NE 180
Midterm II
Fall Semester 2009

17 November 2009

SEVENTY-FIVE MINUTES, CLOSED BOOK. ONE $8-\frac{1}{2}$" × 11" SHEETS OF NOTES ALLOWED. PLASMA FORMULARY ALLOWED.

1. A tokamak plasma has an ion temperature profile given by:

$$T_i(x) = T_0(1 - (\frac{r}{a})^2)^{0.3}$$

and $T_0 = 15.0$ KeV, and $a = 2.0$ m with a circular bore (no elongation). The magnetic field $B_\phi(r = 0)$ is 4.0 T. The aspect ratio A is 3.0. The safety factor $q(r)$ is given by $q(r) = 1.0/(1-(2/3)(r/a)^2)$. Assume that the ion density is 10^{20} m^{-3} everywhere and that the ions are DT with an average mass of 2.5 proton masses.

   (a) At $r = 0.9a$, find T_i, τ_i, $\omega_{ci}\tau_i$, and $\kappa_\perp^i$.

   (b) Find the classical ion heat flux at $r = 0.9a$ in watts per square meter. Give the total heat flux through this magnetic flux surface.

   (c) Find the neoclassical ion heat at $r = 0.9a$, assuming that the ions are in a banana regime (lowest collisionality) as the total heat flux through this magnetic flux surface.

   (d) If the electrons are at a temperature of 10.0 keV at everywhere, then find the volumetric ion-to-electron heat exchange rate at $r = 0$ in megawatts per cubic meter.

(e) Find the volumetric ohmic heating at $r = 0$. Give the answer in megawatts per cubic meter. Hint: note that the toroidal current can be derived from q:

$$J_\phi(0) = \frac{2\,B_\phi(0)}{\mu_0 q(0) R_0}$$

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2. A laser-driven indirect drive ICF target achieves a compressed density such that ninety-nine percent of the blackbody radiation penetrates into the compressed core, which means that $\hbar\omega_{pe} = 0.63kT_\gamma$, where T_γ is the hohlraum radiation temperature. Take this temperature to be $kT_\gamma = 300$ eV.

   (a) Find the value of this compressed density as an electron number density n_e in cm^{-3}.

   (b) Find the compressed mass density ρ in g cm^{-3} if the fuel is D-T. Give this also as a ratio to the density of liquid DT (0.25 g cm^{-3}).

   (c) Take the burnup to be $f_B = \rho R/(6 + \rho R)$ and $\rho R = 1$ g cm^{-2}. Find the yield in megajoules.

   (d) Find the laser energy required if the laser energy equals twice the blackbody radiation from two laser entrance holes, each 3 mm diameter, for 10 ns pulse duration.

   (e) Find the target gain Q from the above.