

<b>Academic Year</b>	2019/20	<b>Semester</b>	2
<b>Course Coordinator</b>	Assoc. Prof. Massimo Pica Ciamarra Asst. Prof. Lu Bing Sui		
<b>Course Code</b>	PH4603		
<b>Course Title</b>	Soft Condensed Matter Physics		
<b>Pre-requisites</b>	PH2103 Thermal Physics		
<b>No of AUs</b>	3 AU		
<b>Contact Hours</b>	PH4603 (2 hr – lecture; 1 hr – tutorial)		
<b>Proposal Date</b>	4 October 2019		

### Course Aims

This course aims to equip you with the key concepts and problem solving skills to the physics of soft matter, such as colloids, foams, granular media and liquid crystals. You will be exposed to the theory and experimental methods used in the development and study of soft matter.

### Intended Learning Outcomes (ILO)

Upon the successful completion of this course, you (as a student) would be **able to**:

1. Describe the force, energy and timescales relevant to soft condensed matter systems
2. Explain why entropy is relevant in the response of soft matter systems
3. Evaluate the conditions under which soft matter systems undergo a phase transition, and solve problems related to the regular solution (Flory-Huggins) model
4. Solve problems concerning the rheological response of soft matter systems to relate the rheological behaviour to experimental.
5. Derive and solve problems concerning Brownian motion and Random walks, identifying the analogies between these two models and their relevance for both soft matter in general (diffusion) and polymer physics in particular.
6. Derive the elastic properties of polymers (ideal and real polymers), starting from the derivation of their free energy.
7. Solve problems related to the elastic properties of polymer networks (rubber), using the theory of classical rubber elasticity of Kuhn and modifications of the theory.
8. Solve problems related to swollen gels such as hydrogels, using a combination of the classical rubber elasticity theory and the regular solution model
9. Describe and explain the origin of the terms in the Poisson-Boltzmann equation
10. Solve problems related to how ions are distributed from a charged surface in counterion-only and salt solutions
11. Explain how entropy can result in the repulsion of charged colloids in solution
12. Explain how entropy can result in attraction of neighboring colloids (as in the depletion effect)
13. Explain the origin of van der Waals interactions
14. Account for the different distance scaling behaviors of van der Waals forces between a pair of molecules, a molecule and a planar slab, and a pair of planar slabs
15. Describe the relevance of soft matter to biological physics and food physics.

### Course Content

#### Basic Principles (BP)

Atomic and molecular forces  
Statistical Mechanics  
Rheological properties  
Phase transitions

**Colloidal dispersions**

Brownian motion  
Colloidal scale forces  
Stability

**Polymers**

Ideal and real polymers  
Rubber elasticity  
Viscoelasticity

**Polymer networks and gels**

Stress and strain in rubber elasticity  
Kuhn's Theory of classical rubber elasticity  
Models of rubber elasticity beyond the Kuhn theory  
Swollen gels

**Colloidal interactions**

Electrostatics in solution  
Depletion effect  
van der Waals interactions

**Assessment (includes both continuous and summative assessment)**

Component	Course LO Tested	Related Programme LO or Graduate Attributes	Weighting	Team / Individual	Assessment Rubrics
1. Final Examination	All	Competence (2,3) (Written)	50%	Individual	Point-based marking (not rubric-based)
2. CA1: Problem Sets	All	Competence (2,3) (Written) Creativity (1) Communication (1)	15%	Individual	Point-based marking (not rubric-based) Using Mastering Physics
3. CA2: Mid-term 1	All topics covered before the break	Competence (2,3) (Written) Communication (1) (Written)	30%	Individual	Point-based marking (not rubric-based)
4. CA3: Quiz	ALL	Competence (2,3) (Written) Creativity (1)	5%	Individual	Learning Catalytics
Total			100%		

**Formative feedback**

You will receive formative feedback is given through discussion within tutorial lessons as well as interactive, computer- based hints in online lessons.

Feedback will also be provided for each problem set, where any particularly problematic areas will be identified.

Finally, feedback will be given after the midterm on the common mistakes and level of difficulty of the problems. Past exam questions and examiner's report are also made available for you.

### Learning and Teaching approach

Approach	How does this approach support students in achieving the learning outcomes?
Problem solving (tutorial and lecture)	Develop competence and perseverance in solving physics problems
Hands-on group activities (during tutorial)	Develop physical intuition and competence in solving real-life problems. Relate everyday phenomena to physics.
Peer Instruction (during lecture)	Develop communication skills and competence in physics. Students are encouraged to discuss their answers to the Clickers questions so that they can learn from one another.

### Reading and References

R.A.L. Jones, Soft Condensed Matter, Oxford University Press, ISBN 978-0198505891  
M. Doi, Soft Matter Physics, Oxford University Press, ISBN 978-0199652952

### Course Policies and Student Responsibilities

#### *Absence Due to Medical or Other Reasons*

If you are sick and unable to attend your class / Mid-terms, you have to:

1. Send an email to the instructor regarding the absence and request for a replacement class and make-up mid-terms.
2. Submit the original Medical Certificate\* or official letter of excuse to administrator.
3. Attend the assigned replacement class (*subject to availability*) and make-up mid-terms.

\* The medical certificate mentioned above should be issued in Singapore by a medical practitioner registered with the Singapore Medical Association.

### Academic Integrity

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU's shared values.

As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you should go to the [academic integrity website](#) for more information. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

### Course Instructors

Instructor	Office Location	Phone	Email
Assoc. Prof. Massimo	SPMS-PAP-03-14	6592 2542	massimo@ntu.edu.sg
Asst. Prof. Lu Bing Sui	SPMS-PAP-05-01A	9723 8943	bslu@ntu.edu.sg

### Planned Weekly Schedule

Week	Topic	Course ILO	Readings/ Activities
1	Introduction & Rheology	1	Jones 1; Note provided Learning Catalytics
2	Molecular Interaction	1	Jones 2; Learning Catalytics
3	Statistical Mechanics (Review) & State of matter	2	Jones Appendix A; Jones 2.2-2.4 Learning Catalytics
4	Solution Theory	3	Jones 3 Learning Catalytics
5	Kinetics of Phase Separation; Diffusion; Random Walk	4,5	Jones 3.4; Jones 4.1 Learning Catalytics
6	Polymers	6	Jones 5.1, 5.2 Learning Catalytics
7	Polymers, Rubber, Viscoelasticity	6	Jones 5.3, 5.4, 5.5 Learning Catalytics
8	Introduction to polymer networks/rubber, stress and strain in elasticity theory	7	Doi 3.1 – 3.2 Mid-term/Learning Catalytics
9	Models of rubber elasticity	7, 8	Doi 3.3 Learning Catalytics
10	Behavior of swollen gels	8	Doi 3.4 Learning Catalytics
11	Introduction to colloids	15	Jones 4.3.1 Learning Catalytics
12	Electrostatics in solution	9,10,11	Jones 4.3.3 Learning Catalytics
13	Van der Waals and depletion forces	12,13,14	Jones 4.3.2, 4.3.5 Revision lecture/Learning Catalytics

## **Graduate Attributes**

### **What we want our graduates from *Physics and Applied Physics* to be able to do:**

Upon the successful completion of the PHY, APHY and PHMA programs, graduates should be able to:

<b>Competency</b>	1	demonstrate a rigorous understanding of the core theories and principles of physics involving (but not limited to) areas such as classical mechanics, electromagnetism, thermal physics and quantum mechanics  [PHMA only] demonstrate a rigorous understanding of the core theories and principles of mathematical sciences involving (but not limited to) areas such as analysis, algebra and statistical analysis
	2	read and understand undergraduate level physics content independently;
	3	make educated guesses / estimations of physical quantities in general;
	4	apply fundamental physics knowledge, logical reasoning, mathematical and computational skills to analyse, model and solve problems;
	5	develop theoretical descriptions of physical phenomena with an understanding of the underlying assumptions and limitations;
	6	critically evaluate and distinguish sources of scientific/non-scientific information and to recommend appropriate decisions and choices when needed;
	7	demonstrate the ability to design and conduct experiments in a Physics laboratory, to make measurements, analyse and interpret data to draw valid conclusions.

<b><i>Creativity</i></b>	1	propose valid approaches to tackle open-ended problems in unexplored domains;
	2	offer valid alternative perspectives/approaches to a given situation or problem.

<b><i>Communication</i></b>	1	describe physical phenomena with scientifically sound principles;
	2	communicate (in writing and speaking) scientific and non-scientific ideas effectively to professional scientists and to the general public;
	3	communicate effectively with team members when working in a group.

<b><i>Character</i></b>	1	uphold absolute integrity when conducting scientific experiments, reporting and using the scientific results;
	2	readily pick up new skills, particularly technology related ones, to tackle new problems;
	3	contribute as a valued team member when working in a group.

<b><i>Civic Mindedness</i></b>	1	put together the skills and knowledge into their work in an effective, responsible and ethical manner for the benefits of society.
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