Examination on '1st Advanced Course ' of the European PhD Network in Fusion Science and Engineering

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In this exam, we will analyse the ITER design according to its physics basis. In the standard Q=10 scenario, ITER has the following nominal operation parameters:

Plasma current:	I_p = 15 MA
Toroidal field:	B_t = 5.2 T
Major radius:	R_0 = 6.2 m
Minor radius:	a = 2.0 m
Safety factor at 95% flux:	q_{95} = 3.0

1.) Operational parameters

In the standard $Q = 10$ scenario, which is an H-mode scenario, ITER will run at 85 % of the Greenwald density with fusion power $P_{FUS} = 400$ MW.

a) What is the absolute value of the line averaged density in this scenario?

b) How much auxiliary heating power will it need?

c) Let us assume that the H-factor will only be 0.95 instead of 1. What would you do to recover $Q = 10$? Which problems do you encounter?

In one of the advanced scenarios, I_p is dropped to 9 MA. Let us assume the shape of the poloidal cross section stays constant with respect to the $Q = 10$ scenario.

d) What is q_{95} in this scenario?

e) If we want to keep the absolute value of the density the same as in $Q = 10$, what will be the Greenwald fraction n/n_{GW}? Is this realistic?

2. Stability

In the $Q = 10$ scenario, we have $\beta_N = 1.8$.

a) What main performance limiting instability do you expect to occur? Give explicit reasons for your answer.

b) How could you control this instability?

c) ELMs may occur and pose a threat to the divertor. How would you try to mitigate them (name two methods and explain the mechanism by which the ELMs are (thought to be) mitigated)?

3.) Transport

a) In the standard H-mode scenario, we expect that the normalised critical gradient length for the temperature is $R_0\ (dT/dr)/T = -5$. For simplicity, we assume that the edge pedestal is located directly at $r = a$. What value does the edge temperature have to be if we want a central temperature of 25 keV?

b) Explain what we know about energy transport in tokamaks that leads to the assumption of constant $R_0 \, \nabla T/T$ in the plasma core!

c) Many people believe that the density profile in ITER will be peaked, although the particle source due to gas puff will be very peripheral. Explain how a peaking of the density profile can occur!

4.) Exhaust

a) The maximum value of the figure of merit for exhaust in ITER is $P_{sep}/R_0 = 15$ MW/m, where P_{sep} is the power crossing the separatrix after subtraction of the radiation. At $Q=10$ and $P_{AUX} = 40$ MW, how much power has to be radiated inside the separatrix to fulfill this limit?

b) For a DEMO design, let us assume, R_0 = 8 m, Q = 50 and P_{fus} = 3 GW. Using the ITER figure of merit for exhaust, how much power has to be radiated inside the separatrix?

c) Fulfilling the figure of merit of $P_{sep}/R = 15$ MW/m at a simultaneous maximum heat flux to the target of $P_{target} = 10$ MW/m^2 is difficult. Explain why this is the case!

d) What methods exist to reduce the heat flux to the target (name two and explain their mechanism!)?