

Condensed Matter Physics
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Lecture - 14
Lattice Vibrations (Continued)
Phonon Thermal Conductivity – Worked Examples


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Problem 37

Choose the correct alternative(s) in the following:

Thermal conductivity of an (electrical) insulator

- A. is proportional to the cube of the absolute temperature T at low temperatures
- B. has a strong exponential temperature dependence at intermediate temperatures
- C. is inversely proportional to T at high temperatures
- D. is a linear function of the temperature



NPTEL

Next we are talking about thermal conductivity of an electrical insulating material, insulator or dielectric material. Now which are the alternatives is correct is proportional to the cube of the absolute temperature T at low temperatures which is obviously correct. Has a strong exponential temperature dependence at intermediate temperatures, this is because of the Umklapp process, this also correct. And it is inversely proportional to T at high temperatures, which is also correct. But it is not linear function of the temperature. So the correct alternatives are a, b and c.


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Problem 38

Choose the correct alternative(s) in the following:

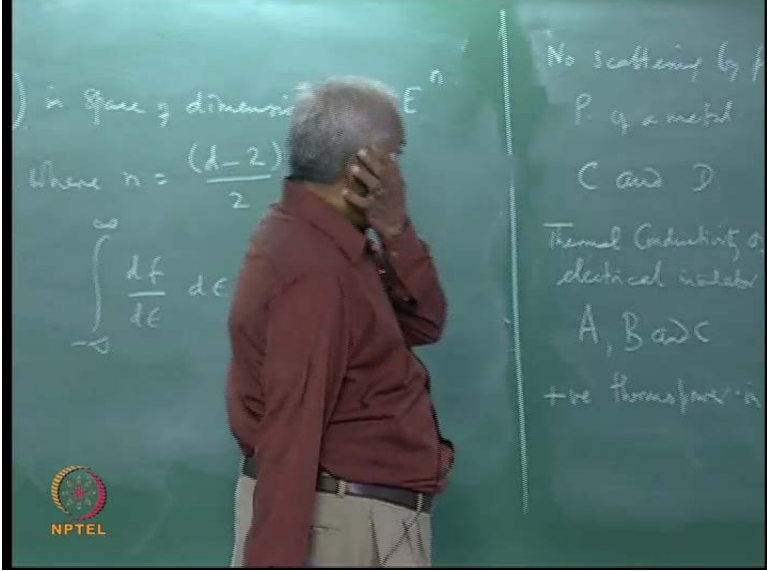
A positive thermoelectric power in a metal may arise from

- A. phonon drag
- B. electron diffusion
- C. normal processes in phonon scattering
- D. Umklapp processes in phonon scattering




Then the next question statement is about positive thermo power.

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in space of dimension E^n
where $n = \frac{(d-2)}{2}$
 $\int_{-\infty}^{\infty} \frac{df}{dE} dE$

No scattering by P of a metal
C and D
Thermal Conductivity of electrical insulator
A, B and C
+ve thermopower in




Usually if it is a metal, in a metal, we know the thermo power has a negative sign. So the only way this can become positive is because of Umklapp which can reverse the phonon wave vector. So obviously the phonon, the alternative d is obviously correct that means alternative a about phonon drag is also correct. So the correct alternatives are a and d.

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Problem 39

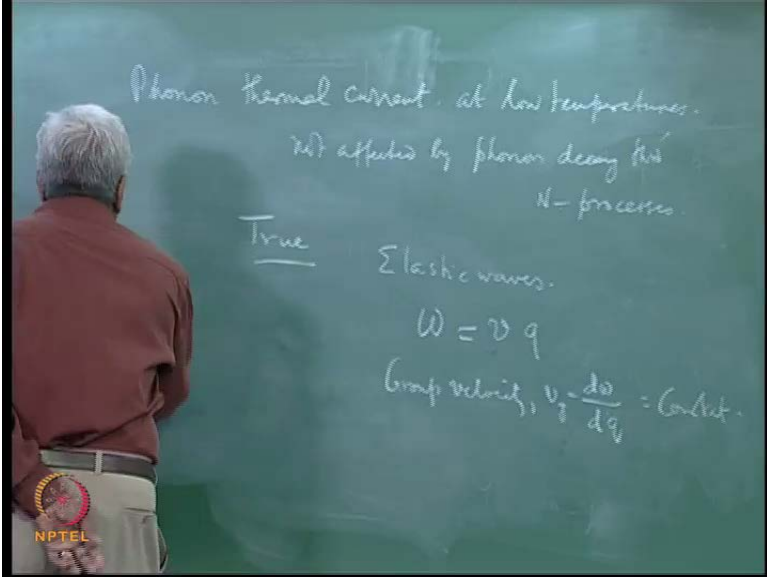
State whether the following statement is true or false, giving reasons for your answer.

The thermal current due to phonons at low temperatures is not affected by phonon decay through N- processes.



Next we are given the statement and ask to check whether it is true or false. And we are ask to justify the answer.


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Phonon thermal current, at low temperatures,
not affected by phonon decay through
N-processes.

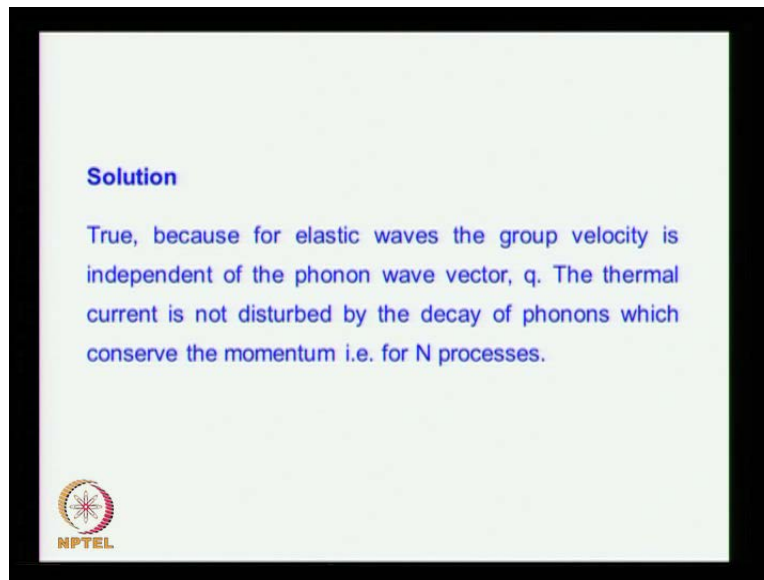
True

Elastic waves.
 $\omega = v q$
Group velocity, $v_g = \frac{d\omega}{dq} = \text{Constant}$.



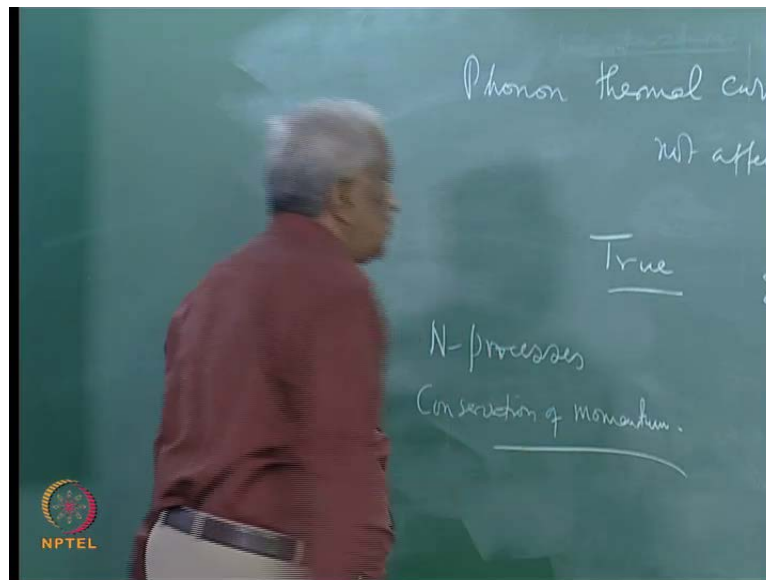
So the thermal current due to phonons at low temperatures, the statement is that this is not affected by phonon decay, not affected by phonon decay through normal N processes.

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So this is the statement and we are asked whether this is correct or not. The statement is true. The reason for this is, if we have elastic waves, phonons are nothing but excitation of elastic waves, and therefore, the group velocity ω , the dispersion relation is $\omega = v q$, where q is phonon wave vector, v is the speed of sound. So the group velocity v_g which is $d\omega/dk$, $d\omega/dq$ in this case is constant. So phonons have a constant group velocity, so the thermal conduction is mainly determined by the group velocity of the phonon. Therefore, the thermal current is not disturbed by the decay of phonon, which conserve the momentum, because the group velocity is constant.

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Therefore, processes – N-processes are one in which momentum is conserved, it is only the u processes in which the momentum is not conserved. So when the momentum is conserved that is consistent with the group velocity being constant, therefore such processes do not affect the thermal current. So the statement is correct.