Mechanics

Objectives:	00UR	**Discipline:**	Physics
Ponderation:	3-2-3	**Course Code:**	203-NYA-05
Prerequisite:	Sec. V Physics 534, Mathematics 536 (or equivalent)	**Course Credit:**	2 2/3
Corequisite:	00UP (*Calculus I*)	**Semester:**	1

Introduction

Mechanics, the first physics course in the Science Program, is taken by all science students in their first semester, concurrently with Calculus I, the differential calculus.

The role of the course in the program is two-fold. It presents the basic principles of mechanics — kinematics, dynamics, and the three conservation laws (energy, momentum and angular momentum) — which are essential to the study of all the natural sciences. It also provides an opportunity for students to develop problem solving skills. In particular students will learn to use vectors to treat many classes of problems, and will apply the techniques of differential calculus to physics as they learn them.

Mechanics is the science of everyday objects. Its applications surround us — the trajectory of a slapshot, the arches of a bridge, the pirouette of a ballerina, the design and flight of a jet fighter. Because its effects are so present in our daily lives, we can visualize the workings of its laws and test the theory against our experience. We can understand some of the technology that permeates our society through the principles of mechanics.

The laws and concepts introduced in this course are the foundation of our scientific view of the world. Ideas about force, motion, energy and momentum arise again and again in all the sciences and in daily life. Understanding them is essential to the education of a scientist or an engineer. In every physics, chemistry, geology and even biology course at college and university concepts, such as energy and momentum, first learned in mechanics will be generalized, broadened, deepened and applied.

Some of the learning activities in *Mechanics* will contribute to the attainment of objective 00UU and are marked **[00UU]**.

In the laboratory there is an opportunity to verify first-hand some of the principles of mechanics in simple experiments. In at least one experiment, computers are used to collect and analyze data.

In the Science Program, *Mechanics* contributes to the following program goals described in the *Exit Profile*:

	Goals of the Science Program	Performance Criteria
1.	To master the knowledge and skills of a basic scientific education	00UR, 00UU
2.	To master the knowledge and skills of a basic general education	
3.	To apply the experimental method	3.1, 3.2, 3.4, 3.5
4.	To take a systematic approach to problem solving	4.1 – 4.6
5.	To use the appropriate data-processing technology	5.2
6.	To reason logically	6.1 – 6.3
7.	To communicate effectively	7.1, 7.3 – 7.6
8.	To learn in an autonomous manner	8.1 – 8.3
9.	To work as members of a team	9.1 – 9.3
10.	To recognize the links between science, technology and the evolution of society	10.1 – 10.3
11.	To construct a personal system of values	
12.	To identify the context in which scientific ideas originated and evolved	12.1
13.	To display attitudes and behaviour compatible with the scientific spirit and method	13.1 – 13.4
14.	To apply acquired knowledge and skills to new situations	14.1

Objectives and Standards for *Mechanics*

In the following chart, italicized items marked with (*) are optional enrichment items which will not be evaluated in the final exam (these are not the only possible enrichment items — they are the most commonly used ones).

OBJECTIVE	STANDARD	LEARNING OBJECTIVES
Course Objective	**Achievement Context**	
To analyze different physical situations and phenomena in terms of the fundamental principles of classical mechanics	1. In theoretical situations, working individually to solve problems taken from a standard college-level Physics textbook 2. In experimental settings, in the lab, working individually or in a group, with the aid of a laboratory write-up, or of scientific documentation, to write lab reports	
	General Performance Criteria	
	1. Appropriate use of concepts, laws and principles 2. Adequate use of diagrams to represent physical situations 3. Appropriate use of terminology and units 4. Appropriate use of vector techniques where appropriate 5. Accurate graphical and mathematical representations of motion 6. Proper justification of the steps taken in analyzing a situation 7. Rigorous application of Newton's Laws and the conservation principles 8. Critical judgment of results 9. Meticulous experimentation 10. Proper interpretation of the limits of models	

Elements of Competency	Specific Performance Criteria	Intermediate Learning Objectives
1. To describe the translational and rotational motion of objects	1.1. Precise use of concepts basic to the description of translational motion	1.1.1. Define displacement, distance, average and instantaneous speed, average and instantaneous velocity, average and instantaneous acceleration.
	1.2. Solution of problems in one dimensional motion with constant acceleration, including free fall problems	1.2.1. Apply the standard equations describing motion in one dimension with constant acceleration using appropriate sign conventions to situations involving: • one object with a single acceleration; • one object whose acceleration takes on different values in different parts of the motion; and • the motions of two objects.
	1.3. Correct interpretation of position, velocity and acceleration graphs	1.3.1. Apply the idea that the slope of a graph represents the rate of change of the y-variable with respect to the x-variable to: • find velocity by taking the slope of a d-t graph; and • find acceleration by taking the slope of a v-t graph. 1.3.2. Apply the idea that area under a graph of the rate of change of y with x versus x represents the change in y to: • calculate displacement from a v-t graph; and • calculate change in velocity from an a-t graph.
	1.4. Correct application of vector techniques to the solution of problems of motion in two dimensions	1.4.1. Define scalar and vector and identify physical quantities correctly as either scalars or vectors. 1.4.2. Find the components of a vector given in polar form - i.e. in terms of magnitude and direction. 1.4.3. From the components of a vector, find its magnitude and direction. 1.4.4. Perform the operations of addition of vectors, subtraction of vectors, and multiplication of a vector by scalar using components. 1.4.5. Solve simple vector equations. 1.4.6. Define the unit vectors: $\hat{i}, \hat{j}, \hat{k}$ and use unit vector notation in problem solving. 1.4.7. Define and calculate the dot product and the cross product of two vectors. 1.4.8. Generalize the equations of motion in one dimension with constant acceleration to vector equations in two dimensions and use them to solve projectile problems. 1.4.9. a) Recognize that uniform circular motion is accelerated motion and calculate the centripetal acceleration. b) Define tangential acceleration and calculate the net acceleration of an object in uniform and non-uniform circular motion.

Elements of Competency	Specific Performance Criteria	Intermediate Learning Objectives
	1.5. Precise use of the concepts basic to the description of rotational motion	1.5.1 Define a rigid body. Define angular position, angular velocity and angular acceleration. 1.5.2 Derive relations between the linear distance travelled, the linear speed and the linear acceleration of a point on a rotating rigid body and the angular variables describing the rotation.
	1.6. Precise solution of problems involving the particular case of a rigid body rotating about a fixed axis	1.6.1. Use the analogy between straight line motion and rotation of a rigid body about a fixed axis to develop a set of equations for rotational motion with constant angular acceleration.
	1.7. Correct application of the techniques of differential calculus to motion.	1.7.1. Use the concept of the derivative and problem solving methods from Calculus I to solve certain simple motion problems. **[00UU]**
2. To apply the concepts and laws of dynamics to the analysis of the motion of objects	2.1. Precise use of the concepts basic to dynamics.	2.1.1. Define inertial frame, equilibrium, weight. Distinguish between mass and weight.
	2.2. Precise statement of Newton's Three Laws	2.2.1. State Newton's Three Laws of Motion.
	2.3. Logical and coherent explanation of everyday phenomena in terms of Newton's Laws	
	2.4. Rigorous application of Newton's Laws to solve a wide variety of problems, following a series of logical and organized steps	2.4.1 Use these steps in presenting problems: a) Draw a free body diagram for each object whose motion is to be analyzed, correctly identifying all the forces acting on the body; b) Choose convenient coordinate axes for each body and resolve the forces and accelerations along these axes; c) Apply Newton's Laws to write equations for each body; d) Solve the resulting equations; and e) Check that the answers obtained are reasonable considering the situation described in the problem. 2.4.2 Calculate the friction forces acting on objects and include these forces in the analysis of their motion. 2.4.3 Calculate the centripetal acceleration of an object in uniform circular motion and apply Newton's Laws to situations involving circular motion.
	2.5. Precise use of concepts basic to rotational dynamics	2.5.1. Define torque, moment of inertia of a rigid body.
	2.6. Rigorous application of the relation $t = Ia$ to solve problems involving rotation of a rigid body about a fixed axis. This includes problems where the rotating object is part of a system, such as a pulley with mass in an Atwood's machine	2.6.1. Calculate the net torque on a rigid body about a particular axis due to several simultaneously applied forces. 2.6.2. Determine the moment of inertia of certain regularly shaped solids using a table and the parallel axis theorem. 2.6.3. Follow the series of steps outlined in 2.4.1 to set up and solve rotation problems.
	2.7. *(*) Rigorous application of laws of dynamics to solve problems of rolling without slipping*	*2.7.1. (*) Describe the motion of a rigid body as a combination of translation of the centre of mass and rotation about the centre of*

Elements of Competency	Specific Performance Criteria	Intermediate Learning Objectives
		mass. *2.7.2. (*) Solve problems concerning the motion of cylinders and spheres rolling without slipping.*
3. To carry out calculations of work, power and energy in simple situations	3.1. Precise use of the concepts basic to the understanding of work, power and energy	3.1.1. Define work done by a force, kinetic energy of a particle, kinetic energy of a rigid body in rotation and/or translation, average power and instantaneous power.
	3.2. Rigorous application of these concepts to the solution of problems	3.2.1 a) Calculate the work done by a constant force. b) Calculate the work done by a variable force using graphical methods. In particular calculate the work done by an ideal spring c) State Hooke's Law. d) Calculate the work done by a constant torque. 3.2.2. Calculate the kinetic energy of a particle or a rotating rigid body. 3.2.3. State the Work-Kinetic Energy Theorem and apply it to simple situations involving translation or rotation. 3.2.4. Calculate average and instantaneous power.
4. To apply the conservation principles of mechanics	4.1. Precise use of the concepts basic to the understanding of the principle of energy conservation	4.1.1. Define conservative and non-conservative forces, potential energy, and stable, unstable and neutral equilibrium. 4.1.2. Use the definition to determine whether a particular force is conservative or non-conservative.
	4.2. Rigorous application of the principle of conservation of energy to solve problems	4.2.1. Calculate the change in potential energy in a given situation. 4.2.2. Define a potential energy function for a given conservative force, in particular for a constant gravitational force and for a Hooke's Law spring. 4.2.3. State the Principle of Conservation of Mechanical Energy and recognize the conditions under which it may be used. 4.2.4. Modify the conservation of energy principle to include work done by non-conservative forces, especially friction and recognize the conditions under which it may be used. 4.2.5. Given a potential energy function, use the derivative to find the force at any position and to identify equilibrium positions and specify their type.
	4.3. Precise use of the concepts basic to the understanding of the principle of conservation of linear momentum	4.3.1. Define linear momentum of a particle and of a system of particles, impulse of a force, elastic, inelastic and completely inelastic collision, centre of mass of a body or a system of particles.
	4.4. Rigorous application of the principle of conservation of linear momentum to solve problems	4.4.1. State the principle of Conservation of Linear Momentum, and recognize the conditions under which it may be used. 4.4.2. Calculate the linear momentum of a particle or a system of particles. 4.4.3. State the relation between impulse and momentum and apply it correctly.

Elements of Competency	Specific Performance Criteria	Intermediate Learning Objectives
		4.4.4. Analyze the motion of the centre of mass of a system of particles.
	4.5. Precise use of the concepts basic to the understanding of the principle of conservation of angular momentum	4.5.1. Define angular momentum of a particle, angular momentum of a rigid body.
	4.6. Rigorous application of the principle of conservation of angular momentum to solve problems	4.6.1. State the principle of Conservation of Angular Momentum, and recognize the conditions under which it may be used. 4.6.2. Calculate the angular momentum of a body or of a system around a fixed axis.
	4.7. Integrate previous physics knowledge - e.g. projectile motion - circular motion with knowledge of the three conservation principles- to solve multi-step problems	
	4.8. Logical and coherent explanation of everyday phenomena in terms of the conservation principles and other laws or principles from the course as necessary	
5. To verify experimentally some of the laws and principles of mechanics	5.1. Careful performance of the laboratory procedures provided	5.1.1. Work cooperatively in a small group to obtain data. 5.1.2. Employ safe procedures and show concern for one's own safety and the safety of others in the lab. 5.1.3. Exercise care in carrying out measurements to obtain the best results possible.
	5.2. Logical analysis of and appropriate mathematical treatment of data	5.2.1. Choose and apply appropriate mathematical, graphical and logical tools.
	5.3. Drawing of coherent and justifiable conclusions	5.3.1. Understand and apply the principles involved in each experiment. 5.3.2. State clearly the conclusions to be drawn from your analysis and justify them.
	5.4. Proper adherence to course norms for submitting laboratory reports	

Methodology

Mechanics is generally presented in a series of lectures, labs and demonstrations. Emphasis is placed on developing a basic grasp of the main principles introduced in the course and a certain facility in the setting up and solving of problems, as this course is the foundation for many other courses in the science program at college and at university. Care is taken to make links to other courses in the program. Calculus is used as it becomes available to the students during the term. Applications to chemistry, such as the connection between momentum and the gas laws, are presented. Examples are taken from familiar fields such as sports and technology.