

Nano-to-Macro Transport Processes

Graduate Course No: 2.57
Undergraduate Course No. 2.570

Spring 2022 Tentative Schedule

Professor Gang Chen
Tel: (617) 253-0006
Email: gchen2@mit.edu

Time: TTh 9:30-11:00 AM

Location: 3-370

Office Hours: Tuesday 11:00-1:00 or by appointment

TAs: Ms. Qian Xu and Mr. Lenan Zhang

TA Office Hour and Location: Wednesday 4-6 pm, 7-008

Catalog Description: Parallel treatments of photons, electrons, phonons, and molecules as energy carriers, aiming at fundamental understanding and descriptive tools for energy and heat transport processes from nanoscale continuously to macroscale. Topics include the energy levels, the statistical behavior and internal energy, energy transport in the forms of waves and particles, scattering and heat generation processes, Boltzmann equation and derivation of classical laws, deviation from classical laws at nanoscale and their appropriate descriptions, transport in liquid, with applications in energy, materials, microelectronics, nano- and microtechnology.

Website:

Homework: Weekly homework (other than noted), due on Thursday Class.

Graduate Students: homework plus weekly paper reading

Undergraduate Students: homework

Grading:	Undergraduate Students:	Graduate Students
	Homework: 70%	Homework: 40%
	One take-home midterm: 30%	One take home midterm: 30%
		Final Project: 30%

For undergraduate students, no weekly paper report

15% Bonus for Undergraduate Following Graduate Assignments

No final exam

Textbook:

G. Chen, Nanoscale Energy Transport and Conversion, Oxford University Press, 2005.

MIT Open Courseware On 2.57

<https://ocw.mit.edu/courses/mechanical-engineering/2-57-nano-to-macro-transport-processes-spring-2012/>

This site has videos, lecture notes, and other materials of 2.57 taught in 2012 and 2004

2. Weekly Paper Readings

Every week includes a list of suggested papers. Weekly homework will include reading assignment to one paper (for graduate students).

3. Project

By March 31, a one-page project proposal due.

Final project report: Applied Physics Letters style

Final project presentation: 10 minutes presentation + 2 minutes Q&A

Tentative Schedule

Week 1

- 2/1 L1: Introduction, classical laws and scaling trend, microscopic pictures of energy, momentum, and heat carriers (C1).
2/3 L2: Characteristic time and length, simple kinetic theory (C1)

Week 2

- 2/8 L3: Materials waves and Schrödinger equation (C2).
2/10 L4: Solutions to Schrödinger equation, energy quantization (C2).
HW No. 1 due

Week 3

- 2/15 L5: Electronic levels in one-dimensional lattice chain (C3)
2/17 L6: Crystal structure and electronic energy levels in crystals (C3)
HW No. 2 due

Week 4

- 2/22 Monday class schedule, no class
2/24 L7: Crystal bonding potential, reciprocal lattice (C3)
HW No. 3 due

Week 5

- 3/1 L8: Phonon energy levels in crystals, density of states (C3)
3/3 L9: Density of states, quantum statistics, specific heat and Planck's blackbody radiation (C4)
HW No. 4 due

Week 6

- 3/8 L10: Fundamental of statistical thermodynamics (C4).
3/10 L11: Plane waves and reflection: materials wave (C5)
HW No. 5 due

Week 7

- 3/15 L12: Electromagnetic waves and reflection at an interface (C5)
3/17 L13: EM wave reflection at a single interface, acoustic waves (C5)
HW No. 6 due

Week 8

Spring Break

Week 9

- 3/29 L14: EM and acoustic waves propagation through multilayers, interference (C5)
3/31 L15 Landauer formalism, group velocity, transition to particle description (C5)
HW No. 7 due

Project proposal due

Week 10

- 4/5 L16: Liouville equation, Boltzmann transport equation (C5, C6)

4/7 **L17:** Fermi golden rule, relaxation time approximation, scattering, derivation of Fourier law from Boltzmann transport equation (C6)
HW No. 8 due

Week 11 (no hw due this week)

4/12 **L18:** Newton's shear stress law, Ohm's law and thermoelectric effect (C6)

Take home midterm out 1:00 pm

4/14 **L19:** Derivation of Navier-Stokes equations from Boltzmann transport equation (C6)

Take home midterm due 11:00 am

Week 12 (no homework due this week)

4/19 **L20:** Classical size effects, parallel direction (C7)

4/21 **L21:** Diffusion approximation with slip boundary condition (C7)

Week 13

4/26 **L22:** Coupled energy transport and conversion, PN junctions and solar cells (C8)

4/28 **L23:** Liquid and their description (C9)

HW No. 9 due

Week 14

5/3 **L24:** Electric double layer, size effects in phase change (C9)

5/5 **L25:** Linear response theory (C10)

HW No. 10 due

Week 15 (no homework due this week)

5/10 **L26:** Final class presentation, 11:00 am-2:00 pm

(extra time reserved depending on number of presentations, may add more time depending on registration)

Project report due 10:00 pm