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NPTEL

Courses » Micro and nano scale energy transport

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Unit 8 - Week 7

Course outline

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Week 7

● Non-equilibrium energy transport at Nanoscales: Boltzmann Transport Equation (BTE)

● Boltzmann Transport Equation under the relaxation time approximation

● Derivation of Continuum laws from Boltzmann Transport Equation Part 1

○ Derivation of Continuum laws from Boltzmann Transport Equation Part 2

○ Quiz : Week 7 Assignment 1

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Week 8

Week 7 Assignment 1

The due date for submitting this assignment has passed. **Due on 2017-09-18, 23:59 IST.**

Submitted assignment

Answer all questions. More than one answer may be correct

1.1)For 1- particle distribution during a transport process, the complex Lionville equation is converted into BTE using   *1 point*

   ☐ A) By adding a collision term to the equation

   ☐ B) Using relaxation time approach

   ☐ C) Using BGK approximation

   ☐ D) None of the above

No, the answer is incorrect.
Score: 0

Accepted Answers:
A) By adding a collision term to the equation
B) Using relaxation time approach
C) Using BGK approximation

2) The scattering integrals are used to   *1 point*

   ☐ A) represent the net change in the scattering of the two particle collision

   ☐ B) calculate the collision term

   ☐ C) convert the multi-body problem into computationally possible single particle problem

   ☐ D) solve both equilibrium and transport phenomena

No, the answer is incorrect.
Score: 0

Accepted Answers:
A) represent the net change in the scattering of the two particle collision
B) calculate the collision term
C) convert the multi-body problem into computationally possible single particle problem

3) Consider the correct statements about Relaxation time approximation   *1 point*

   ☐ A) Relates transport distribution function to equilibrium distribution function

   ☐ B) Simplifies collision term into distribution function and relaxation time

   ☐ C) It is also called as Bhatnagar-Gross-Krook approximation

   ☐ D) All the above

No, the answer is incorrect.
Score: 0

Accepted Answers:
D) All the above

4) Consider the following statements about BGK approximation. Identify the false statements.   *1 point*

☐ A) Particle interaction is explained

☐ B) Change in the wave vector of the particles due to collisions, are considered

☐ C) represents complex collision term into simplified expression

☐ D) All the above

No, the answer is incorrect.
Score: 0

Accepted Answers:
A) Particle interaction is explained
B) Change in the wave vector of the particles due to collisions, are considered

5) The relaxation time used in the BGK approximation refers to   *1 point*

☐ A) the time scale required to bring transport distribution function to equilibrium distribution function

☐ B) The collisions between the particles

☐ C) The scattering of the particles to get back to equilibrium

☐ D) None of these

No, the answer is incorrect.
Score: 0

Accepted Answers:
A) the time scale required to bring transport distribution function to equilibrium distribution function
B) The collisions between the particles
C) The scattering of the particles to get back to equilibrium

6) Consider the true statements regarding Non-dimensional form of BTE   *1 point*

☐ A) Knudsen number will appear in the equation

☐ B) For continuum, the collision term will be significant

☐ C) Advection will be insignificant while approacing the continuum limit

☐ D) Ballistic transport phenomena can be seen when collision term is important

No, the answer is incorrect.
Score: 0

Accepted Answers:
A) Knudsen number will appear in the equation
B) For continuum, the collision term will be significant
C) Advection will be insignificant while approacing the continuum limit

7) Choose the correct statements   *1 point*

☐ A) BTE is self sufficient equation which carries information depending up on the working regime

☐ B) A linear temperature profile will be observed between the walls of hot and cold sides when collision term approaches free molecular limit

☐ C) A high Knudsen number results in ballistic transport of the carriers

☐ D) All the above

No, the answer is incorrect.
Score: 0

Accepted Answers:
A) BTE is self sufficient equation which carries information depending up on the working regime
C) A high Knudsen number results in ballistic transport of the carriers

8) Identify the correct pairs   *1 point*

☐ A) Phonon-phonon scattering -- thermal resistance

☐ B) Electron-phonon scattering -- electrical resistance

☐ C) Phonon- boundary scattering -- free molecular limit

☐ D) Phonon-impurity scattering -- high Knudsen number

No, the answer is incorrect.
Score: 0

Accepted Answers:
A) Phonon-phonon scattering -- thermal resistance
B) Electron-phonon scattering -- electrical resistance
C) Phonon- boundary scattering -- free molecular limit

9) During Umklapp's scattering, the reciprocal vector is used to   *1 point*

    ☐ A) correct the wave vector to be within Brillioun zone

    ☐ B) make the resultant wave vector space physical

    ☐ C) conserve the energy during the collision

    ☐ D) conserve the momentum during the collision

No, the answer is incorrect.
Score: 0

Accepted Answers:
A) correct the wave vector to be within Brillioun zone
B) make the resultant wave vector space physical
D) conserve the momentum during the collision

10) The finite thermal conductivity of the bodies is the result of   *1 point*

    ☐ A) Umklapp scattering

    ☐ B) The resistance applied during post collision of the carriers

    ☐ C) Normal scattering

    ☐ D) all the above

No, the answer is incorrect.
Score: 0

Accepted Answers:
A) Umklapp scattering
B) The resistance applied during post collision of the carriers

11) Limitations of Boltzmann Transport Equation (BTE)   *1 point*

    ☐ A) Particle approach

    ☐ B) Applied to liquid molecules

    ☐ C) Applicable for dilute systems like phonons, electrons and gas molecules

    ☐ D) All the above

No, the answer is incorrect.
Score: 0

Accepted Answers:
A) Particle approach
C) Applicable for dilute systems like phonons, electrons and gas molecules

12) The constitutive equations for continuum transport processes can be derived from BTE   *1 point*

    ☐ A) Assuming the change in the distribution function from equilibrium distribution, is small

    ☐ B) Gradients of change in distribution function are significant

    ☐ C) Transient terms are negligible

    ☐ D) All the above

No, the answer is incorrect.
Score: 0

Accepted Answers:
A) Assuming the change in the distribution function from equilibrium distribution, is small
C) Transient terms are negligible

13) While deriving Fourier's law of heat conduction through BTE   *1 point*

    ☐ A) Thermal conductivity is shown interms of heat capacity, phonon velocity and relaxation time

    ☐ B) The wave vector space is converted into physical space interms of spherical coordinates

    ☐ C) The net heat flux is given interms of energy distribution, phonon velocity and volume of the system

    ☐ D) None of these

No, the answer is incorrect.
Score: 0

Accepted Answers:
A) Thermal conductivity is shown interms of heat capacity, phonon velocity and relaxation time
B) The wave vector space is converted into physical space interms of spherical coordinates
C) The net heat flux is given interms of energy distribution, phonon velocity and volume of the system

14) Choose the correct statements   *1 point*

   ☐ A) Kinetic theory of gases and BTE predicts the same expression for thermal conductivity

   ☐ B) BTE gives the thermal conductivity dependency on frequency

   ☐ C) Kinetic theory of gases captures the size effects on thermal conductivity

   ☐ D) All the above

No, the answer is incorrect.
Score: 0

Accepted Answers:
A) Kinetic theory of gases and BTE predicts the same expression for thermal conductivity
B) BTE gives the thermal conductivity dependency on frequency

15) Ohm's law can be derived from the BTE   *1 point*

   ☐ A) Assuming a Lorentz force due to the electric field

   ☐ B) Considering the effect of Fermi energy level on the equilibrium distribution function

   ☐ C) Isothermal condition for metal/semiconductor, is used

   ☐ D) All the above

No, the answer is incorrect.
Score: 0

Accepted Answers:
D) All the above

16) For the transport processes, the following are to be considered   *1 point*

   ☐ A) The number distribution of quantum states

   ☐ B) The energy associated with the energy states

   ☐ C) The position vector and momentum vector of these states

   ☐ D) All the above

No, the answer is incorrect.
Score: 0

Accepted Answers:
D) All the above

17) Choose the correct statements   *1 point*

   ☐ A) In Phase-space diagram, each point represents a quantum state

   ☐ B) A collection of scattered quantum states identified as an ensemble

   ☐ C) During, the transport process, the ensemble of quantum states will be advected with time

   ☐ D) None of the above

No, the answer is incorrect.
Score: 0

Accepted Answers:
A) In Phase-space diagram, each point represents a quantum state
B) A collection of scattered quantum states identified as an ensemble
C) During, the transport process, the ensemble of quantum states will be advected with time

18) The degrees of freedom for each particle during a transport process is given as   *1 point*

   ○ A) 1

   ○ B) 3

   ○ C) 6

   ○ D) 2

No, the answer is incorrect.

Score: 0

Accepted Answers:

C) 6

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