PHYS 3313 – Section 001
Lecture #3

Wednesday, Jan. 23, 2019
Dr. Jaehoon Yu

- Classical Physics
- Concept of Waves and Particles
- Conservation Laws and Fundamental Forces Atomic
- Theory of Matter
- Unresolved Questions of 1895 and the New Horizon
- Unsolved Questions Today

Announcements

- Office hours: 2:30 – 3:30pm Mon. and Wed.
  - Or by appointment
  - My office is CPB342

Reminder: 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 Monday, Feb. 4!

Special Project #2

1. Compute the value of the speed of light using the formula (5 points):

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = \lambda f$$

2. Derive the unit of speed from the units specified in the back-side of the front cover of the text book. (5 points)

- Be sure to write down the values and units taken from the back-side of the front cover of the text book.
- 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 Wednesday, Feb. 6!

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!!

Primary Results of Statistical Interpretation

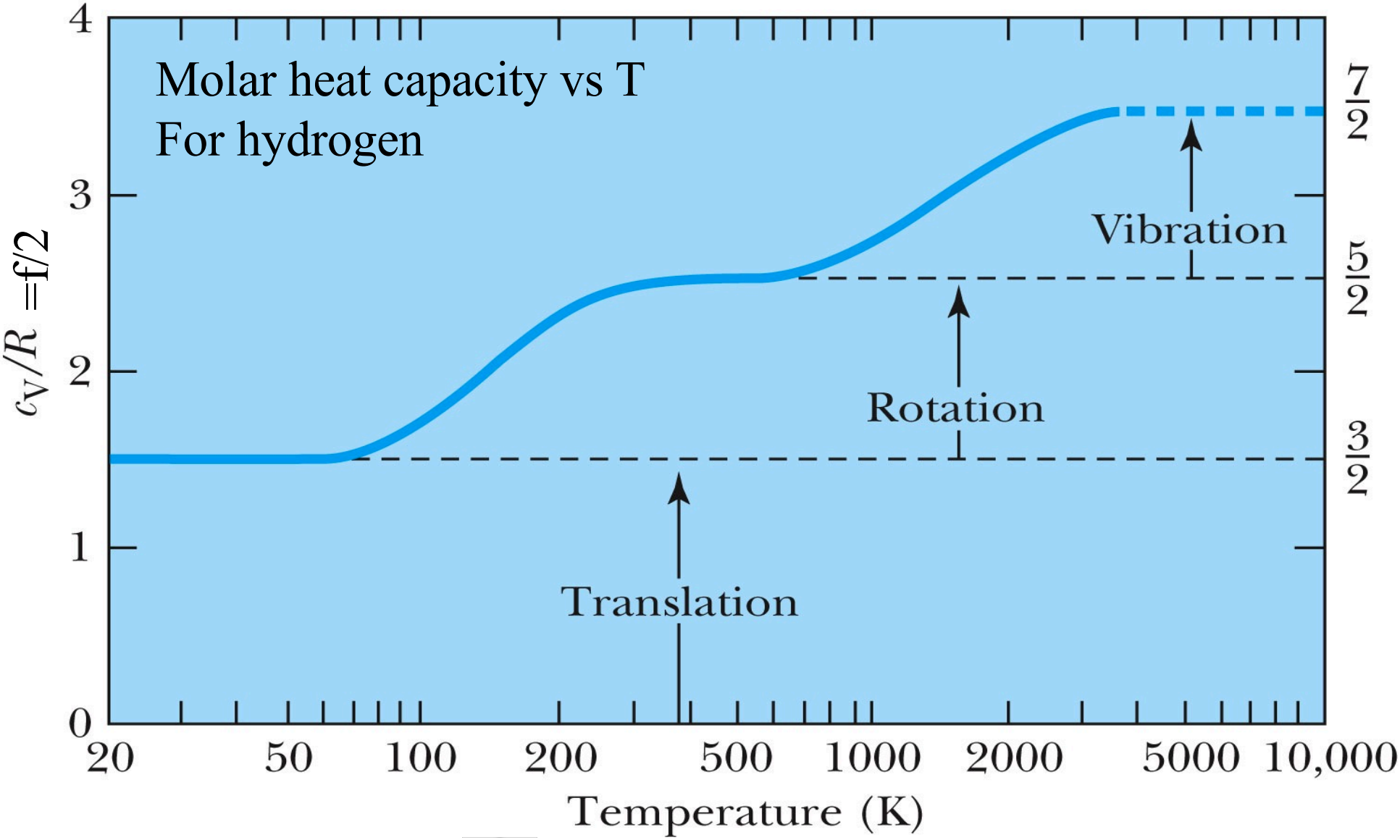
- Average molecular kinetic energy is directly related to the absolute temperature
- **Internal energy** *U* is directly proportional to the average molecular kinetic energy
- Internal energy is equally distributed among the number of degrees of freedom (f) of the system

$$U = nN_A \langle K \rangle = \frac{f}{2} nRT$$

(N_A = Avogadro's Number)

- And many others

Experimental Demonstration of Equi-Partition Principle



Primary Results of Thermodynamics

- Introduced thermal equilibrium concept
- The first law establishes heat as energy
- Introduces the concept of internal energy
- Interprets temperature as a measure of the internal energy
- Generates limitations of the energy processes that cannot take place

Concept of Waves and Particles

Two ways in which energy is transported:

- Point mass interaction – transfers of momentum and kinetic energy: *particles*
- Extended regions wherein energy transfers by way of vibrations and rotations – *waves*

Particles vs. Waves

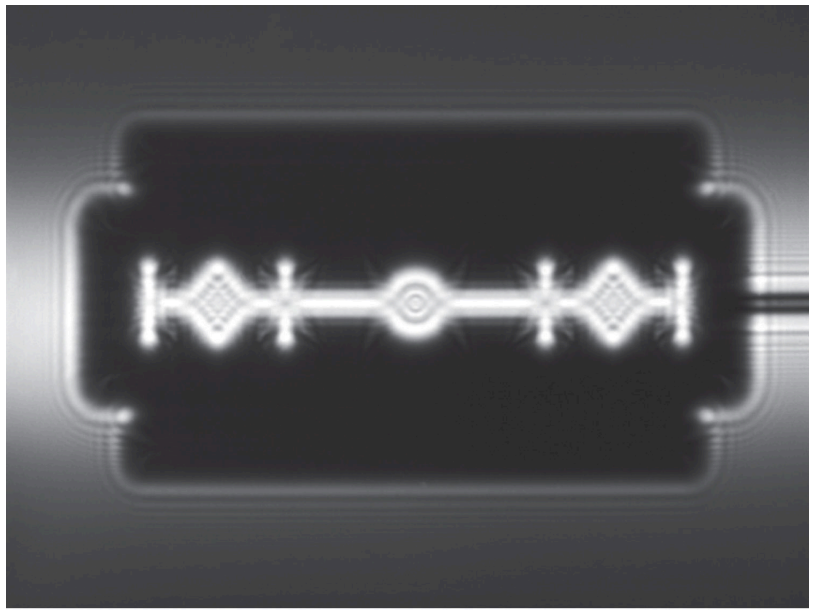
- Two distinct phenomena describing physical interactions
  - Both require Newtonian mass
  - Particles in the form of point masses and waves in the form of perturbation in a mass distribution, i.e., a material medium
  - The distinctions are observationally quite clear
    - although, not so obvious for the case of visible light
  - Thus as the 17th century begins the major disagreement arose concerning the nature of light

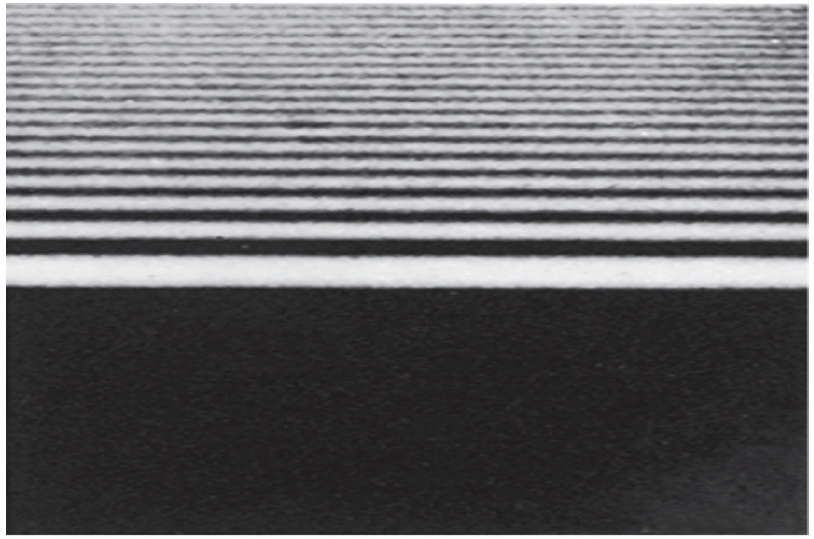
The Nature of Light

- Isaac Newton promoted the corpuscular (particle) theory
  - Published a book "Optiks" in 1704
  - Particles of light travel in straight lines or rays
  - Explained "sharp" shadows
  - Explained reflection and refraction
- Christian Huygens (1629 -1695) promoted the wave theory
  - Presented the theory in 1678
  - Light propagates as a wave of concentric circles from the point of origin
  - Explained reflection and refraction
  - Could not explain the "sharp" edges of the shadow
- Thomas Young (1773 -1829) & Augustine Fresnel (1788 – 1829) ➔ Showed in 1802 and afterward that light clearly behaves as wave through two slit interference and other experiments
- In 1850 Foucault showed that light travel slowly in water than air, the final blow to the corpuscular theory in explaining refraction

The Wave Theory Advances…

- Contributions by Huygens, Young, Fresnel and Maxwell
- Double-slit interference patterns
- Refraction of light from the vacuum to a medium
- Light was an electromagnetic phenomenon
- Shadows are not as sharp as once thought with the **advancement of experimental precision**
- *Establishes the idea that light propagates as a wave*

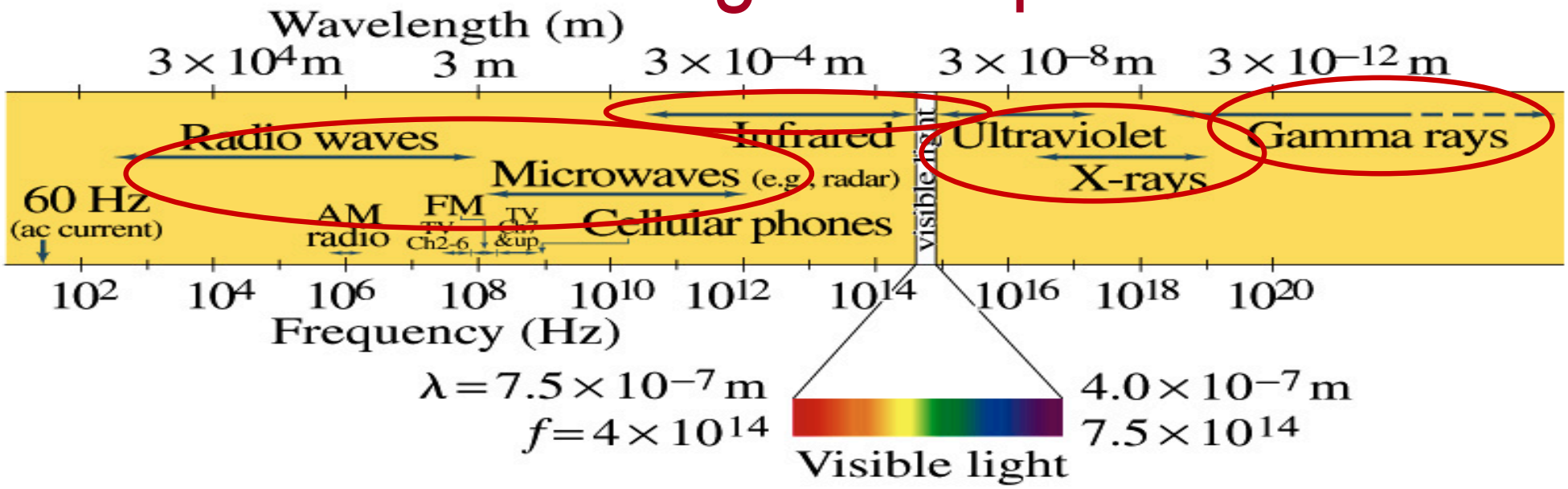




The Electromagnetic Spectrum

- Visible light covers only a small range of the total electromagnetic spectrum

Electromagnetic Spectrum



- Low frequency waves, such as radio waves or microwaves can be easily produced using electronic devices
- Higher frequency waves are produced natural processes, such as emission from atoms, molecules or nuclei
- Or they can be produced from acceleration of charged particles
- Infrared radiation (IR) is mainly responsible for the heating effect of the Sun
  - The Sun emits visible lights, IR and UV
    - The molecules of our skin resonate at infrared frequencies so IR is preferentially absorbed and thus warm up

The Electromagnetic Spectrum

- Visible light covers only a small range of the total electromagnetic spectrum
- All electromagnetic waves travel in vacuum with the speed *c* given by:

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = \lambda f$$

(where μ_0 and ε_0 are the respective permeability and permittivity of "free" space)

Conservation Laws and Fundamental Forces

- Conservations laws are the guiding principles of physics
- Recall the fundamental conservation laws:
  - Conservation of energy
  - Conservation of linear momentum
  - Conservation of angular momentum
  - Conservation of electric charge
- In addition to the classical conservation laws, two modern results include:
  - The conservation of baryons and leptons
  - The fundamental invariance principles for time reversal, distance, and parity

Also in the Modern Context…

- The three fundamental forces are introduced
  - **Gravitational**: $\vec{F}_g = -G\frac{m_1 m_2}{r^2}\hat{r}$
    - Responsible for planetary motions, holding things on the ground, etc
  - **Electroweak (unified at high energies)**
    - **Weak**: Responsible for nuclear beta decay and effective only over distances of ~10^{-15} m
    - **Electromagnetic**: Responsible for all non-gravitational interactions, such as all chemical reactions, friction, tension….
    - $\vec{F}_C = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}\hat{r}$ (Coulomb force)
  - **Strong**: Responsible for "holding" the nucleus together and effective in the distance less than ~10^{-15} m

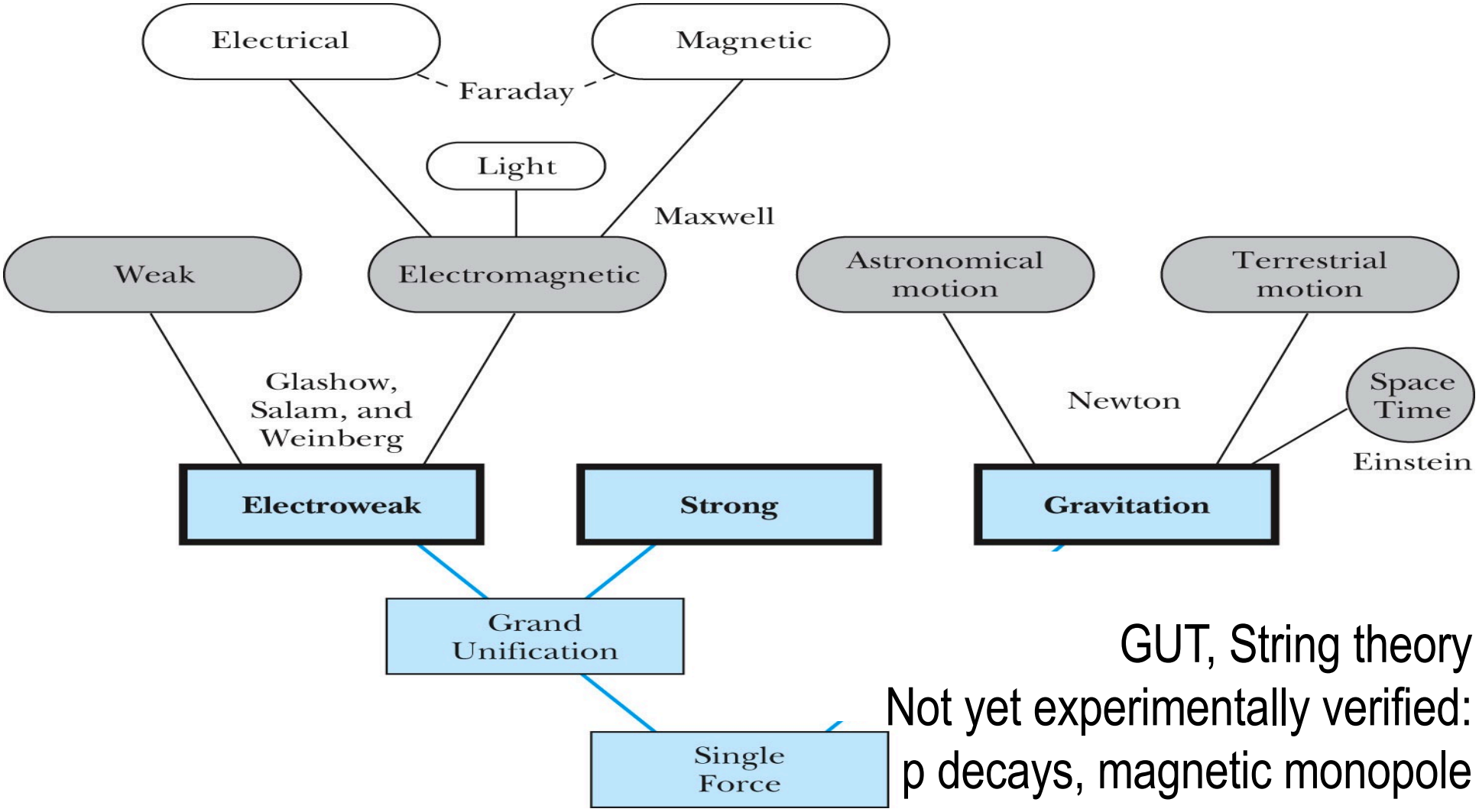
Relative Strength of Fundamental Forces

Table 1.1 Fundamental Forces

Interaction		Relative Strength*	Range
Strong		1	Short, $\sim 10^{-15}$ m
Electroweak	Electromagnetic	10^{-2}	Long, $1/r^2$
	Weak	10^{-9}	Short, $\sim 10^{-15}$ m
Gravitational		10^{-39}	Long, $1/r^2$

*These strengths are quoted for neutrons and/or protons in close proximity.

Unification of Forces



GUT, String theory
Not yet experimentally verified:
p decays, magnetic monopole