Physics 111 Course Description

This course aims to introduce freshmen students to the concepts and methods of experimental physics. The chief goal is to provide students with the necessary skills that they can apply for conducting experiments successfully. The skills acquired can also be useful in other labs which may not be necessarily for a physics major. The students essentially learn how to analyze and interpret their data efficiently and accurately, a very important component in experimental investigations. Working in groups, they are encouraged to exchange ideas between them as they gain a feeling for team work. In what follows, the experiments are briefly introduced. For more information, the reader is referred to the Phys 111 Lab manual.

1) Significant Figures and Errors

In this introductory experiment, the students are exposed to methods of mastering the experimental data and the representation of numbers most effectively. Next to this, the difference between systematic and statistical errors is outlined. The students are introduced to the meaning of standard deviation as well as to the Gaussian distribution of numbers.

2) Measurements

Particularly, the propagation of systematic errors of measured physical quantities into equations utilizing the latter quantities is explained. By allowing students to measure the lengths of certain geometrical shapes, such as a hollow cylinder, solid sphere, etc., they are instructed to methods of computing the volume or surface area of the latter objects along with their systematic errors. That way, they obtain initial necessary skills to present their results in standard scientific form.

3) Vectors

In this experiment, the conditions for achieving static mechanical equilibrium are explored. The students learn to adjust the magnitudes and directions of a set of forces acting on the center of a particle, here a metal ring, in order to stabilize it in its position. During the experimentation, the students gain the necessary skills to deal with and understand vector forces. The acquire a practical understanding of the meaning of equilibrium.

The instrument is a force table which has four pulleys attached to the circumference of a horizontal circular disk, serving as the work bench. On this work bench there lies a protractor whose center coincides with the center of the horizontal disk. Three or four weights are hung vertically by strings, each string passing over one of the pulleys, and the other ends of the strings are connected together by a ring, whose center at equilibrium should be positioned above the center of the protractor. The students initially vary the angles and weights until the four pulleys are in equilibrium. Then they graphically and analytically verify the laws of mechanical equilibrium.

4) Newton’s Laws

This experiment allows students to verify Newton’s second law. The experiment is conducted on an air track, which contains two photo gates used to measure the time it takes an object to slide between them on the air track. The velocity of an object is determined via a flag of certain length attached to the moving object. The photo gate counts the time it takes the flag to move through it. Air is pumped through the air track in order to minimize frictio
forces. One object is placed on the air track, connected to another one by a string, which passes over a pulley and hangs vertically at the end of the air track providing a pulling force. The students measure the force accelerating the object on the air track and its acceleration in order to determine the direct relationship between force and acceleration. Then, by fixing the accelerating force, the relationship between acceleration and inverse mass is explored.

5) Friction

Here, the concept of friction along with its two types, static and kinetic, are studied. Particularly, the relationship between frictional force and normal force is explored. The students are instructed to determine the coefficients of kinetic and static friction and learn how to distinguish between them. Next to this, they learn that frictional forces are largely governed by the type of rough surface and the magnitude of the normal force resulting from weight of an object acting on the surface.

6) Pendulum

In this experiment, the students are introduced to the concept of oscillatory motion using a pendulum. They learn how to determine the relationship between the oscillation period of the pendulum and its length. The students are requested to determine the gravitational acceleration and whether the mass of the oscillating bob has any influence on the pendulum’s motion. The chief goal is to determine the gravitational acceleration and to demonstrate that the gravitational acceleration is independent of the mass of the “falling” object, in this case the mass of the bob.

7) Hooke’s Law

Here, the students verify Hooke’s law and are instructed to determine the spring constant. They consequently get an understanding and feeling for the relationship between spring elongation (or compression) and the stretching (or compressing) force applied to the spring. Essentially, the frequency of oscillation of a spring is shown to be dependent on the oscillating mass attached to the spring, but that the amplitude of oscillation has no effect on the period of oscillation. The experiment is conducted within the regime of elasticity of the spring.

8) Gravitational Potential Energy

The students in this experiment are introduced to the concept of conservation of energy. They are given the chance to practically demonstrate how gravitational potential energy is converted to kinetic energy when a massive object descends in the gravitational field. The same experimental setup is used as for the Newton’s Laws experiment, and object sliding on an air track is connected to and pulled by another hanging object, via a string passing over a pulley at the end of the air track.

9) Uniform Circular Motion

This experiment exposes the students to the concept of circular motion. It introduces the concept of centripetal acceleration and the corresponding centripetal force. The students learn how to compute the centripetal acceleration from a simple setup. The instrument is a small mass of cork attached to a string on one end and another heavier object at the other end. The string passes through a plastic tube. By holding the tube vertically, the student rotates the piece of cork via the tube at a certain radius, the motion of which is stabilized by the large mass hanging at the lower end of the tube. The students study this motion from various angles. For example, they explore the relationship between the radius of the circular path and the frequency of rotation. Next to this, they learn that the centripetal acceleration in this experiment is determined by the mass of the cork and the larger hanging mass, although this is largely related to the experimental tool used.

10) Collisions
The goal of this experiment is to verify the laws of conservation of momentum. The students use to colliding metallic spheres of the same mass and radius in order to study elastic collisions. For this purpose, one sphere slides down a small track, placed on the edge of a table, and then collides with another stationary sphere positioned at the bottom end of the track. After collision, the two spheres fall and glide through the air until they hit a sheet of carbon paper placed at the floor in front of the table. Having determined a reference point on the carbon sheet of paper, which lies immediately under the center of the initially stationary metal sphere, one can draw the momentum vectors before and after collision of the two spheres. It is demonstrated that in an elastic collision, the sum of kinetic energies of the colliding objects before and after collision is conserved. The students get to verify the laws of conservation of momentum graphically.