### General Information

Instructor: Mr. Jerry McCoy  
Phone: (918) 631-3072  
FAX: (918) 631-2995  
e-mail: jerry-mccoy@utulsa.edu  
Office: KEH L163  
Office Hours: M W F 10:00 - 11:30 a.m., Tu Th 9:30 – 11:00 a.m., and by appointment. *You are always welcome to come see me, even outside my office hours.*  
Lecture: M W F 9:00 - 9:50 am, KEH U4

### Catalog Description

Introduction to the theories and applications of atomic, nuclear, quantum, relativistic, and solid state physics with applications. Prerequisites: Phys 2063.

### Materials

Required:  
- Class Notes: may be purchased in the bookstore.  
- Scientific calculator, any kind.

Optional:  

### Grading

Your final course grade will be determined by the following items and weights:

<table>
<thead>
<tr>
<th>Item</th>
<th>% of Final Course Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular Exams (4, drop 1, @20%)</td>
<td>60.0%</td>
</tr>
<tr>
<td>Final Exam (1, cannot be dropped)</td>
<td>20.0%</td>
</tr>
<tr>
<td>Homework</td>
<td>17.0%</td>
</tr>
<tr>
<td>Attendance (38 class sessions @ ~0.08%)</td>
<td>3.0%</td>
</tr>
<tr>
<td>Total</td>
<td>100.0%</td>
</tr>
</tbody>
</table>
I will assign your final course grade according to the following criteria:

<table>
<thead>
<tr>
<th>Final Course %</th>
<th>Final Course Grade</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>89.5 ≤ % ≤ 100</td>
<td>A</td>
<td>Superior</td>
</tr>
<tr>
<td>79.5 ≤ % &lt; 89.5</td>
<td>B</td>
<td>Good</td>
</tr>
<tr>
<td>69.5 ≤ % &lt; 79.5</td>
<td>C</td>
<td>Average</td>
</tr>
<tr>
<td>59.5 ≤ % &lt; 69.5</td>
<td>D</td>
<td>Poor</td>
</tr>
<tr>
<td>0 ≤ % &lt; 59.5</td>
<td>F</td>
<td>Failure</td>
</tr>
</tbody>
</table>

If you withdraw from this course prior to the start of the fourth week of the semester, the course will not be shown on your academic record. If you withdraw after the start of the fourth week and up to and including the twelfth week of the semester, you will receive a grade of W (withdraw) or WF (withdraw failing) depending on your grade in the course at the time of your withdrawal.

If you are doing passing work but are unable to complete your course work due to a legitimate and documented extenuating circumstance (serious illness or severe personal problems, for instance), at my discretion I may grant you a grade of “I” (incomplete). To receive an incomplete, you will need to sign a “Record of Incomplete” form which will specify what work you must do and when the work must be finished to remove the incomplete. This form will be filed in the dean’s office. The incomplete grade can remain on your record for one year. If the unfinished work is not completed in that time, your course grade will change from an I to an F.

I will be happy to discuss your grade with you up until the time of the final exam. After that, I will not discuss grades with you until after your grades have been posted.

**Homework Standards**

Unless I note otherwise, please adhere to the following standards when you prepare material for me to grade:

1. Use 8 1/2 x 11" paper (no torn-out spiral paper!). Graphs must be computer-drawn or on graph paper or on axes neatly drawn by hand. In any case, axes must be appropriately labeled.

2. Use pencil (no pen!). Be neat and legible.

3. Order problems sequentially (do not mix up the order of problems!) and number them vertically down the page. Skip a space between problems. Show all your work for full credit. Include appropriate significant figures (usually three) and correct units in all calculations; avoid excessive rounding. Clearly identify your answer. For discussion questions, provide a concise justification (usually about a paragraph in length) for your answer.

4. Staple multiple pages together, fold lengthwise, and put your name on the outside.

5. Turn in assignments on time. I will not accept assignments past the deadline unless you have arranged with me in advance or have a proven emergency.

6. Allow one full week for return of graded materials.
**Reading Assignments**

Please read the appropriate section in the text and class notes before coming to class. As you read each assignment, I suggest you highlight the following:

1. Terms: list and define important terms;
2. Key Concepts: outline important concepts;
3. Laws and Equations: list laws and important equations, what each may be used for, and any assumptions, approximations, conditions, restrictions, etc., on their use.
4. Questions: list questions that occur to you, or things that are not clear.

**Homework**

Homework assignments consist of problems and discussion questions for each chapter we cover in the text. *The assignments must be turned in by 3:00 pm each Friday* and may be placed in the box outside my office door. I will make solutions to each homework assignment available shortly after they are due.

Discussion questions require your answer *and* your reasoning or justification for your answer in order to receive credit for the problem. The remaining homework assignments will be worth 17% of your final course grade. *You should consider the assigned homework to be the minimum necessary to learning the material.* Working more problems on your own will improve your understanding of the material.

**Regular Exams**

There will be four regular exams administered during the semester. Exams will be a combination of multiple choice, true/false, short answer, and partial credit problems. Exams are closed-book; however, you may bring one Help Sheet to each exam. A Help Sheet is an 8.5" x 11" sheet of paper that you may fill (both sides) with *any* information you think might be helpful. (I will not supply formulas or common constants for exams.) This sheet must be in your own writing (no photocopying) and must be handed in with your exam. I will deduct points from your exam for an illegal Help Sheet.

I will drop the lowest of your four regular-exam grades. If you miss a regular exam for any reason, that will be the exam you will drop. If you miss more than one regular exam, your score for the second missed exam will be a zero. Your remaining three regular exam grades will be worth 60% of your final course grade, or 20% per exam.

A good way to study for an exam is as follows:

1. Create your Help Sheet by reviewing your class notes, text, and graded homework.
2. Work additional problems from the text. Practice working as quickly as possible. Add to your Help Sheet as needed.

**Final Exam**

There will be one, comprehensive final exam (see "Course Calendar" for the date and time of the final). You may bring up to five Help Sheets as described under "Regular Exams" to the final exam.

The final exam will be worth 20.0% of your final course grade. The final exam cannot be dropped or made up. *Under no circumstances will I administer the final exam to anyone at any other time than that scheduled. Please don't even ask for an exception.*
Help Sessions

Each of the four hour exams will be on a Monday. On the previous Friday, there will be a Help Session from 3:00 to 4:30 p.m. to help you prepare for the exam. I will prepare no lesson for the session, but will be prepared to answer any questions you may have.

Attendance

Data I have collected indicate that when a student misses a class, he or she lowers their final course grade by about 1% on average. For this and other compelling reasons, I require attendance. I will circulate an attendance sheet at the beginning of each class session. There are 38 class sessions excluding exams. Attendance is worth 3.0% of your final grade, so each attendance is nominally worth about 0.08% of your final grade. My attendance policy is intended to be an incentive for you to come to class regularly and on time since it will help decide borderline grades. If you miss class for a valid reason, at my discretion, you can make up the missed attendance credit by preparing a typed summary of the text material corresponding to the material I covered in class. You must hand in this summary upon return to class.

Extra Credit

You can do extra credit work to improve your grade. The work consists of an office visit at the beginning of the semester, a scientific article review and Mathematica assignments during the course of the semester. These are optional but could improve your grade by several percentage points.

Office Visit: I will add 1% to your final course grade if you will drop by my office within the first two weeks of class and introduce yourself (even if I already know you).

Article Review: I will give you article review standards during the course of the semester. The article review is worth up to 2% added to your final course grade.

Mathematica Assignments: I will make these assignments during the course of the semester; they are each worth up to 2% added to your final course grade.

Courtesy

As a courtesy to me and to the students in the class, please

- arrive class on time;
- stay awake in class;
- pay attention to what is going on (in particular, don't bring other work to class);
- let me know in advance if you need to leave early.

Academic Misconduct

Cheating is usually of little value and is surprisingly easy to detect. I have no tolerance for cheating and will pursue it aggressively. I will follow the "Policies and Procedures Relating to Student Academic Misconduct in the College of Engineering and Applied Sciences" which may be obtained from the Dean's office. The minimum penalty for cheating is a zero grade on the assignment in question which cannot then be dropped in the calculation of the final grade.

Work you submit for grading must be your own and must demonstrate some level of original thinking. Verbatim copying or even edited copying of assignments from other sources that demonstrates no original thinking constitutes cheating.
Ten Tips for Success

1. Read the textbook sections to be covered before coming to class. (A word of advice: Physics textbooks do not make for light reading. They require extra perseverance to be digested.)

2. Attend every class, take notes, ask questions, and participate in the lecture, even when you feel completely lost. Do not skip classes for any but the most urgent of reasons--skipping classes is one of the surest tickets to a poor grade.

3. Exchange phone numbers and calling times with classmates to obtain class notes and assignments in the event you must be absent from class.

4. Form study groups. (Make sure, however, that all work you submit for grading is your own.)

5. Do the assigned homework from each section before the next class session--don't fall behind! Come to class with any questions you have from the homework.

6. Develop the ability to check your work apart from answers in the text or solution manual. This skill will serve you well on exams and in the work-world.

7. Learn from your mistakes. Examine graded work carefully to understand your errors. Rework missed problems whenever possible.

8. Be tenacious! Persevere in your work until you understand the material or solve the problem.

9. Save all class materials--lecture notes, homework, exams, and handouts--in a notebook to use in studying and exam preparation.

10. Come see me regularly; don’t wait until you get into trouble. If you do get into trouble, get help immediately--don't wait! Please, please, please come see me!

My Teaching Philosophy

My primary goal in teaching this class is that you learn as much as possible. I have thought carefully about each aspect of this course and have structured the course so as to maximize your learning. Though I know that grades are usually of primary importance to students, they are of secondary importance to me. By that I mean that I am much more interested in your learning the material than the grade you make. Therefore, I am much more impressed with a student who works hard and learns a lot--even if their final course grade is less than stellar--than I am with a student who makes a high grade with little effort.

There is a direct relationship between the amount of time you invest in a course and how much you learn. In keeping with my goal of maximizing your learning, this course will require a significant amount of your time. You can rest assured that however hard you have to work to learn this course, I will work as hard or harder to teach it well.

Experience has taught me that if I set low expectations, students usually perform at a low level. On the other hand, when I set high standards, most students raise their level of performance (though they might gripe about it!). Therefore, my goal will always be to challenge students with high but attainable standards.

I intend for grades to mean what they are supposed to mean: A = Superior, B= Good, C = Average, D = Poor, and F = Failure. Though I am sure everyone would like to have an A, an A would then lose its meaning. Also, I do not give grades; rather, students earn their grade. I want students to be proud of their grade precisely because they earned it. Don’t expect to be able to negotiate your grade with me. This syllabus tells you exactly what you need to do to make any particular grade. And I don’t bend the rules.
## Course Calendar

(#{}) = Class Number  
HW = Homework  
EX = Exam

<table>
<thead>
<tr>
<th>Week</th>
<th>Monday</th>
<th>Wednesday</th>
<th>Friday</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1/8 (1): Syllabus</td>
<td>1/10 (2):</td>
<td>1/12 (3):</td>
</tr>
<tr>
<td>2</td>
<td>1/15: Holiday—no class!</td>
<td>1/17 (4):</td>
<td>1/19 (5): HW1 due; Last day for office visit</td>
</tr>
<tr>
<td>3</td>
<td>1/22 (6)</td>
<td>1/24 (7):</td>
<td>1/26 (8): HW2 due</td>
</tr>
<tr>
<td>4</td>
<td>1/29 (9):</td>
<td>1/31 (10):</td>
<td>2/2 (11): HW3 due</td>
</tr>
<tr>
<td>5</td>
<td>2/5 (12):</td>
<td>2/7 (13):</td>
<td>2/9 (14): HW4 due; Exam I Help Session</td>
</tr>
<tr>
<td>6</td>
<td>2/12: Exam I</td>
<td>2/14 (15):</td>
<td>2/16 (16): HW5 due</td>
</tr>
<tr>
<td>7</td>
<td>2/19 (17):</td>
<td>2/21 (18):</td>
<td>2/23 (19): HW6 due</td>
</tr>
<tr>
<td>Spring Break</td>
<td>3/5: No class!</td>
<td>3/7: No class!</td>
<td>3/9: No class!</td>
</tr>
<tr>
<td>9</td>
<td>3/12 (23): Exam II Help Session</td>
<td>3/14: Exam II</td>
<td>3/16 (24): HW8 due</td>
</tr>
<tr>
<td>16</td>
<td>4/30: No class!</td>
<td>5/2: No class! Final Exam Help Session</td>
<td>5/3 <strong>Thursday</strong>: Final Exam, U4, 8:00-10:25am, Comprehensive</td>
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</table>
## Homework Assignments

<table>
<thead>
<tr>
<th>Ch</th>
<th>Prob</th>
<th>Assignment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2, 4, 9, 10, 13, 15, 18, 22, 24 (not d), 25, 26, 30, 33, 34, 40, 42 (not c), 43, 46, 54, 57</td>
</tr>
</tbody>
</table>
| 1  | Quest| 1. Explain in your own words what is meant by the term “relativity.” Are there different theories of relativity? Explain.  
2. Does the Michelson-Morley experiment show that the ether does not exist? If not, explain what it does show.  
3. How does relativity combine space and time coordinates into spacetime?  
4. Explain in your own words the terms *time dilation* and *length contraction*. |
|    | Prob | 3, 4, 5, 7, 9, 11, 12, 15, 17, 18, 19, 24, 27, 29, 30, 31, 39, 40, 41, 44 |
| 2  | Quest| 1. Is it possible to have particles that travel at the speed of light? Explain. What would be required of such particles?  
2. “In special relativity, mass and energy are equivalent.” Discuss this statement and give examples.  
4. Which is more massive: (a) an object at low temperature or the same object at high temperature? (b) A spring at its natural length or the same spring under compression? (c) A container of gas at low pressure or at high pressure? (d) A charged capacitor or an uncharged one? Explain your answers. |
|    | Prob | 12, 15, 19, 20, 21, 24, 26, 27, 30, 34, 36, 38, 39, 45, 46, 48, 49, 52, 53 (use result of #47), 54 |
| 3  | Quest| 1. In what region of the electromagnetic spectrum do room-temperature objects radiate? What problems would we have if our eyes were sensitive in that region?  
2. What would be the effects on a photoelectric-effect experiment of (a) doubling the frequency of the incident light? (b) Doubling the wavelength? (c) Doubling the intensity? Explain your answers.  
3. What are x-rays? How are x-rays produced? Describe the two types of x-ray spectra and how each arises.  
4. The Compton-scattering formula suggests that objects viewed from different angles should reflect light of different wavelengths. Why don’t we observe a change in color of objects as we change the viewing angle? |
<table>
<thead>
<tr>
<th>Ch</th>
<th>Assignment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Prob 1, 5, 8, 9, 12, 18, 21, 22, 23, 25, 29, 30, 31, 32, 33, 35, 43, 45, 47, 49</td>
</tr>
</tbody>
</table>
| 4  | Quest 1. What assumptions were made in the derivation of the Rutherford theory?  
      2. What assumptions were made in the derivation of the Bohr theory?  
      3. Both the Rutherford and Bohr theories are non-relativistic. Estimate the maximum velocity of an electron in the Bohr atom and of an alpha particle in a typical scattering experiment to decide if this assumption is justified.  
      4. The behavior of the microscopic quantum world is radically different than the macroscopic non-quantum world, and yet the macroscopic world is built from the quantum world. Explain how the behaviors of these two sharply contrasting worlds are reconciled. |
PHYSICS III INSTRUCTIONAL OBJECTIVES

At the end of each chapter, you should be able to ...

Ch. 1: Relativity

• explain reference frames and inertial reference frames;
• explain classical relativity;
• apply a Galilean transformation to transform measurements between inertial reference frames;
• explain how the laws of electromagnetism are not invariant under a Galilean transformation;
• describe an interferometer and explain how it works;
• explain the Michelson-Morley experiment and its implications;
• state the postulates of special relativity and explain their meaning;
• explain the implications of the postulates of special relativity, especially: length contraction, time dilation, simultaneity, speed limit c
• explain how events simultaneous in one frame are not simultaneous in other inertial frames moving relative to the first;
• explain the confirmation of the special relativity provided by muon decay and by lost time on flying clocks;
• differentiate between classical and relativistic behavior and at what relative velocities each applies;
• explain how the relativistic transformation equations for space and time were derived;
• transform position, time, velocity, and acceleration between inertial reference frames classically and relativistically;
• explain proper time interval and proper length;
• calculate relativistic length contraction, time dilation, simultaneity for events;
• calculate the Doppler shift for relative motion of light sources toward or away from a receiver;
• calculate redshift for starlight;
• explain the twin paradox and its resolution;

Ch. 2: Relativistic Mechanics

• explain rest mass and how it differs from the mass of a moving object;
• calculate relativistic force and momentum and how they differ from the classical definitions of force and momentum;
• explain rest energy of a mass;
• calculate relativistic kinetic energy, rest energy, and total energy and how they differ from the corresponding classical definitions;
• apply the principles of conservation of total relativistic energy and momentum;
• explain mass-energy equivalence and the conversion of mass to energy and vice versa; give specific examples of mass-to-energy conversion and energy-to-mass conversion;
• calculate the change in the mass of a system due to a change in the system’s energy;
• explain binding energy of a system;
• calculate binding energy of a system from the difference in mass between its free and bound constituents;
• calculate total energy from momentum and rest energy;
• calculate the energy and momentum of a massless particle and identify its speed; give examples of massless particles;
• explain the processes of mass production and annihilation, giving an example of both;
• calculate the threshold energy for mass production;

Ch. 3: Quantization of Energy
• explain the source of electromagnetic radiation;
• explain the evidence for the wave nature of electromagnetic radiation;
• explain thermal radiation and its source;
• explain and calculate emittance and energy density and their relationship; do the same for their respective spectral distributions;
• explain blackbodies; identify specific examples of blackbody radiators;
• explain the characteristics of a blackbody’s emittance and/or energy density spectral distribution, including their dependence on temperature;
• apply Wien’s displacement law and the Stefan-Boltzmann law;
• give specific examples of common thermal phenomena that are described by Wien’s displacement law and the Stefan-Boltzmann law;
• explain the Rayleigh-Jeans classical law of blackbody radiation, its assumptions, and its inadequacy;
• explain Planck’s quantum hypothesis for oscillator energy; contrast this quantum behavior with classical oscillator behavior;
• calculate the energy quantum of an oscillator;
• calculate the energy spectral density of a blackbody radiator according to Planck’s law;
• explain applications of Planck’s law to optical thermometry and cosmic background radiation;
• explain the photoelectric effect and describe experimental apparatus used to investigate the effect;
• describe the following relationships and their significance:
  - photoelectron current versus light intensity;
  - photoelectron current versus stopping potential;
  - stopping potential versus light frequency;
  - time delay between illumination and photoelectron emission;
• explain Einstein’s particle model of light and how it accounts for all experimental observations of the photoelectric effect;
• calculate stopping potential, threshold frequency, work function, and Planck’s constant from photoelectric data;
• explain the nature (including wavelength and frequency range) and origin of x-rays; describe typical apparatus used to produce x-rays;
• explain the difference between Bragg and Laue diffraction and the diffraction patterns they produce;
• state the conditions for constructive interference in Bragg reflection both in words and formula;
• calculate angles of constructive interference for Bragg reflection;
• describe x-ray spectra including bremsstrahlung and characteristic spectra and cutoff wavelength;
• calculate cutoff wavelength for a given accelerating potential;
• explain Compton scattering and its significance for the particle model of light;
• calculate the change in wavelength of a photon due to Compton scattering;
• explain the evidence for the particle nature of light.

Ch 4: Model of the Atom

• explain the Rutherford model of the atom and its experimental basis;
• calculate quantities associated with alpha-particle scattering, e.g., coulombic repulsion, minimum separation during collision, scattering angle, etc.
• identify the size of the nucleus, its density, and the size of atoms;
• identify the types of spectra and how they are produced and the types of emission spectra and how they are produced;
• calculate wavelengths or frequencies for the Lyman, Balmer, Paschen, Brackett and Pfund series of the hydrogen spectrum;
• explain the Bohr model of the atom, its postulates;
• identify strengths and limitations of the Bohr model;
• explain emission and absorption spectra in terms of the Bohr model;
• calculate the radius, speed, and energy of Bohr orbits; calculate the frequency and wavenumber of photons emitted or absorbed in transitions between energy levels;
• explain the correction to the Bohr model for finite nuclear mass; calculate spectral lines corrected for finite nuclear mass;
• calculate the kinetic energy of an ionized electron;
• explain the correspondence principle; demonstrate that for large quantum number, classical and quantum calculations agree;
• explain the Franck-Hertz experiment, especially its experimental apparatus, data, and conclusions;
• explain spectral fine structure;
• identify the fine-structure constant;
• identify the various series and lines of a characteristic x-ray spectra;
• explain the Moseley plot and its importance;
• explain Moseley’s model of x-ray production, including screening of nuclear charge;
• explain the transitions that give rise to the spectrum of a typical heavy element;
• calculate the frequencies of x-ray lines;
• explain Auger electrons and what they may be used for;
• explain energy loss spectroscopy.

Ch 5: Wave Nature of Matter

• explain the deBroglie hypothesis;
• calculate the frequency and wavelength of a particle of matter;
• explain the connection between deBroglie’s hypothesis and Bohr’s angular momentum postulate;
• explain the Davisson-Germer experiment and its significance;
• calculate the scattering of particle waves from a crystal;
• explain wave groups and the difference between group and phase velocity;
• calculate a wave group by superposing waves;
• calculate group and phase velocity of a wave group;
• explain the probabilistic interpretation of a wave function;
• explain Heisenberg’s uncertainty principle and its origin in the wave nature of matter;
• calculate the uncertainty in a particle’s position and momentum or its energy and time;
• explain minimum energy of a confined particle and spectral line width and how they are due to the uncertainty principle;
• calculate the zero-point energy of a particle and the fractional spread in wavelength in a transition;
• explain the dual wave-particle nature of both light and matter.

Ch 6: The Schrodinger Wave Equation

• identify Schrodinger’s 1-D wave equation; explain its origin and significance;
• identify the normalization condition and explain its origin and significance;
• identify the 1-D wave equation, normalization condition, and wave function for a time-independent potential function;
• identify the conditions for acceptable solutions of the wave equation;
• solve the 1-D, time-independent Schrödinger equation including any applicable initial and boundary conditions to find the wave function for a free particle and a particle in an infinite square well;
• apply the normalization condition to calculate applicable constants in a wave equation
• calculate the wave functions and allowed energies of a particle in an infinite square well;
• explain the standing-wave nature of the solution of the wave equation for a particle in an infinite square-well;
• compare the solution to Schrödinger’s equation to the classical solution for a particle in an infinite square well.