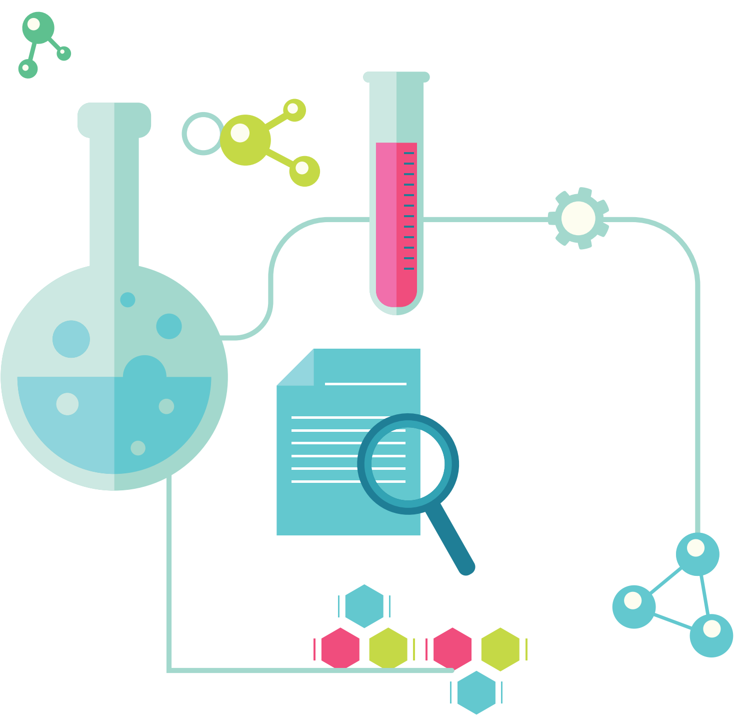
المركز الوطني للقياس
National Center for Assessment

هيئة تقويم التعليم والتدريب
Education & Training Evaluation Commission

LEARNING OUTCOMES

PHYSICS



بسم الله الرحمن الرحيم

مخرجات التعلم

تخصص الفيزياء

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Introduction :

Higher Education in Saudi Arabia has witnessed a rapid development in the recent years, through inaugurating new public and private universities around the country. However, this may have an impact upon the teaching system in general and program outcomes in particular. Therefore, the Ministry of Education has endeavored to improve the quality of program outcomes in all Saudi universities. It then launched the project of learning outcomes (LOs) in Higher Education, in collaboration with the National Center for Assessment. The Bologna process which focuses primarily on LOs has been adopted widely, particularly in most European countries. Thus, this promising project will draw on the Bologna process to come up with LOs for academic programs that are being taught in Saudi universities.

LOs are basically used to ensure the quality of learning and teaching. By using them, it becomes easier to compare two different programs of the same major (i.e. benchmarking). They also help academic departments and teachers to develop course materials and determine course objectives. More importantly, they play a key role in linking teaching and learning with assessment and assisting academic programs to gain accreditation.

Furthermore, LOs have some benefits for students (stakeholders). They will provide them with the necessary information of the program they would like to join. In other words, LOs help stakeholders to know what kind of achievement they will gain by completing a certain program in cognitive (essential knowledge), behavioral (skills and abilities) and affective (attitudes, values or beliefs) domains.

Stages of the project :

This project has gone through various stages, as illustrated in Figure 1. It began with forming the main committees that will participate in this project. The National Center for Assessment ran workshops on how to write LOs and exam items based on LOs in which faculty members from various Saudi universities participated. Here are the main stages in more details.

Figure 1. Stages of the LOs project

First Phase: Surveying current academic programs

This phase aims to survey the content of national and international academic programs. The objective is to establish the LOs based on these programs and identify the extent of coverage of these LOs in the academic programs in Saudi universities. The most important steps of this phase include:

1.1 Identifying LOs

A comprehensive survey has been conducted on all programs of Physics in Saudi universities, in an attempt to identify the LOs of this major.

1.2 Analyzing the content of the national programs

After collecting the content of relevant programs, a thorough analysis was done in order to identify the common components in these programs and the ones that are unique to certain programs. This procedure includes the following:

- Identifying the main components of the major in all Saudi universities.
- Determining the percentages of the main components in these programs.
- Identifying the common sub-components in these programs.
- Determining the percentages of the sub-components in these programs.

1.3 Analyzing the content of some international programs:

The previous procedure was done on the programs of the following universities:

- Lehigh University.
- Michigan State University
- University of Illinois at Urbana-Champaign .

1.4 Comparing the content of the national and international programs:

A comparison was made among the components of the national and international programs in order to identify the common main and sub-components in these programs and the ones that are unique to certain programs.

Second Phase: Proposing the LOs of the program

This phase focuses mainly on identifying the components and their importance in the program. This procedure includes the following:

1. Defining the major accurately and comprehensively in order to determine the features that distinguish it from other similar programs.
2. Proposing the components of the program, based on the survey in the previous phase, and identifying the programs to which they are compared for benchmarking purposes.
3. Determining the importance of each component. To do so, the teaching hours of each component in the program have been calculated.
4. Dividing the main components into sub-components.
5. Identifying the importance of the sub-components, as is illustrated in Table 1.
6. Defining the main components and sub-components of the program on which the LOs will be based.

Table 1. Percentages of main components and sub-components of Physics

Main component	%	Sub-component	%
Classical Mechanics	11	Newtonian Mechanics	75
		Fluid Mechanics	5
		Lagrangian and Hamiltonian Formalism	20
Wave phenomena	11	Waves and vibration	50
		Optics	50
Thermal and Statistical Physics	10	Thermodynamics	50
		Statistical Physics	50
Electromagnetism	22	Electricity	25
		Magnetism	15
		Electrodynamics	25
		Circuits and electronics	35
Analytical and Experimental methods		Sequence and Series	20
		Integral transforms	15
		Differential equations	30
		Complex analysis	10
		Linear algebra	15
		Experimental methods	10
Modern Physics	32	special relativity	5
		Atomic physics	20
		Quantum Mechanics	45
		Solid state physics	15
		Nuclear physics	15
Total			%100

Third Phase: Writing LOs

When writing LOs, the following points have been taken into consideration:

1. Drawing on the criteria of writing LOs reported in the literature, e.g. using measurable verbs.
2. Covering Bloom›s Taxonomy levels, particularly knowledge, application and analysis.
3. Determining the target content, taking into account the division of the program (i.e. main components, sub-components and LOs) as well as the identification importance of program main and sub-components.

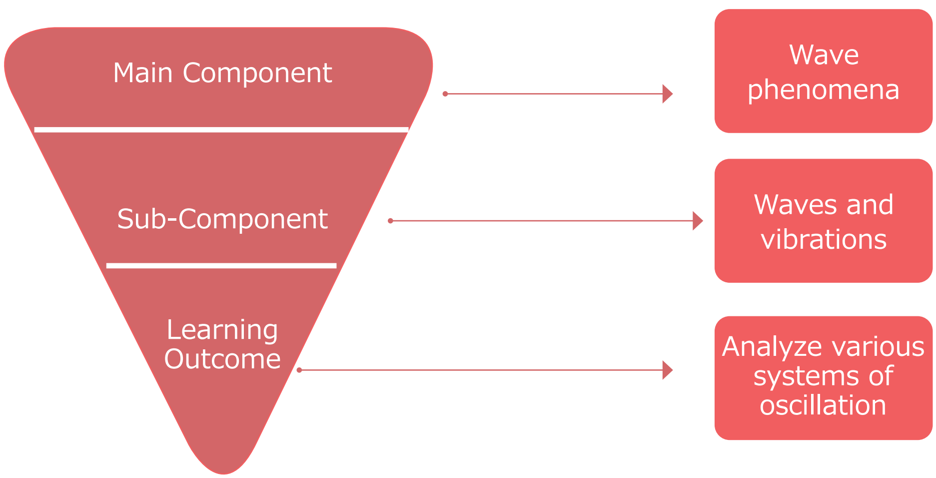

Figure 2. Illustration of the program division into main components, sub-components and LOs

Fourth Phase: Reviewing LOs

To ensure the quality of the writing process and the use of criteria of writing LOs, the review process went through three stages:

1. Program experts

Three experts of the program were recruited for reviewing the LOs. They were trained on how to assess LOs.

2. National universities

A draft of the LOs was sent to all Saudi universities, in an attempt to get feedback from the faculty members of Physics Department in these universities. This was a very crucial step as it showed us to what extent the LOs covered the major and whether the importance of main components and sub-components was determined properly.

3. Electronic review

The draft of the LOs was also posted on the website of the National Center for Assessment, in an attempt to get feedback from experts of Physics everywhere. Then, it was advertised that the LOs for Physics were available online for review.

Fifth Phase: Revising LOs

The comments and feedback received from the review process were approved by the reviewing committee and then sent to the committee of writing LOs to revise them accordingly. After revising the LOs, the reviewing committee approved the changes that were made.

Sixth Phase: Final draft of LOs

After the revision process, the final draft of the LOs for Physics was written for official use in the future, as is shown in Table 2.

1. Main Component: Classical Mechanics:

Graduates are expected to:

Describe the kinematics and dynamics of objects and fluids.

Sub-Components	Learning Outcomes
1.1Newtonian Mechanics: To know the laws of motion and Newton, and apply them to some systems.	1) Apply Newton's laws for linear motion in 1,2, and 3 dimensions.
	2) Examine rotational motion of an object.
	3) Investigate rigid body motion.
	4) Analyze the gravitational force.
	5) Apply work and energy theorem and relate it to Force.
	6) Apply the laws of conservation.
	7) Analyze the equilibrium state.

Sub-Components	Learning Outcomes
1.2 Fluid Mechanics: Explain the characteristics of fluids and their interaction with environment and describe their motion.	1) Analyze fluid properties and buoyant force.
	2) Apply the concept of continuity in fluids.
	3) Apply Bernoulli's Equation to different systems.
	4) Explain some applications of fluid mechanics.
	5) Apply the laws of conservation.
	6) Analyze the equilibrium state.

Sub-Components	Learning Outcomes
1.3 Lagrangian and Hamiltonian Formalism: Comprehend the variation principle and Lagrange and Hamilton formalism, and apply them to mechanical systems.	1) Relate the variation principle to Hamilton and Lagrange formalism.
	2) Extend the idea of coordinates to the generalized coordinates.
	3) Construct the Hamiltonian and Lagrangian for simple mechanical systems, rigid bodies and coupled oscillations.
	4) Solve the canonical equations of motion.

2. Main Component: Wave Phenomena:

Graduates are expected to

Describe waves and vibrations and analyze their behavior.

Sub-Components	Learning Outcomes
2.1 Waves and vibration: To describe oscillations and their propagation under different circumstances, and deduce their properties and applications.	1) Analyze various systems of oscillation.
	2) Investigate wave nature based on the superposition concept.
	3) Analyze the role of driving and damping forces in oscillating systems.
	4) Analyze the behavior of various types of waves.
	5) Generalize the idea of oscillation to other physical systems.
	6) Describe resonance and normal modes in oscillations.
	7) Explain Doppler Effect.

Sub-Components	Learning Outcomes
2.2 Optics: To explain the nature of light and its propagation and handle geometrical and wave optics.	1) Utilize ray tracing in studying geometrical optics.
	2) Explain polarization phenomenon of light.
	3) Analyze constructive and destructive interference of light waves.
	4) Analyze some practical examples of interference and diffraction.

3. Main Component: Thermal and Statistical Physics:

Graduates are expected to:

Survey thermodynamics and its microscopical origin

Sub-Components	Learning Outcomes
3.1Thermodynamics: To grasp the concepts of heat and its transformations, and apply the laws of thermodynamics.	1) List the laws of thermodynamics and apply them to physical systems.
	2) Utilize equilibrium conditions.
	3) Derive the free energies (Gibbs, Helmholtz) for simple systems.
	4) Calculate the entropy and its implications on thermodynamical variables.
	5) Describe phase transformation and utilize it to calculate phase diagrams.

Sub-Components	Learning Outcomes
3.2 Statistical Physics: To investigate the statistical nature of entropy, and relate microscopical physics to macroscopical thermodynamical variables.	1) Apply kinetic theory of gases and ideal gas law in various situations.
	2) Compare the statistical distributions (Maxwell-Boltzmann, Fermi-Dirac, Bose-Einstein) and apply them appropriately.
	3) Derive entropy from a microscopic behavior of a system.
	4) Relate thermodynamical properties to atomic states.
	5) Differentiate between the statistical ensembles.
	6) Apply the statistical nature of atomic distribution to calculate specific heat.

4. Main Component: Electromagnetism

Graduates are expected to:

Realize charge interactions with electric and magnetic fields, the mutual relations of fields, and some applications of the theory.

Sub-Components	Learning Outcomes
4.1 Electricity To analyze the concept of electric charge, its effect on objects and environment, and its relation to energy.	1) Apply Coulomb`s law, electric field and potential of static charge.
	2) Relate electric field to electric flux.
	3) Solve Poisson equation for symmetric systems.
	4) Extract electric potential from electric field.
	5) Describe the interaction of electric field with matter.
	6) Extract energy flux in electric field.

Sub-Components	Learning Outcomes
4.2 Magnetism: To describe the effect of a moving charge on its environment and the relation of such an effect on other moving charges and energy.	1) Calculate magnetic field in a point from various sources.
	2) Relate magnetic field to magnetic flux.
	3) Solve Ampere's equation for symmetric systems.
	4) Describe the interaction of magnetic field with matter.
	5) Extract energy flux from magnetic field.
	6) Extract vector potential from magnetic field.

Sub-Components	Learning Outcomes
4.3 Electrodynamics: To connect electricity and magnetism to become one concept and understand the effect of such connection on objects, surrounding environment and propagation.	1) Extract the relations between electricity and magnetism.
	2) Investigate the charge motion in electric and magnetic fields.
	3) Solve Maxwell equations for plane waves.
	4) Extract speed of light from Maxwell equations.
	5) Derive the propagation of electromagnetic energy.

Sub-Components	Learning Outcomes
4-4 Circuits and electronics: To illustrate the application of static and moving charge in electric and electronic circuits.	1) Analyze AC and DC electric circuits.
	2) Describe electrical properties of semiconductors.
	3) Describe diode and transistor operations.
	4) Use electronic devices in amplifier and timing circuits.

5. Main Component: Analytical and Experimental methods

Graduates are expected to:

Handle series, sequences, integral transforms, differential equations, complex analysis, and linear algebra and to apply them in treating different physical systems analytically and numerically.

Sub-Components	Learning Outcomes
5.1 Sequence and Series: To handle sequences and series and understand their properties and applications.	1) Apply series expansions and convergence.
	2) Analyze the limit of a sequence.
	3) Represent analytical functions as power series.
	4) Use Fourier series to analyze periodic functions.
	5) Generalize the idea of factorial to Gamma function.

Sub-Components	Learning Outcomes
5 - 2 Integral transforms: To employ Laplace and Fourier transforms in analyzing physical systems.	1) Apply Fourier transform and its inversion.
	2) Apply Laplace transform and its inversion.
	3) Relate momentum to space representations.
	4) Employ Fourier and Laplace transforms to solve mathematical problems.

Sub-Components	Learning Outcomes
5-3 Differential equations: To know the types of differential equations, their solutions, and their applications.	1) Solve 1st and 2nd order linear ordinary differential equations.
	2) Analyze partial differential equations using separation of variables.
	3) Solve second order partial differential equations.
	4) Generalize orthogonal function
	5) Utilize special functions (Bessel, Hermite, Legendre…)

Sub-Components	Learning Outcomes
5-4 Complex analysis To use complex analysis in the treatment of physical systems.	1) Manipulate functions of complex variables
	2) Utilize Cauchy integral theorem in analyzing physical problems.
	3) Draw complex numbers geometrically.
	4) Represent trigonometric functions as complex functions.
	5) Apply the residual theorem.

Sub-Components	Learning Outcomes
5-5 Linear algebra: To outline the concepts of vector space, linear transformations and systems.	1) Handle the gradient, divergence and curl of vectors.
	2) Manipulate matrices and determinants.
	3) Calculate the eigenvalues and eigenvectors.
	4) Explain vector spaces and their properties.

Sub-Components	Learning Outcomes
5 - 6 Experimental methods To collect and analyze data and then deduce controlling laws from the results.	1) Extract data from experiments and inspect its integrity.
	2) Apply standard practices in work environment.
	3) Analyze results based on their behavior and extract physical interpretation.

6. Main Component: Modern Physics

Graduates are expected to:

Identify the limits of classical physics, know quantum mechanics and relativity, and analyze the crystal, atomic, and nuclear structure of matter.

Sub-Components	Learning Outcomes
6-1 Special relativity: To handle transformation of physical properties between different inertial frames.	1) State the postulates of special relativity.
	2) Deduce and apply the relation of length contraction and time dilation.
	3) Construct Lorentz transformations and apply them.
	4) Apply the concept of simultaneity.
	5) Apply the energy – momentum relationship in relativistic terms.

Sub-Components	Learning Outcomes
6-2 Atomic physics: To apprehend the atom as a system composed of electrons surrounding a nucleus and the operations that affect.	1) Recognize atomic structure and Pauli's principle.
	2) Explain the spectra of atomic transitions.
	3) Relate light frequency to photon energy.
	4) Relate black body radiation to light quantization.
	5) Apply the wave particle complementarity.
	6) Analyze Bohr atom and its applications.

Sub-Components	Learning Outcomes
6-3 Quantum Mechanics: To analyze physical phenomena on nano-scale where effects are of order of Planck's constant.	1) Recall the limits of classical physics.
	2) State the postulates of quantum mechanics.
	3) Describe time-dependent Schrodinger equation.
	4) Analyze commutation relations in quantum mechanics.
	5) Solve time-independent Schrodinger equation for simple systems.
	6) Analyze and compare bound and scattering states.
	7) Analyze Schrodinger equation for radial potential.

Sub-Components	Learning Outcomes
6-4 Solid state physics: To recall the types of atoms and their arrangements in matter and connect that to physical properties.	1) Analyze crystal structure of matter.
	2) Interpret physical properties of matter according to atomic nature.
	3) Relate crystal vibrations to heat capacity and thermal conductivity.
	4) Discriminate between materials according to their electrical and optical properties.
	5) Derive band structure of ordered materials.
	6) Explain magnetic properties of matter.

Sub-Components	Learning Outcomes
6-5 Nuclear physics: To explain structure and forces of the nucleus and describe their interactions and applications	1) Describe nuclear structure.
	2) Analyze nuclear forces.
	3) Describe radioactive decay, fission and fusion processes.
	4) Describe nuclear models.
	5) Explain radiation detections.