هيئة تقويم التعليم والتدريب
Education & Training Evaluation Commission

اعتماد
NCAAA

Key Learning Outcomes for Physics Programs

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بِسْمِ اللَّـهِ الرَّحْمَـٰنِ الرَّحِيمِ

Introduction

Based on the mandate of the Education and Training Evaluation Commission (ETEC), issued by Royal Decree No. 108, dated 14/2/1440 H, ETEC is mandated to “building systems for evaluation and accreditation - including institutional and programmatic - in education and training, including rules, standards, frameworks and indicators and its terms, procedures, approval, and application.” And based on the authority’s keenness to build and develop high-quality national academic programs, the authority has worked on preparing specialized academic standards for Physics programs.

The standards contribute to setting the minimum curriculum requirements of Physics undergraduate programs to ensure their academic quality, and to assure their ability to produce highly qualified professionals in the field of Physics with the knowledge and skills required by the market and the national needs, in line with best practices and academic requirements for this field.

Goals

The main goal of this work is to develop specialized Learning Outcomes (SLOs) that should represent the minimal achieved by Physics students at graduation. It will direct programs, course design and organization, building the curriculum map including the appropriate teaching and learning strategies, assessment tools, evaluation strategy, and link academic and professional aspects.

Methodology

This document describes the minimum knowledge units (KUs) and learning outcomes (LOs) in the field of Physics which graduates are expected to obtain upon completion of the program. The KU-specific learning outcomes specify the minimum of what students should know or be able to do after successfully completing the KU.

The methodology follows the following phases:

1. Identifying International Benchmarks.
2. Identifying Program Key Learning Outcomes.
3. Identifying Curriculum General Criteria
4. Identifying the General Knowledge Units.
5. Identifying the Specialized Knowledge Units for each General Knowledge Unit.
6. Identifying the Specialized Learning Outcomes for each Specialized Knowledge Unit.

It is important for educational institutions to take into account the depth and expansion; and to include LOs related to communication skills and values in the curricula. Educational institutions can offer the desired elective KUs that are relevant to their programs and students can choose from them to complete their graduation requirements. It is important to note that a KU is not necessarily a credit course. A KU may be covered by one or more credit courses and a credit course may cover one or more KUs partially or completely. The KUs are derived from analyzing of 6 QS high ranked International Universities (see Appendix A).

This document was developed by the ETEC in cooperation and coordination with different entities in the field of Physics, such as University of Colorado-Boulder, Penn State University, University of Waterloo, McGill University, Imperial College and The University of Manchester.

Scope and Uses

This document covers the bachelor's degree programs in the field of Physics. The document can be used and applied to Physics programs offered by higher educational public and private institutions in Saudi Arabia.

Terms

The main terms, you can use ETEC glossary:

ETEC: Education and Training Evaluation Commission – Saudi Arabia.

Knowledge Units: Thematic groupings that encompass multiple related topics; where the topics cover the required curricular content for each KU. Each KU contains a set of learning outcomes.

Essential Knowledge Units (EKUs): The required topics in Mathematics and computer programming

General Knowledge Units (GKUs): Knowledge Units that introduce students to the main topics in Physics. All students majoring in any field of Physics should complete these GKU's.

Key Learning Outcomes (KLOs): It describes what students are expected to know and will be able to do by the time of graduation. These relate to the knowledge, skills, and behaviors that students acquire as they progress through the program.

Learning Outcomes (LOs): Phrases describing what a learner should know, understand, and be able to do at the end of the program. They represent the bottom line of the learning process.

NQF: National Qualifications Framework.

Specialized Key Learning Outcomes (SLOs): The specificity needed for interpretation of the general criteria as applicable to a given discipline.

Specialized Knowledge Units (SKUs): Knowledge Units that introduce students to intermediate and advanced topics in a major.

Key Learning Outcomes

Write learning Outcomes at the program level with a maximum of (10) considering logical sequence and the requirements of writing Learning outcomes mentioned in the (Learning outcomes guide).

Key Learning Outcomes (KLOs) should describe the essential knowledge, skills and attitudes that graduates of the Physics undergraduate program will be able to demonstrate once completing the program. They are aspiration statements for a typical or average Physics student.

On successful completion of a bachelor's degree in Physics, graduates should be able to:

KLO1: Comprehend deeply the major fields of Physics: Classical Mechanics, Electricity and Magnetism, Waves and Optics, Thermal Physics, Modern and Quantum Physics, Quantum Mechanics and Statistical Physics.

KLO2: Analyze physical systems based on the principles of physics.

KLO3: Demonstrate the ability of utilizing relevant mathematical tools and computer software to describe physical phenomena.

KLO4: Apply laws of physics to solve problems in the major fields of Physics.

KLO5: Design experiments, employing relevant instrumentations; exploiting statistics and laws of physics for data analysis.

KLO6: Participate in teamwork and develop communication skills in verbal, written, and presentational forms.

Curriculum General Criteria

Based on benchmarking study of leading universities (Appendix A), and analyzing all knowledge units (KUs) and skills using Physics programs, it is found that these KUs are grouped in the following categories:

1. Essential knowledge units: 23 units (credit hours)
2. General knowledge and skills units: 40 units (credit hours)
3. Specialized knowledge units

Each group consists of different subgroups that is essential in any typical Physics. To show the importance of each of the subgroups, a range of allocated credit hours in a typical Physics is shown in the next section.

knowledge Units

The following table provides an overall view of the curriculum distribution of Knowledge Units: essential, general, specialized and others. The tables also provide general recommendation on the acceptable range of credit hours for each knowledge unit.

Essential Knowledge Units (EKU)

Calculated based on a minimum of 23 credits for Mathematics, and programming. This part of the knowledge units should not be used in standardized tests.

Table 1: Essential Knowledge Unit of physics

#	EKU	Description	Minimum Requirements (credit hours)
1	Mathematics	Mathematics plays an important role in physics. Physics problems can be described mathematically, and mathematical methods can be employed to find their solutions. Hence, it is crucial to have an understanding of calculus, differential equations, linear algebra, and vector calculus. Furthermore, to appreciate the role of approximations in simplifying physics problems. Eventually the solutions have to be physically justified since there could be solutions acceptable mathematically with no physical significance.	20
2	Programming	Programming plays an important role in solving and simulating physics problems. By using coding techniques to write a full-functioning program, many skills are developed such as planning, logic, problem-solving, attention to detail, troubleshooting errors, resilience, and creativity, and numerical limitations. Moreover, with the fast advancement in machine and laboratory automation, such programming skills and the employment of simulation packages are key components to investigate complicated systems.	3

Program core Knowledge Units

Percentages are calculated based on a minimum of 40 credits for the Physics program.

Table 2: Generalized and Specialized Knowledge Units of Physics

#	GKU	Weight%	SKU	Weight%
1	Classical Mechanics	25	1.1. Kinematics	7.5
			1.2. Newtonian Mechanics	6.25
			1.3 Circular Mechanics	6.25
			1.4 Fluid dynamics	2.5
			1.5 Lagrangian and Hamiltonian	2.5
2	Electricity and Magnetism	20	2.1. Electricity	8
			2.2. Magnetism	8
			2.3 Electromagnetism	4
3	Waves and Vibrations	18	3.1 Wave Motion and properties	7.2
			3.2 Optics	10.8
4	Modern Physics (Relativity and Quantum Theory)	15	4.1 Special Relativity	3
			4.2 Nature of waves and particles	4.5
			4.3 matter, atomic, and nuclear structures	4.5
			4.4 Semiconductors	3
5	Quantum Mechanics	10	5.1 Operators	4
			5.2 Mathematical representations of Quantum Systems	6
6	Thermodynamics and Statistical Mechanics	12	6.1 Thermal Physics	7.8
			6.2 Statistical Mechanics	4.2

[Write the general and specialized knowledge units (KUs) of the program with maximum of (20) SKUs.]

Appendix (A): International Practices analysis

The KUs are derived from the following sources:

1. IOP institute of Physics
2. University of Colorado
3. Penn State University
4. University of waterloo
5. McGill University
6. Imperial College
7. The University of Manchester

Table A1: International and local universities considered in the analysis of physics program requirements.

#	University	Department name	QS University Ranking 2023
1	University of Colorado-Boulder	Department of Physics	99
1	Penn State University	Department of Physics	71
2	University of waterloo	Department of Physics and Astronomy	85
3	McGill University	Department of Physics	65
4	Imperial College	Department of Physics	12
5	The University of Manchester	Department of Physics and Astronomy	44

Required Subjects/Topics in Top International and Local Universities

Table A2: [Physics] program required Subjects/Topics in elite International and local Universities.

GKUs	SKUs	U1	U2	U3	U4	U5	U6	Count	
								Tot	Not
Classical Mechanics	1.1 Kinematics	✓	✓	✓	✓	✓	✓	6	A
	1.2 Newtonian Mechanics	✓	✓	✓	✓	✓	✓	6	A
	1.3 Circular Mechanics	✓	✓	✓	✓	✓	✓	6	A
	1.4 Fluid dynamics	✓	✓	✓	✓	✓	✓	6	A
	1.5 Lagrangian and Hamiltonian	✓	✓	✓	✓	✓	✓	6	A
Electricity and Magnetism	2.1 Electricity	✓	✓	✓	✓	✓	✓	6	A
	2.2 Magnetism	✓	✓	✓	✓	✓	✓	6	A
	2.3 Electromagnetism	✓	✓	✓	✓	✓	✓	6	A
Waves and Vibrations	3.1 Wave Motion and properties	✓	✓	✓	✓	✓	✓	6	A
	3.2 Optics	✓	✓	✓	✓	✓	✓	6	A
Modern Physics (Relativity and Quantum Theory)	4.1 Special Relativity	✓	✓	✓	✓	✓	✓	6	A
	4.2 Nature of waves and particles	✓	✓	✓	✓	✓	✓	6	A
	4.3Matter, Atomic, and Nuclear structures	✓	✓	✓	✓	✓	✓	6	A
	4.4Semiconductors	✓		✓	✓	✓	✓	5	A
Quantum Mechanics	5.1 Operators	✓	✓	✓	✓	✓	✓	6	A
	5.2 Mathematical representations of Quantum Systems	✓	✓	✓	✓	✓	✓	6	A
Thermodynamics and Statistical Mechanics	6.1 Thermal Physics	✓	✓	✓	✓	✓	✓	6	A
	6.2 Statistical Mechanics	✓	✓	✓	✓	✓	✓	6	A

- Any specialized knowledge unit that was taught by 65 % or more of the universities should be considered an important SKU and should be recommended and Labeled "A."
- If the comparison showed that a particular SKU scored below 65% and was believed to be important, they should be further screened by applying another acceptance condition as defined in the FE exam by QIYAS and SCE. The SKUs that satisfy this condition are recommended and labeled by "B."
- SKUs not meeting the above conditions should not be recommended, labeled by "C," and eliminated from Specialized Learning Outcomes.
- The comparisons should be made based on the course descriptions. If no syllabus is available, a consensus should be made.

Appendix (B): Alignment of Key Learning Outcomes of Physics with NQF.

Alignment of the Key Learning Outcomes for Physics with the NQF.

[Physics] Key Learning Outcomes	NQF Learning Areas		
	Knowledge and understanding	Skills	Values, Autonomy, and Responsibility
1	✓		
2	✓	✓	
3	✓	✓	✓
4	✓	✓	✓
5	✓	✓	✓
6			✓

Appendix (C): Learning Outcomes and Topics for Knowledge Units

Essential Knowledge Unit (EKU.1): Mathematics

Description

Mathematics plays an important role in physics. Physics problems can be described mathematically, and mathematical methods can be employed to find their solutions. Hence, it is crucial to have an understanding of calculus, differential equations, linear algebra, and vector calculus. Furthermore, to appreciate the role of approximations in simplifying physics problems. Eventually the solutions have to be physically justified since there could be solutions acceptable mathematically with no physical significance.

Topics

The following topics must be included in this SKU:

1. Trigonometric and hyperbolic functions
2. Complex numbers
3. Series
4. Matrices
5. Calculus
6. Ordinary and partial differential equations
7. Vectors calculus
8. Fourier series and transforms
9. Probability distributions

Specialized Learning Outcome

By completing this EKU, students should be able to:

1. Demonstrate the use of series and expansions of trigonometric, exponential and logarithmic functions.
2. Illustrate skills in using complex numbers of representations, operations and applications.
3. Perform and relate differentiation and integration for applications in real physics problems.
4. Use partial differential equations to model real life problems based on laws of physics.
5. Employ vector calculus to formulate the laws of physics
6. Relate Fourier transform to wave phenomena.
7. Discuss the use of probability distributions and statistical procedures.

The table below shows maps the Specialized Learning Outcomes for the SKU to the KLOs

SLOs	KLOs							
	KLO1	KLO2	KLO3	KLO4	KLO5	KLO6	KLO7	KLO8
1		✓	✓	✓				
2		✓	✓	✓				
3		✓	✓	✓				
4		✓	✓	✓				
5	✓	✓	✓	✓				
6		✓	✓	✓				
7	✓		✓	✓	✓	✓		

Essential Knowledge Unit (EKU.2): Programming

Description	Programming plays an important role in solving and simulating physics problems. By using coding techniques to write a full-functioning program, many skills are developed such as planning, logic, problem-solving, attention to detail, troubleshooting errors, resilience, creativity, and numerical limitations. Moreover, with the fast advancement in machine and laboratory automation, such programming skills and the employment of simulation packages are key components to investigate complicated systems.
Topics	**The following topics must be included in this SKU:** **1.** Elements of Programming. **2.** Algorithms and visualization **3.** Scientific programming libraries **4.** Physics simulation programs
Specialized Learning Outcome	**By completing this EKU, students should be able to:** **1.** Develop a code in a programming language to produce analytical solutions to basic mathematical problems. **2.** Employ simple library routines to solve advanced problems in physics. **3.** Utilize coding techniques to carry out a programming project aimed at stimulating physical phenomena. **4.** Perform simulations of physics phenomena using simulation packages. **The table below shows maps the Specialized Learning Outcomes for the SKU to the KLOs**

SLOs	KLOs					
	KLO1	KLO2	KLO3	KLO4	KLO5	KLO 6
1		✓	✓	✓	✓	
2		✓	✓	✓	✓	
3	✓	✓	✓	✓	✓	✓
4		✓	✓	✓	✓	✓

General Knowledge Unit (GKU 1): Classical Mechanics

Description

Classical mechanics is the main field of physics based on which most of physics definitions are founded. It deals mainly with the motion of the bodies considering time as an independent physical quantity. The cause of motion is attributed to the forces and potentials influencing the bodies, and these forces and potentials are connected to the motional parameters, mainly: distance, velocity, acceleration, and time. The concept of mechanics is extended to cover the angular motion of bodies about themselves or other points in space.

Specialized Knowledge Unit (SKU1.1): Kinematics:

Description

The physical quantities of time, displacement, and acceleration are connected to each other through the equation of motions while considering time as an independent variable. The specific case of constant acceleration is very important due to several natural physical phenomena; however, the general case of variable acceleration is also important and is taken into account in constructing the equations of time.

Topics

The following topics must be included in this SKU:

1. Units of physical quantities
2. Distance and displacement
3. Average and instantaneous velocity, and acceleration
4. Equations of motion in multi-dimensions

Specialized Learning Outcome

By **completing this SKU, students should be able to:**

1. Define physical quantities by units.
2. Distinguish scalar and vector physical quantities.
3. Differentiate between average and instantaneous displacement, velocity, and acceleration.
4. Calculate displacement and velocity as a function of time for constant and variable acceleration.
5. Construct the differential equations of motion.
6. Combine equations of motions of multi-dimensions.
7. Apply the equations of motion to practical scenarios, including: free fall and projectile motions.
8. Design and perform experiments validating equations of motions.

The table below shows maps the Specialized learning Outcomes for the SKU to the KLOs

SLOs	KLOs					
	KLO1	KLO2	KLO3	KLO4	KLO5	KLO6
1	✓		✓	✓	✓	✓
2	✓	✓	✓	✓	✓	
3	✓	✓	✓	✓	✓	
4	✓	✓	✓	✓	✓	
5	✓		✓	✓		
6	✓	✓	✓	✓		
7	✓	✓	✓	✓	✓	
8	✓	✓	✓	✓	✓	✓

Specialized Knowledge Unit (SKU1.2): Newtonian Mechanics

Description

Newton laws connect the basic quantities with the applied forces. The net force at each moment represents the instantaneous direction and magnitude of acceleration, and accordingly the equation of motion is constructed. The acting force will create a work accordingly providing a change in the momentum and kinetic energy. The total mechanical energy is conserved as long as the field potential causing the force is conservative.

Topics

The following topics must be included in this SKU:

1. Newton's laws
2. Static equilibrium
3. Types of forces
4. Work and energy
5. Impulse and momentum
6. Collisions
7. Gravitational force
8. Potential energy

Specialized Learning Outcome

By completing this SKU, students should be able to:

1. Recall Newton laws.
2. Calculate the net force of forces acting on a point in space.
3. Identify the types of forces.
4. Relate scalar quantities to vector quantities of motion.
5. Apply the concept of conservation principles to energy and momentum.
6. Analyze real-life systems based on the acting forces and related energies.
7. Solve the equations of two body systems.
8. Describe the motion in a gravitational field.
9. Design and perform experiments validating equations of mechanical systems influenced by forces.

The table below shows maps the Specialized Learning Outcomes for the SKU to the KLOs

SLOs	KLOs					
	KLO1	KLO2	KLO3	KLO4	KLO5	KLO 6
1	✓					
2	✓	✓	✓	✓	✓	
3	✓					
4	✓	✓	✓	✓		
5	✓	✓	✓	✓	✓	
6	✓	✓	✓	✓	✓	
7	✓	✓	✓	✓		
8	✓	✓	✓	✓		
9	✓	✓	✓	✓	✓	✓

Specialized Knowledge Unit (SKU1.3): Circular Mechanics

Description	Non-point systems suffer from rotational motions requiring the introduction of representative physical quantities related to the mass distribution as a function of the system geometry. Angle, angular velocity and angular acceleration are connected to each other mimicking the linear relation of motions. Angular momentum and kinetic energy are described in similarity with the linear ones.
Topics	**The following topics must be included in this SKU:** 1. Angular displacement, velocity and acceleration 2. Angular momentum and torque 3. Rigid body motion 4. Moment of inertia
Specialized Learning Outcome	**By completing this SKU, students should be able to:** 1. Relate linear quantities to circular quantities. 2. Evaluate the central force acting on a rotating system. 3. Develop a conceptual understanding of simple harmonic motion. 4. Calculate the center of mass and moment of inertia for discrete and continuous bodies. 5. Assess the stability of an extended body. 6. Design and perform experiments on rotational systems. **The table below shows maps the Specialized Learning Outcomes for the SKU to the KLOs**

SLOs	KLO1	KLO2	KLO3	KLO4	KLO5	KLO6
1	✓	✓	✓	✓	✓	
2	✓	✓	✓	✓	✓	
3	✓	✓	✓	✓		
4	✓	✓	✓	✓		
5	✓	✓	✓	✓		
6	✓	✓	✓	✓	✓	✓

Specialized Knowledge Unit (SKU1.4): Fluid Dynamics

Description

Fluids are described as bodies having no conservative shapes yet maintaining their mass; they can be either gases, liquids or a combination of both. In all cases, the laws of matter and energy conservations are still valid, providing bases to construct suitable equations concerning the nature of fluidic systems compared to the solid case.

Topics

The following topics must be included in this SKU:

1. Fluid in static equilibrium
2. Flow rate and speed
3. Viscosity
4. Continuity equation
5. Bernoulli equation

Specialized Learning Outcome

By completing this SKU, students should be able to:

1. Describe the physical properties of fluids.
2. Derive the equations of fluids based on the physical principles.
3. Appraise the effect of viscosity in fluids.
4. Calculate the physical parameters of static and flowing fluids.
5. Apply the continuity and Bernoulli equations in different geometries.
6. Compute physical fluidic quantities in the same system at different points.
7. Design and perform experiments related to basic fluidic systems.

The table below shows maps the Specialized Learning Outcomes for the SKU to the KLOs

SLOs	KLOs					
	KLO1	KLO2	KLO3	KLO4	KLO5	KLO6
1	✓	✓	✓	✓	✓	
2	✓	✓	✓	✓	✓	
3	✓	✓	✓	✓	✓	
4	✓	✓	✓	✓	✓	
5	✓	✓	✓	✓	✓	
6	✓	✓	✓	✓	✓	
7	✓	✓	✓	✓	✓	✓

Specialized Knowledge Unit (SKU1.5): Lagrangian and Hamiltonian

Description	Advanced mathematical representation of deep physical perspective is treated with higher levels of combination of math and physics. There are two main approaches in such; 1) Lagrangian and 2) Hamiltonian. In such treatments physical quantities are defined in differential form of functions, so accordingly complicated systems can be resolved in a more convenient tactics.
Topics	**The following topics must be included in this SKU:** 1. Lagrangian and Hamiltonian equations 2. Orbital Motion 3. Coupled oscillators. 4. Constrained systems 5. Vibrational Motion and modes
Specialized Learning Outcome	**By completing this SKU, students should be able to:** 1. Identify fundamental concepts of Lagrangian and Hamiltonian mechanics. 2. Apply Lagrangian and Hamiltonian methods to solve the motion of mechanical systems. 3. Comprehend the key computational methods in solving Lagrangian and Hamiltonian equations. **The table below shows maps the Specialized Learning Outcomes for the SKU to the KLOs**

SLOs	KLOs					
	KLO1	KLO2	KLO3	KLO4	KLO5	KLO6
SLO1	✓	✓	✓	✓		
SLO2		✓	✓	✓		
SLO3			✓			

General Knowledge Unit (GKU 2): Electricity and Magnetism

Description

The field of electricity and magnetism is concerned with the effects of the electric charge as part of the matter components in the universe. Such existing electric charge influences the surrounding through electrical fields and potentials. These electric fields and potentials can be seen through the interaction with other electric charges. Besides the electric field, magnetic field is also imposing an effect of the electric charge. Interestingly, the electricity can be created by magnetism and vice versa introducing the concept of electromagnetism.

Specialized Knowledge Unit (SKU2.1): Electricity

Description

Electric charges construct the foundations of electricity. The way the charge interacts with each other and their individual or collective influences on the surrounding through either scalar or vector physical quantities are of interest. The conventional laws of physics set the basis for defining new parameters in the field of electricity.

Topics

The following topics must be included in this SKU:

1. Electric charges
2. Coulomb Law
3. Electric fields and potentials
4. Gauss law and electric flux
5. Capacitance and resistance
6. Circuits and Kirchhoff rules
7. AC circuits

Specialized Learning Outcome

By completing this SKU, students should be able to:

1. Discuss the basic concepts of electric charges and Coulomb law.
2. Analyze electric forces, fields and potentials formed by distributed charges.
3. Examine electric field interaction with matter.
4. Relate resistance, capacitance, and inductance to voltage through charges and currents.
5. Distinguish between work, energy and power of electric circuits.
6. Employ Kirchhoff rules in circuit analysis.
7. Relate electric currents and potentials in an alternating-current circuit to its components.
8. Evaluate real-life applications of electric phenomena.
9. Design and perform experiments related to electrostatics and circuits.

The table below shows maps the Specialized learning Outcomes for the SKU to the KLOs

SLOs	KLOs					
	KLO1	KLO2	KLO3	KLO4	KLO5	KLO 6
1	✓	✓	✓	✓	✓	
2	✓	✓	✓	✓	✓	
3	✓	✓	✓	✓	✓	
4	✓	✓	✓	✓	✓	
5	✓	✓	✓	✓	✓	
6	✓	✓	✓	✓	✓	
7	✓	✓	✓	✓	✓	
8	✓	✓	✓	✓	✓	
9	✓	✓	✓	✓	✓	✓

Specialized Knowledge Unit (2.2): Magnetism

Description

Magnetism is the field of physics relating magnetic fields to moving charged bodies. The magnetic field can be seen as vector quantity creating a force on the charge depending on the amount of the charge, magnetic field, and velocity. Similarly, the moving electric charge creates a magnetic field on the surrounding as well.

Topics

The following topics must be included in this SKU:

1. Magnetic fields
2. Magnetic force
3. Charge particles in a magnetic field
4. Magnetic flux
5. Ampere and Biot-Savart Laws
6. Relative permittivity and susceptibility
7. Induction and inductance

Specialized Learning Outcome

By completing this SKU, students should be able to:

1. Calculate the magnetic force acting on moving charges.
2. Explain the significance of total magnetic flux on a closed surface.
3. Employ Ampere and Biot-Savart laws to relate the magnetic field and current density in systems of different geometries.
4. Examine magnetic field interaction with matters.
5. Calculate the inductance of straight and wound wires.
6. Design and perform experiments related to magnetism.

The table below shows maps the Specialized Learning Outcomes for the SKU to the KLOs

SLOs	KLOs							
	KLO1	KLO2	KLO3	KLO4	KLO5	KLO6	KLO7	KLO8
1	✓	✓	✓	✓	✓			
2	✓	✓	✓	✓				
3		✓	✓	✓				
4	✓	✓	✓	✓	✓			
5		✓	✓	✓	✓			
6	✓	✓	✓	✓	✓	✓		

Specialized Knowledge Unit (2.3): Electromagnetism

Description

As both electricity produces magnetism and magnetism produces electricity, the concept of electromagnetism is considering how the laws describe the combination of electricity and magnetism as one field.

Topics

The following topics must be included in this SKU:

1. Lorentz force
2. Faraday law
3. Maxwell equations
4. Electromagnetic waves

Specialized Learning Outcome

By completing this SKU, students should be able to:

1. Evaluate systems' behaviors based on Lorentz force.
2. Discuss and apply Faraday law of induction in different configurations.
3. Derive Maxwell equations in vacuum and matter.
4. Employ Maxwell equations in free space to construct the wave equation.
5. Evaluate electromagnetic wave propagation in matter and at interfaces.
6. Use Poynting vector to determine energy transported by electromagnetic waves.
7. Design and perform experiments related to electromagnetism.

The table below shows maps the Specialized Learning Outcomes for the SKU to the KLOs

SLOs	KLOs							
	KLO1	KLO2	KLO3	KLO4	KLO5	KLO6	KLO7	KLO8
1	✓	✓	✓	✓	✓			
2		✓	✓	✓	✓			
3	✓	✓	✓					
4	✓	✓	✓					
5	✓	✓	✓	✓	✓			
6			✓	✓				
7	✓	✓	✓	✓	✓	✓		

General Knowledge Unit (GKU3): Waves and Vibrations

Description	The field of waves and vibration represents different physical phenomena related to changes of physical quantities in a periodic manner as a function of displacement and time. This field considers the nature of these physical quantities and how they are affected by other governing physical parameters. Accordingly, this periodic variation of quantities can be explored to understand and predict the way this behavior creates a wave, and how the wave can travel as a function of time and displacement.

Specialized Knowledge Unit (SKU3.1): Waves Motion and properties

Description

Alternation of a physical quantity as a function of time and displacement can be seen as a motion of a wave in a certain direction with a speed, wavelength, and frequency. Complicated alternation is analyzed by considering multi-wave superposition, and each wave has its own properties. So, the collective properties are related to each individual wave constructing the collective one.

Topics

The following topics must be included in this SKU:

1. Simple harmonic motion
2. Traveling waves
3. Standing waves
4. Interference and diffraction
5. Doppler effect

Specialized Learning Outcome

By completing this SKU, students should be able to:

1. Identify examples of oscillating systems and wave motion across many areas of physics.
2. Analyze quantitatively vibrating systems and wave propagation in many different physical media.
3. Interpret damped, forced oscillations, and resonance.
4. Distinguish between the phenomena of interference and diffraction.
5. Explain the Doppler effect and its utilization in different areas of physics.
6. Design and perform experiments related to waves and their properties.

The table below shows maps the Specialized Learning Outcomes for the SKU to the KLOs

SLOs	KLOs					
	KLO1	KLO2	KLO3	KLO4	KLO5	KLO 6
SLO1	✓				✓	
SLO2	✓	✓	✓	✓	✓	
SLO3	✓	✓	✓	✓	✓	
SLO4	✓	✓	✓	✓	✓	
SLO5		✓	✓	✓	✓	
6	✓	✓	✓	✓	✓	✓

Specialized Knowledge Unit (SKU 3.2): Optics

Description

Optics is devoted to understanding light and its characteristics such as interference, diffraction, and polarization. Due to these properties, optics and optical instruments have a major impact on human lives and contribute to other scientific fields, for example, medicine, industry, and astronomy. Furthermore, the discovery of lasers opened a new door to modern optics.

Topics

The following topics must be included in this SKU:

1. Plane and spherical Waves
2. Wavefronts, rays, Poynting vector; and time-averaged optical field
3. Reflection and refraction
4. Light propagation
5. Polarization
6. Geometrical optics
7. Interferometry
8. Lasers

Specialized Learning Outcome

By completing this SKU, students should be able to:

1. Use complex notation competently to describe electromagnetic waves.
2. Apply the laws of reflection and refraction at the light-matter interface.
3. Differentiate between ray-optics, wave-optics, and quantum optics.
4. Compute the energy and power of an electromagnetic wave.
5. Derive the electromagnetic wave equation and its relation to Maxwell's equation.
6. Analyze simple examples of interference and diffraction phenomena observed in real life.
7. Explain the principles and use of modern optics equipment such as the Michelson interferometer and Fabry-Perot etalon (interferometer).
8. Discuss the concept of polarization of light and how it changes at interfaces.
9. Distinguish between coherent and incoherent light sources.
10. Design and perform experiments related to optics and lasers

The table below shows maps the Specialized Learning Outcomes for the SKU to the KLOs

SLOs	KLOs					
	KLO1	KLO2	KLO3	KLO4	KLO5	KLO6
1	✓	✓	✓	✓		
2		✓	✓	✓	✓	
3	✓	✓	✓	✓	✓	
4			✓	✓		
5	✓	✓	✓	✓		
6	✓	✓	✓	✓	✓	
7	✓	✓	✓	✓	✓	
8	✓	✓	✓	✓	✓	
9	✓	✓	✓	✓	✓	
10	✓	✓	✓	✓	✓	✓

General Knowledge Unit (GKU4): Modern Physics (Relativity and Quantum Theory)

Description

Modern physics introduces new concepts in the field of physics, maintaining the same meaning of quantities with different perceptions. The concept of relativity in space, as it is known in classical physics, is generalized to cover even the time, which is unusual in the classical picture. Moreover, the classical representation of light as a wave is still maintained with the introduction of that the light is behaving as a particle, and this applies as well to the particles by associating them with waves having their natures from the known classical quantities. Interestingly, this non-conventional and non-classical proven behavior established the concept of quantization in energy and eliminated the pervious belief.

Specialized Knowledge Unit (SKU4.1): Special Relativity

Description

Our understanding of space and time has changed through the introduction of Einstein's postulates and the theory of special relativity. Concepts such as inertial frames of reference, Lorentz transformation, and relativistic effects of space and time require a new perspective to the physics of motion in a relativistic viewpoint.

Topics

The following topics must be included in this SKU:

1. Galilean Transformations
2. Postulates of Special relativity
3. Lorentz Transformations
4. Time dilation and length contraction
5. Energy-mass relation
6. Momentum and total energy

Specialized Learning Outcome

By completing this SKU, students should be able to:

1. Define the border between classical and modern physics and the need to introduce the Special Theory of Relativity.
2. Explain the concept of frame of reference and the application of Galilean transformation.
3. Recall Einstein's postulates.
4. Relate space and time coordinates of two frames by applying Lorentz transformation.
5. Distinguish relativistic forms of kinetic energy, total energy, rest energy and momentum.
6. Describe the mass-energy concept as one physical quantity.
7. Solve problems in kinematics and dynamics at relativistic velocities.

The table below shows maps the Specialized learning Outcomes for the SKU to the KLOs

SLOs	KLOs							
	KLO1	KLO2	KLO3	KLO4	KLO5	KLO6	KLO7	KLO8
1	✓			✓				
2	✓	✓	✓	✓				
3	✓							
4	✓		✓					
5	✓							
6	✓							
7	✓	✓	✓	✓				

Specialized Knowledge Unit (SKU4.2): Nature of Waves and Particles

Description

Major physics experiments discovered the quantization of energy. The light-matter interaction experiments gave evidence of the quantum nature of light and matter. This established the wave-particle duality and the realization of matter waves. Such concepts had a great impact in providing innovative solutions to real-life applications.

Topics

The following topics must be included in this SKU:

1. Black Body Radiation
2. Photoelectric effect
3. X-ray radiation
4. Compton effect
5. Photon energy
6. De Broglie wavelength
7. Heisenberg's Uncertainty Principle

Specialized Learning Outcome

By completing this SKU, students should be able to:

1. Discuss the failure of the wave theory to explain the photoelectric effect and blackbody radiation leading to the birth of quantum theory.
2. Describe the concept of quantization of energy and photons.
3. Justify the wave-particle duality based on the interpretation of scientific experiments.
4. Solve problems in quantum physics using the ideas of wave-particle duality and the uncertainty principle.
5. Design and perform experiments related to wave-particle duality.

The table below shows maps the Specialized Learning Outcomes for the SKU to the KLOs

SLOs	KLOs					
	KLO1	KLO2	KLO3	KLO4	KLO5	KLO 6
SLO1	✓	✓	✓	✓	✓	
SLO2	✓				✓	
SLO3	✓				✓	
SLO4			✓	✓		
SLO5	✓	✓	✓	✓	✓	✓

Specialized Knowledge Unit (SKU 4.3): Matter, Atomic, and Nuclear Structures

Description

The new picture of particles behaving as waves constrains the path-length of electrons around the nucleus to be as integer multiplications of the wave associated with it. Accordingly, due to this energy discreetness, x-ray characteristics of atoms can be justified. Directed x-ray interference as a result of reflection from a crystal can be correlated to the atomic ordering inside the crystal. The nucleus structures and reactions is related to the law of conversation of mass-energy and charge as well.

Topics

The following topics must be included in this SKU:

1. Bohr theory
2. Atomic quantum numbers
3. Crystal structure and Bragg law
4. Nuclear structure
5. Ionizing radiations
6. Nuclear decay

Specialized Learning Outcome

By completing this SKU, students should be able to:

1. Derive Rydberg equation based on quantization of angular momentum
2. Estimate the magnitude of x-ray, energy and wavelength, characteristics of atoms
3. Describe simple crystal structures
4. Derive and apply Bragg law to crystalline materials
5. Identify nuclear particles and decay processes
6. Calculate the nuclear reaction energy based on mass changing
7. Design and perform experiments related to nuclear, atomic and matter structures

The table below shows maps the Specialized Learning Outcomes for the SKU to the KLOs

SLOs	KLOs					
	KLO1	KLO2	KLO3	KLO4	KLO5	KLO6
SLO1	✓	✓	✓	✓		
SLO2	✓	✓	✓	✓		
SLO3	✓					
SLO4	✓	✓	✓	✓	✓	
SLO5	✓					
SLO6		✓	✓	✓		
SLO7	✓	✓	✓	✓	✓	✓

Specialized Knowledge Unit (SKU4.4): Semiconductors

Description	The field of Semiconductors is described as solid matter having certain conditions regarding the electronic structures and the occupancy of electrons within the available states. It is the basis of Electronics dealing with electric charges based on the electronic structure of the materials. Mainly, the motion of elections in the conduction band and holes in the valence band.
Topics	**The following topics must be included in this SKU:** 1. Band structures and bandgap 2. Free charge carriers 3. Doping 4. Electric transport 5. p-n junctions 6. Applications
Specialized Learning Outcome	**By completing this SKU, students should be able to:** 1. Relate the fundamental properties of metals, insulators and semiconductors to the electronic structure. 2. Discuss the concepts of mobility and conductivity of electrons and holes. 3. Compare and contrast n-type and p-type doping. 4. Formulate mathematical equations governing the depletion layer and internal electric field of a p-n junction. 5. Identify different applications of diodes in solar cells, electric current rectification, and LED's. 6. Design and perform experiments related to semiconductor physics. **The table below shows maps the Specialized Learning Outcomes for the SKU to the KLOs**

SLOs	KLOs					
	KLO1	KLO2	KLO3	KLO4	KLO5	KLO6
1	✓					
2	✓				✓	
3	✓	✓	✓	✓	✓	
4	✓	✓	✓	✓		
5	✓				✓	
6	✓	✓	✓	✓	✓	✓

General Knowledge Unit (GKU 5): Quantum Mechanics

Description

The physical system with proper potentials is seen in a different approach suitable with the picturing the particles as waves. This wave nature of particle is represented by the so called wave function. Conventional physical quantities are extracted from the wave function by applying mathematical operators representing the classical physical quantities in a differential or matric form. Both forms result in the same results, providing a match between the observed world and the mathematical quantum equations.

Specialized Knowledge Unit (SKU5.1): Operators

Description

Due to the realization of the waves associated with particles and advanced treatment of classical mechanics, the concept of introducing mathematical operators to represent physical quantities is valid. Accordingly, it is found that systems can be seen through the mathematical functions or matrices upon which the eigenvalues of associated operators result in the physical quantity value as realized in the classical picture.

Topics

The following topics must be included in this SKU:

1. Wave function and operators
2. Schrodinger equation
3. Dirac notations
4. Mathematical formulas of the uncertainty
5. Expectation values

Specialized Learning Outcome

By completing this SKU, students should be able to:

1. Relate quantum mechanical operators to classical and measurable physical quantities.
2. Utilize and interpret wavefunction to predict physical quantities.
3. Derive Schrodinger equation based on free particle wavefunction.
4. Construct time-dependent and time-independent Schrodinger equations for different potentials.
5. Apply Dirac notations in describing quantum states and systems.
6. Compute the expectation value of operators in quantum states.

The table below shows maps the Specialized Learning Outcomes for the SKU to the KLOs

SLOs	KLOs					
	KLO1	KLO2	KLO3	KLO4	KLO5	KLO6
1	✓		✓			
2	✓	✓	✓	✓		
3	✓		✓			
4			✓			
5			✓			
6	✓	✓	✓	✓		

Specialized Knowledge Unit (SKU5.2): Mathematical representations of Quantum Systems

Description	Mathematical representations in quantum mechanics provide the formulas of systems from which the physical quantities and their expectation values can be extracted utilizing the proper operators acting upon such representations. Therefore, the representative formulas have to be constructed based on the nature of the acting potentials and energies of the physical systems the formulas represent.
Topics	**The following topics must be included in this SKU:** 1. Free particle wave function 2. Infinite and finite Quantum Wells 3. Quantum barriers and tunneling 4. Quantum Harmonic Oscillator 5. Central Potential wave equation
Specialized Learning Outcome	**By completing this SKU, students should be able to:** 1 Solve Schrodinger equation for a multi-dimensional confined particle in a quantum well. 2 Solve Schrodinger equation for one-dimensional transport cases. 3 Discuss the concept of quantum tunneling. 4 Calculate discrete eigenvalues of a harmonic oscillator. 5 Express time-independent Schrodinger equation in spherical coordinates 6 Rearrange central potential Schrodinger equation in three separated equations of φ, θ and r. 7 Identify the concept of perturbation theory in quantum mechanics. **The table below shows maps the Specialized Learning Outcomes for the SKU to the KLOs**

SLOs	KLOs					
	KLO1	KLO2	KLO3	KLO4	KLO5	KLO6
1	✓		✓			
2	✓		✓			
3	✓					
4	✓	✓	✓	✓		
5			✓			
6			✓			
7	✓		✓			

General Knowledge Unit (GKU 6): Thermodynamics and Statistical Mechanics

Description	Heat is one kind of energy forms, and increasing it in a closed physical system can be seen through the temperature. Temperature shows several effects in macro-quantities in physics, such as: dimension and pressure. The transfer of heat is governed by several parameters including the nature of the media in which the heat transfers and the temperature variation. More insight of the heat and temperature effects is seen though the employment of quantum mechanics and the statistical distribution functions.

Specialized Knowledge Unit (SKU6.1): Thermal Physics

Description	The temperature of a system can be seen as a physical quantity related to other macroscopic physical quantities, such as pressure and volume. Heat is defined as one kind of energy, so the laws of energy conservation can be applied to relate heat to other energies; moreover, the heat transfer is connected to temperature.
Topics	**The following topics must be included in this SKU:** 1. Temperature and heat 2. Thermal equilibrium 3. Ideal Gas law 4. First law of thermodynamics 5. Thermodynamic cycles 6. Heat transfer 7. Second and third laws of thermodynamics
Specialized Learning Outcome	**By completing this SKU, students should be able to:** 1. Explain the meaning of temperature and thermodynamic equilibrium (Zeroth Law of thermodynamics) 2. Relate macroscopic properties of gas through the ideal gas law. 3. Derive and utilize the first law of thermodynamics. 4. Analyze Thermodynamic cycles and calculate their thermal efficiencies. 5. Compute entropy changes for some thermodynamic processes. 6. Construct Maxwell relations. 7. Distinguish the types of heat transfer and calculate the amount of transferred heat. 8. Argue the applications of the second and third laws of thermodynamics. 9. Design and perform experiments related to thermal physics. **The table below shows maps the Specialized Learning Outcomes for the SKU to the KLOs**

SLOs	KLOs					
	KLO1	KLO2	KLO3	KLO4	KLO5	KLO6
1	✓	✓		✓	✓	
2	✓	✓	✓	✓	✓	
3	✓	✓	✓	✓	✓	
4	✓	✓	✓	✓	✓	
5	✓	✓	✓	✓		
6	✓	✓	✓			
7	✓	✓	✓	✓	✓	
8	✓		✓	✓		
9	✓	✓	✓	✓	✓	✓

Specialized Knowledge Unit (SKU6.2): Statistical Mechanics

Description

The basic interactions of particles are reflected in the macroscopic behavior of any system. This requires a deep understanding of the quantum states available and the number of particles occupying these states. Due to the fact that there are a huge number of sub-systems influencing the main system, this requires the use of statistical approaches within the framework of physical laws.

Topics

The following topics must be included in this SKU:

1. Density of states
2. Ensembles
3. Statistical distribution functions
4. Applications

Specialized Learning Outcome

By completing this SKU, students should be able to:

1. Relate the microscopic properties to the macroscopic properties of matter.
2. Explain the concepts of density of states and degrees of freedom.
3. Analyze quantum gases utilizing the proper statistical distributions.
4. State the importance of ensemble theory and its configurations.
5. Relate entropy to the possible real microstates in a system.
6. Employ partition function in calculating thermodynamic properties.
7. Apply statistical mechanics for phonons in solids.

The table below shows maps the Specialized Learning Outcomes for the SKU to the KLOs

SLOs	KLOs					
	KLO1	KLO2	KLO3	KLO4	KLO5	KLO6
1	✓	✓	✓	✓	✓	
2	✓	✓	✓	✓		
3	✓	✓	✓	✓		
4	✓		✓			
5	✓	✓	✓	✓		
6	✓	✓	✓	✓		
7	✓		✓	✓		