PHYS-E0463 Fusion Energy Technology **11.1.2021**
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General information

The exercise sessions will be held as blackboard sessions, where the participants will present their solutions to the group. As such, the problems should be set up and solved before the session. The focus of the exercises lies on analyzing and discussing the task at hand together with the group: thus, a perfect solution is not required to be awarded points. Each student will mark down the exercises they are ready to present on the MyCourses "Exercises" page at the start of each session: a point will be awarded for each question, and a person will be chosen to present their solution from the pool.

Exercise 1.

Global energy demand, projections and energy consumption

a) Shortly outline the global energy situation in 2040 compared to today, and explain the development

b) Shortly outline the pros and cons of present-day means of power production (e.g. fossils, fissiles, PV, wind, hydro,...)

c) Explain the main pros and cons of producing energy by fusion power

Exercise 2.

Deuterium fusion and fossils

a) Calculate the theoretical energy content and fuel mass in 1l of seawater from deuterium-deuterium (D-D) fusion. Assume the deuterium content of seawater to be 16 ppm (16 deuterium atoms per 1 million water molecules), the density of seawater to be 1000 kg/m^3, and consider the full deuterium cycle.

b) How many liters of oil does this energy content correspond to? Assume the energy content of oil to be 40 MJ/l.

c) How many years could the deuterium in our seas support our current energy consumption? Assume the mass of seawater to be 1.5×10^{21} kg, the utilization of the deuterium in seawater to be 1%, and the current annual energy consumption to be 30 TW a.

Exercise 3.

Fusion and fission

a) Show that the energy released in deuterium-tritium (D-T) fusion is 17.6 MeV

$$\mathrm{D} + \mathrm{T} \rightarrow {}^{4}\mathrm{He} + \mathrm{n}$$

b) Calculate the energy released by the fission of the uranium isotope ${}^{235}_{92}\mathrm{U}$ and compare to the above value:

$$\mathrm{n} + {}^{235}_{92}\mathrm{U} \rightarrow {}^{236}_{92}\mathrm{U} \rightarrow {}^{141}_{56}\mathrm{Ba} + {}^{92}_{36}\mathrm{Kr} + 3\mathrm{n}$$

c) How much natural uranium is required to produce the same energy as 1 g of pure D-T fuel? The natural abundance of ${}^{235}_{92}\mathrm{U}$ is 0.7%.

d) Tritium is a radioactive isotope of hydrogen with $T_{\frac{1}{2}} = 12.32$ a, making its natural abundance small. Instead, tritium can be bred from lithium according to

$$\begin{aligned} &{}^{6}\mathrm{Li} + \mathrm{n} \rightarrow {}^{4}\mathrm{He} + \mathrm{T} + 4.8\ \mathrm{MeV}\ (7.5\%), \\ &{}^{7}\mathrm{Li} + \mathrm{n} \rightarrow {}^{4}\mathrm{He} + \mathrm{T} + \mathrm{n} - 2.5\ \mathrm{MeV}\ (92.5\%), \end{aligned}$$

where the parentheses refers to the natural occurrence of the isotopes. How many years could the economically viable lithium supplies last if our current energy production is supported solely by D-T fusion? Assume the available lithium sources to be 10^{11} kg and the annual energy production to be 30 TW a.

e) What competing uses of lithium can you think of?

Exercise 4.

a) State some similarities and differences of fusion power plants to conventional power plants?

b) Currently, fusion power plants are expected to use magnetic confinement to confine fusion plasmas. What are the critical components of such fusion power plants?

c) Give a general breakdown of the costs of a fusion power plant, and identify the dominant costs.[1]

d) What are the challenges needed to be overcome to achieve commercial fusion power production?

References:

[1] J. Wesson, Tokamaks 3rd or 4th edition, Chapter 1.9