated. When it is heated, the relation is reversed i.e. the magnetization becomes inversely proportional to temperature.

Mathematically, it is written as

$M = C \times (B / T)$, where

M is the magnetization

B is the magnetic field, measured in teslas

T is absolute temperature, measured in kelvins

C is a material-specific Curie constant

BUT.....

- On increasing temperature, the magnetic susceptibility of paramagnetic materials decreases and vice versa.
- The magnetic susceptibility of ferromagnetic substances does not change according to curie law.

Various experiments by Pierre Curie showed that for many substances the susceptibility is inversely proportional to the absolute temperature T

$x = C/T$.

This relationship is defined as the Curie's law. The constant 'C' is called the curie constant. The above equation may also be modified to $x = C/(T - \theta)$, where θ is a constant. This equation is called the Curie –Weiss Law which will be discussed later.

CURIE- WEISS LAW

The Curie–Weiss law describes the magnetic susceptibility *x* of a ferromagnet in the paramagnetic region above the Curie point.

Mathematically, it is written as

$X = C/ (T-T_C)$,

Here C is a material specific Curie constant

T is the absolute temperature measured in Kelvin

T_c is the Curie temperature measured in Kelvin.

This law envisages a singularity in the susceptibility at $T=T_c$. but below this temperature, the magnet will have a spontaneous magnetization.

WIESS THEORY

In 1907, Weiss developed a theory of effective fields

Magnetic moments (spins*) in ferromagnetic material aligned in an internal (Weiss) field:

Weiss' Assumption

- **Molecular field** is acting in FM not only above Tc but also below Tc and this field is so strong that it could magnetize the substance to saturation even in the absence of an applied field. → **spontaneously magnetized** **(Self-saturating)**

- **Magnetic domain** : In demagnetized state, a ferromagnetic material is divided into a number of small regions called **domains**, each of which is spontaneously magnetized.

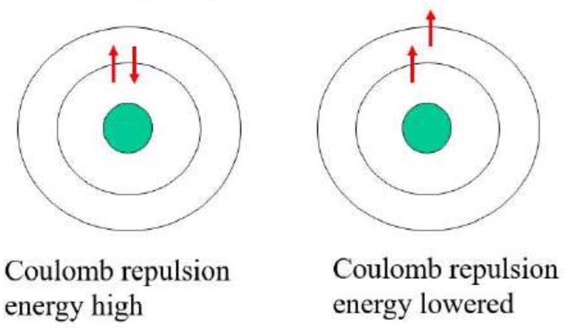
LIMITATION OF WEISS THEORY

Weiss theory is a good phenomenological theory of magnetism, But does not explain source of large Weiss field.

Heisenberg and Dirac showed later that ferromagnetism is a quantum mechanical effect that fundamentally arises from Coulomb (electric) interaction.

Key: The Exchange Interaction

- Central for understanding magnetic interactions in solids
- Arises from Coulomb electrostatic interaction and the Pauli exclusion principle



BASIC CONCEPT OF DOMAIN

- On a small scale, ferromagnetic materials are actually made up of tiny regions known as domains. Each domain behaves like a tiny magnet with a North and South pole.
- In an unmagnetized piece of iron, these domains are arranged randomly pointing in all directions. The magnetic effects end up cancelling each other out.

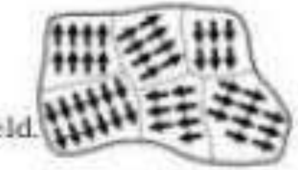
FERROMAGNETIC DOMAIN

Weiss domain theory

- Atomic magnetic moments were in **permanent existence** (Weber's hypothesis)
- Atomic magnetic moments were ordered **even in the demagnetized state**. It was the domains only which were randomly aligned in the demagnetized state.
- The **magnetization process** consisting of reorienting the domains so that more domains were aligned with field.

Magnetic Domains

- A ferromagnetic material is divided into a *large number of small region* is called domains.
- Each domain is *spontaneously magnetized.*
- The direction of magnetization various from domain to domain and the *net magnetization is zero*, in the absence external mag. field.

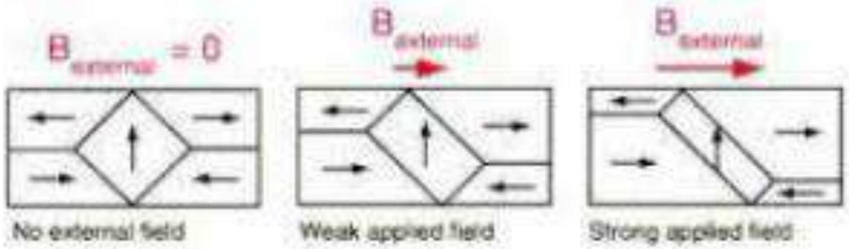


- The two domain separates by *domain wall or Block wall.*

When the magnetic field is applied to the Ferromagnetic material, the magnetizations produced by two ways.

1. ***By the motion of Domain walls***
   The weak magnetic filed is applied, the domains having dipoles parallel to the applied magnetic field *increases in area by the motion* of domain walls.

2. ***By the rotation of Domains***
   If the strong magnetic field applied, the *domains are rotated* parallel to the field direction



Energies involved in the domain growth

The total internal energy of the domain structure in a ferromagnetic material is made up from the following contributions.

1. Exchange energy
2. Crystalline energy
3. Domain wall energy
4. Magnetostriction energy.

ASSINGMENT

Explain the figure below