Course Title: "**Plasma Physics**"
"**離子體物理**" (PHYS 535)

Teacher: Prof. **Tsun-Hsu Chang (張存續)**

Department of Physics, National Tsing Hua University, Taiwan
Room 417, Tel. 42978, E-mail: thschang@phys.nthu.edu.tw

Teaching Assistant: **Tien-Fu Yang (楊添福)**
steven168168168@gmail.com

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1. Description: Plasma Physics is an extension of Electrodynamics. We will start with the introduction of plasma, followed by the single-particle motion, and then discuss the Vlasov equation with the knowledge of complex variables and contour integration. Mathematical capability and high-level knowledge of plasma physics will be covered. The aim of the course is to cultivate students to have independent learning capability and presentation capability.

2. Textbook: Dwight R. Nicholson, "Introduction to Plasma Theory" Chapters 1, 2, and 6 (supplemented by Special Topic(s)).

3. Principal References:

- Francis F. Chen, "Introduction to Plasma Physics and Controlled Fusion"; https://link.springer.com/book/10.1007/978-3-319-22309-4
- Krall and Trivelpiece, "Principles of Plasma Physics";
- E. Kreyszig, "Advanced Engineering Mathematics";
- J. D. Jackson, "Classical Electrodynamics".

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4. Time: Thursdays R5R6R7 (13:20-14:40 & 14:50-16:00). 150 min will be used for lecture. Others may be used for Q&A, etc.

5. Classroom: Physics Building R50?

6. Conduct of Class: The course is offered in English, but important physical concepts may be reiterated in Chinese. Students have to go through the math in the lecture notes before attending classes. Questions are strongly encouraged.

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7. Grading Policy: Midterm and final oral presentations (50%×2); Class participation (5% extra). The overall score will be normalized to reflect an average consistency with other courses.

Week	Date	Content
1	02/17	Course Introduction & Chap.1 Introduction
2	02/24	Chap.1
3	03/03	Chap.1
4	03/10	Chap.2 Single Particle Motion & PowerPoint preparation guideline
5	03/17	Chap.2
6	03/24	Open cavity (EM wave only)
7	03/31	Linear efficiency and bunching mechanism (linear)
8	04/07	Intercollegiate activities (no class)
9	04/14	**Oral presentation**
10	04/21	Chap.6 Vlasov Equation
11	04/28	Gain and bandwidth (dispersion relation, linear)
12	05/05	Start-oscillation currents (linear)
13	05/12	Non-linear, fixed-field oscillation (nonlinear)
14	05/19	Non-linear, self-consistent oscillation (nonlinear)
15	05/26	Chap.6
16	06/02	Chap.6
17	06/09	Make-up (if necessary)
18	06/16	**Oral presentation**

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* This table is for your reference only. The practical schedule depends on the students' learning condition.

8. Lecture Notes:

The first three chapters of the lecture notes come from Nicholson and then follow by two selected topics, all starting from basic equations.

As in Nicholson, we adopt the Gaussian unit system. The conversion between different unit system can be found in Jackson.

Equations numbered in the format of (1.1), (1.2)... refer to Nicholson. Supplementary equations derived in lecture notes, which will later be referenced, are numbered (1), (2)... [restarting from (1) in each chapter.] Equations in Appendices A, B…of each chapter are numbered (A.1), (A.2)…and (B.1), (B.2)…

Page numbers cited in the text (e.g. p. 120) refer to Nicholson.

Section numbers (e.g. Sec. 1.1) refer to Nicholson. Main topics within each section are highlighted by **boldfaced** characters. Some words are typed in *italicized* characters for attention. Technical terms which are introduced for the first time are underlined.

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9. Core capabilities: to be cultivated through this course:

- ●物理相關數學能力 Mathematical capability in physics (25%)
- ●高階物理知識 High-level knowledge of physics (25%)
- ●自主學習能力 Independent learning capability (20%)
- ●溝通表達能力 Communication and expression capability (30%)

10. Course keywords: plasma frequency, single particle motion, Vlasov equation, magnetized plasma, instability, electron cyclotron maser.

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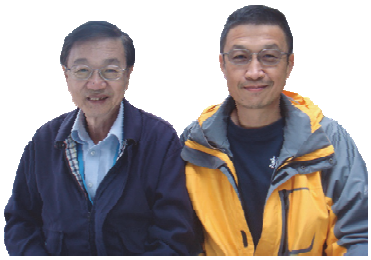

Special thanks to Prof. Kwo-Ray Chu (朱國瑞), who provided the original version of the lecture notes.
Professor Kwo-Ray Chu taught me Plasma Physics 20+ years ago.

朱國瑞教授曾獲得之學術榮譽

- Fellow, American Physical Society (1983)
- 國科會物理傑出研究獎 Outstanding Research Award, National Science Council（1986-1995, five times）
- 中華民國物理學會第一屆會士 Fellow, The Physical Society of Republic of China（1994）
- 教育部第一屆國家講座 National Chair Professor, Ministry of Education（1997）
- Fellow, Institute of Electrical and Electronics Engineers (IEEE) (1997)
- 2001 IEEE Plasma Science and Application Award (IEEE Nuclear and Plasma Sciences Society)
- 2001 K.J. Button Medal and Prize (Institute of Physics, Great Britain)
- 教育部理科學術獎 Academic Award, Ministry of Education（2002）
- 中央研究院院士 Academician, Academia Sinica, R.O.C.（2002）
- 中華民國總統科學獎 Presidential Science Prize, R.O.C.（2003）
- 行政院傑出科技榮譽獎（2004）
- 斐陶斐榮譽學會傑出成就獎（2006）
- 臺灣大學傑出校友（2007）
- 國科會五十科學成就（2009）

Training Materials

- Open cavity (EM wave only)
  - Lecture notes: "Time-Domain Analysis of Open Cavity".
  - T. H. Chang*, T. Idehara, I. Ogawa, L. Agusu, C. C. Chiu, and S. Kobayashi, "Frequency tunable gyrotron using backward-wave components", J. Appl. Phys. 105, 063304 (2009).
- Linear efficiency and bunching mechanism (linear)
  - Lecture notes: "Gyrotron: Linear Theory of Electron Cyclotron Maser".
  - K. R. Chu, "The electron cyclotron maser," Rev. Mod. Phys. 76, 489 (2004).
  - T. H. Chang*, W. C. Huang, H. Y. Yao, C. L. Hung, W. C. Chen, and B. Y. Su, "Asymmetric linear efficiency and bunching mechanisms of TM modes for electron cyclotron maser," Physics of Plasmas, 24, 023302 (2017).
- Gain and bandwidth (dispersion relation, linear)
  - K. R. Chu and A. T. Lin, "Gain and bandwidth of the Gyro-TWT and CARM amplifiers," IEEE Trans. Plasma Sci., 16, 90 (1988).
  - Tsun-Hsu Chang* and Kun-Jie Xu, "Gain and bandwidth of the TM-mode gyrotron amplifiers," Physics of Plasmas, **25**, 112109 (2018).
- Start-oscillation currents (linear)
  - C. S. Kou, "Starting oscillation conditions for gyrotron backward wave oscillators," Phys. Plasmas, 1, 3093 (1994).
  - Hsin-Yu Yao, Chih-Chieh Chen, and Tsun-Hsu Chang*, "Starting behaviors of the TM mode gyrotrons", Physics of Plasmas, 27, 022113 (2020).
- Non-linear, fixed-field oscillation (nonlinear)
  - Lecture notes: "Numerical calculation of electron orbit in RF fields of a cavity".
  - Tsun-Hsu Chang*, Hsin-Yu Yao, Bo-Yuan Su, Wei-Chen Huang, and Bo-Yuan Wei, "Nonlinear oscillations of TM-mode gyrotrons", Physics of Plasmas, 24, 122109 (2017).
- Non-linear, self-consistent oscillation (nonlinear)
  - Lecture notes: "A Formalism for Nonlinear Calculations".
  - K. R. Chu, H. Y. Chen, C. L. Hung, T. H. Chang, L. R. Barnett, S. H. Chen, T. T. Yang, and D. Dialetis, "Theory and Experiment of Ultra High Gain Gyrotron Traveling-Wave Amplifier," IEEE Trans. Plasma Sci. 27, pp. 391-404, (1999).
  - Hsin-Yu Yao, Cheng-Hsiung Wei, and Tsun-Hsu Chang*, "Nonlinear and self-consistent simulation of TM-mode gyrotrons," to be submitted to Physics Review E, (2021).
- Multi-modes, time-dependent simulation (Nonlinear, nonstationary, competition)
  - T. H. Chang, S. H. Chen, L. R. Barnett, and K. R. Chu, "Characterization of Stationary and Nonstationary Behavior of Gyrotron Oscillators," Phys. Rev. Lett. 87, 064802, (2001).
  - K. F. Pao, T. H. Chang, C. T. Fan, S. H. Chen, C. F. Yu, and K. R. Chu, "Dynamics of Mode Competition in the Gyrotron Backward-Wave Oscillator," Phys. Rev. Lett., 95, 185101 (2005).