NE 180
Final Exam
Fall Semester 2003
Solutions

December 19, 2005

1. a.

$$\boldsymbol{P_f = < n_e^2 > /4 < \sigma v > E_f} \cdot \mathrm{Vol}$$
$$\boldsymbol{= (1/4)(1.019 \times 10^{-19})^2 (6.8 \times 10^{-23})(17.6 \times 10^6)(1.6 \times 10^{-19})}$$
$$\boxed{\boldsymbol{= 416}\ \mathrm{MW}}$$

1. b.

$\boldsymbol{P_{f\alpha} = Pf/5 =} \boxed{\boldsymbol{= 83.2}\ \mathrm{MW}}$

1. c.

$\boldsymbol{Q = \frac{P_f}{P_{inj}} = 416/40 =} \boxed{10.4}$

1. d.

$$\boldsymbol{P_{hc} = P_{f\alpha} + P_{inj} - P_{rad} = 83.2 + 40 - 48 = 75.2}\mathrm{MW}$$
$$\boldsymbol{U_{th} = \frac{3}{2} < n_e(T_e + T_i) > V = 3.47 \times 10^8}\mathrm{J}$$

$$\tau_E = \frac{U_{th}}{P_{hc}} = \boxed{4.62\text{ s}}$$

1. e.

$$<\beta_{tor}> = \frac{<n_e(T_e+T_i)>}{(B_\phi^2/2\mu_0)}$$

$$\boxed{=0.02478}$$

1. f.

$$Z_{eff} = \frac{P_{brem}^{rad}}{V<n_e^2>(5.35\times 10^{-37})<T_e^{1/2}>}$$

$$\boxed{=1.6659}$$

2. a.

$$E_\infty^{Z-1} = 13.6Z^2 = 74.473\text{keV} < 3T_e$$

$$\boxed{\text{Fully Stripped}}$$

2. b.

$$E^\gamma(2p \rightarrow 1s) = E_\infty^{Z-1}\left(\frac{1}{1^2}-\frac{1}{2^2}\right) = \boxed{55.855\text{ keV}}$$

2. c.

$$\frac{n_e(dirty)}{n_e(clean)} = 1 - f<Z> = 0.95$$

$$\frac{P_f(dirty)}{P_f(clean)} = \left(\frac{n_e(Dirty)}{n_e(clean)}\right)^2 = 0.9025$$

$$\boxed{= 9.75\ \%\text{ Reduction}}$$

3. a.

$f = c/\lambda = 3 \times 10^8/(0.35 \times 10^{-6}) = 8.57 \times 10^14$ Hz

$$n_{crit} = 10^{14}\left(\frac{f}{89 \times 10^9}\right)^2$$

$$\boxed{n_{crit} = 9.27 \times 10^{21}\text{cm}^{-3}}$$

3. b.

Using Formula [29] on p. 56 in the NRL Plasma Formulary,

$$P^{rad} = 1.03 \times 10^5 T_{eV}^4 \text{W cm}^{-2}$$

Area of holes = $(2)(\pi/4)D^2) = (\pi/2)(0.28)^2 = 0.123$ cm^2 Laser Power= $\dfrac{1.4 \times 10^6}{3.5 \times 10^{-9}} = 0.4$ PW
Solving $\sigma T^4 = P/A$ gives

$$\boxed{T = 421 \text{ eV}}$$

3. c.

$V = 4\pi/3(D/2)^3 = (1/6\pi)(0.19)^3$

$$M_{fuel} = 500\frac{V}{22400}(5) = 4.06 \times 10^{-5}\text{g}$$

$Y' = 3.39 \times 10^{11}$ J/g for DT. So $Y_{max} = 13.7$ MJ. Then

$$\boxed{f_B = 1.4/13.7 = 0.102}$$

3. d.

Using $M_f = (4/3)\pi R_f^3 \rho$ and $\rho = 1000$ gives $R_f = 0.00213$ cm and thus $\boxed{\rho R_f = 2.13\text{g cm}^{-3}}$

4. a.

$\theta = 2\pi/18$ and $d = 2R\sin(\theta/2)$ gives $\boxed{d = 72.9 \text{ cm}}$

4. b.

$$NI = 5RB$$

with R in cm and B in gauss. Thus $I = \dfrac{(5)(53000)(620)}{(134)(18)} = \boxed{68.117 \text{ kA}}$

4. c.

$d_{sc} = d/14 = 5.2$ cm. $A_c = 0.8(3/4)(\pi/4)d_{sc}^2 = 0.0012784\text{m}^2$. $P_{sc} = (\pi + \pi/2)d_{sc} = 0.24$ m. So

$$\frac{I^2 \rho_s}{A_s} \leq q'' p$$

which gives $\boxed{I_{crit} = 64.699 \text{ kA}}$

4. d.

$F' = IB = (68117)(5.3)(6.2/2.1) = \boxed{= 1.06 \times 10^6 \text{N m}^{-1}}$.

5. a.

Number of tritons per container = $N_A M/3 = 150/3N_A = 3.01 \times 10^{25}$. Decay rate= $\ln(2)/t_{1/2} = 0.693/(12.3 \cdot 3.15 \times 10^7) = 1.789 \times 10^{-9}\text{s}^{-1}$. Heating rate= $\lambda N E_\beta = \boxed{47 \text{ W}}$.

5. b.

Tritium in machine = $0.5 < n_e > V = 4.26 \times 10^{22}$. Tritium throughput = $N_T/\tau = 4.26 \times 10^{21}\text{s}^{-1}$. Inventory = 1000 moles= 6.02×10^{26} Lifetime supply= $6.02 \times 10^{26}/4.26 \times 10^{21} = \boxed{1.6 \text{ days}}$

5. c.

Dose per curie is $\boxed{\text{between 58 and 70 R}}$.

6. a.

Engineering design: Inadequate magnet structural support, major radius too small giving too high heat and neutron flux at first wall, inadequate tritium isolation for health physics safety issues, inadequate cryogenic thermal design.

6. b.

WMD issues: Pu breeding is a proliferation risk and/or evidence of WMD development in country.

6. c.

Oil Economy issues: Fusion electric power beneficial. H production could be exported to world market to "sweeten" other crude oil, such as US product.