Plasma II - Exercises

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Exercise 1 - Ideal Ignition

Consider the power balance of a 50:50 D-T thermonuclear fusion reactor, in which *direct* losses can be completely avoided (*ideal* confinement). In this case the only remaining losses are due to bremsstrahlung radiation.

a) Calculate the corresponding *ideal ignition temperature.* Remember that radiation losses due to Bremsstrahlung are well described by

$$\frac{P_\mathrm{b}}{V} \simeq A n_\mathrm{e}^2 Z_\mathrm{eff} T_\mathrm{e}^{1/2} \quad \text{with} \quad A = 5 \times 10^{-37} \frac{\mathrm{Wm}^3}{\sqrt{\mathrm{keV}}} \quad . \tag{1}$$

Also assume that the Maxwell averaged cross section of the D-T reaction can be approximated by

$$\langle \sigma v \rangle_\mathrm{DT} \simeq 1.1 \times 10^{-24} \frac{\mathrm{m}^3}{\mathrm{s\,keV}^2}\, T^2 \quad , \tag{2}$$

which is valid for typical fusion relevant temperatures in the range from 10 keV to 20 keV.

b) The answer to the previous question shows that the ideal ignition temperature lies outside the applicable temperature range of the quadratic expansion of $\langle \sigma v \rangle_\mathrm{DT}$ given above. Revise your answer using

$$\langle \sigma v \rangle_\mathrm{DT} \simeq 10^{-6} \frac{\mathrm{m}^3}{\mathrm{s}} \exp\left(\frac{a_{-1}}{T^\alpha} + a_0 + a_1 T \right) \qquad \begin{cases} \alpha = 0.2935 \\ a_{-1} = -21.38 \\ a_0 = -25.20 \\ a_1 = -7.101 \times 10^{-2} \end{cases}$$

where T is expressed in keV (Hint: Use a computer to find the solution).

c) Is *ideal ignition* a stable or unstable operating point? How does it react to a small perturbations in the plasma temperature? Note that a more realistic case with direct losses will be examined in problem set 6.