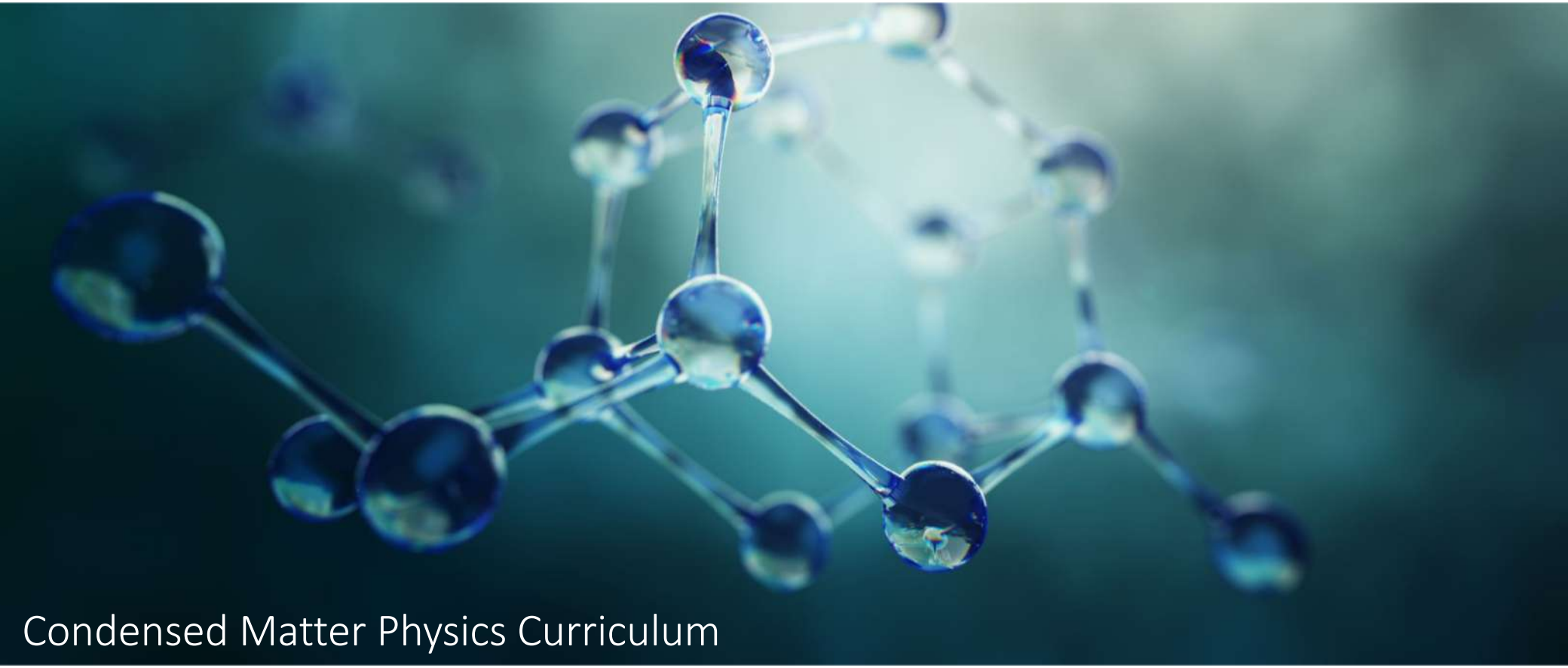


Condensed Matter Physics Curriculum

Giornata di presentazionealle matricole, 22/9/2023

Thanks to: Marta De Luca, Bernard van Heck, Paolo Postorino

Responsible for the Curriculum

Prof. Paolo Postorino

- E-mail: **paolo.postorino@roma1.infn.it** & **paolo.postorino@uniroma1.it**
- **@ Fermi building**
- **Office room 401** & **Lab HPS room 418 (**IV floor)
- **Lab LTS room 115 (**I floor)

Condensed Matter Physics @Sapienza

- ***Condensed Matter (CM) Physics group:*** *more than 50 scientists (researchers, associate and full profs.), several affiliated researchers (mostly CNR) and tens of Ph.D. students and Post. Docs.*

- ***Main Research Areas:*** *hard matter, nano-structures, soft and bio matter, photonics and quantum technologies.*

https://www.phys.uniroma1.it/fisica/ricerca/aree-tematiche-e-gruppi-di-ricerca

Condensed Matter Curriculum

Why should I choose it?

- **International Atmosphere:** The curriculum is in English, Many international Collaborations, Erasmus Mundus Quarmen.
- **Challenging Problems:** Fast Progress, Small Research Groups/Teams (Experiments are Cheap)
- **Applied and Fundamental Research.**
- **Many Career Opportunities in Italy and Abroad** in Research and Development (semiconductor electronics, automotive, microelectronics), Data Science, Quantitative Science.

What is condensed matter physics?

It deals with macroscopic and microscopic physical properties of matter, primarily **solids and liquids**.

- Necessity to **understand systems of many interacting particles or components.**
- Realization that "**more is different": new properties emerge** that are not attributes of individual constituents, leading to a huge variety of phenomena and applications.

NOBEL PRIZES IN THE LAST 15 YEARS

2022, "*for experiments with **entangled photons**, establishing the violation of Bell inequalities and pioneering **quantum information science***", Alain Aspect, John F. Clauser and Anton Zeilinger

2018, *"For groundbreaking inventions in the field of **laser physics**"*, A. Ashkin, G. Mourou, D. Strickland

2016 *"For theoretical discoveries of **topological phase transitions** and **topological phases of matter**"*, D. J. Thouless, F.M.D. Haldane, J.M. Kosterlitz

2014 *"For the invention of efficient blue **light-emitting diodes** which has enabled bright and energy-saving white light sources"*, I. Akasaki, H. Amano and S. Nakamura

2012 *"For ground-breaking **experimental methods** that enable measuring and manipulation of **individual quantum systems**"*, S. Haroche and D. J. Wineland

2010 *"For groundbreaking experiments regarding the **two-dimensional material graphene**"*, A. Geim, K. Novoselov

2009 *"For the invention of an **imaging semiconductor circuit – the CCD sensor**"*, W.S. Boyle and G.E. Smith

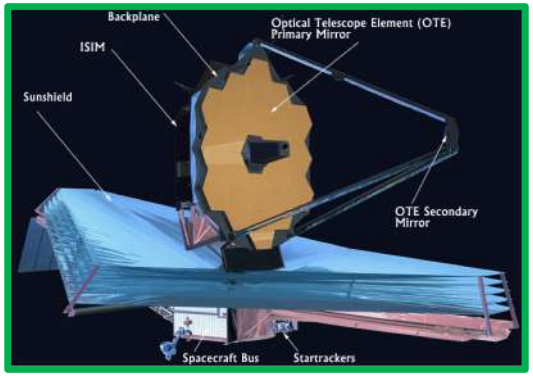
Taken from B. Van Heck, M. de Luca

Why is it important?

Condensed matter is **the largest subfield of physics** (~1/3 physicists are in Condensed Matter): ***why?***

- **It is all around us.** We spend most of our day interacting with "condensed matter". It gives the answers to simple questions, *e.g.*: why do we like coffee in ceramic cups? Why is a piece of gold shiny?

- It provides the ideal **laboratory to study, apply and develop quantum mechanics and statistical physics**



…which are in turn enabling new discoveries in other fields

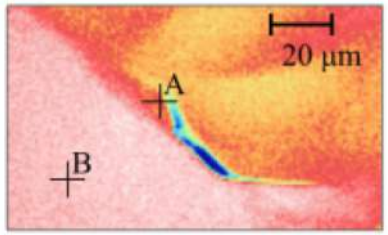
Taken from B. Van Heck, M. de Luca

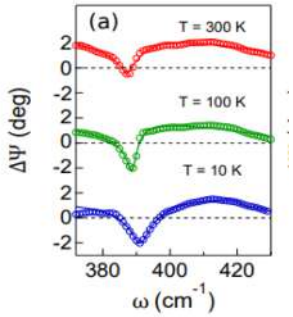
Experimental Condensed Matter (Sapienza)

HARD CONDENSED MATTER

Superconductivity, strongly-correlated systems, and topological states

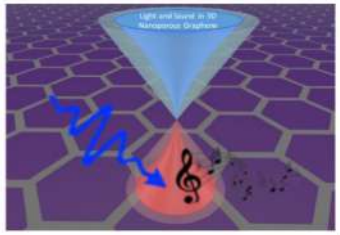
[Saini, Nucara, Ortolani, Del Re, Conti, Postorino]

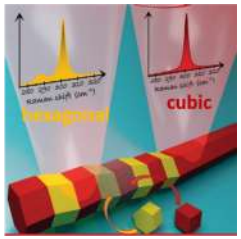




Surface Physics, Nanostructures

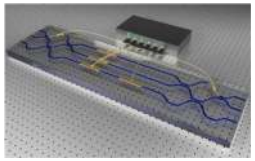
[Baldassarre, Ortolani, Nucara, Lupi, Betti, Mariani, Frisenda, Postorino, Felici, Polimeni, De Luca M., Trotta, Placidi, Scopigno, Trequattrini]

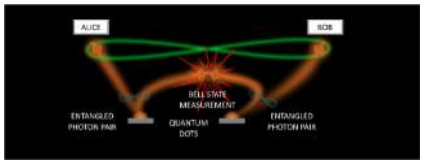




PHOTONICS & QUANTUM TECHNOLOGIES

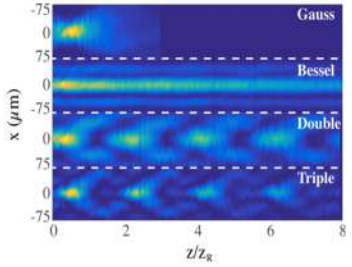
[Sciarrino, Spagnolo, Mataloni, Conti, Del Re, Trotta]

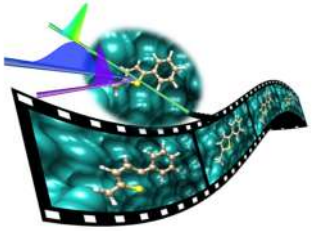


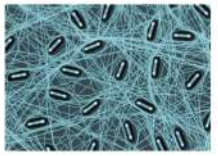


ACTIVE MATTER, SOFT MATTER & BIOPOLYMERS

[Postorino, Baldassarre, Ortolani, Ruocco, Conti, Del Re, Di Leonardo, Scopigno, Sarti, Bordi, Bove, Trequattrini]



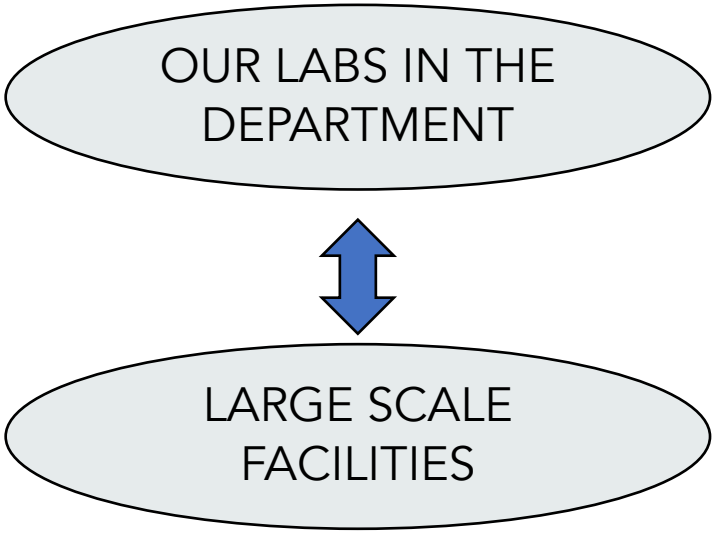




Adapted from B. Van Heck, M. de Luca

Experimental Condensed Matter (Sapienza)

Electrons, neutrons, ions and photons are the main probes in condensed matter experiments



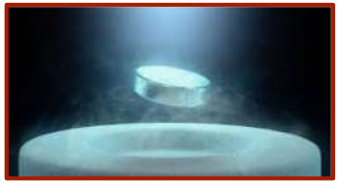
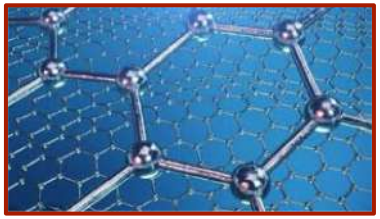
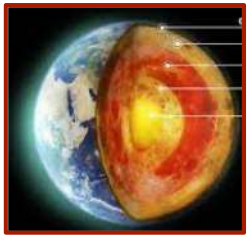
Taken from B. Van Heck, M. de Luca

- Synchrotron sources
- Free electron lasers
- Neutron sources
- European magnetic field laboratories
- Micro/nano fabrication labs

Theoretical Condensed Matter (Sapienza)

QUANTUM MATTER

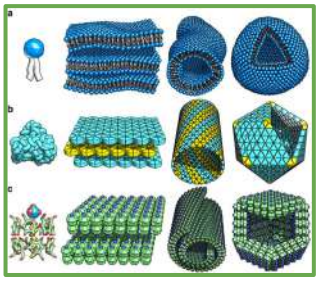
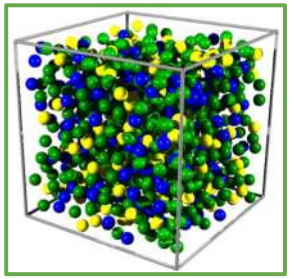
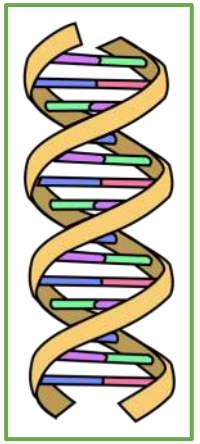
[Lara Benfatto, Lilia Boeri, Sergio Caprara, Marco Grilli, Francesco Mauri, Riccardo Mazzarello, Bernard van Heck]

- Superconductivity
- Magnetism
- 2D Materials
- Matter @ Extreme conditions
- Topological Matter
- Quantum Devices

SOFT MATTER

[Andrea Crisanti, Cristiano De Michele, Lorenzo Rovigatti, John Russo, Francesco Sciortino]

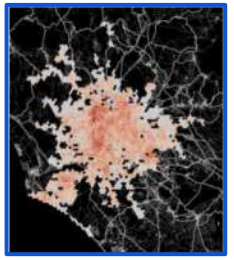




- Complex liquids
- Self-assembly
- Biopolymers
- Phase-Change Materials
- Active Matter

COMPLEXITY

[Vittorio Loreto, Francesca Tria]





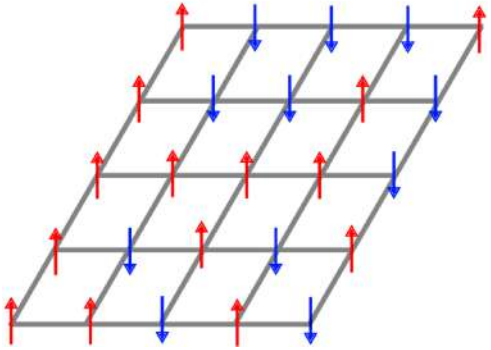
- Networks
- Human Dynamics
- Innovation dynamics
- Sustainable Cities

Taken from B. Van Heck, M. de Luca

Theoretical Condensed Matter (Sapienza)

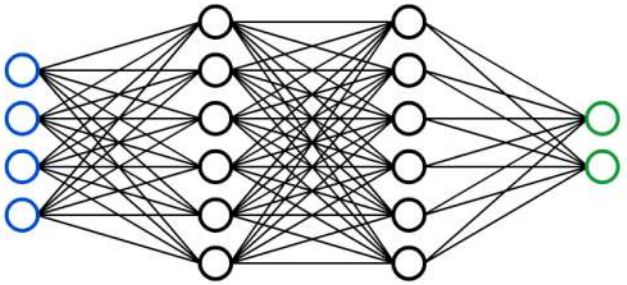
Research in theoretical condensed matter theory requires to learn, use and develop advanced methods in theoretical physics, both analytical and numerical.

Many-Body Theory



Statistical Mechanics

Computer Simulations (Quantum & Classical)



Machine Learning & AI

Taken from B. Van Heck, M. de Luca

Curriculum

Standard:
Mandatory (6) and eligible courses (6) chosen within the groups: A(1), B(2) , C(1), free choice (2)

5 recommended curricula:

- Complexity Science
- Disordered systems: liquid, glassy and soft matter
- Photonics and Quantum Technologies
- Superconductivity, Strongly Correlated Systems, and Functional Materials
- Surface Physics and Nanostructures

Customized:
Mandatory courses are always mandatory but eligible courses can be chosen more freely. The individual plan must be motivated and possibly discussed with the responsible of the curriculum.

Talk to P. Postorino

Information and syllabus for courses:
https://corsidilaurea.uniroma1.it/it/corso/2021/30055/cds

Corso di laurea in Fisica (LM-17) - Curriculum Condensed matter physics: Theory and experiment							
N.	**Insegnamenti**	**CFU**	**anno**	**sem.**	**SSD**	**eng**	**ambito**
1	Introduction to Quantum Field Theory	6	1	1	FIS/02	Y	caratt.
2	Condensed Matter Physics	6	1	1	FIS/03	Y	caratt.
3	Physics Laboratory I (propedeutico a Physics Laboratory II) *	6	1	1	FIS/01	Y	caratt.
4	Physics Laboratory II *	9	1	2	FIS/01	Y	caratt.
5	Condensed Matter Physics II	6	1	2	FIS/03	Y	caratt.
6	Computing Methods for Physics *	6	1	1	INF/01	Y	aff.-int.
7	English Language	4	1	2		Y	AAF
8	Elective (within group A)	6	1 / 2	1 / 2		Y	aff.-int.
9	Elective (within group B)	6	1 / 2	1 / 2	FIS/03	Y	caratt.
10	Elective (within group B)	6	1 / 2	1 / 2	FIS/03	Y	caratt.
11	Elective (within group C)	6	1 / 2	1 / 2		Y	aff.-int.
12	Elective (free choice)	6	1/2	1/2			
13	Elective (free choice)	6	1/2	1/2			
14	Internship	3	2	1		Y	AAF
15	Thesis Project	38	2	2		Y	AAF

* internal multiple choice

Corso di laurea in Fisica (LM-17) - Curriculum Condensed matter physics: Theory and experiment

N.	Insegnamenti	CFU	anno	sem.	SSD	eng	ambito
1	Introduction to Quantum Field Theory	6	1	1	FIS/02	Y	caratt.
2	Condensed Matter Physics	6	1	1	FIS/03	Y	caratt.
3	Physics Laboratory I (propedeutico a Physics Laboratory II)	6	1	1	FIS/01	Y	caratt.
4	Physics Laboratory II	9	1	2	FIS/01	Y	caratt.
5	Condensed Matter Physics II	6	1	2	FIS/03	Y	caratt.
6	Computing Methods for Physics	6	1	1	INF/01	Y	aff.-int.
7	English Language	4	1	2		Y	AAF
8	Elective (within group A)	6	1 / 2	1 / 2		Y	aff.-int.
9	Elective (within group B)	6	1 / 2	1 / 2	FIS/03	Y	caratt.
10	Elective (within group B)	6	1 / 2	1 / 2	FIS/03	Y	caratt.
11	Elective (within group C)	6	1 / 2	1 / 2		Y	aff.-int.
12	Elective (free choice)	6	1/2	1/2			
13	Elective (free choice)	6	1/2	1/2			
14	Internship	3	2	1		Y	AAF
15	Thesis Project	38	2	2		Y	AAF

Corso di laurea in Fisica (LM-17) - Curriculum Condensed matter physics: Theory and experiment

N.	Insegnamenti	CFU	anno	sem.	SSD	eng	ambito
1	Introduction to Quantum Field Theory	6	1	1	FIS/02	Y	caratt.
2	Condensed Matter Physics	6	1	1	FIS/03	Y	caratt.
3	Physics Laboratory I (propedeutico a Physics Laboratory II)	6	1	1	FIS/01	Y	caratt.
4	Physics Laboratory II	9	1	2	FIS/01	Y	caratt.
5	Condensed Matter Physics II	6	1	2	FIS/03	Y	caratt.
6	Computing Methods for Physics	6	1	1	INF/01	Y	aff.-int.
7	English Language	4	1	2		Y	AAF
8	Elective (within group A)	6	1 / 2	1 / 2		Y	aff.-int.
9	Elective (within group B)	6	1 / 2	1 / 2	FIS/03	Y	caratt.
10	Elective (within group B)	6	1 / 2	1 / 2	FIS/03	Y	caratt.
11	Elective (within group C)	6	1 / 2	1 / 2		Y	aff.-int.
12	Elective (free choice)	6	1/2	1/2			
13	Elective (free choice)	6	1/2	1/2			
14	Internship	3	2	1		Y	AAF
15	Thesis Project	38	2	2		Y	AAF

1

Gruppo A (aff.– int.)							
1	Statistical Mechanics and Critical Phenomena	6	1	1	FIS/02	Y	
2	Physics of liquids	6	1	2	FIS/03	Y	
3	Physics of solids	6	2	1	FIS/03	Y	

1

Gruppo A (aff.– int.)							
1	Statistical Mechanics and Critical Phenomena	6	1	1	FIS/02	**Y**	
2	Physics of liquids	6	1	2	FIS/03	**Y**	
3	Physics of solids	6	2	1	FIS/03	**Y**	

2

Gruppo B (caratt.)							
1	Soft and Biological Matter	6	1	1	FIS/03	Y	
2	Nonlinear and Quantum Optics	6	1	1	FIS/03	**Y**	
3	Photonics	6	1	2	FIS/03	**Y**	
4	Physics of liquids	6	1	2	FIS/03	Y	
5	Spectroscopy Methods and Nanophotonics	6	1	2	FIS/03	**Y**	
6	Superconductivity and Superfluidity	6	1	2	FIS/03	Y	
7	Many Body Physics	6	2	1	FIS/03	**Y**	
8	Physics of solids	6	2	1	FIS/03	**Y**	
9	Physics of Complex Systems	6	2	1	FIS/03	Y	
10	Surface Physics and Nanostructures	6	2	1	FIS/03	Y	

1

Gruppo C (aff.-int..)							
1	Computational Biophysics	6	1	1	INF/01	Y	
2	Nonlinear and Quantum Optics	6	1	1	FIS/03	Y	
3	Soft and Biological Matter	6	1	1	FIS/03	Y	
4	Statistical Mechanics and Critical Phenomena	6	1	1	FIS/02	**Y**	
5	Biophysics	6	1	2	FIS/03	Y	
6	Computer architecture for Physics	6	1	2	INF/01	Y	
7	Advanced Machine Learning for Physics	6	1	2	INF/01	Y	
8	Mathematical Physics	6	1	2	MAT/07	Y	
9	Neural Networks	6	1	2	FIS/02	Y	
10	Nonlinear waves and solitons	6	1	2	FIS/02	**Y**	
11	Photonics	6	1	2	FIS/03	Y	
12	Physics of liquids	6	1	2	FIS/03	Y	
13	Spectroscopy Methods and Nanophotonics	6	1	2	FIS/03	**Y**	
14	Superconductivity and Superfluidity	6	1	2	FIS/03	**Y**	
15	Theoretical Biophysics	6	1	2	FIS/02	Y	
16	Molecular Biology	6	1	2	BIO/11	Y	
17	Quantum Field Theory	6	2	1	FIS/02	Y	
18	Physics of Solids	6	2	1	FIS/03	**Y**	
19	Medical Applications of Physics	6	2	1	FIS/01	Y	
20	Many-Body Physics	6	2	1	FIS/03	Y	
21	Physics of Complex Systems	6	2	1	FIS/03	**Y**	
22	Quantum Information and Computation	6	2	1	FIS/01	**Y**	
23	Solid State Sensors	6	2	1	FIS/01	Y	
24	Statistical Mechanics of Disordered Systems	6	2	1	FIS/02	**Y**	
25	Surface Physics and Nanostructures	6	2	1	FIS/03	Y	
26	Statistical Physics and Machine Learning	6	2	1	FIS/02	Y	

Responsible for the Curriculum

Prof. Paolo Postorino

- E-mail: **paolo.postorino@roma1.infn.it** & **paolo.postorino@uniroma1.it**
- **@ Fermi building**
- **Office room 401** & **Lab HPS room 418 (**IV floor)
- **Lab LTS room 115 (**I floor)

Complexity Science

ANNO	SEM.	CFU
1	1	
Introduction to Quantum Field Theory		6
Condensed Matter Physics		6
Physics Lab I		6
Computing Methods for physics (C-INF)		6
Statistical mechanics and Critical Phenomena (A)		6
		30

ANNO	SEM.	
1	2	
Physics Lab II		9
Condensed Matter Physics II		6
Meccanica Statistica del Non Equilibrio (C)		6
English Language		4
One among (Free Choice):		
Advanced Machine Learning for Physics;		
Deep learning and applied artificial intelligence (Informatica)		6
		31

ANNO	SEM.	
2	1	
Machine Learning (C-INF)		6
Physics of Complex Systems (B)		6
One among (free choice):		
Superconductivity and Superfluidity;		
Statistical mechanics of disordered systems;		
Introduzione alla teoria dei processi stocastici;		
Statistical physics and Machine learning		6
Internship		3
		21

ANNO	SEM.	
2	2	
Thesis project		38

Disordered systems: liquid, glassy and soft matter

ANNO	SEM.	
1	1	CFU
Introduction to Quantum Field Theory		6
Condensed Matter Physics		6
Physics Lab I		6
Computing Methods for Physics (C-INF)		6
Soft and Biological Matter (B)		6
		30

ANNO	SEM.	
1	2	
Physics Lab II		9
Condensed Matter Physics II		6
Physics of Liquids (A)		6
Biophysics (C)		6
One among:		
Deep learning and applied artificial intelligence;		
Machine Learning;		
Advanced Machine Learning for Physics;		
or another non-FIS course		6
English Language		4
Totale		37

ANNO	SEM.	
2	1	
Two among (free choice):		
Statistical mechanics of disordered systems;		
Introduzione alla teoria dei processi stocastici ed applicazioni alla fisica		
Statistical mechanics and Critical Phenomena		12
Internship		3
Totale		15

ANNO	SEM.	
2	2	
Thesis project		38

Photonics and Quantum Technologies

ANNO	SEM.	CFU
1	1	
Introduction to Quantum Field Theory		6
Condensed Matter Physics		6
Physics Lab I		6
Nonlinear and Quantum Optics (B)		6
Computing methods for physics (C-Inf)		6
		30

ANNO	SEM.	
1	2	
Physics Lab II		9
Condensed Matter Physics II		6
English Language		4
Photonics (B)		6
One among:		
Spectroscopy methods and nanophotonics;		
Nonlinear waves and solitons;		
One free choice non-FIS		6
		31

ANNO	SEM.	
2	1	
Physics of Solids (A)		6
Quantum Information and Computation (C)		6
One among:		
Solid State Sensors;		
Surface Physics and Nanostructures;		
One free choice non-FIS (required)		6
Internship		3
		21

ANNO	SEM.	
2	2	
Thesis project		38

Superconductivity, Strongly Correlated System, and Functional Materials

ANNO	SEM.	CFU
1	1	
Introduction to Quantum Field Theory		6
Condensed Matter Physics		6
Physics Lab I		6
Computing methods for physics (C-Inf)		6
One among:		
Statistical mechanics and Critical Phenomena (C);		
Nonlinear and Quantum Optics (C)		6
		30

ANNO	SEM.	
1	2	
Physics Lab II		9
Condensed Matter Physics II		6
English Language		4
Superconductivity and Superfluidity (B)		6
One or Two among:		
Spectroscopy methods and nanophotonics (B);		
Mathematical Physics (C-Mat);		
Photonics (C);		
Physics of liquids (C);		
another non-fis exam of group C		6 or 12
		31 or 37

ANNO	SEM.	
2	1	
Physics of Solids (A)		6
Many-Body Physics (B)		6
Zero or One:	Surface Physics and Nanostructures (B);	
	Quantum Information and Computation (C);	
	Solid State Sensors (C);	
	Machine Learning (C-Inf -Informatica);	
	Advanced Machine Learning for Physics;	
	or other non-Fis exam	0 or 6
Internship		3
		21 or 15

ANNO	SEM.	
2	2	
Thesis project		38

Surface Physics and Nanostructures

ANNO	SEM.	CFU
1	1	
Introduction to Quantum Field Theory		6
Condensed Matter Physics		6
Physics Lab I		6
Computing methods for physics (C-Inf)		6
One among:	Nonlinear and Quantum Optics (C);	
	Statistical mechanics and Critical Phenomena (C)	6
		30

ANNO	SEM.	
1	2	
Physics Lab II		9
Condensed Matter Physics II		6
English Language		4
Spectroscopy methods and nanophotonics (B)		6
One or two among:		
Superconducitvity and Superfluidity (B);		
Photonics (C);		
Physics of liquids (C);		
Mathematical Physics (C-mat);		
or another non-Fis exam		6 o 12
		31 or 37

ANNO	SEM.	
2	1	
Physics of Solids (A)		6
Surface Physics and Nanostructures (B)		6
One or zero among:		
Many Body Physics (B);		
Quantum Information and Computation (C);		
Solid State Sensors (elective free choice);		
Machine Learning (C-inf);		
Advanced Machine Learning for Physics;		
or another non-fis exam		6 o 0
Internship		3
		21 or 15

ANNO	SEM.	
2	2	
Thesis project		38