

## Solutions to Chen's Plasma Physics

Kalman Krizhnik

1-1. Compute the density (in units of  $m^{-3}$ ) of an ideal gas under the following conditions:

a) At  $0^\circ\text{C}$  and 760 Torr pressure (1 Torr = 1mm Hg). This is called the Loschmidt number.

b) In a vacuum at  $10^{-3}$  Torr at room temperature ( $20^\circ\text{C}$ ). This number is a useful one for the experimentalist to know by heart ( $10^{-3}$  Torr = 1 micron).

a) Avogadro's number is  $N_A = 6.022 \times 10^{23}$ . One mole of gas at STP occupies 22.4 liters. 1 liter is  $1 \times 10^{-3}$  cubic meters. Thus, the number per cubic meter is  $N_A/n = 6.022 \times 10^{23}/(22.4 \times 10^{-3}) = 2.66 \times 10^{25} m^{-3}$ . Thus, the Loschmidt number is  $2.66 \times 10^{25}$   $\square$

b) Using  $PV=NkT$ , we obtain (with  $R=1.4 \times 10^{-23} J K^{-1}$  and 1 Torr = 133 Pa):

$$n = \frac{N}{V} = \frac{P}{kT} = \frac{10^{-3} \times 133}{1.4 \times 10^{-23} \times (20 + 273)} = 3.3 \times 10^{19} m^{-3} \quad \square \quad (1)$$

1-2. Derive the constant  $A$  for a normalized one-dimensional Maxwellian distribution

$$f(u) = Ae^{-mu^2/2kT} \quad (2)$$

such that

$$\int_{-\infty}^{\infty} f(u) du = 1 \quad (3)$$

This one is straightforward. Just integrate:

$$1 = \int_{-\infty}^{\infty} Ae^{-mu^2/2kT} du = A \sqrt{\frac{2\pi kT}{m}} \Rightarrow A = \sqrt{\frac{m}{2\pi kT}} \quad \square \quad (4)$$

1-4. Compute the pressure, in atmospheres and in  $\text{tons}/ft^2$ , exerted by a thermonuclear plasma on its container. Assume  $kT_e = kT_i = 20\text{keV}$ ,  $n = 10^{21} m^{-3}$  and  $p = nkT$ , where  $T = T_i + T_e$ .

This is just unit conversion, albeit with units that nobody really ever remembers. For reference,  $1 \text{keV} = 1.6 \times 10^{-19} J$ , so

$$p = 10^{21} \times (20\text{keV} + 20\text{keV}) = 4 \times 10^{22} m^{-3} \text{keV} = 4 \times 10^{22} m^{-3} J = 4 \times 10^3 N/m^2 \quad (5)$$

But  $1 \text{atm} = 10^5 N/m^2 = 1 \text{ton}/ft^2$ , so (Note: I think there is a mistake in Chen's solutions here. If I am mistaken, please let me know).

$$p = 0.04 \text{atm} = 0.04 \text{ton}/ft^2 \quad \square \quad (6)$$

1-5. In a strictly steady state situation, both the ions and the electrons will follow the Boltzmann relation

$$n_j = n_0 e^{-e\phi/kT_j} \quad (7)$$

For the case of an infinite, transparent grid charged to a potential  $\phi$ , show that the shielding distance is given approximately by

$$\lambda_D^{-2} = \frac{ne^2}{\epsilon_0} \left( \frac{1}{kT_e} + \frac{1}{kT_i} \right) \quad (8)$$

Show that  $\lambda_D$  is determined by the temperature of the colder species.

We'll use Poisson's equation

$$\nabla^2 \phi = \frac{en_e - en_i}{\epsilon_0} = \frac{en_0}{\epsilon_0} (e^{-e\phi/kT_e} - e^{-e\phi/kT_i}) \approx \frac{en_0}{\epsilon_0} \left( 1 + \frac{e\phi}{kT_e} - 1 - \frac{-e\phi}{kT_i} \right) = \frac{e^2 n_0}{\epsilon_0} \left( \frac{\phi}{kT_e} + \frac{\phi}{kT_i} \right) \quad (9)$$

# Chen Plasma Physics Solutions

**Mohamed Atef Helal**



## Chen Plasma Physics Solutions:

Introduction to Plasma Physics and Controlled Fusion Francis F. Chen, 1984-01-31 This complete introduction to plasma physics and controlled fusion by one of the pioneering scientists in this expanding field offers both a simple and intuitive discussion of the basic concepts of this subject and an insight into the challenging problems of current research In a wholly lucid manner the work covers single particle motions fluid equations for plasmas wave motions diffusion and resistivity Landau damping plasma instabilities and nonlinear problems For students this outstanding text offers a painless introduction to this important field for teachers a large collection of problems and for researchers a concise review of the fundamentals as well as original treatments of a number of topics never before explained so clearly This revised edition contains new material on kinetic effects including Bernstein waves and the plasma dispersion function and on nonlinear wave equations and solitons

Solitons Mohamed Atef Helal, 2022-11-12 This newly updated volume of the Encyclopedia of Complexity and Systems Science ECSS presents several mathematical models that describe this physical phenomenon including the famous non linear equation Korteweg de Vries KdV that represents the canonical form of solitons Also there exists a class of nonlinear partial differential equations that led to solitons e g Kadomtsev Petviashvili KP Klein Gordon KG Sine Gordon SG Non Linear Schrödinger NLS Korteweg de Vries Burger s KdVB etc Different linear mathematical methods can be used to solve these models analytically such as the Inverse Scattering Transformation IST Adomian Decomposition Method Variational Iteration Method VIM Homotopy Analysis Method HAM and Homotopy Perturbation Method HPM Other non analytic methods use the computational techniques available in such popular mathematical packages as Mathematica Maple and MATLAB The main purpose of this volume is to provide physicists engineers and their students with the proper methods and tools to solve the soliton equations and to discover the new possibilities of using solitons in multi disciplinary areas ranging from telecommunications to biology cosmology and oceanographic studies

**Nonlinear Optics** İlkyay Bakırtaş, Nalan Antar, 2021-01-27 With this book we aim to capture different perspectives of researchers on nonlinear optics and optical devices and we intend to cover the latest developments in optics from theoretical numerical and experimental aspects The eleven selected chapters cover a variety of topics related to nonlinear optics including bright dark kink solitary waves in various media magnetic solitons lattice solitons rogue waves solid state lasers laser cladding optical sensors optical vortices and molecular switches The book is intended to draw the attention of scientists in academia as well as researchers and engineers in industry since the field has a significant potential for the production and design of novel optical devices and other technological applications

*Advance Elements of Laser Circuits and Systems* Ofer Aluf, 2021-03-09 This book on Advance Elements of Laser circuits and systems Nonlinearity applications in engineering addresses two separate engineering and scientific areas and presents advanced analysis methods for Laser circuits and systems that cover a broad range of engineering and scientific applications The book analyzed Laser circuits and systems as linear and nonlinear dynamical

systems and their limit cycles bifurcation and limit cycle stability by using nonlinear dynamic theory Further it discussed a broad range of bifurcations related to Laser systems and circuits starting from laser system differential equations and their bifurcations delay differential equations DDEs are a function of time delays delay dependent parameters followed by phase plane analysis limit cycles and their bifurcations chaos iterated maps period doubling It combines graphical information with analytical analysis to effectively study the local stability of Laser systems models involving delay dependent parameters Specifically the stability of a given steady state is determined by the graphs of some functions of which can be expressed explicitly The Laser circuits and systems are Laser diode circuits MRI system Laser diode circuitry Electron photon exchanges into VCSEL Ti Sapphire laser systems Ion channel and long wavelength lasers Solid state lasers Solid state laser controlled by semiconductor devices microchip solid state laser Q switched diode pumped solid state laser Nd YAG Mid Infrared and Q switched microchip lasers Gas laser systems copper vapor laser CVL circuitry Dual wavelength laser systems Dual wavelength operation of a Ti sapphire laser Diode pumped Q switched Nd YVO4 yellow laser Asymmetric dual quantum well lasers Tm3 doped silica fibre lasers Terahertz dual wavelength quantum cascade laser The Book address also the additional areas Laser X guiding system Plasma diagnostics Laser Beam shaping Jitter and crosstalk Plasma mirror systems and High power Laser Target diagnostic system optical elements The book is unique in its emphasis on practical and innovative engineering and scientific applications All conceptual Laser circuits are innovative and can be broadly implemented in many engineering applications The dynamics of Laser circuits and systems provides several ways to use them in a variety of applications covering wide areas This book is aimed at electrical and electronics engineers students and researchers in physics as well It is also aimed for research institutes in lasers and plasma physics and gives good comprehensive in laser and plasma systems In each chapter the concept is developed from basic assumptions up to the final engineering and scientific outcomes The scientific background is explained at basic and advance levels and closely integrated with mathematical theory Many examples are presented in this book and it is also ideal for intermediate level courses at graduate level studies It is also ideal for engineer who has not had formal instruction in nonlinear dynamics but who now desires to fill the gap between innovative Laser circuits systems and advance mathematical analysis methods Plasma Physics Index ,1971

**Gas Dynamics with Applications in Industry and Life Sciences** Mohammad Asadzadeh,Larisa Beilina,Shigeru Takata,2023-10-30 This proceedings volume gathers selected contributions presented at two instances of the JSPS SAC Seminar On Gas Kinetic Dynamics and Life Science held by the Chalmers University of Technology and University of Gothenburg Sweden on March 25 26 2021 virtual and March 17 18 2022 virtual Works in this book provide a concise approach to the theoretical and numerical analysis of kinetic type equations that arise for example in modeling industrial medical and environmental problems Readers will find some of the most recent theoretical results newly developed numerical methods in the field and some open problems Possible application areas encompass fission fusion energy

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**Plasma Physics** ,1989-07 **The Physics of High Brightness Beams** Jamie Rosenzweig,2000 This book contains the proceedings of the 1999 ICFA workshop on the physics of high brightness beams The workshop took a snapshot in time of a fast moving interdisciplinary field driven by advanced applications such as high gradient high energy physics linear colliders high gain free electron lasers heavy ion fusion and transmutation of nuclear materials While the field of high brightness beam physics has traditionally been divided into disparate electron and heavy ion communities the workshop brought the two types of researchers together so that a sharing of insights and methods could be achieved Thus this book represents a unifying step in the development of the diverse fascinating discipline of high brightness beam physics with its challenges rooted in collective nonlinear particle motion and ultra high electromagnetic energy density **Computer Simulation of Mesoscale Phenomena** Stefan Schwarzer,2002 **Engineering Education** ,1982 **Nuclear Science Abstracts** ,1967

**McGraw-Hill Concise Encyclopedia of Physics** McGraw Hill,2005 Hundreds of well illustrated articles explore the most important fields of science Based on content from the McGraw Hill Concise Encyclopedia of Science Technology Fifth Edition the most widely used and respected science reference of its kind in print the new Concise Encyclopedia Series delivers Detailed well illustrated explanations not just definitions Hundreds of concise yet authoritative articles in each volume An easy to understand presentation accessible and interesting to non specialists A portable convenient format Bibliographies appendices and other information to supplement the articles *Documentation of Plasma Physics. Pt. 1, Experimental Plasma Physics [and] Theoretical Plasma Physics* ,1972 **Spatio-temporal Coherence and Chaos in Physical Systems** Alan R. Bishop,George Grüner,Basil Nicolaenko,1986 *Journal of the Physical Society of Japan* ,2017

**Plasma Physics Reports** ,2001 Publishes papers on plasma physics The journal covers the following topics high temperature plasma physics connected with the problem of controlled nuclear fusion based on magnetic and inertial confinement physics of cosmic plasma including magnetosphere plasma sun and stellar plasma etc gas discharge plasma and plasma generated by laser and particle beams **Mathematical Reviews** ,2001 **International Conference on Plasma Physics** ,1980 **ICPP 96 Contributed Papers** Hideo Sugai,Takaya Hayashi,1997 [Government Reports Announcements & Index](#) ,1979-03

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