“Modern Physics” Course Syllabus

《现代物理学（英文)》课程教学大纲

I. Basic Information

Name	Modern Physics	Course Code	PHYS1027
Course Category	Required coursed	Majors	Physics
Credit	3	Total Hours	54
Instructors	Tianyi Cai(蔡田怡) Sheng Ju(睢胜)	Date	2021.9
Textbooks	Hugh D. Young and Roger A. Freedman，Sears and Zemansky’s University Physics with Modern Physics，13th Edition, Pearson Education, 2010		

II. Teaching aim

1） Overall objectives:

Modern Physics encompasses the large and the small, the old and the new. From the atom to galaxies, from electrical circuitry to aerodynamics, Modern physics is very much a part of the world around us. The sutudents probably are taking this introductory course in calculus based physics because it is required for subsequent courses you plan to take in preparation for a career in science or engineering. The teacher wants the students to learn physics and to enjoy the experience.

Modern Physics is a branch of physics including relativity, quantum physics, and their applications.

2） Course objectives:

1. Basic concepts of relativity and quantum mechanics including relativity, quantization of charge, light, and energy, the nuclear atom, the wavelike properties of particles and the Schrodinger Equation.

2. Application of quantum mechanics and relativity including molecular structure, spectra solid state physics, nuclear physics, particle physics astrophysics and cosmology.

3) Corresponding relationship between curriculum objectives, graduation requirements and curriculum content

Table I. Correspondence between course objectives, course contents and graduation requirements

Course objectives	**Corresponding course content**	**Corresponding graduation requirements**
Course objective 1	Chapter 1 Relativity Chapter 2 Photon: Light Waves behaving as particles Chapter 3 Particles Behaving as Waves Chapter 4 Quantum Mechanics	Graduation requirement 3: understand the frontier and development of physics, the physical thought in new technology, and be familiar with the impact of new discoveries, theories and technologies in physics on society. Graduation requirements 8: have the awareness of independent learning and lifelong learning and the ability to adapt to the society.
Course objective 2	Chapter 5 Atomic Structure Chapter 6 Molecules and Condensed Matter Chapter 7 Nuclear Physics Chapter 8 Particle Physics and Cosmology	Graduation requirement 2: master the basic knowledge, basic physical experiment methods and experimental skills related to mathematics and physics, and have the ability to solve problems, explain or understand physical laws by using physical theories and methods. Graduation requirements 7: have the ability of

		subject research, design, data processing and academic exchange. Graduation requirements 8: have the awareness of independent learning and lifelong learning and the ability to adapt to the society.

III. Contents

Chapter One: Relativity

1. Teaching aims

The two postulates of Einstein’ s special theory of relativity, and what motivates these postulates;

Why different observers can disagree about whether two events are simultaneous;

How relativity predicts that moving clocks run slow, and that experimental evidence confirms this;

How the length of an object changes due to the object’ s motion;

How the velocity of an object depends on the frame of referencefrom which it is observed;

How the theory of relativity modifies the relationship between velocity and momentum;

How to solve problems involving work and kinetic energy for particles moving at relativistic speeds;

Some of the key concepts of Einstein’ s general theory of relativity.

2. Keypoints and Difficulties

Keypoints: Einstein’ s special theory of relativity

Difficulties: Relativistic Momentum

3. Contents

1.1 Invariance of physical laws

1.2 Relativity of Simultaneity

1.3 Relativity of Time Intervals

1.4 Relativity of Length

1.5 The Lorentz Transformation

1.6 Relativistic Momentum

1.7 Relativistic Work and Energy

1.8 Newton Mechanics and Relavitity

4.Teaching method

Teaching; Group Discussion; Autodidacticism under the guidance of the teacher

5.Comments

Carefully prepare lessons, prepare students and make preparations before class; In the teaching process, we pay attention to cultivating students' creative thinking, take students as the main body and enhance students' sense of participation; Corresponding exercises and supplementary exercises after class.

Problems：

1. Suppose the two lightning bolts shown in Fig. 37.5a are simultaneous to an observer on the train. Show that they are not simultaneous to an observer on the ground. Which lightning strike does the ground observer measure to come first?

2. A spaceship flies past Mars with a speed of 0.985c relative to the surface of the planet. When the spaceship is directly overhead, a signal light on the Martian surface blinks on and then off.

An observer on Mars measures that the signal light was on for 75.0 μs(a) Does the observer on Mars or the pilot on the spaceship measure the proper time? (b) What is the duration of the light pulse measured by the pilot of the spaceship?

3. A spacecraft of the Trade Federation flies past the planet Coruscant at a speed of 0.600c. A scientist on Coruscant measures the length of the moving spacecraft to be 74.0m. The spacecraft later lands on Coruscant, and the same scientist measures the length of the now stationary spacecraft. What value does she get?

4. A pursuit spacecraft from the planet Tatooine is attempting to catch up with a Trade Federation cruiser. As measured by an observer on Tatooine, the cruiser is traveling away from the planet with a speed of 0.600c. The pursuit

ship is traveling at a speed of 0.800c relative to Tatooine, in the same direction as the cruiser. (a) For the pursuit ship to catch the cruiser, should the velocity of the cruiser relative to the pursuit ship be directed toward or away from the pursuit ship? (b) What is the speed of the cruiser relativeto the pursuit ship?

5. A source of electromagnetic radiation is moving in a radial direction relative to you. The frequency you measure is 1.25 times the frequency measured in the rest frame of the source. What is the speed of the source relative to you? Is the source moving toward you or away from you?

6. (a) At what speed is the momentum of a particle twice as great as the result obtained from the nonrelativistic expression. Express your answer in terms of the speed of light. (b) A force is applied to a particle along its direction of motion. At what speed is the magnitude of force required to produce a given acceleration twice as great as the force required to produce the same acceleration when the particle is at rest? Express your answer in terms of the speed of light.

7. What is the speed of a particle whose kinetic energy is equal to (a) its rest energy and (b) five times its rest energy?

Chapter Two: Photon: Light Waves behaving as particles

1. Teaching aims

How experiments involving the photoelectric effect and x rays pointed the way to a radical reinterpretation of the nature of light;

How Einstein’s photon picture of light explains the photoelectric effect;

How experiments with x rays and gamma rays helped confirm the photon picture of light;

How the wave and particle pictures of light complement each other;

How the Heisenberg uncertainty principle imposes fundamental limits on what can be measured.

2. Keypoints and Difficulties

Keypoints: The Photoelectric Effect; Compton Scattering; Wave－Particle Duality

Difficulties: Compton Scattering; Wave－Particle Duality; Uncertainty

3. Contents

2.1 Light Absorbed as Photons: The Photoelectric Effect

2.2 Light Emitted as Photons: X-Ray Production

2.3 Light Scattered as Photons: Compton Scattering and Pair Production

2.4 Wave－Particle Duality, Probability, and Uncertainty

4. Teaching method

Teaching; Group Discussion; Autodidacticism under the guidance of the teacher

5. Comments

Carefully prepare lessons, prepare students and make preparations before class; In the teaching process, we pay attention to cultivating students’ creative thinking, take students as the main body and enhance students’ sense of participation; Corresponding exercises and supplementary exercises after class.

Problems：

1. A photon of green light has a wavelength of 520 nm. Find the photon’s frequency, magnitude of momentum, and energy. Express the energy in both joules and electron volts.
2. The cathode-ray tubes that generated the picture in early color televisions were sources of x rays. If the acceleration voltage in a television tube is 15.0 kV, what are the shortest-wavelength x rays produced by the television? (Modern televisions contain shielding to stop these x rays.)
3. An x ray with a wavelength of 0.100 nm collides with an electron that is initially at rest. The x ray’s final wavelength is 0.110 nm. What is the final kinetic energy of the electron?
4. An ultrashort pulse has a duration of 9.00 fs and produces light at a wavelength of 556 nm. What are the momentum and momentum uncertainty of a single photon in the pulse?

Chapter Three: Particles Behaving as Waves

1. Teaching aims

De Broglie’s proposal that electrons, protons, and other particles can behave like waves;

How electron diffraction experiment provided evidence for de Broglie’s ideas;

How electron microscopes can provide much higher magnification than visible-light microscopes;

How physicists discovered the atomic nucleus;

How Bohr’ s model of electron orbits explained the spectra of hydrogen and hydrogenlike atoms;

How a laser operates;

How the idea of energy levels, coupled with the photon model of light, explains the spectrum of light emitted by a hot, opaque object;

What the uncertainty principle tells us about the nature of the atom.

2. Keypoints and Difficulties

Keypoints: Electron Waves; Bohr Model; The Uncertainty Principle

Difficulties: Electron Waves; Bohr Model

3. Contents

3.1 Electron Waves

3.2 The Nuclear Atom and Atomic Spectra

3.3 Energy Levels and the Bohr Model of the Atom

3.4 The Laser

3.5 Continuous Spectra

3.6 The Uncertainty Principle Revisited

4. Teaching method

Teaching; Group Discussion; Autodidacticism under the guidance of the teacher

5. Comments

Carefully prepare lessons, prepare students and make preparations before class; In the teaching process, we pay attention to cultivating students’ creative thinking, take students as the main body and enhance students’ sense of participation; Corresponding exercises and supplementary exercises after class.

Problems：

1. For crystal diffraction experiments, wavelengths on the order of 0.20 nm are often appropriate. Find the energy in electron volts for a particle with this wavelength if the particle is (a) a photon; (b) an electron; (c) an alpha particle.

2. A 4.78-MeV alpha particle from a decay makes a head-on collision with a uranium nucleus. A uranium nucleus has 92 protons. (a) What is the distance of closest approach of the alpha particle to the

center of the nucleus? Assume that the uranium nucleus remains at rest and that the distance of closest approach is much greater than the radius of the uranium nucleus. (b) What is the force on the alpha particle at the instant when it is at the distance of closest approach?

3. The silicon–silicon single bond that forms the basis of the mythical silicon-based creature the Horta has a bond strength of 3.80 eV. What wavelength of photon would you need in a (mythical) phasor disintegration gun to destroy the Horta?

4. Removing Birthmarks. Pulsed dye lasers emit light of wavelength 585 nm in 0.45-ms pulses to remove skin blemishes such as birthmarks. The beam is usually focused onto a circular spot 5.0 mm in diameter. Suppose that the output of one such laser is 20.0 W. (a) What is the energy of each photon, in eV? (b) How many photons per square millimeter are delivered to the blemish during each pulse?

5. A 100-W incandescent light bulb has a cylindrical tungsten filament 30.0 cm long, 0.40 mm in diameter, and with an emissivity of 0.26. (a) What is the temperature of the filament? (b) For what wavelength does the spectral emittance of the bulbpeak? (c) Incandescent light bulbs are not very efficient sources of visible light. Explain why this is so.

6. A pesky 1.5-mg mosquito is annoying you as you attempt to study physics in your room, which is 5.0 m wide and 2.5 m high. You decide to swat the bothersome insect as it flies toward you, but you need to estimate its speed to make a successful hit. (a) What is the maximum uncertainty in the horizontal position of the mosquito? (b) What limit does the Heisenberg uncertainty principle place on your ability to know the horizontal velocity of this mosquito? Is this limitation a serious impediment to your attempt to swat it?

Chapter Four: Quantum Mechanics

1. Teaching aims

About the wave function that describes the behavior of a particle and the Schrödinger equation that this function must satisfy;

How to calculate the wave functions and energy levels for a particle confined to a box;

How to analyze the quantum mechanical behavior of a particle in a potential well;

How quantum mechanics makes it possible for particles to go where Newtonian mechanics says they cannot;

How to use quantum mechanics to analyze a harmonic oscillator.

2. Keypoints and Difficulties

   Keypoints: One-Dimensional Schrödinger Equation; Potential Wells; The Harmonic Oscillator

   Difficulties: Potential Wells; The Harmonic Oscillator

3. Contents

   4.1 Wave Functions and the One-Dimensional Schrödinger Equation

   4.2 Particle in a Box

   4.3 Potential Wells

   4.4 Potential Barriers and Tunneling

   4.5 The Harmonic Oscillator

4. Teaching method

   Teaching; Group Discussion; Autodidacticism under the guidance of the teacher

5. Comments

   Carefully prepare lessons, prepare students and make preparations before class; In the teaching process, we pay attention to cultivating students' creative thinking, take students as the main body and enhance students' sense of participation; Corresponding exercises and supplementary exercises after class.

Problems:

1. An electron is moving as a free particle in the x-direction with momentum that has magnitude $4.50*10^{-24}$ kg·m/s. What is the one-dimensional time-dependent wave function of the electron?

2. Ground-Level Billiards. (a) Find the lowest energy level for a particle in a box if the particle is a billiard ball (m=0.20 kg) and the box has a width of 1.3 m, the size of a billiard table. (Assume that the billiard ball slides without friction rather than rolls; that is, ignore the rotational kinetic energy.) (b) Since the energy in part (a) is all kinetic, to what speed does this correspond? How much time would it take at this speed for the ball to move from one side of the table to the other? (c) What is the difference in energy between the n=2 and n=1 levels? (d) Are quantum-mechanical effects important for the game of billiards?

3. An electron is bound in a square well with a depth equal to six times the ground-level energy E1-IDW of an infinite well of the same

width. The longest-wavelength photon that is absorbed by the electron has a wavelength of 400.0 nm. Determine the width of the well.

4. An electron with initial kinetic energy 6.0 eV encounters a barrier with height 11.0 eV. What is the probability of tunneling if the width of the barrier is (a) 0.80 nm and (b) 0.40 nm?

5. A wooden block with mass 0.250 kg is oscillating on the end of a spring that has force constant 110N/m. Calculate the ground-level energy and the energy separation between adjacent levels. Express your results in joules and in electron volts. Are quantum effects important?

Chapter Five: Atomic Structure

1. Teaching aims

How to extend quantum-mechanical calculations to three-dimensional problems;

How to solve the Schrödinger equation for a particle trapped in a cubical box;

How to describe the states of a hydrogen atom in terms of quantum numbers;

How magnetic fields affect the orbital motion of atomic electrons;

How we know that electrons have their own intrinsic angular momentum;

How to analyze the structure of many-electron atoms;

How x rays emitted by atoms reveal their inner structure.

2. Keypoints and Difficulties

Keypoints: Three-dimensional Schrödinger equation

Difficulties: The Hydrogen Atom

3. Contents

5.1 The Schrödinger Equation in Three Dimensions

5.2 Particle in a Three-Dimensional Box

5.3 The Hydrogen Atom

5.4 The Zeeman Effect

5.5 Electron Spin

5.6 Many-Electron Atoms and the Exclusion Principle

5.7 X-Ray Spectra

4. Teaching method

Teaching; Group Discussion; Autodidacticism under the guidance of the teacher

5. Comments

Carefully prepare lessons, prepare students and make preparations before class; In the teaching process, we pay attention to cultivating students' creative thinking, take students as the main body and enhance students' sense of participation; Corresponding exercises and supplementary exercises after class.

Problems:

1. Model a hydrogen atom as an electron in a cubical box with side length L. Set the value of L so that the volume of the box equals the volume of a sphere of radius $a=5.29*10^{-11}$ m, the Bohr radius. Calculate the energy separation between the ground and first excited levels, and compare the result to this energy separation calculated from the Bohr model.
2. Consider an electron in the N shell. (a) What is the smallest orbital angular momentum it could have? (b) What is the largest orbital angular momentum it could have? Express your answers in terms of and in SI units. (c) What is the largest orbit angular momentum this electron could have in any chosen direction? Express your answers in terms of and in SI units. (d) What is the largest spin angular momentum this electron could have in any chosen direction? Express your answers in terms of and in SI units. (e) For the electron in part (c), what is the ratio of its spin angular momentum in the z-direction to its orbital angular momentum in the z-direction?
3. A hydrogen atom in the 5g state is placed in a magnetic field of 0.600 T that is in the z-direction (a) Into how many levels is this state split by the interaction of the atom's orbital magnetic dipole moment with the magnetic field? (b) What is the energy separation between adjacent levels? (c) What is the energy separation between the level of lowest energy and the level of highest energy.
4. A hydrogen atom in a particular orbital angular momentum state is found to have quantum numbers 7/2 and 9/2. What is the letter that labels the value of for the state?
5. (a) Write out the ground-state electron configuration ($1s^2$, $2s^2$,……) for the beryllium atom. (b) What element of next-larger Z has chemical properties similar to those of beryllium? Give the ground-state electron configuration of this element. (c) Use the procedure of part (b) to predict what element of next-larger Z than in (b) will have chemical properties similar to those of the element you found in part (b), and give its ground-state electron configuration.
6. A K_α x ray emitted from a sample has an energy of 7.46 keV. Of which element is the sample made?

Chapter Six: Molecules and Condensed Matter

1. Teaching aims

The various types of bonds that hold atoms together;

How the rotational and vibrational dynamics of molecules are revealed by molecular spectra;

How and why atoms form into crystalline structures;

How to use the energy-band concept to explain the electrical properties of solids;

A simple model for metals that explains many of their physical properties;

How the character of a semiconductor can be radically transformed by adding small amounts of an impurity;

Some of the technological applications of semiconductor devices;

Why certain materials become superconductors at low temperature.

2. Keypoints and Difficulties

Keypoints: Molecular Bonds; Molecular Spectra; Free-Electron Model

Difficulties: Free-Electron Model

3. Contents

6.1 Types of Molecular Bonds

6.2 Molecular Spectra

6.3 Structure of Solids

6.4 Energy Bands

6.5 Free-Electron Model of Metals

6.6 Semiconductors

6.7 Semiconductor Devices

6.8 Superconductivity

4. Teaching method

Teaching; Group Discussion; Autodidacticism under the guidance of the teacher

5. Comments

Carefully prepare lessons, prepare students and make preparations before class; In the teaching process, we pay attention to cultivating students' creative thinking, take students as the main body and enhance students' sense of participation; Corresponding exercises and supplementary exercises after class.

Problem

1.For the H_2 molecule the equilibrium spacing of the two protons is 0.074 nm. The mass of a hydrogen atom is $1.67 * 10^{-27}$kg. Calculate the wavelength of the photon emitted in the rotational transition l = 2 to l = 1.

2.When a hypothetical diatomic molecule having atoms 0.8860 nm apart undergoes a rotational transition from the l =2 state to the next lower state, it gives up a photon having energy $8.841 * 10^{-4}$ eV. When the molecule undergoes a vibrational transition from one energy state to the next lower energy state, it gives up 0.2560 eV. Find the force constant of this molecule.

3.Density of NaCl. The spacing of adjacent atoms in a crystal of sodium chloride is 0.282 nm. The mass of a sodium atom is and the mass of a chlorine atom is $5.89 * 10^{-26}$ kg Calculate the density of sodium chloride.

4.The gap between valence and conduction bands in silicon is 1.12 eV. A nickel nucleus in an excited state emits a gamma-ray photon with wavelength $9.31 * 10^{-4}$ nm. How many electrons can be excited from the top of the valence band to the bottom of the conduction band by the absorption of this gamma ray?

5.The Fermi energy of sodium is 3.23 eV. (a) Find the average energy E_{av} of the electrons at absolute zero. (b) What is the speed of an electron that has energy (c) At what Kelvin temperature T is kT equal to E_F? (This is called the Fermi temperature for the metal. It is approximately the temperature at which molecules in a classical ideal gas would have the same kinetic energy as the fastest-moving electron in the metal.)

6.Pure germanium has a band gap of 0.67 eV. The Fermi energy is in the middle of the gap. (a) For temperatures of 250 K, 300 K, and 350 K, calculate the probability f(E) that a state at the bottom of the conduction band is occupied. (b) For each temperature in part (a), calculate the probability that a state at the top of the valence band is empty.

7.At a temperature of 290 K, a certain p-n junction has a saturation current I_S = 0.500 mA. (a) Find the current at this temperature when the voltage is (i) 1.00 mV, (ii) -1.00 mV, (iii) 100 mV, and (iv) -100mV. (b) Is there a region of applied voltage where the diode obeys Ohm’ s law?

Chapter Seven: Nuclear Physics

1. Teaching aims

Some key properties of atomic nuclei, including radii, densities, spins, and magnetic moments;

How the binding energy of a nucleus depends on the numbers of protons and neutrons that it contains;

The most important ways in which unstable nuclei undergo radioactive decay;

How the decay rate of a radioactive substance depends on time;

Some of the biological hazards and medical uses of radiation;

How to analyze some important types of nuclear reactions;

What happens in a nuclear fission chain reaction, and how it can be controlled;

The sequence of nuclear reactions that allow the sun and stars to shine.

2. Keypoints and Difficulties

   Keypoints: Nuclei;
   Difficulties: Nuclear Binding and Nuclear Structure

3. Contents

   7.1 Properties of Nuclei

   7.2 Nuclear Binding and Nuclear Structure

   7.3 Nuclear Stability and Radioactivity

   7.4 Activities and Half-Lives

   7.5 Biological Effects of Radiation

   7.6 Nuclear Reactions

   7.7 Nuclear Fission

   7.8 Nuclear Fusion

4. Teaching method

   Teaching; Group Discussion; Autodidacticism under the guidance of the teacher

5. Comments

   Carefully prepare lessons, prepare students and make preparations before class; In the teaching process, we pay attention to cultivating students' creative thinking, take students as the main body and enhance students' sense of participation; Corresponding exercises and supplementary exercises after class.

Problem

1. Hydrogen atoms are placed in an external 1.65-T magnetic field. (a) The protons can make transitions between states where the nuclear spin component is parallel and antiparallel to the field by absorbing or emitting a photon. Which state has lower energy: the state with the nuclear spin component parallel or antiparallel to the field? What are the frequency and wavelength of the photon? In which region of the electromagnetic spectrum does it lie? (b) The electrons can make transitions between states where the electron spin component is parallel and antiparallel to the field by absorbing or emitting a photon. Which

state has lower energy: the state with the electron spin component parallel or antiparallel to the field? What are the frequency and wavelength of the photon? In which region of the electromagnetic spectrum does it lie?

2. What is the maximum wavelength of a ray that could break a deuteron into a proton and a neutron? (This process is called photodisintegration.)

3. Tritium is an unstable isotope of hydrogen; its mass, including one electron, is 3.016049 u. (a) Show that tritium must be unstable with respect to beta decay because the decay products plus an emitted electron) have less total mass than the tritium. (b) Determine the total kinetic energy (in MeV) of the decay products, taking care to account for the electron masses correctly.

4. Radiocarbon Dating. A sample from timbers at an archeological site containing 500 g of carbon provides 3070 decays/min. What is the age of the sample?

5. (a) If a chest x ray delivers 0.25 mSv to 5.0 kg of tissue, how many total joules of energy does this tissue receive? (b) Natural radiation and cosmic rays deliver about 0.10 mSv per year at sea level. Assuming an RBE of 1, how many rem and rads is this dose, and how many joules of energy does a 75-kg person receive in a year? (c) How many chest x rays like the one in part (a) would it take to deliver the same total amount of energy to a 75-kg person as she receives from natural radiation in a year at sea level, as described in part (b)?

6. Consider the nuclear reaction

$$^{4}_{2}\mathrm{He} + {}^{7}_{3}\mathrm{Li} \rightarrow \mathrm{X} + {}^{1}_{0}\mathrm{n}$$

where X is a nuclide. (a) What are Z and A for the nuclide X? (b) Is energy absorbed or liberated? How much?

Chapter Eight: Particle Physics and Cosmology

1. Teaching aims

The key varieties of fundamental subatomic particles and how they were discovered;

How physicists use accelerators and detectors to probe the properties of subatomic particles;

The four ways in which subatomic particles interact with each other;

How the structure of protons, neutrons, and other particles can be explained in terms of quarks;

How physicists probe the limits of the standard model of particles and interactions;

The evidence that the universe is expanding and that the expansion is speeding up;

The history of the first 380,000 years after the Big Bang.

2. Keypoints and Difficulties

Keypoints: Particles; Quarks
Difficulties: Particles and Interactions

3. Contents

8.1 Fundamental Particles—A History

8.2 Particle Accelerators and Detectors

8.3 Particles and Interactions

8.4 Quarks and the Eightfold Way

8.5 The Standard Model and Beyond

8.6 The Expanding Universe

8.7 The Beginning of Time

4. Teaching method

Teaching; Group Discussion; Autodidacticism under the guidance of the teacher

5. Comments

Carefully prepare lessons, prepare students and make preparations before class; In the teaching process, we pay attention to cultivating students' creative thinking, take students as the main body and enhance students' sense of participation; Corresponding exercises and supplementary exercises after class.

Problems

1. A neutral pion at rest decays into two photons. Find the energy, frequency, and wavelength of each photon. In which part of the electromagnetic spectrum does each photon lie? (Use the pion mass given in terms of the electron mass in Section 44.1.)

2. An electron with a total energy of 20.0 GeV collides with a stationary positron. (a) What is the available energy? (b) If the electron and positron are accelerated in a collider, what total energy corresponds to the same available energy as in part (a)?

3. How much energy is released when a μ− muon at rest decays into an electron and two neutrinos? Neglect the small masses of the neutrinos.

4. The weak force may change quark flavor in an interaction. Explain how decay changes quark flavor. If a proton undergoes decay, determine the decay reaction.

5. The spectrum of the sodium atom is detected in the light from a distant galaxy. (a) If the 590.0-nm line is redshifted to 658.5 nm, at what speed is the galaxy receding from the earth? (b) Use the Hubble law to calculate the distance of the galaxy from the earth.

6. The 2.728-K blackbody radiation has its peak wavelength at 1.062 mm. What was the peak wavelength at t=700000 y when the temperature was 3000 K?

IV. Class hour allocation

Table II. Specific contents of each chapter and class hour allocation table

Chapter	Chapter content	Class hour allocation
Chapter One	Relativity	Two Weeks, 6 Hours
Chapter Two	Photon: Light Waves behaving as particles	Two Weeks, 6 Hours
Chapter Three	Particles Behaving as Waves	Two Weeks, 6 Hours
Chapter Four	Quantum Mechanics	Two Weeks, 6 Hours
Chapter Five	Atomic Structure	Two Weeks, 6 Hours
Chapter Six	Molecules and Condensed Matter	Two Weeks, 6 Hours
Chapter Seven	Nuclear Physics	Two Weeks, 6 Hours
Chapter Eight	Particle Physics and Cosmology	Two Weeks, 6 Hours

V. Teaching progress

Table III. Teaching schedule

Week	Date	Chapter	Content	Teaching hours	Requirements	Remarks
1		Chapter One	Relativity of Simultaneity; Relativity of Time Intervals; Relativity of Length	Three	Problem	
2		Chapter One	The Lorentz Transformation; Relativistic Momentum	Three	Problem	
3		Chapter Two	The Photoelectric Effect; X-Ray Production	Three	Problem	
4		Chapter Two	Compton Scattering and Pair Production; Wave - Particle Duality, Probability, and Uncertainty	Three	Problem	
5		Chapter Three	Electron Waves; The Nuclear Atom and Atomic Spectra	Three	Problem	
6		Chapter Three	Energy Levels and the Bohr Model of the Atom; The Laser;	Three	Problem	

			Continuous Spectra			
7		Chapter Four	Wave Functions; Particle in a Box; Potential Wells	Three	Problem	
8		Chapter Four	Potential Barriers and Tunneling; The Harmonic Oscillator	Three	Problem	
9		Chapter Five	The Schrödinger Equation in Three Dimensions; Particle in a Three-Dimensional Box; The Hydrogen Atom	Three	Problem	
10		Chapter Five	The Zeeman Effect; Electron Spin; Many-Electron Atoms	Three	Problem	
11		Chapter Six	Molecular Spectra; Structure of Solids; Energy Bands	Three	Problem	
12		Chapter Six	Free-Electron Model of Metals; Semiconductors	Three	Problem	
13		Chapter Seven	Properties of Nuclei; Nuclear Binding and	Three	Problem	

			Nuclear Structure; Nuclear Stability and Radioactivity			
14		Chapter Seven	Activities and Half-Lives; Biological Effects of Radiation; Nuclear Reactions	Three	Problem	
15		Chapter Eight	Particles and Interactions	Three	Problem	
16		Chapter Eight	Quarks and the Eightfold Way	Three	Problem	

VI. Textbook and References

Textbooks: Hugh D. Young and Roger A. Freedman, Sears and Zemansky’ s University Physics with Modern Physics, 13th Edition, Pearson Education, 2010

References:

1. Kenneth S. Krane, Modern Physics, 3nd edition, Wiley, 2012.

2. Paul A. Tipler, Ralph Llewellyn, Modern Physics, 6th revised international edition, W.H.Freeman & Co Ltd, 2012.

3. H. D Young and R. A. Freedman, Sear and Zemansky’s University Physics with Modern Physics, 12th Edition, Pearson Education, 2008 (chapter 37 - 44).

VII. Teaching method

1. Fully leverage the educational role of theoretical physics courses to establish a solid foundation in mathematical and physical principles. Emphasize the inclusion of cutting-edge scientific content, enrich the teaching materials in a progressive manner, integrate modern physics with courses such as quantum mechanics, and focus on complex quantum model systems at the forefront of interdisciplinary research. Cultivate scientific thinking and research innovation abilities.

2. Combine chalkboard and PowerPoint presentations, taking advantage of both traditional and modern teaching methods. Utilize a combination of lectures, discussions, and flipped classroom approaches for teaching.

3. Integrate relevant innovation projects, train students' ability to solve complex problems through thematic seminars, literature research, and group collaboration, among other activities.

4. Utilize information technology: Create an information-based teaching environment that combines offline classroom teaching, making the teaching format interactive. For example, use an online platform to distribute quizzes in real-time to assess teaching effectiveness and assist in activities such as flipped classrooms and thematic seminars.

VIII. Assessment method and evaluation method

[1] Corresponding relationship between curriculum assessment and curriculum objectives

Table IV. Correspondence between course assessment and course objectives

Course objectives	Key points of assessment	Assessment method
Course objectives1	Related teaching content	Regular learning performance evaluation + Process-oriented assessment + The final exam
Course objectives2	Related teaching content	Regular learning performance evaluation + Process-oriented assessment + The final exam

[2] Appraising method

[1] Appraising method

Multifaceted assessment: from in-class to out-of-class, from final exams to process-oriented assessments, from in-class activities to project-based assessments, etc. Utilize an information-based app to export pre-class, in-class, and post-class learning data, along with out-of-class thematic discussions, process-oriented assessments, and closed-book exams. Calculate the final grade based on weighted scores.

The regular assessment accounts for 10% of the total grade, with four formative assessments contributing 60% (15% each), and the final assessment accounting for 30% of the total grade.

[2] Analysis of assessment proportion and achievement degree of curriculum objectives

Table V. Analysis of assessment proportion and achievement degree of curriculum objectives

考核占比 课程目标	平时	过程化考核	期末	总评达成度
Course objectives1	40%	40%	40%	Degree of achievement for Course Objective 1 = {0.1 x regular performance score for Objective 1 + 0.6 x process-oriented exam score for Objective 1 + 0.3 x the final exam score for Objective 1} / Total score for Objective 1. Degree of achievement for Course Objective 2 = {0.1 x regular performance score for Objective 2 + 0.6 x process-oriented exam score for Objective 2 + 0.3 x the final exam score for Objective 2} / Total score for Objective 2. Overall degree of achievement = 0.4 x Degree of achievement for Course Objective 1 + 0.6 x Degree of achievement for Course Objective 2.
Course objectives2	60%	60%	60%	

[3] Scoring criteria

Course objectives	Scoring criteria				
	90-100	80-89	70-79	60-69	＜60
	优	良	中	合格	不合格
	A	B	C	D	F
Course objectives 1	Demonstrate a comprehensive understanding of the basic concepts of relativity and quantum mechanics, including relativity, quantization of charge, light, and energy, the nuclear atom, the wavelike properties of particles, and the Schrodinger Equation. Provide clear explanations, demonstrate the interconnections between these concepts, and apply them to various contexts.	Show a solid understanding of the basic concepts of relativity and quantum mechanics, including relativity, quantization of charge, light, and energy, the nuclear atom, the wavelike properties of particles, and the Schrodinger Equation. Provide accurate explanations and demonstrate the ability to apply these concepts in different situations.	Demonstrate a satisfactory understanding of the basic concepts of relativity and quantum mechanics, including relativity, quantization of charge, light, and energy, the nuclear atom, the wavelike properties of particles, and the Schrodinger Equation. Provide basic explanations and show some ability to apply these concepts.	Exhibit a limited understanding of the basic concepts of relativity and quantum mechanics, including relativity, quantization of charge, light, and energy, the nuclear atom, the wavelike properties of particles, and the Schrodinger Equation. Provide incomplete or inaccurate explanations and show limited ability to apply these concepts.	Lack a sufficient understanding of the basic concepts of relativity and quantum mechanics, including relativity, quantization of charge, light, and energy, the nuclear atom, the wavelike properties of particles, and the Schrodinger Equation. Unable to provide accurate explanations or apply these concepts effectively.
Course objectives 2	Demonstrate an excellent application of quantum mechanics and relativity in various fields, including molecular	Show a solid application of quantum mechanics and relativity in fields such as molecular structure, spectra, solid-	Demonstrate a satisfactory application of quantum mechanics and relativity in fields such as molecular	Exhibit a limited application of quantum mechanics and relativity in fields such as molecular	Lack a sufficient application of quantum mechanics and relativity in fields such as molecular

Course objectives	Scoring criteria				
	90-100	80-89	70-79	60-69	＜60
	优	良	中	合格	不合格
	A	B	C	D	F
	structure, spectra, solid-state physics, nuclear physics, particle physics, astrophysics, and cosmology. Show a deep understanding of the theories and principles and effectively apply them to analyze and solve complex problems within these areas.	state physics, nuclear physics, particle physics, astrophysics, and cosmology. Demonstrate a good understanding of the theories and principles and effectively apply them to analyze and solve problems within these areas.	structure, spectra, solid-state physics, nuclear physics, particle physics, astrophysics, and cosmology. Show a basic understanding of the theories and principles and apply them to analyze and solve problems to some extent.	structure, spectra, solid-state physics, nuclear physics, particle physics, astrophysics, and cosmology. Show a partial understanding of the theories and principles and have limited ability to apply them to analyze and solve problems.	structure, spectra, solid-state physics, nuclear physics, particle physics, astrophysics, and cosmology. Show a lack of understanding of the theories and principles and unable to effectively apply them to analyze and solve problems.