PHYS 3313 – Section 001
Lecture #2

Wednesday, Jan. 16, 2019
Dr. Jaehoon Yu

- Class Information
- What is Physics?
- Brief history of modern physics
- Classical Physics
- Concept of Waves and Particles
- Conservation Laws and Fundamental Forces

Announcements

- Quiz #1 on appendices 3, 5, 6 and 7 and what we will have learned today
  - Beginning of the class
  - Next Wednesday, Jan. 23
- Class web page:
  - http://www-hep.uta.edu/~yu/teaching/spring19-3313-001/spring19-3313-001.html
  - Lecture notes and other class info are posted here.
- Office hours: 2:30 – 3:30pm Mon. and Wed.
  - Or by appointment
  - My office is CPB342

Special Project #1

1. Compute the electric force between the two protons separate the farthest in an intact U^{238} nucleus. Use the actual size of the U^{238} nucleus. (10 points)
2. Compute the gravitational force between the two protons separate the farthest in an intact U^{238} nucleus. (10 points)
3. Express the electric force in #1 above in terms of the gravitational force in #2. (5 points)

- You must look up the mass of the proton, actual size of the U^{238} nucleus, etc, and clearly write them on your project report
- You MUST have your own, independent answers to the above three questions even if you worked together with others. All those who share the answers will get 0 credit if copied. Must be handwritten!
- Due for the submission is Monday, Jan. 28!

Evaluation Policy

- Homework: 30%
- Exams
  - Mid-term Exam (Wed., Mar. 6): 20%
  - Final Comprehensive Exam (11 – 1:30pm, Fri, May. 10): 25%
  - Missing an exam is not permissible unless pre-approved
    - No makeup test
    - You will get an F if you miss any of the exams without a prior approval
- Group Research Project: 15%
- Pop-quizzes: 10%

100%

- Extra credits: 10% of the total
- Grading will be done on a sliding scale
- 55% of the grade is in your hand!!

Homework

- Solving homework problems is the only way to comprehend class material
- Consists of a lot of reading, deriving and writing
- Each homework carries the same weight
- **ALL** homework grades will be used for the final grade
- Home work will constitute **30% of the total**
  - A good way of keeping your grades high
- Strongly encouraged to collaborate
  - Just make sure to submit your own hand-written answers written in your OWN way!!
  - No copies! All copied versions will get 0!

Group Research Projects

- Detailed studies on important discoveries and theories that set the foundation of modern physics
- Final project consists of
  - A 5 – 10 page paper each : 10% of the total
  - A 10+2 minute power point presentation for each group: 5% of total
- Report Due and Presentation Dates
  - Presentation: Monday, Apr. 22 and Wednesday, Apr. 24
  - Report Due: At the beginning of the class on Wed. Apr. 24

Research Topics

1. Blackbody radiation
2. Michelson–Morley Experiment
3. The Photoelectric Effect
4. The Brownian Motion
5. Compton Effect
6. Discovery of Electron
7. Rutherford Scattering
8. Super-conductivity
9. The Discovery of Radioactivity

Attendances and Class Style

- Attendances:
  - Will be taken randomly
  - Will be used for extra credits
- Class style:
  - Lectures will be on electronic media
    - The lecture notes will be posted on the web **AFTER** each class
    - Class web page: http://www-hep.uta.edu/~yu/teaching/spring19-3313-001/spring19-3313-001.html
  - Will be mixed with traditional methods
  - Active participation through questions and discussions are **STRONGLY** encouraged
  - Communication between you and me is extremely important
    - If you have problems, please do not hesitate talking to me

Extra credit

- Up to 10% addition to the total
  - Could boost a B to A, C to B or D to C
- What constitute for extra credit?
  - Random attendances
  - Physics Colloquium Participations
  - Strong participation in the class discussions
  - Special projects (BIG!!)
  - Watch the valid planetarium shows
  - Many other opportunities

Valid Planetarium Shows

- Regular running shows
  - Sat.: We are Astronomers (2pm), Our Violent Planet (6pm)
  - 1:30pm Sundays: From Earth to the Universe
- Shows that need special arrangements
  - Can watch up to 2 times: Black Holes & Phantom of the Universe
  - Rosetta, Seeing, We are Astronomers, Back to the Moon for Good; Experience the Aurora; Magnificent Sun, The Hot and Energetic Universe
  - Stars of the Pharaohs; Two Small Pieces of Glass; Unseen Universe; Violent Universe and several more
- How to submit for extra credit?
  - Obtain the ticket stub that is signed and dated by the planetarium star lecturer of the day
  - Collect the ticket stubs throughout the semester
  - Tape ONLY one edge of all of the ticket stubs on a sheet of paper with your name and ID written on it
  - Submit the sheet at the end of the semester at the final exam

What can you expect from this class?

- All A's would be perfect for you, wouldn't it?
  - But easy come easy go
  - Must put in earnest efforts to make it last and meaningful
- This class is going to be challenging!!
- You will earn your grade in this class.
  - You will need to put in sufficient time and sincere efforts
  - Exams and quizzes will be tough!!
    - Sometimes problems might not look exactly like what you learned in the class (but they are driven from them!)
    - Just putting the right answer in free response problems does not work!

What can you expect from this class?

- But you have a great control of your grade in your hands, up to 55%!!!
  - Homework is 30% of the total grade!!
    - Means you will have many homework problems
      - Sometimes much more than any other classes
      - Sometimes homework problems will be something that you have yet to learn in class
      - Exam's problems will be easier than homework problems but the same principles!!
  - Group research project: 15%
  - Extra credit 10%
- I will work with you so that your efforts are properly rewarded

What do we want to learn in this class?

- The physics that provided fundamentals to the technical progress for us, especially in the last 150 years or so
- Learn concepts of quantum theory for microscopic phenomena and relativity for phenomena at high speed
- Learn physical principles that we still exploit
- Learn skills to express observations and measurements in mathematical language
- Learn skills to research literatures and express your research in systematic manner in writing
- Build up confidence in your physics abilities and to take on any challenges laid in front of you!!

Most importantly, let us have a lot of FUN!!

Specifically, you will learn…

- Concepts and derivations of many of the modern physics
  - History at the beginning of the new era
  - Special relativity
  - Quantum theory
  - Atomic physics
  - Condensed Matter physics
  - Nuclear physics
  - Particle Physics
- Focus on learning about the concepts with less complicated math
  - You will learn some quantum calculations and understand the concept of probabilities
- Expectation at the end of the semester: You will be able to understand what bases fundamental physics provides to the current technology

Why do Physics?

Exp.
- To understand nature through experimental observations and measurements (**Research**)

Theory
- Establish limited number of fundamental laws, usually with mathematical expressions
- Predict nature's course

⇒Theory and Experiment work hand-in-hand

⇒Theory works generally under restricted conditions

⇒Discrepancies between experimental measurements and theory are good for improvements

⇒Improves our everyday lives, even though some laws can take a while till we see them amongst us

Brief History of Physics

- AD 18th century:
  - Newton's Classical Mechanics: A theory of mechanics based on observations and measurements, concepts of many kinematic parameters, including forces
    - First unification of forces – planetary forces and forces on the Earth
- AD 19th Century:
  - Electricity, Magnetism, and Thermodynamics
- Late AD 19th and early 20th century (Modern Physics Era, after 1895)
  - Physicists thought everything was done and nothing new could be discovered

State of Minds in late 19th Century

- **Albert A. Michelson, 1894**

  The more important fundamental laws and facts of physical science have all been discovered, and these are now so firmly established that the possibility of their ever being supplanted in consequence of new discoveries is exceedingly remote. Our future discoveries must be looked for in the sixth place of decimals!

- **William Thompson (Lord Kelvin), 1900**

  There is nothing new to be discovered in physics now. All that remains is more and more precise measurement.

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  - Concept of atoms did not quite exist
  - There were only handful of problems not well understood late 19th century, which formed the basis for new discoveries in 20th century
  - That culminates in understanding of phenomena in microscopic scale and extremely high speed approaching the speed of light ($3x10^8$m/s)
  - Einstein's theory of relativity: Generalized theory of space, time, and energy (mechanics)
  - Quantum Mechanics: Theory of atomic phenomena

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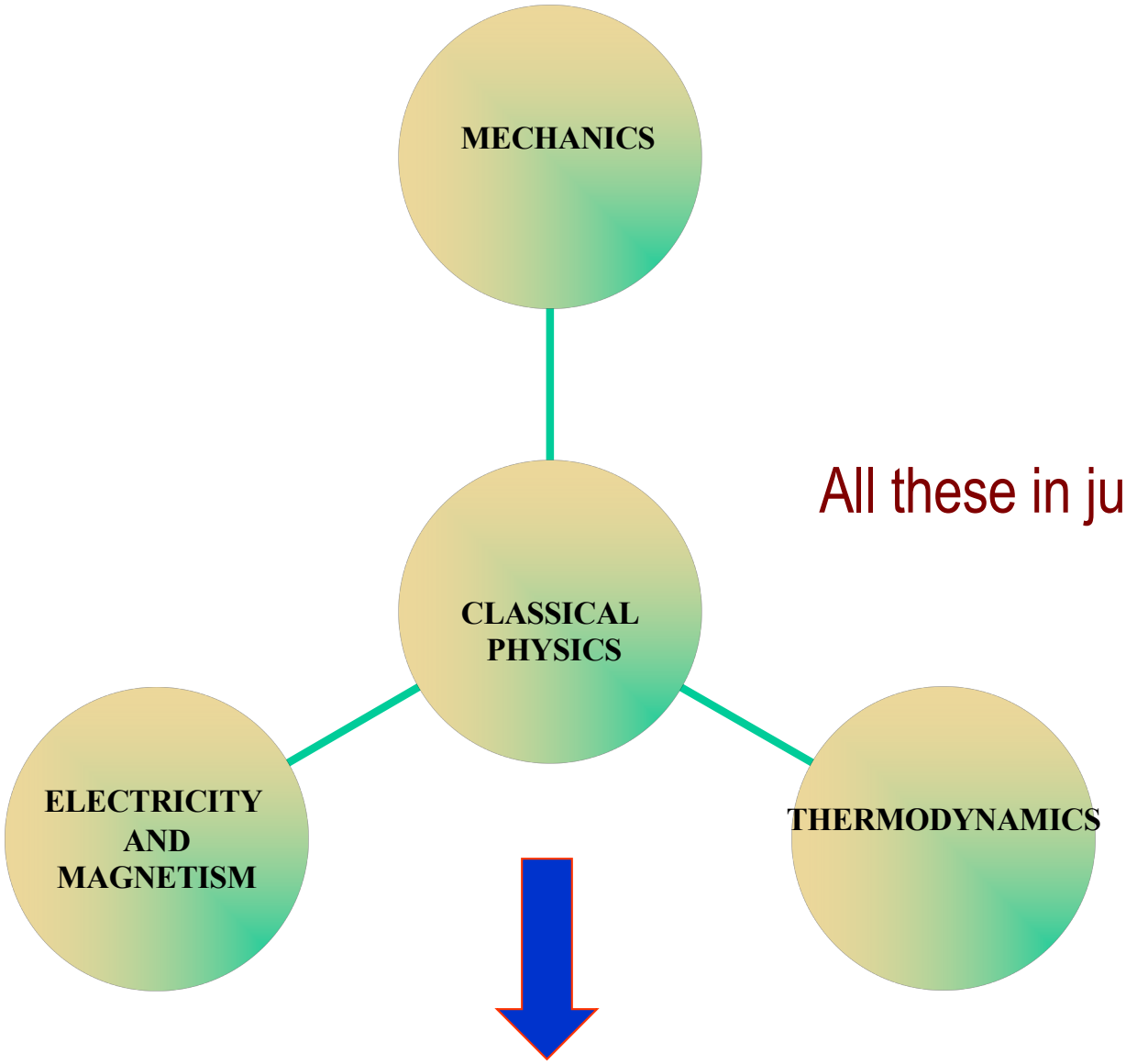

All these in just 300 years!!

Triumph of Classical Physics: The Conservation Laws

- **Conservation of energy**: The total sum of energy (in all its forms) is conserved in all interactions.
- **Conservation of linear momentum**: In the absence of external forces, linear momentum is conserved in all interactions.
- **Conservation of angular momentum**: In the absence of external torque, angular momentum is conserved in all interactions.
- **Conservation of charge**: Electric charge is conserved in all interactions.

Mechanics

- Galileo (1564-1642)
  - First great experimentalist
  - Principle of inertia
  - Established experimental foundations

Isaac Newton (1642-1727)

Three laws describing the relationship between mass and acceleration, concept of forces ➔ First unification of forces!!

- **Newton's first law** (*law of inertia*): An object in motion with a constant velocity will continue in motion unless acted upon by some net external force.
- **Newton's second law**: Introduces force (F) as responsible for the the change in linear momentum (**p**):
- $\vec{F} = m\vec{a}$ **or** $\vec{F} = \frac{d\vec{p}}{dt}$
- **Newton's third law** (*law of action and reaction*): The force exerted by body 1 on body 2 is equal in magnitude and opposite in direction to the force that body 2 exerts on body 1.

$$\vec{F}_{21} = -\vec{F}_{12}$$

Electromagnetism

- Contributions made by:
  - Coulomb (1736-1806)
  - Oersted (1777-1851)
  - Young (1773-1829)
  - Ampère (1775-1836)
  - Faraday (1791-1867)
  - Henry (1797-1878)
  - Maxwell (1831-1879)
  - Hertz (1857-1894)

Culminates in Maxwell's Equations

- In the absence of dielectric or magnetic materials, the four equations developed by Maxwell are:

$$\oint \vec{E} \cdot d\vec{A} = \frac{Q_{encl}}{\varepsilon_0}$$

Gauss' Law for electricity

A generalized form of Coulomb's law relating electric field to its sources, the electric charge

$$\oint \vec{B} \cdot d\vec{A} = 0$$

Gauss' Law for magnetism

A magnetic equivalent of Coulomb's law relating magnetic field to its sources. This says there are no magnetic monopoles.

$$\oint \vec{E} \cdot d\vec{l} = -\frac{d\Phi_B}{dt}$$

Faraday's Law

An electric field is produced by a changing magnetic field

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{encl} + \mu_0 \varepsilon_0 \frac{d\Phi_E}{dt}$$

Generalized Ampére's Law

A magnetic field is produced by an electric current or by a changing electric field

Thermodynamics

- Deals with temperature (T), heat (Q), work (W), and the internal energy (U) of systems
- Contributions made by:
  - Benjamin Thompson (1753-1814)
  - Sadi Carnot (1796-1832)
  - James Joule (1818-1889)
  - Rudolf Clausius (1822-1888)
  - William Thompson (1824-1907)

The Kinetic Theory of Gases

Contributions made by:

- Robert Boyle (1627-1691) ➔ PV = constant (fixed T)
- Jacques Charles (1746-1823) & Joseph Louis Gay-Lussac (1778-1823) ➔ V/T=constant (fixed P)
- Culminates in the **ideal gas equation** for *n* moles of a "simple" gas:

$$PV = nRT$$

(where *R* is the ideal gas constant, 8.31 J/mol · K)

- We now know that gas consists of rapidly moving molecules bouncing off each other and the wall!!

Additional Contributions

- Amedeo Avogadro (1776-1856) ➔ Hypothesized in 1811 that the equal V of gases at the same T and P contain equal number of molecules (N_A=6.023x10^{23} molecules/mol)
  - 1 mole of Hydrogen molecule is 2g & 1 mole of carbon is 12g.
- John Dalton (1766-1844) opposed due to confusion between his own atomic model and the molecules
- Daniel Bernoulli (1700-1782) ➔ Kinetic theory of gas in 1738
- By 1895, the kinetic theory of gases are widely accepted
- Ludwig Boltzmann (1844-1906), James Clerk Maxwell (1831-1879) & J. Willard Gibbs (1939-1903) made statistical interpretation of thermodynamics bottom half of 19th century