General Physics I

Lect1. Physics and Natural Philosophy Theories

李圣超

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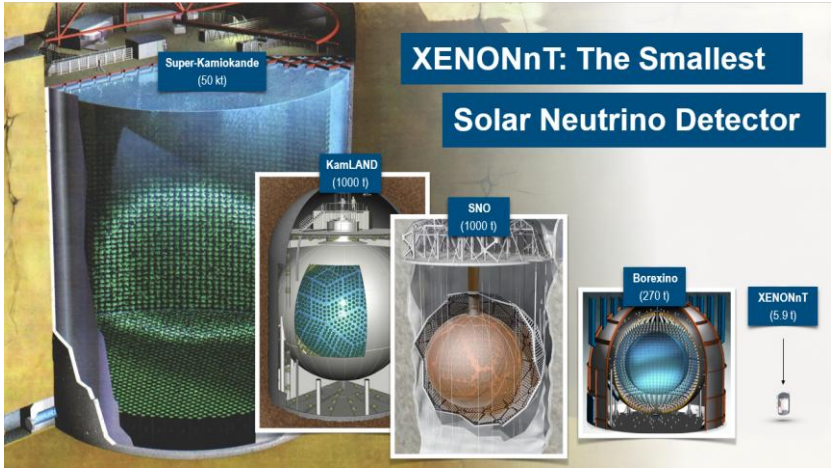
2025.9

About me

西湖大学 | 暗物质与中微子实验室



Shengchao Li
Experimental Particle Physics

Courses: General Physics I (Westlake, 2023, 2024), The Data Mine (Purdue, 2022-3), Galaxies and Large Scale Structure (Purdue, 2022), General Physics I (VT, 2015-2020); Waves and Optics (HKU, 2014)

Teaching Assistants

西湖大学 | 暗物质与中微子实验室

Xiaoyu Wang, Siyin Li, Zhenhao Liang (PhD2024)

Laboratory of Dark Matter and Neutrinos

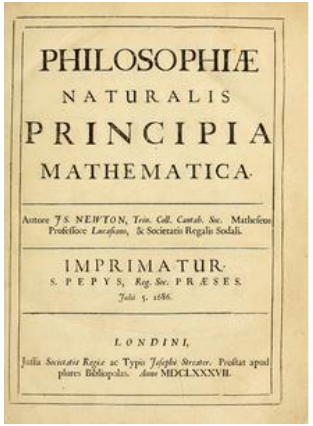
TA office: E5-228, Yungu Campus

Tutorial/office hour: Wednesday 11:30-12:30

Syllabus

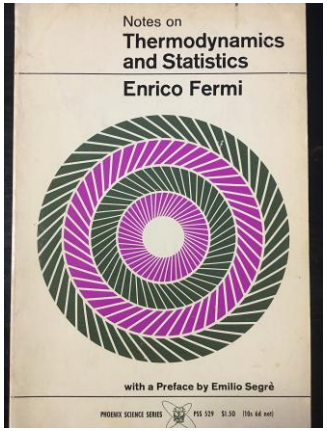
理 **Classical Mechanics:**
vectors, kinematics, Newton's laws, and conservation laws (energy, momentum, angular momentum), motion of planets.

---The Study of "Principle"



物 **Thermodynamics and Statistical Mechanics:**
gas dynamics, temperature, distributions, and the laws of thermodynamics, including key concepts like entropy, enthalpy, and free energy.

---The Study of "Matter"



Assessment

Type of Assessment	Percentage of Final Score	Notes
Attendance	/	
Class Performance	/	
Quiz	/	
Project	/	
Assignments	25	
Mid-term Exam	25	
Final Exam	30	
Other	20	Experiment

Physics Lab

Week of	Lab	Topic
09/01	0	Introduction and Safety Rules
09/15	1	Error Analysis
09/22	2	Projectile Motion
09/29-10/10	3	Friction
10/20	4	Centripetal Force
10/27	5	Conservation of Energy
11/03	6	Impulse
11/10	7	Conservation of Momentum
11/17	8	Rotational Inertia
11/24	9	Conservation of Angular Momentum
12/01	10	Ideal Gas Law
12/08	11	Electrical Equivalent of Heat
12/15	12	Heat Engine Cycles

1. The lab grade will count 20% of the final grade for the lecture course.

2. The grade one receives for the lab course will be the same as the grade for the lecture course.

3. If one fails the lab, they also fail the lecture course.

Contact your lab instructor directly for any questions

Materials

Website

https://scli.lab.westlake.edu.cn/info/1062/1260.htm

- Lecture notes
- Homework (~weekly, due in class)
- Contacts

WeChat

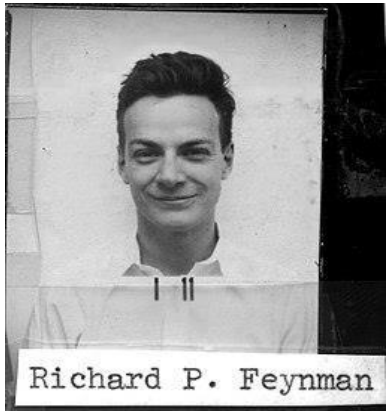
群聊: General Physics I
(Fall 2025)

该二维码7天内(9月8日前)有效，重新进入将更新

- Announcements
- Question and Answers
- Study groups, etc.

The philosophy of nature, and an ambitious course about it

Richard P. Feynman



- 1918, born in New York
- 1942, Ph. D of Princeton
- 1943-1945, the Manhattan Project
- 1945-1949, Cornell
- 1952-1987, Caltech
- 1988, died of cancer

- **1961-1963, general physics teaching for undergrads**
- 1965, Nobel Prize in physics for establishing quantum electrodynamics (shared with Schwinger and Tomonaga)
- **1986, commission member for the Challenger disaster**

- Path integral method for quantum mechanics
- Theory of superfluid helium
- Theory of beta-decay for weak interaction
- Parton model for strong interaction
- **Autobiography and popular science writings**

“Surely You’re Joking, Mr. Feynman!”

The Feynman Lectures on Physics (Vol I, II, III)

The Feynman Lectures on Physics including Feynman's *Tips on Physics: The Definitive and Extended Edition* (2nd edition, 2005)

- https://www.feynmanlectures.caltech.edu/
- "Tough, but nourishing and full of favor. After 25 years it is the guide for teachers and for the best of beginning students" – Scientific American
- Reformulating physics, reducing deep ideas into simple, understandable terms
- "The lectures… are very serious. I thought to address them to the most intelligent in the class, …, and even the most intelligent student was unable to completely encompass everything… "
- "Many of the students and faculty… said that having 2 years of physics with Feynman was the experience of a lifetime. But that's not how it seemed at that time. Many of the students dreaded the class, and as the course wore on, attendance by the registered students start dropping alarmingly.

Methodology for science

鱼 or 渔?

Know Understand

《费曼学习法》

Asking (the right) questions

If, in some cataclysm, all of scientific knowledge were to be destroyed, and only one sentence passed on to the next generations of creatures, what statement would contain the most information in the fewest words?

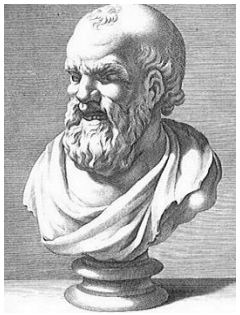
--- The Feynman lectures on physics Vol I Chapter 1

"all things are made of atoms" --- Feynman's choice

In that one sentence, you will see, there is an *enormous* amount of information about the world, if just a little imagination and thinking are applied.

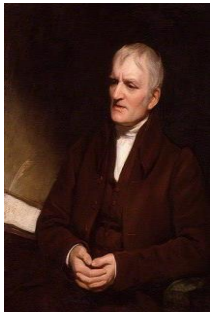
The atomic hypothesis

- The modern concept of atom is inspired by the fact that the appearance of integer numbers in chemical reactions
- Small particles in motion even at zero temperature (thermal and quantum motions).
- Repulsion when inter-particle distances are small, and attraction when large.



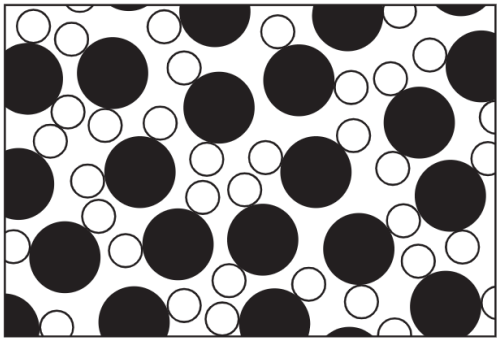
Democritus
(460BC-370BC)

墨子
(468BC-376BC)



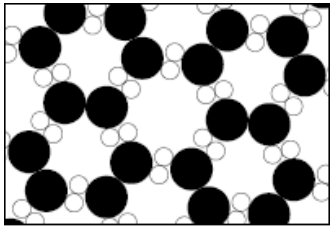
John Dalton
(1766-1844)

‘斫zhuó必半，“无”与“非半”，不可斫也。’



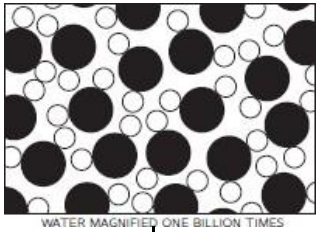
WATER MAGNIFIED ONE BILLION TIMES

Phase transitions



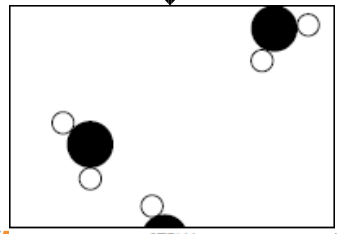
ice crystal: long-range ordered, rigidity, form a pattern, a symmetry

increase T



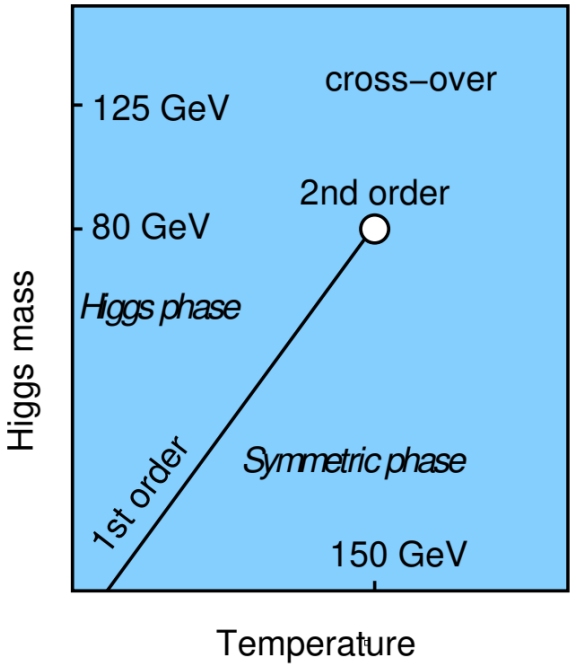
water: long-range disordered

increase T



vapor: volume expansion ~ 1000 times

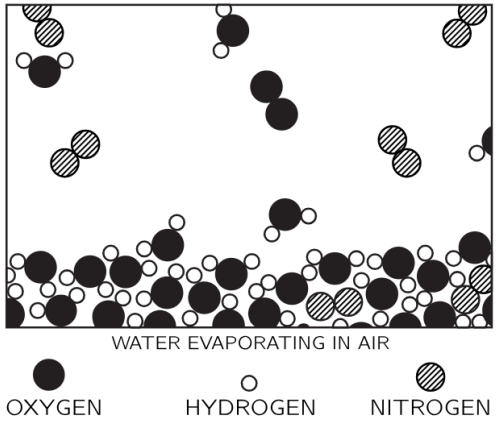
Phase transition of the early universe



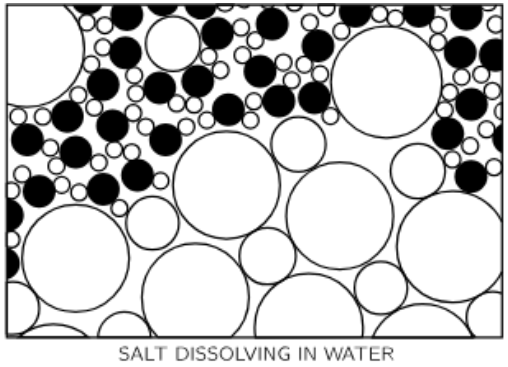
The phase diagram of the Standard model.

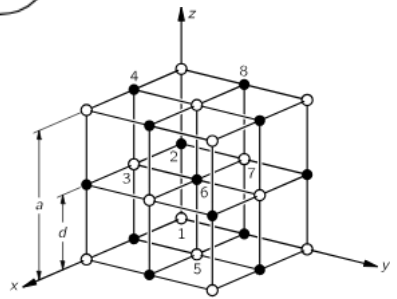
Atomic processes and Chemical reactions

Evaporation



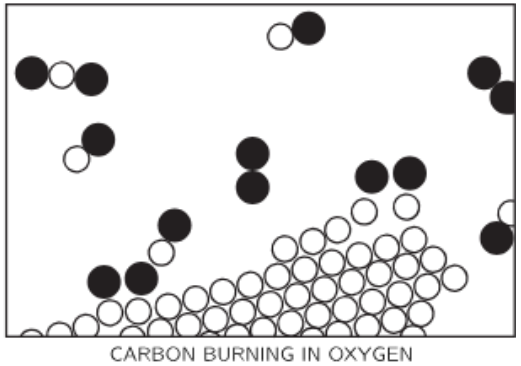
Dissolving

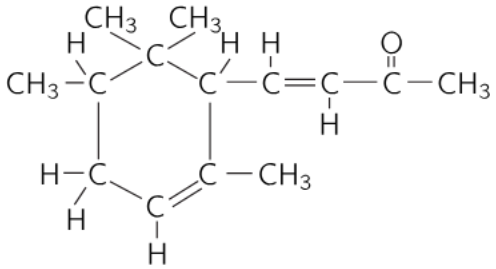




Nearest neighbor distance $d = a/2$

Burning





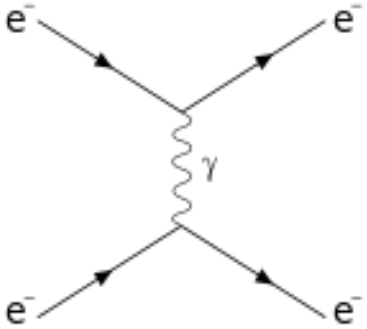
α-irone(鸢尾酮)

What do we mean by “understanding”

1.Simple Scenarios: Test rules in situations with few variables to easily predict outcomes and verify accuracy.

scattering

classical



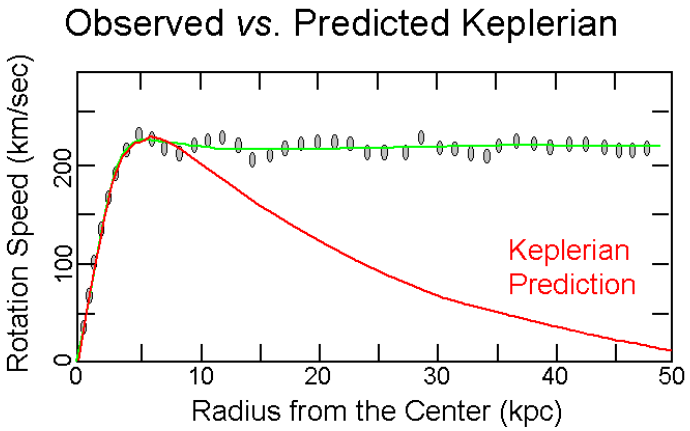
quantum

Figuring out the rules of a chess game by watching it.
Goal: learn the rules, predict or explain specific events.

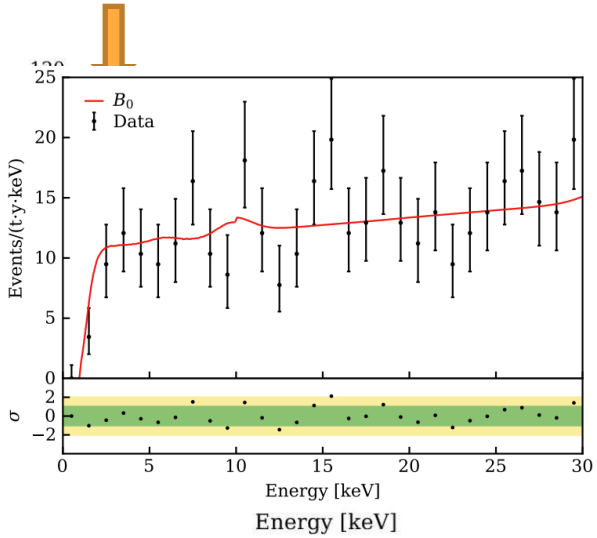
What do we mean by “understanding”

Figuring out the rules of a chess game by watching it.
Goal: learn the rules, predict or explain specific events.

2. Derived Predictions: Check broad consequences of rules; if predictions fail (anomaly), it suggests a need for new rules.



“Dark Matter”!

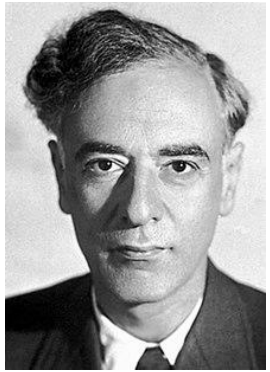


~~“Dark Matter”?~~

What do we mean by “understanding”

Figuring out the rules of a chess game by watching it.
Goal: learn the rules, predict or explain specific events.

3. Rough Approximation: Understand general patterns or strategies, even without knowing every detail, to grasp overall behavior. *The world is too complex to be described exactly.*



Lev Landau
(1908-1962)

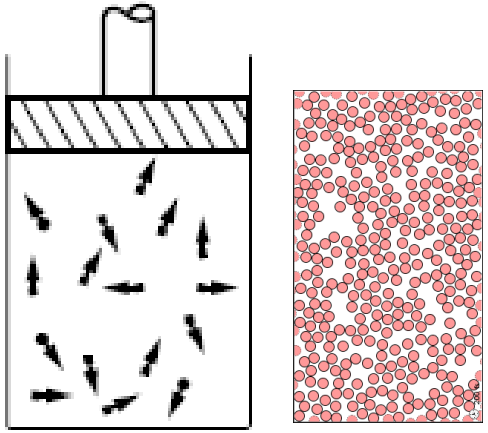
Fermi Liquid Theory:
Approximated the interactions in a group of fermions as non-interacting particles, which simplified the analysis at low temperatures.

Second-order Phase Transitions:
Expanding the free energy in a power series around an order parameter, laid the foundation for modern condensed matter physics.

Example: kinetic theory of gases

- Pressure comes from collisions of atoms on walls
- **Unification** of heat and mechanics, where heat was understood as the motion of atoms, linking temperature effects to the laws of mechanics.

  => Temperature $\propto$ velocity^2
  => Ideal Boltzmann gas: $\mathbf{PV = Nk_BT}$



- **Amalgamation**（融合） of theories to explain different phenomena is the key for physics; e.g., electricity, magnetism, and light (next semester)

Feynman's philosophy of science

Elegant writing style ☺

A poet once said, "The whole universe is in a glass of wine." We will probably never know in what sense he meant that, for poets do not write to be understood. But it is true that if we look at a glass of wine closely enough we see the entire universe. There are the things of physics: the twisting liquid which evaporates depending on the wind and weather, the reflections in the glass, and our imagination adds the atoms. The glass is a distillation of the earth's rocks, and in its composition we see the secrets of the universe's age, and the evolution of stars. What strange array of chemicals are in the wine? How did they come to be? There are the ferments（发酵物）, the enzymes（酶）, the substrates（基质）, and the products. There in wine is found the great generalization: all life is fermentation. Nobody can discover the chemistry of wine without discovering, as did Louis Pasteur（巴斯德）, the cause of much disease. How vivid is the claret, pressing its existence into the consciousness that watches it! If our small minds, for some convenience, divide this glass of wine, this universe, into parts—physics, biology, geology, astronomy, psychology, and so on—remember that nature does not know it! So let us put it all back together, not forgetting ultimately what it is for. Let it give us one more final pleasure: drink it and forget it all!

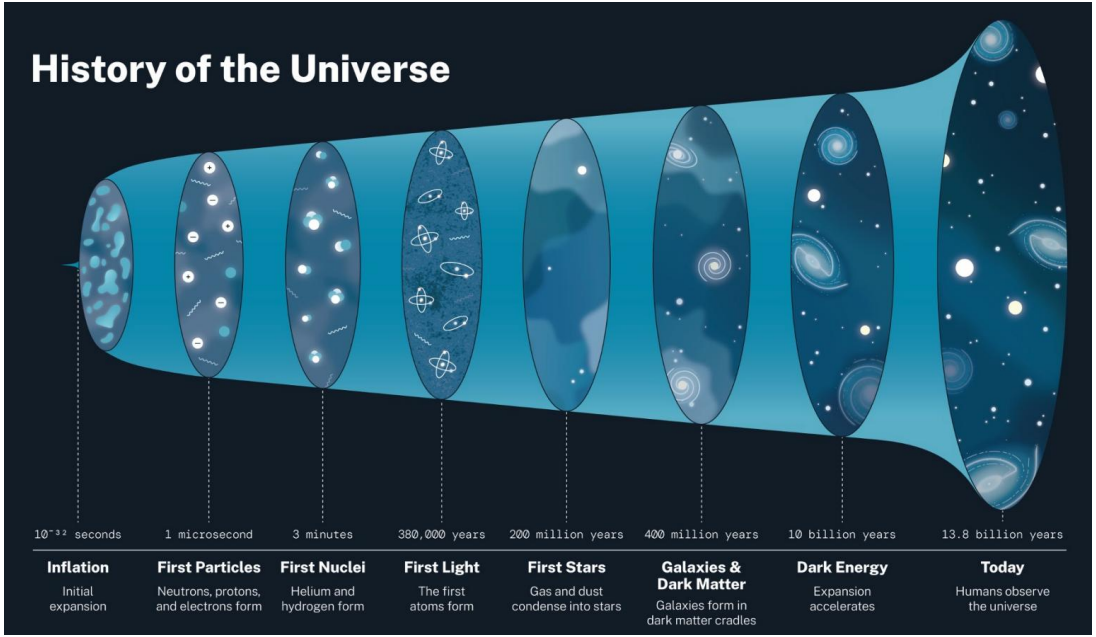
--- The Feynman lectures on physics Vol I Chapter 3

The fields of physics

based on Feynman's notes

Astrophysics and cosmology

- Physics at the **largest** space-time scales.

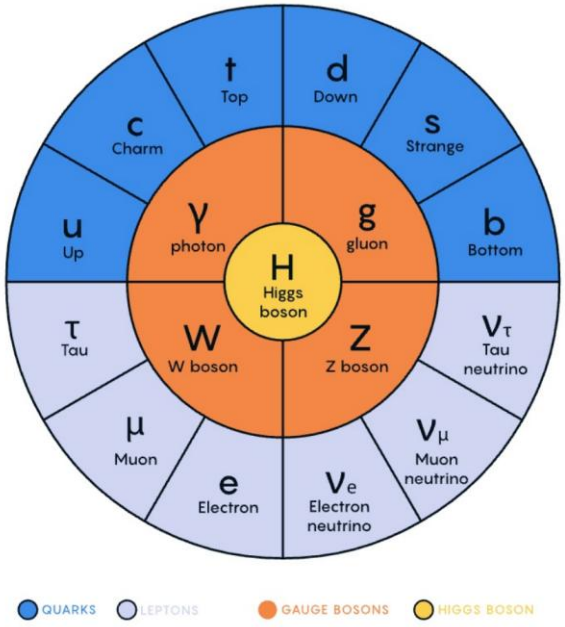


- The birth, evolution and fate of the universe
- **Big Bang** and nucleosynthesis – 3K cosmic background radiation, star formation
- **Dark energy** -- Universe expansion, Hubble's law
- **Dark matter** – mysterious components of the universe that merely interacts, so far only detected through their gravitational effects

High energy and particle physics

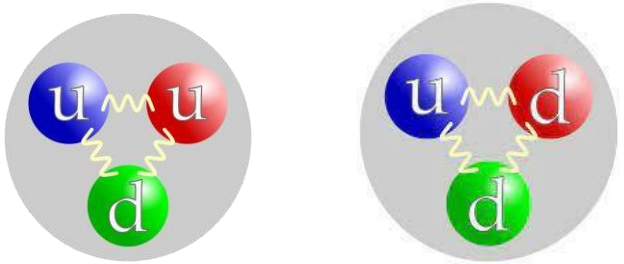
- Physics at the **smallest** space-time scales.

Microscopic structure of space-time, fundamental particles/interactions.



Nucleon: proton, neutron

Quark color: R, G, B



Quark flavors: (fractional charge)

+2/3e	-1/3e
up	down
charm	strange
top	bottom

Leptons: electron, muon, tauon, neutrino
Gauge bosons mediate interactions**:** photon (EM), W+, W-, Z0 (weak interaction), gluon (Strong interaction)

Higgs particle – mass generation

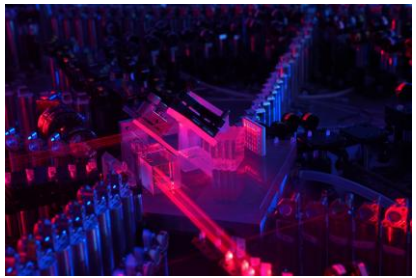
Atom, molecular, and optical (AMO) physics

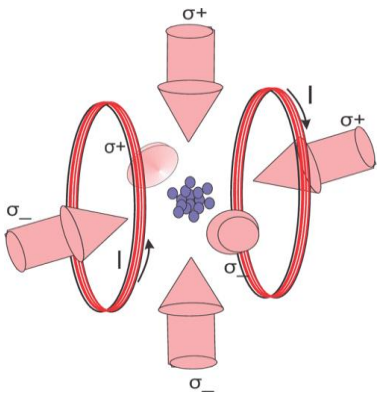
- The physics with most **precise controllability –** Laser, atomic clock

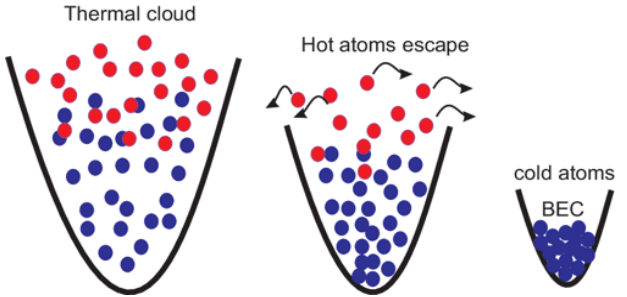
Bose-Einstein condensation of alkali atoms: Li, Na, K, Rb, Cs. Nearly all atoms condense into a **single quantum state**.

Laser cooling to 10^{-5}K, evaporative cooling to below 10^{-6}K.

Quantum entanglement, information, computation, sensing







Condensed matter physics

- Physics for the **crowd behavior (sociology)** of particles.

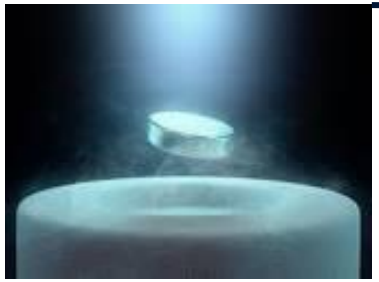
Solid, liquid, gas

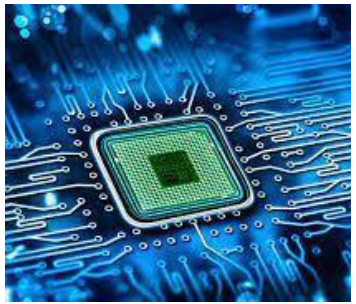
Metal, insulator, magnetism, superconductivity/superfluidity

Strong correlation and quantum effects

Semiconductor physics -- electronic industry

Soft condensed matter: polymer, protein, membrane, relation to biology…





一沙一世界

Math and Physics

Warning: this is a **physics** course,
and you cannot escape **math**

Full video: https://youtu.be/QR4s-j3rpio

My suggestions

- For Olympia students: contents (knowledge vs. methodology), language barrier? exam-oriented -> self-motivated, **decide for yourself**
- For students good at math/physics: **most suitable**, big picture incentive (absence in others), use extra time for reading, learn to be a “physicist”
- For students not good at math/physics: need to spend more time for the class, **tutorials** will be provided to catch up
- For all students: find your **study group** now
- **Place-out test** will be held in September. Three hour long, all answers must be written in English.

Math diagnosis quiz: 10 min

We need math to make physics simple

And use this lecture as your English quiz :)