Introduction to Nuclear Fusion (409.308A)

Final Examination

7 December, 2010

1. (10 points) The tokamak equilibrium can be described by the Grad-Shafranov equation as shown below. Explain the meaning of the equation term by term.

$$\Delta^{*}\psi = -\mu_0 R^2 \frac{dp}{d\psi} - \mu_0^2 F \frac{dF}{d\psi}$$

2. Answer the following questions.

(a) (5 points) Draw the two possible particle trajectories in poloidal cross section of tokamak plasmas if the magnetic field in a tokamak is expressed as

$$B(r,\theta) = \frac{B_0}{1+\varepsilon\cos\theta}.$$

(b) (5 points) Calculate the fraction of trapped particles in a tokamak if inverse aspect ratio (ε) is 1/3.

3. (a) (10 points) The Ohmic heating power density in a tokamak is expressed as

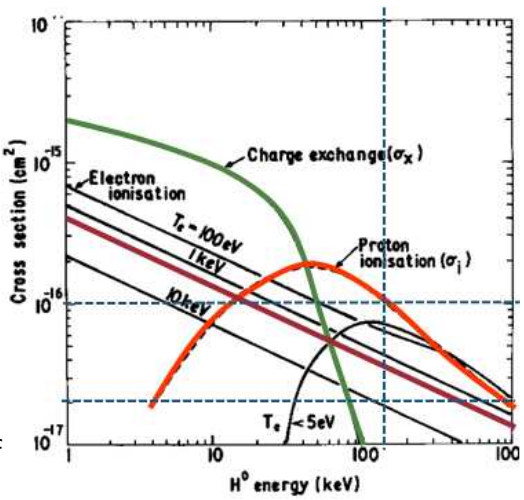
$$P_{\Omega} = \eta\left\langle j^2\right\rangle = 1.0\times10^5\left(\frac{Z_{eff}}{T^{3/2}}\right)\left[\frac{1}{q_o(q_a - q_o/2)}\right]\left(\frac{B_\phi}{R}\right)^2.$$

Discuss the possibility of its application to fusion reactors in terms of fusion reaction, radiation, instability and engineering limits.

(b) (10 points) Attenuation of a neutral beam particles in a plasma can be described as

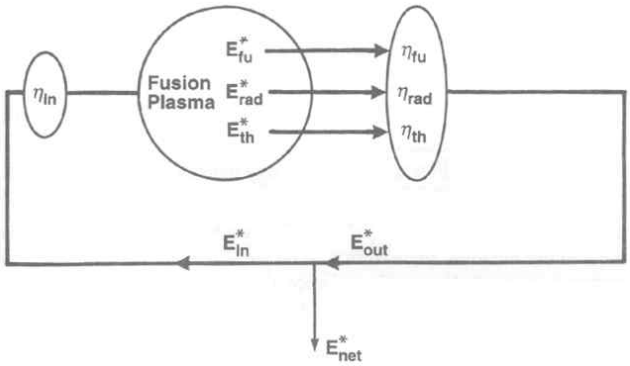
$$\frac{dN_b(x)}{dx} = -N_b(x)n(x)\sigma_{tot}.$$

Evaluate the penetration length of the beam in KSTAR if the beam energy is 120 keV, the density is 10^{20} m^{-3}, and the electron temperatue is 10 keV.



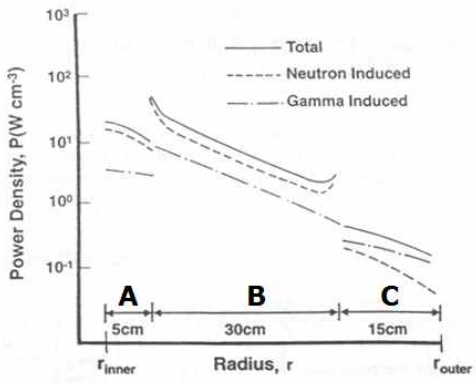
4. (10 points) What are the principles of limiter and divertor?

5. (10 points) Using the diagram below, derive the Lawson's criterion for DT reaction in terms of $n\tau_E$. Assume that bremsstrahlung is the only radiation source with $P_{brems} = A_{br} n^2 \sqrt{T} \tau_E$ where $n_D = n_T = n$.



6. (a) (10 points) Explain the role of blankets in a fusion reactor.

(b) (10 points) The neutron power distribution is shown below. Which components of a blanket do correspond with A, B, and C?



7. Evaluate the statements: O if correct, X otherwise.

(a) (5 points) The bootstrap current is present in stellarators and it provides beneficial effects to the stability of stellarators. ( )

(b) (5 points) The ballooning mode is a type of ideal MHD instability and driven by the pressure gradient at bad-curvature regions. ( )

(c) (5 points) The H-mode can be established by modifying the shape of the current density profile in the plasma. ( )

(d) (5 points) To explain the surface interaction phenomena of plasma with carbon, chemical sputtering should be taken into account particularly at low impact energy range. ( )

"Wisdom is supreme; therefore get wisdom. Though it cost all you have, get understanding."
(Proverb 4:7)