Fusion Physics

Newest version (link)

Elias Wachmann & David Obermaier

December 27, 2023

Contents

Α.	Chapter 0: Energy and Global Income Distribution	4
	A.1. How is income distributed globally, and how does it relate to energy consumption?	4
	A.2. Compute the primary energy consumption in a fully developed country per capita	
	and day from:	4
	A.2.1. a) Estimating a person's individual consumption (heating, electricity, car,	
	etc.)	4
	A.2.2. b) From the macroeconomic perspective of a whole country	4
	A.3. Explain energy intensity	4
	A.4. How do primary energy consumption and consumer electricity differ?	4
	A.5. What's the energy mix in Austria?	4
	A.6. Given a number for reserves of a single fossil resource, compute:	5
	A.6.1. a) What part of the energy mix it can contribute sustainably (1000 years)	- L
	A.6.2. b) How long would it last at current consumption levels	
	A.7. How much W/m^2 can various energy sources produce? How would you compute	-
	it?	-
	A.8. Discuss whether renewables compete with a able land for food production. What	-
	about biofuels?	ز
	such as future fusion energy	1
	A.10.Discuss the question of perceived and quantitative risk for the environment from	٠
	various aspects of civilization (e.g., birds vs cats/wind turbines)	15
	A.11. Are there CO_2 -free energy sources? Why/why not?	6
	$\mathcal{J}_{\mathcal{J}}$	
В.	Chapter 1: Nuclear Energy and Fusion	7
	3.1. Give a historical perspective of the controlled use of nuclear energy in general	
	and fusion in particular	7
	3.2. Draw and explain a schematic fusion power plant	7
	3.3. Explain the difference between magnetic and inertial confinement fusion	1
C	Chapter 2: Discoveries Leading to Fusion	8
О.	C.1. Give a historical perspective on the scientific discoveries that led to the discovery	
	of fusion.	8
	C.2. Explain how the mass defect of various isotopes can be used to extract energy in	
	fission and fusion	8
D.	Chapter 3: Stellar Energy and Fusion	Ĉ
	D.1. Where does the energy in stars come from, and how was it conjectured?	G
	D.2. Write the reaction of the proton-proton cycle. Why is it important for stars?	6
	D.3. How are stars able to generate conditions for fusion, and why do we need other	_
	ways on earth?	Ć
	0.4. What's the meaning of different star stages and their composition? What stage	(
	is the Sun and elements can it produce?	6
	5.6. Explain printordial indeleosynthesis and now it led to the current universe	Č
E.	Chapter 4: Fusion on Earth 1	1
	E.1. Write equations and explain similarities and differences between fusion reactions	
	v x	1(
	· ·	10
	E.3. Draw the overall fuel cycle of a D-T fusion plant	L(

G.	G.1. Give a historical international perspective on the development of the H-bomb. G.2. Explain the requirement for a H-bomb and advantages over pure fission G.3. Discuss limited resources and processing for Uranium and Tritium G.4. How does an H-bomb in the Teller-Ulam design work? Draw and explain G.5. Discuss ideas for civil uses of nuclear bombs and why they failed	•	13 13 13 13
G.	 G.1. Give a historical international perspective on the development of the H-bomb. G.2. Explain the requirement for a H-bomb and advantages over pure fission. G.3. Discuss limited resources and processing for Uranium and Tritium. 		13 13 13
G.	G.1. Give a historical international perspective on the development of the H-bomb. G.2. Explain the requirement for a H-bomb and advantages over pure fission		13 13
G.	G.1. Give a historical international perspective on the development of the H-bomb.		13
G.			_
G.			TJ
	6. Chapter 6: The Hydrogen Bomb		13
F.	. Chapter 5: MISSING		12
	technical break-even and ignition for various fusion technologies	•	11
	E.8. Discuss from a historical perspective how close we are to reach scientific and		
	high value in magnetic and inertial confinement fusion		11
	E.7. What is the fusion triple-product? Explain all three terms and the ways to get a		
	E.6. Explain the power amplification factor, break-even point, and ignition criterion		10
	to the reaction cross-section		10
	E.5. What temperatures are needed for thermonuclear fusion? Explain with regard	ł	
	makes it easier than an estimation via classical physics?		10
	1 0	t	

A. Chapter 0: Energy and Global Income Distribution

consumption?	
Solution	
A.2. Compute the primary energy consumption in a fully developed country per capita and day from:	
A.2.1. a) Estimating a person's individual consumption (heating, electricity, car, etc.)	
Solution	
A.2.2. b) From the macroeconomic perspective of a whole country	
Solution	
A.3. Explain energy intensity	
Solution	
A.4. How do primary energy consumption and consumer electricity differ?	
Solution	
A.5. What's the energy mix in Austria?	
Solution	

- A.6. Given a number for reserves of a single fossil resource, compute:
- A.6.1. a) What part of the energy mix it can contribute sustainably (1000 years)

Solution			

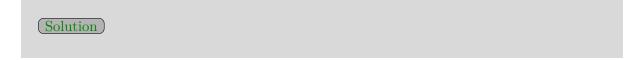
A.6.2. b) How long would it last at current consumption levels



A.7. How much W/m^2 can various energy sources produce? How would you compute it?



A.8. Discuss whether renewables compete with arable land for food production. What about biofuels?



A.9. Discuss the ongoing price-drop in solar, and what it means for other alternatives, such as future fusion energy



A.10. Discuss the question of perceived and quantitative risk for the environment from various aspects of civilization (e.g., birds vs cats/wind turbines)



A.11. Are there CO_2 -free energy sources? Why/why not?

Solution

B. Chapter 1: Nuclear Energy and Fusion

B.1.	Give a historical perspective of the controlled use of nuclear energy in	1
	general and fusion in particular.	

Solution	
----------	--

B.2. Draw and explain a schematic fusion power plant.



B.3. Explain the difference between magnetic and inertial confinement fusion.



C. Chapter 2: Discoveries Leading to Fusion

C.1. Give a historical perspective on the scientific discoveries that led to the discovery of fusion.

C.2. Explain how the mass defect of various isotopes can be used to extract energy in fission and fusion.

Solution			

D. Chapter 3: Stellar Energy and Fusion

D.1.	Where doe	s the	energy	in sta	rs come	from,	and	how	was it	conjectured	?
------	-----------	-------	--------	--------	---------	-------	-----	-----	--------	-------------	---

Solution

D.2. Write the reaction of the proton-proton cycle. Why is it important for stars?

Solution

D.3. How are stars able to generate conditions for fusion, and why do we need other ways on earth?

Solution

D.4. What's the meaning of different star stages and their composition? What stage is the Sun and elements can it produce?

Solution

D.5. Explain primordial nucleosynthesis and how it led to the current universe.

Solution

E.1. Write equations and explain similarities and differences between fusion

E. Chapter 4: Fusion on Earth

(Solution)

reactions that are realistically possible to do on earth.
Solution
E.2. Why is tritium a scarce resource and how to produce it?
Solution
E.3. Draw the overall fuel cycle of a D-T fusion plant.
Solution
E.4. Explain the difficulty to achieve fusion regarding the Coulomb barrier. What makes it easier than an estimation via classical physics?

E.5. What temperatures are needed for thermonuclear fusion? Explain with regard to the reaction cross-section.

Solution

E.6. Explain the power amplification factor, break-even point, and ignition criterion.

Solution

E.7. What is the fusion triple-product? Explain all three terms and the ways to get a high value in magnetic and inertial confinement fusion.

Solution			

E.8. Discuss from a historical perspective how close we are to reach scientific and technical break-even and ignition for various fusion technologies.

Solution

F. Chapter 5: MISSING

G. Chapter 6: The Hydrogen Bomb

G .1.	Give a historical	international	perspective (on the	development	of the
	H-bomb.					



G.2. Explain the requirement for a H-bomb and advantages over pure fission.



G.3. Discuss limited resources and processing for Uranium and Tritium.



G.4. How does an H-bomb in the Teller-Ulam design work? Draw and explain.



G.5. Discuss ideas for civil uses of nuclear bombs and why they failed.



H. Chapter 7: MISSING