TEST QUESTIONS
– PLASMA

Plasma flashcard Q's

1) Give a physical explanation of the Debye length.

2) Why does one use matching units for electron temperature?

3) Equation for the density of electrons around charge Q

4) Poisson's equation for a plasma equation

5) Relate $\nabla^2 \phi$ to spherical coordinates

6) What is the solution to $\frac{1}{r^2}\frac{\partial^2}{\partial r^2}(r^2\phi) = n_p \frac{e}{\varepsilon_0}\left[e^{\frac{e\phi}{k_B T}} - 1\right]$?

7) What are the assumptions made to derive an expression for the potential from an infinit 1D plate? (3)

8) How does one go about solving $\frac{d^2\phi}{dx^2} = \beta \, \phi(x)$?

9) How does one get from $\phi(x) = c_1 e^{\gamma x} + c_2 e^{-\gamma x}$ to the final solution?

10) How does one arrive at $E(x) = e n_p s / \varepsilon_0$?

11) After getting $E(x)$, what is the next step in deriving the plasma frequency ω?

12) Discuss the interaction between a plasma and an electromagnetic wave of frequency f.

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1) Give the ~~equation~~ expression for the radius of gyration, r_c.

2) Give the expression for the gyration frequency, ω_c.

3) Derive the gyration frequency.

4) Why must $E_{\parallel} = 0$ for a physical solution and what is $\dot{z}$?

5) What is the general solution to $\ddot{x} = c - \omega^2 x$?

6) What substitutions (2) need to be made to get the solutions of $\dot{x}$ and $\dot{y}$ in terms of u and ~~B~~ α?

7) Give the expression for $\vec{E} \times \vec{B}$ drift.

8) What is the general drift velocity for some force $\vec{F}$?

9) What are the steps to demonstrate constant kinetic energy of a charged particle moving in a magnetic field. given that $\vec{A} \cdot (\vec{A} \times \vec{B}) = \vec{0}$?
   ↳ Assume $\vec{E} = 0$
   ↳ Multiply $\vec{F}_L = q(\vec{v} \times \vec{B})$ by $\vec{v}$ on both sides
   ↳ Since $\vec{v} \perp \vec{F}_L$ → magnetic field does no work to particle.
   ↳ $d\vec{v}/dt = 0$ in direction of $\vec{F}_L$.
   ↳ $\Rightarrow dU_h/dt = 0$

10) Express $\nabla \cdot \vec{B}$ in spherical coordinates.

~~11) Get B_r in terms of r_c and $\partial B_z/\partial z$.~~

11) Get B_r in terms of r_c and $\partial B/\partial z$

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12) Provide the expression for the magnetic moment of a charged particle in a magnetic bottle.

13) Arrive at $m \, dv_\parallel / dt = -\mu \, \partial B / \partial z$

14) Show that $d/dt \left(\frac{1}{2} m v_\parallel^2 \right) = -\mu \, dB/dt$

15) ~~Give the expression~~ Show that $d\mu/dt = 0$ for $B \neq 0$.

16) How does μ being an adiabatic invariant lead to the possibility of a magnetic mirror?

17) Give the expression for the pitch angle, $\tan \theta$.

18) Give an expression relating μ to θ and B

19) What condition must be met for particles to undergo reflection?

20) What is the mirror ratio?

1) Give the collision term for the equation of motion of an electron in a plasma.

2) Give the equation of motion when allowing for the possibility of non-isotropic conditions.

3) Give the expression for the momentum transfer collision frequency.

4) Give the expression for electron mobility in terms of ν_m.

5) Given that $E_x(t) = \tilde{E}_x e^{i\omega t}$ is a time-varying electric field, how does one arrive at $\tilde{u}_x$, the amplitude of the velocity?

6) Give the expression for $\tilde{u}_x$.

7) Give the expression for the convective current, $\mathcal{I}_c$

8) Give the expression for the displacement current, $\mathcal{I}_D$.

9) Provide the expanded expression for $\tilde{\mathcal{I}}_T$.

10) Provide the expression for $\tilde{\mathcal{I}}_T$ in terms of the dielectric constant.

11) Give $\tilde{\mathcal{I}}_T$ in terms of σ_p.

12) Give the general expression for plasma conductivity, σ_p

13) Give the expression for σ_{De} $(\omega \to 0)$.

[4]

1) Give the diffusion relation in the presence of electric field E.

2) Give D as modelled by a random walk in 1D.

3) How does one arrive at the Einstein relationship?

4) Give the condition for ambipolar diffusion.

5) Give the expression for D_a, the ambipolar diffusion coefficient.

6) Provide the expression for the ambipolar electric field.

Sheath Qs

1) What is a plasma sheath? Draw the ~~setup~~ plots

2) How does a plasma sheath arise?

3) Why is a pre-sheath needed in a plasma?

4) Give the equation for charge continuity

5) Give the steady-state expression for I

6) What is the sheath width dependence on λ_D?

7) Give the conservation of energy for a sheath.

8) Give the chain rule expression used in sheath derivations.

9) Give the expression for the ion energy at the Sheath edge.

10) What is the Taylor series expansion for e^x?

11) What is the Maclaurin series expansion for $(1+x)^{\frac{1}{2}}$?

12) What is the Bohm speed? (Equation & description)

13) What are the starting equations to derive the collisionless sheath? (Get n_i as function of ϕ, u_s, n_{is})

14) How do we get from the ~~expression~~ $n_i(x)$ result to an expression of $\frac{d^2\phi}{dx^2}$? What is the starting Poisson equation?

15) How do we apply the mathematical trick to the Poisson equation result?

16) How do we arrive at the Bohm criterion?

17) How do we find the average energy at the sheath edge?

18) How does one find the potential of the wall, ϕ_w, for a collisionless sheath? What are the respective ion Γ and electron fluxes? What assumption is needed for $\bar{u}_e$?

19) What is the key assumption made for the high voltage sheath? ($n_e = 0$, $n_i = const. = n_s$)

20) How do we find $E(x)$, and what is $E(0)$? What is $\phi(0)$?

21) What do we set the potential of the wall to be? What important quantity can we find from this?

22) What is the key assumption for the Child Law sheath?

23) What are the starting equations for the Child law sheath, given by conservation of energy and the charge continuity in steady-state?

24) What are $\phi(0)$ and $\phi'(0)$ equal to for a Child law sheath?

25) What is I_0 equal to at $x=s$? ~~condition~~

Waves in Plasma

1) What is assumed to be the form of a wave travelling in 1D in the $+\hat{x}$ direction?

2) What is the expression for the ~~~~ ~~~~ condition of a point of constant phase?

3) What is the phase speed v_ϕ? Give qualitative & quantitative answers.

4) What is the dispersion relationship and how is it attained?

5) When does the group speed naturally arise?

6) If a superpositional wave is to remain a wave, what is the condition that must hold? Give this condition mathematically.

7) What is the expression for v_g?

8) What 2 equations do we start with for the unmagnetized plasma case?

9) How are the variables (3) linearized?

10) What are the assumptions for a uniform plasma?

11) What can we say for stationary ions?

12) What is the first case we consider, relating to p?

13) What can we say about $(\vec{u_e} \cdot \nabla)\vec{u_e}$?

14) What is the Poisson equation, under the assumption of stationary ions?

15) What are the operators $\partial/\partial t$ and ∇ for an assumed harmonic solution?

16) For $\nabla p \neq 0$, what can we say for an adiabatic process?

17) For an adiabatic process, what can we say about the number density, pressure and volume (2 equations)?

18) What is p/n equal to? What are the units?

19) What is the thermal speed of electrons?

20) What is the electron Boltzmann potential distribution? What does this linearize to?

21) What is the linearized Poisson equation?

22) What is the phase speed of an ion wave?