THE GOVERNOR'S SCHOOL for SCIENCE AND TECHNOLOGY

Modern Physics PHY-243
2020-2021

Teacher Name: Ibrahim H. Albayrak, Dr.
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Class Fees: none

Course Title: Modern Physics

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Office Hours: After school and by appt.

1. **Course Description:** Learning fundamental knowledge of physics and engineering disciplines and the requisite skills to problem-solve, be innovative, and create opportunities in the real world are the overarching goals of this course. Extending the first year physics material, the course includes also investigations in calculus-based modern physics topics such as relativity, quantum mechanics, and nuclear physics, including, for example, conceptual understanding and practical applications of relativity of time and space, the wave function, Schrödinger's Equation, and radiation and radioactivity. This course includes also various physical and virtual laboratory activities with which students will be able to enhance and apply their comprehension of the course material.

2. **Course Texts:** Physics for Scientists and Engineers (2nd edition) by Randall D. Knight.

3. **Prerequisites/Co-requisites**
   - Engineering Physics I, II

4. **Required Materials**
   - Notebook (3-ring binder preferred)
   - Pencil(s), erasers, graduated straight edge
   - Scientific Calculator (e.g. TI-30, Casio fx-300, or better)

5. **Academic Integrity:** Any cheating on any exams or quizzes will result in a grade of "0" for that test. Cheating is defined as either the giving or the receiving of unauthorized help. Any indication of cheating will result in a grade of zero for the exam; **a second violation and there will be conferencing with the director**.

6. **Grading:** Each course consists of classwork, homework, exams and quizzes, and projects. Student work will be evaluated using the following weighted components and grade scale. All assessments will be timed to correspond to nationally normed standardized testing.

7. **Evaluation**

Weighted Components

a. 30% Attendance, Research reports and presentations
b. 30% Quizzes, Problem sessions and homework
c. 40% Exams, projects

Course Grade Scale

Final course grades will be assigned using the following scale as a guide:

90-100 A
80-89 B
70-79 C
60-69 D
0-59 F

8. **Course Outline**

I. **Modern Physics** - Survey of contemporary physics including special theory of relativity, an introduction to general theory of relativity, quantum mechanics, atomic, nuclear and particle physics, and topics of recent and future of physics research.

a. Special Theory of Relativity
    i. Einstein's Theories
    ii. Simultaneity
    iii. Time Dilation
    iv. Length Contraction
    v. Lorentz Transformations
    vi. Relativistic Momentum
    vii. Relativistic Energy
b. General Theory of Relativity
    i. Invariance Principle
    ii. Accelerated Reference Frames
    iii. Gravitation and Curvature of Space-Time
    iv. Expansion of the universe, black holes and neutron stars
c. Limits of Classical Physics
    i. Thomson and the electron
    ii. Rutherford and the Nuclear Atom
    iii. Absorption and Emission of Light – Wien's Law and Balmer's formula
d. Quantization
    i. Photoelectric Effect
    ii. Einstein's postulates and quantized energy
    iii. DeBroglies' postulate and matter waves
    iv. Bohr's hydrogen atom
    v. The hydrogen spectrum

e. Wave Functions and Uncertainty
    i. Wave properties of matter
    ii. Normalization
    iii. Wave Packets
    iv. Heisenberg Uncertainty Principle
f. Quantum Mechanics
    i. Schrödinger's Equation
    ii. Correspondence Principle
    iii. Potential Wells
        1. Infinite wall
        2. Finite wall
        3. Forbidden regions
    iv. Sample Quantum Mechanical models
        1. Quantum well oscillator
        2. Molecular vibrations
        3. Quantum capacitor
        4. Covalent bonds
        5. Quantum mechanical tunneling
g. Atomic Physics
    i. The hydrogen atom
    ii. Electron spin
    iii. Multi-electron atoms
    iv. Excited states of the atom
h. Nuclear & Particle Physics
    i. Nuclear structure
    ii. Nuclear stability
    iii. Shell model
    iv. Radiation and Radioactivity
    v. Nuclear Decay

9. Laboratory activities include:
    a. Cosmic muon lifetime experiment
    b. Photoelectric effect
    c. Plancks constant
    d. Heisenberg experiment
    e. Cloud chamber particle detector
    f. Milikan oil drop experiment

10. Times and topics are subject to change. Updated schedules will be announced.

THE GOVERNOR'S SCHOOL for SCIENCE AND TECHNOLOGY

Physics & Engineering III & IV – Physics Unit
Experimental Methods for Measurements and Data Analysis Module
Academic Year 2020-21

Physics Engineering Strand – Governor's School for Science and Technology

Teacher Name: Ibrahim H. Albayrak, Dr.
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Class Fees: none

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I. Introduction

11. **Course Description:** Introduces the data analysis concepts including measurements, handling errors and uncertainties, data fitting. Reviews hand calculators, number systems, and unit conversions. Introduces the data analysis tools and data analysis techniques using computer software.
12. **Course Credits:** 3 credit hours. Total 1-5 hours per week, 2-3 hours lecture with 0-2 hours lab.
13. **Prerequisites/Co-requisites**
    - Engineering Physics I, II
14. **Required Materials**
    - Notebook (3-ring binder preferred)
    - Engineering notebook
    - Pencil(s), erasers, graduated straight edge
    - Scientific Calculator (e.g. TI-30, Casio fx-300, or better)

II. Course Content

1. **Measurement –** Introduction to basic principles of measurement in science and engineering, determination of statistical and systematical uncertainties.
    a. Fundamental Dimensions, Unit Conversions, and Significant Figures
    b. Measurement of data, accuracy, precision, error analysis

2. **Probability Distributions –** Introduction to cumulative distributions expectation values, mean and variance.
    a. Cumulative distributions
    b. Expectation values
    c. Distribution moments
    d. Covariance
    e. Common probability distributions: Binomial, Poisson, Gaussian, Chi-square

3. **Treatment of Errors –** Introduction to different types of uncertainties in measurements, error propagation.
    a. Treatment of Systematic and Random (Statistic) Errors.
    b. Error Propagation

4. **Sampling and Parameter Estimation –** Introduction to techniques for sampling data and estimation of parameters.
    a. Sample Moments
    b. The maximum likelihood method.
    c. The Weighted Mean

5. **Data Fitting** - Introduction to data fitting methods.
    a. Fitting Functions to Data, Linear and Polynomial fits.
    b. The least square Method of Fitting
    c. Interpolations and Extrapolations

6. **Using Data Analysis Tools –** Tools such as Microsoft EXCEL and Mathlab that are used to undertake analyses and graphical representations of data.
    a. Performing basic data analysis operations and fits using Excel
    b. Standards in the Proper Graphical Display of Data
    c. Choosing and designing graphical displays of data appropriate to the given problem or analysis

7. **Simulation of Data –** Introduction to tools that are used for simulation of data.
    a. Basic simulation concepts
    b. Monte Carlo Simulations

8. **Data Analysis Practice** - Students demonstrate skills in the measurement of data and data analysis. A series of small-group, hands-on demonstration projects of measurement and data analysis are completed, with assessment of data measurement and analysis skills; methods; team skills; instrumentation, data acquisition and display; and outcomes analysis. Projects will require maintaining laboratory notebooks and the written and oral presentation of methods and results.

i. Measuring the distance from Moon.
    i. Introduction to theoretical and empirical background in the measurements of distances of celestial objects.
    ii. Design and fabrication of a data acquisition system for distance measurement from Moon or Sun
    iii. Determination of errors and uncertainties in the process and application of error propagation and analysis of the data.
j. Mean and Error from a Series of Measurements
k. Combining Data with Different Errors

III. Instructional Methods

Course Texts: William R. Leo, Techniques for Nuclear and Particle Physics Experiments, ISBN 978-3-540-57280-0 ISBN 978-3-642-57920-2 (eBook).

The course will be taught through lectures, in class and homework problem assignments, reading and reporting assignments and team projects. Classroom participation is critical as learning assessments are continuous and individually focused. Group work is strongly encouraged to accelerate learning. Programming and other computer work is accomplished on student-assigned laptops with preloaded software.

IV. Student Learning Outcomes

Upon completion of this course students will be able to:

a. Express the meaning of unit conversions, significant figures, statistics, and software tools
b. Perform a measurement process through designing and constructing data acquisition devices
c. Demonstrate data analysis skills through the use of error propagation, curve fitting, parameter estimation.
d. Construct graphs for qualitative and quantitative data in Microsoft EXCEL
e. Construct basic MATLAB programs

V. Evaluation and Assessment

Grading: Each course consists of classwork, homework, exams and quizzes, and projects. Student work will be evaluated using the following weighted components and grade scale. All assessments will be timed to correspond to nationally normed standardized testing.

30% Projects, Notebook, Written Reports, and Oral Presentations
30% Problem sessions and homework
20% Quizzes/Exams
20% Final Exam

Course Grade Scale

Final course grades will be assigned using the following scale as a guide:

90-100 A
80-89 B
70-79 C
60-69 D
0-59 F