

## Solutions to Chen's Plasma Physics

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**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  $tons/ft^2$ , exerted by a thermonuclear plasma on its container. Assume  $kT_e = kT_i = 20keV$ ,  $n = 10^{21}m^{-3}$  and  $p = nkT$ , where  $T = T_i + T_e$ .

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

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

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

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

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

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

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

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

# Chen Plasma Physics Solutions

**M Mark**



## **Chen Plasma Physics Solutions:**

**Nonlinear Optics** İlkey 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

*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 Schr dinger 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

*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 there 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

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Serafini,2000-12-18 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

**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

*Nuclear Science Abstracts* ,1967 *Computer Simulation of Mesoscale Phenomena* Stefan Schwarzer,2002 *Spatio-temporal Coherence and Chaos in Physical Systems* Alan R. Bishop,George Grüner,Basil Nicolaenko,1986 *Engineering Education* ,1982 **Documentation of Plasma Physics. Pt. 1, Experimental Plasma Physics [and] Theoretical Plasma Physics** ,1972 *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

*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 *International Conference on Plasma Physics* ,1980 **Mathematical Reviews** ,2001 **Journal of the Physical Society of Japan** ,2017 **Discrete and Continuous Dynamical Systems** ,2009 *Physics Briefs* ,1989

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