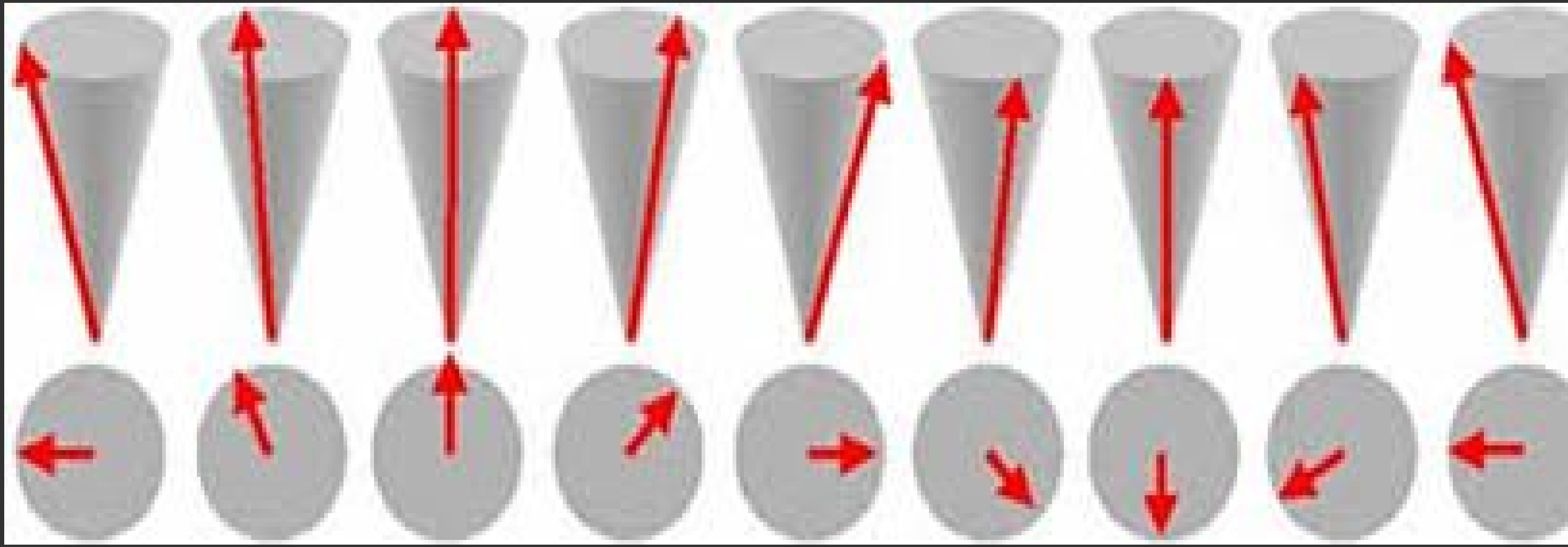
CONDENSED MATTER PHYSICS-Magnons

MAGNONS

- A Magnons is a quantization of spin waves.
- Classical interpretation of magnons in ground state.



What is magnons?

- A Magnon is a quasi particle.
- It is a collective excitation of the electron's spin structure in a crystal lattice.
- Magnons carry fixed amount of energy and momentum.

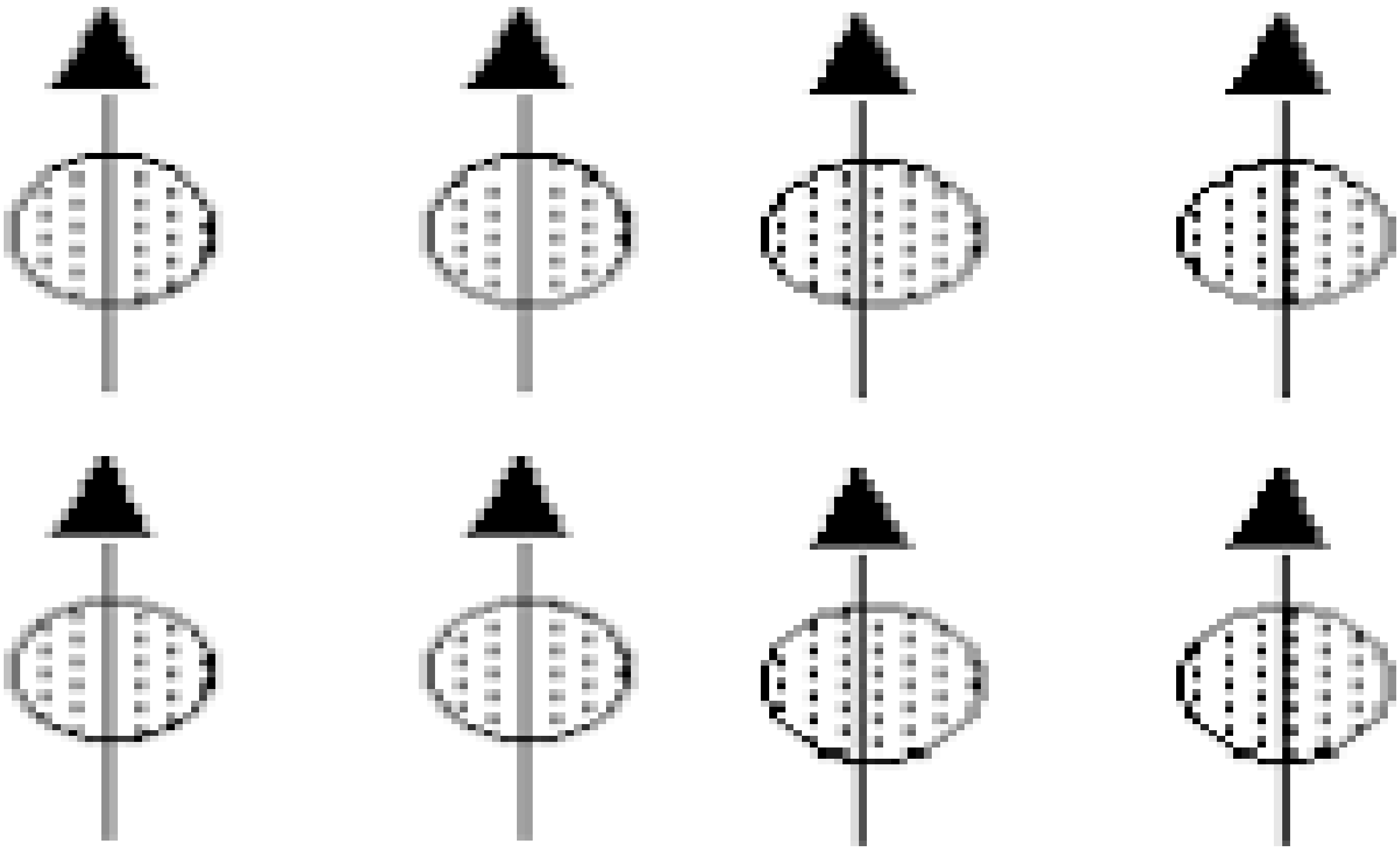
Introduction

- The concept of a magnons was introduced by FELIX BLOCH, in order to explain the reduction of the spontaneous magnetization in a Ferromagnet.

- At absolute zero temperature, a ferromagnet reaches the state of lowest energy in which all the atomic spins points in the same direction.

- When temperature increases, spin deviate randomly from the alignment.

parallel alignment



Ferromagnetism

Cont…

- This led to the increase in the internal energy and reducing in the net magnetization.
- These are called as Paramagnons.
- Paramagnons are magnons in the magnetic material which are in their high temperature, disordered phase.

PROPERTIES

- MAGNONS behaves as Bose gas with no chemical potential.
- Micro waves pumping can be used to excite spin waves and create additional non equilibrium magnons which thermalize into phonons.

To find the magnon dispersion relation

we have to quantize the magnon energy and interpret the quantization in terms of spin reversal.

"The ground state of simple Ferromagnet has all spins parallel".

- Consider N spins each of magnitude s on a line with the nearest neighbor spins coupled by Heisenberg picture.
- $U=-2J\sum S_P.S_{P+1}$
- Here, j is the exchange integral and ħsp is the angular momentum of the spin.

cont…

If we treated the spin s_p as classical vectors, then in GROUND STATE,

$$S_p . S_{p+1} = S^2$$

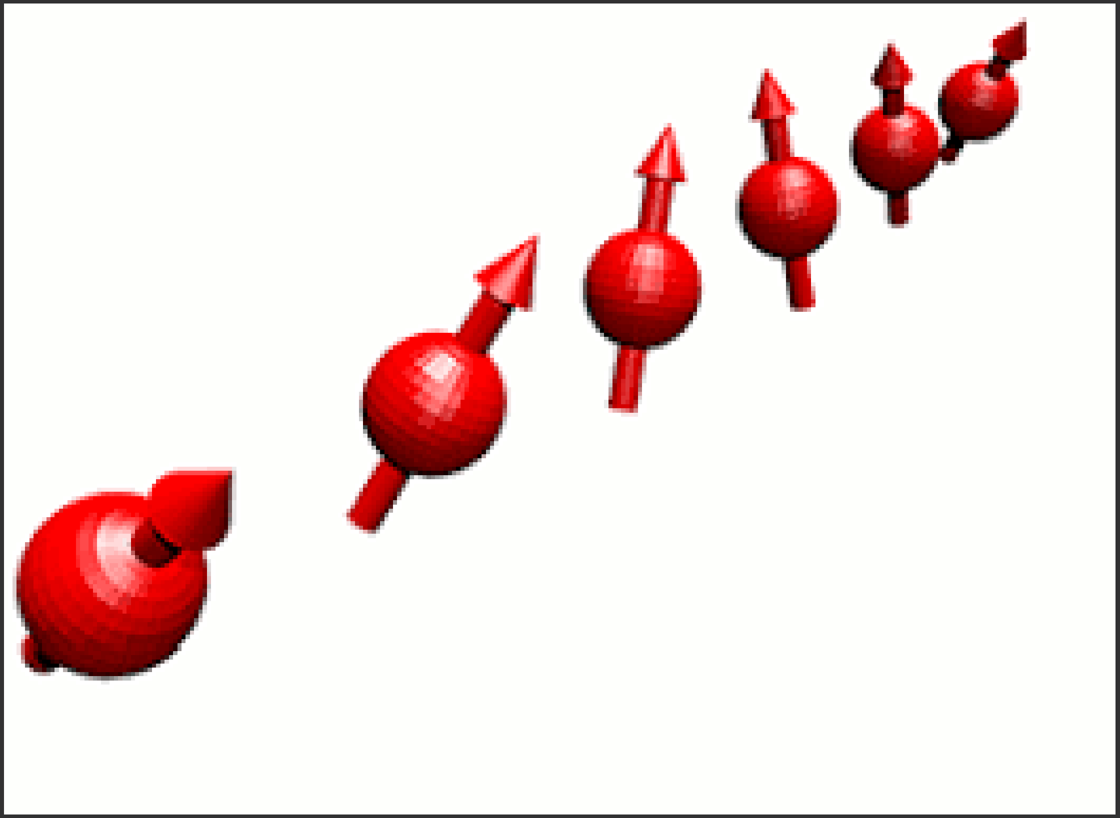
Therefore the exchange in the energy of the system U0= -2JNS^2.

FOR THE ENERGY IN THE EXCITED STATE

- Consider an excited state with one particular spin reversed.

  It increases the energy by 8JS^2.

- $U_1 = U_0 + 8JS^2$.



We can form an excitation of much lower energy if we let all the spins share the reversal.

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THE ELEMENTARY EXCITATION OF SPIN SYSTEM HAVE A WAVELIKE FORM AND ARE CALLED AS MAGNONS.

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These are analogous to phonons.

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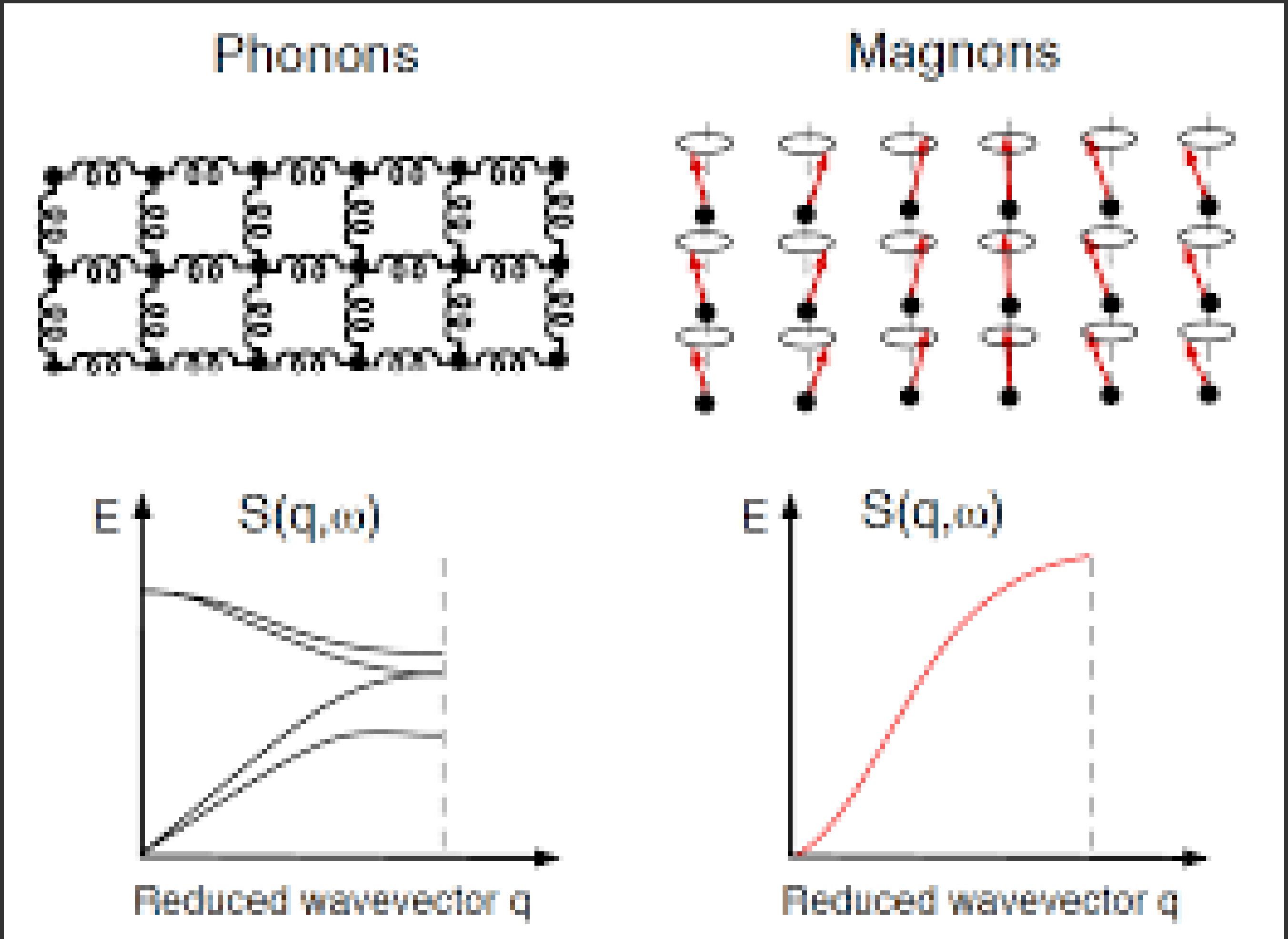
spin waves are oscillations in the relative orientations of a spin in lattice. *[for magnons]*

Lattice vibrations are the oscillations in the relative positions of atoms on a lattice. [for phonons]


Phonons
Magnons
E
S(q,ω)
Reduced wavevector q
E
S(q,ω)
Reduced wavevector q

Classical derivation of the magnon dispersion relation

- These terms involve
- Magnetic moment (μ_p),
- Effective magnetic field (B_p),
- Rate of change of the angular momentum $\hbar S_p$.
- These equations involves the product of spin components and non linear.

Cont…

- $\hbar\omega = 4JS(1 - \cos ka)$
- The above equation is the dispersion relation for spin waves in one dimension.
- Here the frequency is proportional to k^2.

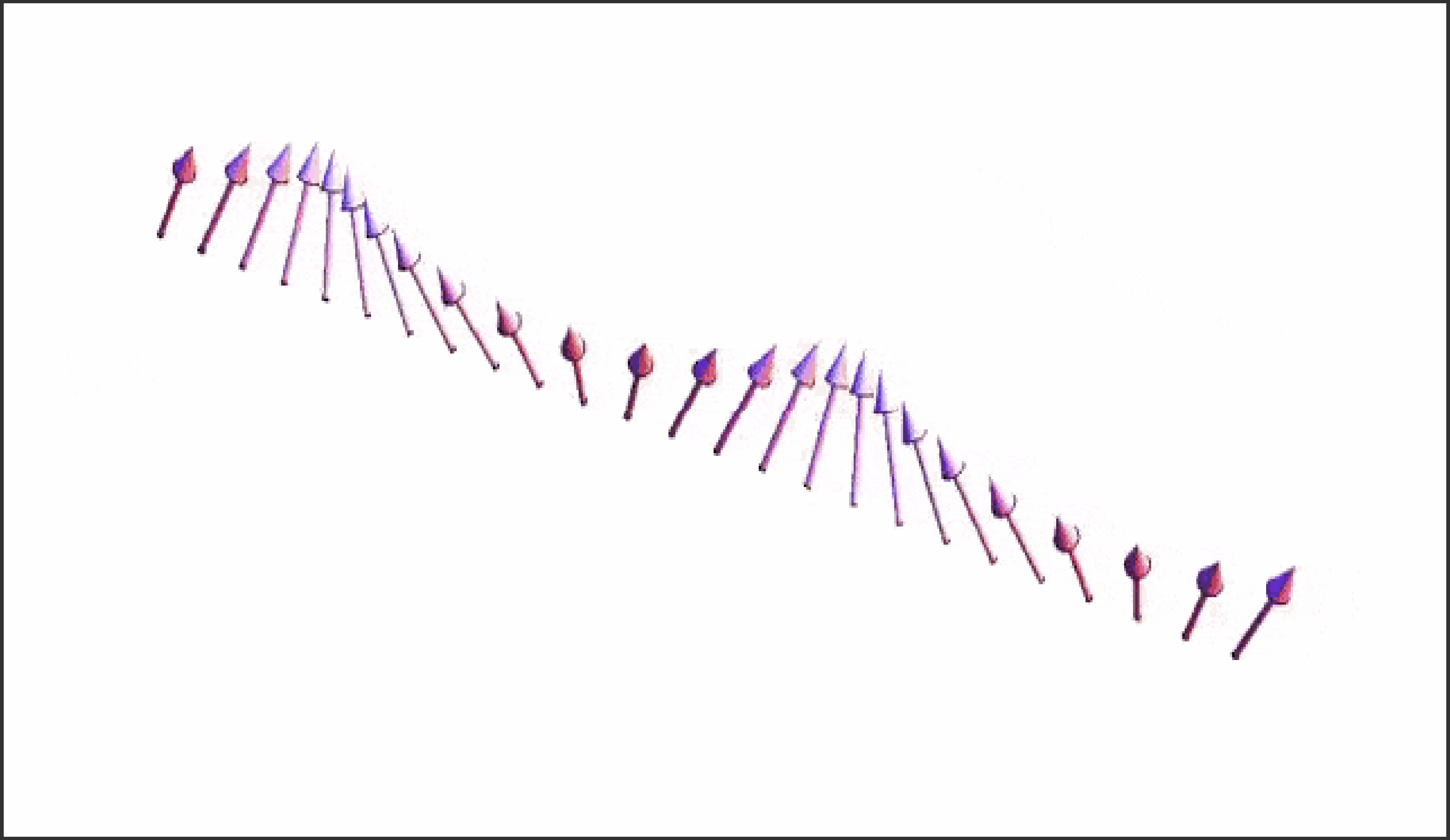
The coefficient of K^2 may be determined accurately by the spin wave resonance in the thin films.

Quantization of spin waves

- The quantization of spin waves proceeds exactly as for phonons and photons.
- The energy of a mode of frequency ω_k with n_k magnons is given by

$$\varepsilon_k=(n_k+1/2)h\omega_k$$

- The excitation of magnons corresponds to the reversal of one spin ½.



Thermal excitation of magnons

- When temperature T is applied, the total number of magnons excited be
- $\sum n_k = \int d\omega\, \mathcal{D}_\omega \langle n(\omega) \rangle$
- where $D\omega$ is the number of magnon modes per unit frequency.
- At sufficiently low temperature, the integral ranges from 0 to ∞.

BLOCH $T^{3/2}$ LAW

The number N of atoms per unit volume is Q/a^3.

Where Q=1,2,4 for sc, bcc, fcc lattices respectively.

$\Delta M/M(0)=(0.0587/SQ).(K_BT/2JS)^{3/2}$.

In neutron scattering experiments, spin waves have been observed up to temperatures near the curie temperatures and even above the curie temperature

THANK YOU