

Heavy nuclei and fission

Teo Banica

DEPARTMENT OF MATHEMATICS, UNIVERSITY OF CERGY-PONTOISE, F-95000
CERGY-PONTOISE, FRANCE. teo.banica@gmail.com

2010 *Mathematics Subject Classification.* 81V35

Key words and phrases. Heavy nucleus, Nuclear fission

ABSTRACT. This is an introduction to heavy nuclei and fission, with emphasis on the mathematical aspects of the fission mechanism, and with a discussion as well of the mathematical questions appearing in relation with the super-heavy elements.

Preface

This is an introduction to heavy nuclei and fission, with emphasis on the mathematical aspects of the fission mechanism, and with a discussion as well of the mathematical questions appearing in relation with the super-heavy elements.

Contents

Preface	3
Part I. Heavy nuclei	9
Chapter 1.	11
1a.	11
1b.	11
1c.	11
1d.	11
1e. Exercises	11
Chapter 2.	13
2a.	13
2b.	13
2c.	13
2d.	13
2e. Exercises	13
Chapter 3.	15
3a.	15
3b.	15
3c.	15
3d.	15
3e. Exercises	15
Chapter 4.	17
4a.	17
4b.	17
4c.	17
4d.	17
4e. Exercises	17

Part II. Atomic fission	19
Chapter 5.	21
5a.	21
5b.	21
5c.	21
5d.	21
5e. Exercises	21
Chapter 6.	23
6a.	23
6b.	23
6c.	23
6d.	23
6e. Exercises	23
Chapter 7.	25
7a.	25
7b.	25
7c.	25
7d.	25
7e. Exercises	25
Chapter 8.	27
8a.	27
8b.	27
8c.	27
8d.	27
8e. Exercises	27
Part III. Nuclear technology	29
Chapter 9.	31
9a.	31
9b.	31
9c.	31
9d.	31
9e. Exercises	31

CONTENTS

7

Chapter 10.	33
10a.	33
10b.	33
10c.	33
10d.	33
10e. Exercises	33
Chapter 11.	35
11a.	35
11b.	35
11c.	35
11d.	35
11e. Exercises	35
Chapter 12.	37
12a.	37
12b.	37
12c.	37
12d.	37
12e. Exercises	37
Part IV. Beyond actinides	39
Chapter 13.	41
13a.	41
13b.	41
13c.	41
13d.	41
13e. Exercises	41
Chapter 14.	43
14a.	43
14b.	43
14c.	43
14d.	43
14e. Exercises	43
Chapter 15.	45

15a.	45
15b.	45
15c.	45
15d.	45
15e. Exercises	45
Chapter 16.	47
16a.	47
16b.	47
16c.	47
16d.	47
16e. Exercises	47
Bibliography	49

Part I

Heavy nuclei

*Run away from all your boredom
Run away from all your whoredom
And wave your worries
And cares goodbye*

CHAPTER 1

1a.

1b.

1c.

1d.

1e. Exercises

Exercises:

EXERCISE 1.1.

EXERCISE 1.2.

EXERCISE 1.3.

EXERCISE 1.4.

EXERCISE 1.5.

EXERCISE 1.6.

EXERCISE 1.7.

EXERCISE 1.8.

Bonus exercise.

CHAPTER 2

2a.

2b.

2c.

2d.

2e. Exercises

Exercises:

EXERCISE 2.1.

EXERCISE 2.2.

EXERCISE 2.3.

EXERCISE 2.4.

EXERCISE 2.5.

EXERCISE 2.6.

EXERCISE 2.7.

EXERCISE 2.8.

Bonus exercise.

CHAPTER 3

3a.

3b.

3c.

3d.

3e. Exercises

Exercises:

EXERCISE 3.1.

EXERCISE 3.2.

EXERCISE 3.3.

EXERCISE 3.4.

EXERCISE 3.5.

EXERCISE 3.6.

EXERCISE 3.7.

EXERCISE 3.8.

Bonus exercise.

CHAPTER 4

4a.

4b.

4c.

4d.

4e. Exercises

Exercises:

EXERCISE 4.1.

EXERCISE 4.2.

EXERCISE 4.3.

EXERCISE 4.4.

EXERCISE 4.5.

EXERCISE 4.6.

EXERCISE 4.7.

EXERCISE 4.8.

Bonus exercise.

Part II

Atomic fission

*We're running out of alibis
On the second of May
Reminds me of the summertime
On this winter's day*

CHAPTER 5

5a.

5b.

5c.

5d.

5e. Exercises

Exercises:

EXERCISE 5.1.

EXERCISE 5.2.

EXERCISE 5.3.

EXERCISE 5.4.

EXERCISE 5.5.

EXERCISE 5.6.

EXERCISE 5.7.

EXERCISE 5.8.

Bonus exercise.

CHAPTER 6

6a.

6b.

6c.

6d.

6e. Exercises

Exercises:

EXERCISE 6.1.

EXERCISE 6.2.

EXERCISE 6.3.

EXERCISE 6.4.

EXERCISE 6.5.

EXERCISE 6.6.

EXERCISE 6.7.

EXERCISE 6.8.

Bonus exercise.

CHAPTER 7

7a.

7b.

7c.

7d.

7e. Exercises

Exercises:

EXERCISE 7.1.

EXERCISE 7.2.

EXERCISE 7.3.

EXERCISE 7.4.

EXERCISE 7.5.

EXERCISE 7.6.

EXERCISE 7.7.

EXERCISE 7.8.

Bonus exercise.

CHAPTER 8

8a.

8b.

8c.

8d.

8e. Exercises

Exercises:

EXERCISE 8.1.

EXERCISE 8.2.

EXERCISE 8.3.

EXERCISE 8.4.

EXERCISE 8.5.

EXERCISE 8.6.

EXERCISE 8.7.

EXERCISE 8.8.

Bonus exercise.

Part III

Nuclear technology

*In the shape of things to come
Too much poison come undone
Cause there's nothing else to do
Every me and every you*

CHAPTER 9

9a.

9b.

9c.

9d.

9e. Exercises

Exercises:

EXERCISE 9.1.

EXERCISE 9.2.

EXERCISE 9.3.

EXERCISE 9.4.

EXERCISE 9.5.

EXERCISE 9.6.

EXERCISE 9.7.

EXERCISE 9.8.

Bonus exercise.

CHAPTER 10

10a.

10b.

10c.

10d.

10e. Exercises

Exercises:

EXERCISE 10.1.

EXERCISE 10.2.

EXERCISE 10.3.

EXERCISE 10.4.

EXERCISE 10.5.

EXERCISE 10.6.

EXERCISE 10.7.

EXERCISE 10.8.

Bonus exercise.

CHAPTER 11

11a.

11b.

11c.

11d.

11e. Exercises

Exercises:

EXERCISE 11.1.

EXERCISE 11.2.

EXERCISE 11.3.

EXERCISE 11.4.

EXERCISE 11.5.

EXERCISE 11.6.

EXERCISE 11.7.

EXERCISE 11.8.

Bonus exercise.

CHAPTER 12

12a.

12b.

12c.

12d.

12e. Exercises

Exercises:

EXERCISE 12.1.

EXERCISE 12.2.

EXERCISE 12.3.

EXERCISE 12.4.

EXERCISE 12.5.

EXERCISE 12.6.

EXERCISE 12.7.

EXERCISE 12.8.

Bonus exercise.

Part IV

Beyond actinides

*There's a world outside my doorstep
Flames over everyone's heart
Don't you see them shining
I want to hear them beating for me*

CHAPTER 13

13a.

13b.

13c.

13d.

13e. Exercises

Exercises:

EXERCISE 13.1.

EXERCISE 13.2.

EXERCISE 13.3.

EXERCISE 13.4.

EXERCISE 13.5.

EXERCISE 13.6.

EXERCISE 13.7.

EXERCISE 13.8.

Bonus exercise.

CHAPTER 14

14a.

14b.

14c.

14d.

14e. Exercises

Exercises:

EXERCISE 14.1.

EXERCISE 14.2.

EXERCISE 14.3.

EXERCISE 14.4.

EXERCISE 14.5.

EXERCISE 14.6.

EXERCISE 14.7.

EXERCISE 14.8.

Bonus exercise.

CHAPTER 15

15a.

15b.

15c.

15d.

15e. Exercises

Exercises:

EXERCISE 15.1.

EXERCISE 15.2.

EXERCISE 15.3.

EXERCISE 15.4.

EXERCISE 15.5.

EXERCISE 15.6.

EXERCISE 15.7.

EXERCISE 15.8.

Bonus exercise.

CHAPTER 16

16a.

16b.

16c.

16d.

16e. Exercises

Congratulations for having read this book, and no exercises for this final chapter.

Bibliography

- [1] A.A. Abrikosov, *Fundamentals of the theory of metals*, Dover (1988).
- [2] A.A. Abrikosov, L.P. Gorkov and I.E. Dzyaloshinski, *Methods of quantum field theory in statistical physics*, Dover (1963).
- [3] V.I. Arnold, *Mathematical methods of classical mechanics*, Springer (1974).
- [4] V.I. Arnold and B.A. Khesin, *Topological methods in hydrodynamics*, Springer (1998).
- [5] N.W. Ashcroft and N.D. Mermin, *Solid state physics*, Saunders College Publ. (1976).
- [6] T. Banica, *Introduction to modern physics* (2024).
- [7] T. Banica, *Principles of thermodynamics* (2024).
- [8] G.K. Batchelor, *An introduction to fluid dynamics*, Cambridge Univ. Press (1967).
- [9] R.J. Baxter, *Exactly solved models in statistical mechanics*, Academic Press (1982).
- [10] S.M. Carroll, *Spacetime and geometry*, Cambridge Univ. Press (2004).
- [11] P.M. Chaikin and T.C. Lubensky, *Principles of condensed matter physics*, Cambridge Univ. Press (1995).
- [12] A.R. Choudhuri, *Astrophysics for physicists*, Cambridge Univ. Press (2012).
- [13] D.D. Clayton, *Principles of stellar evolution and nucleosynthesis*, Univ. of Chicago Press (1968).
- [14] W.N. Cottingham and D.A. Greenwood, *An introduction to the standard model of particle physics*, Cambridge Univ. Press (2012).
- [15] P.A. Davidson, *Introduction to magnetohydrodynamics*, Cambridge Univ. Press (2001).
- [16] P.A.M. Dirac, *Principles of quantum mechanics*, Oxford Univ. Press (1930).
- [17] S. Dodelson, *Modern cosmology*, Academic Press (2003).
- [18] A. Einstein, *Relativity: the special and the general theory*, Dover (1916).
- [19] E. Fermi, *Thermodynamics*, Dover (1937).
- [20] R.P. Feynman, R.B. Leighton and M. Sands, *The Feynman lectures on physics*, Caltech (1963).
- [21] R.P. Feynman and A.R. Hibbs, *Quantum mechanics and path integrals*, Dover (1965).
- [22] A.P. French, *Special relativity*, Taylor and Francis (1968).

- [23] N. Goldenfeld, Lectures on phase transitions and the renormalization group, CRC Press (1992).
- [24] H. Goldstein, C. Safko and J. Poole, Classical mechanics, Addison-Wesley (1980).
- [25] D.L. Goodstein, States of matter, Dover (1975).
- [26] D.J. Griffiths, Introduction to electrodynamics, Cambridge Univ. Press (2017).
- [27] D.J. Griffiths and D.F. Schroeter, Introduction to quantum mechanics, Cambridge Univ. Press (2018).
- [28] D.J. Griffiths, Introduction to elementary particles, Wiley (2020).
- [29] D.J. Griffiths, Revolutions in twentieth-century physics, Cambridge Univ. Press (2012).
- [30] W.A. Harrison, Solid state theory, Dover (1970).
- [31] W.A. Harrison, Electronic structure and the properties of solids, Dover (1980).
- [32] K. Huang, Introduction to statistical physics, CRC Press (2001).
- [33] K. Huang, Quarks, leptons and gauge fields, World Scientific (1982).
- [34] L.P. Kadanoff, Statistical physics: statics, dynamics and renormalization, World Scientific (2000).
- [35] T. Kibble and F.H. Berkshire, Classical mechanics, Imperial College Press (1966).
- [36] C. Kittel, Introduction to solid state physics, Wiley (1953).
- [37] T. Lancaster and K.M. Blundell, Quantum field theory for the gifted amateur, Oxford Univ. Press (2014).
- [38] R.K. Pathria and P.D. Beale, Statistical mechanics, Elsevier (1972).
- [39] B.M. Peterson and B. Ryden, Foundations of astrophysics, Cambridge Univ. Press (2010).
- [40] B. Ryden, Introduction to cosmology, Cambridge Univ. Press (2002).
- [41] B. Ryden and R.W. Pogge, Interstellar and intergalactic medium, Cambridge Univ. Press (2021).
- [42] D.V. Schroeder, An introduction to thermal physics, Oxford Univ. Press (1999).
- [43] J.R. Taylor, Classical mechanics, Univ. Science Books (2003).
- [44] J. von Neumann, Mathematical foundations of quantum mechanics, Princeton Univ. Press (1955).
- [45] S. Weinberg, Foundations of modern physics, Cambridge Univ. Press (2011).
- [46] S. Weinberg, Lectures on quantum mechanics, Cambridge Univ. Press (2012).
- [47] S. Weinberg, Lectures on astrophysics, Cambridge Univ. Press (2019).
- [48] S. Weinberg, Cosmology, Oxford Univ. Press (2008).
- [49] H. Weyl, Space, time, matter, Princeton Univ. Press (1918).
- [50] J.M. Yeomans, Statistical mechanics of phase transitions, Oxford Univ. Press (1992).