Experiment No. 2:

Verification of Newton's Second Law of Motion by Atwood Machine.

2.1 Objective:

The main objective of this lab is to establish the relationship between force and acceleration, thus verify Newton's second law of motion.

2.2 Prelab:

Student should read the lab manual and have clear idea about the objective, time frame and outcomes of the lab.

2.3 Outcomes:

After completing this experiment student should be able to answer the following questions:

- What is the relationship between force and acceleration for an object according to Newton's second law of motion?
- What is the basic concept of net force?
- How an Atwood machine can be constructed? How different forces and acceleration work for the Atwood machine.
- Why the experimental accelerations vary from the theoretical accelerations?
- What is the meaning of a linear relationship and how it looks in a graph?

2.4 Timing and Length of Investigation (Total 3 Hours):

- **Lab Preparation (15 minutes):**
    - Students will sit for the lab class with preparations and class attendance will be taken.
- **Lecture on Theory (30 minutes):**
    - Teacher will clarify the objective and theory of the experiment.
- **Lecture on Procedure (15 minutes):**
    - Students will learn about the procedure of the experiment through a video lecture.
- **Experimental Work (90 to 100 minutes):**
    - A sample data will be provided to students and teacher will clarify every part of it.
    - Students will do all calculations and complete the result part.
- **Post Lab Discussion (15 to 20 minutes):**
    - Teacher will summarize the total lab work and have a discussion with the students related with the questions given in the outcomes part.
- **Report Submission:**
    - After completing the lab reports students will upload their lab reports as groups in the assignment section of MS Teams.

2.5 Theory:

Newton's second of motion tells that force causes acceleration and the relationship between net force acting on an object, F_{net} and its acceleration, a is: $F_{net} = ma$, where m is the mass of that object.

In Atwood machine, two masses m and M are suspended by a piece of inelastic light string that passes over a pulley in a vertical plane as the fig. 2.1 shows. The two masses are connected with a string, because of this, they must have same tension, T and acceleration, a.

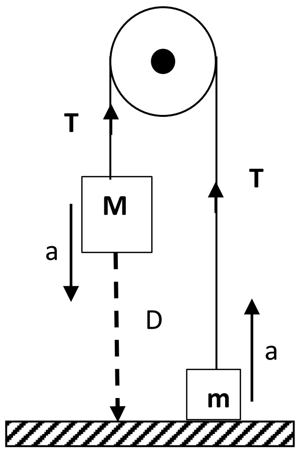

Figure 2.1: Arrangement of an Atwood machine. Here M > m.

Considering the upward direction as positive, neglecting friction and mass of the pulley and applying Newton's second law of motion we get

for M: $F_{net} = T - Mg = - Ma$,

for m: $F_{net} = T - mg = ma$

Solving these two equations, we get the theoretical acceleration as

$$a_{th} = \frac{g}{(M+m)}\,(M-m)$$

As acceleration due to gravity g is constant in a particular place and taking total mass (M+m) constant for the Atwood machine, according to Newton's second law we get

$$a_{th} \propto (M-m)$$

According to fig. 2.1 the mass M falls a distance D in time t from rest. Applying the knowledge of equations of motion ($D = ut + 1/2\, at^2$), we can calculate the experimental acceleration by

$$a_{ex} = \frac{2D}{t^2}$$

For different mass combination, (M-m) we will get different experimental accelerations, $a_{ex.}$ If we find a linear relationship between a_{ex} and (M-m) for the Atwood machine, we can say that Newton's second law is verified.

2.6 Apparatus:

Pulley, two hangers, different masses, string, stand and clamp, meter scale and stop watch.

2.7 Procedure:

- Hold the lighter mass on the floor attached to one end of a string. The heavier one attached to the other end of the string is up in the air at a height D from the floor. Measure D with a meter scale.
- Now release the lighter mass and measure the time the heavier mass takes to fall onto the floor. Run the experiment for 7 different mass-differences, (M - m). For each run, obtain the value of the acceleration in (m/s^2) experimentally as well as theoretically. Make sure to keep total mass (M + m) always constant.
- Using Excel plot acceleration (a_{th} and a_{ex}) versus mass difference (M - m) graph.

2.8 Experimental Data:

Table 2.1: Acceleration for different mass combination.

M (gm)	m (gm)	Height D (cm)	Time t (s)	Mean Time t (s)	$a_{exp} = \frac{2D}{t^2}$ (cm.s^{-2})	$a_{th} = \frac{(M-m)}{(M+m)}g$ (cm.s^{-2})	(M – m) (gm)
500	200						
475	225						
450	250						
425	275						
400	300						
375	325						
350	350	___	0		0	0	0

2.9 Result:

From the 'acceleration vs mass difference' graph, the relationship between experimental acceleration and mass difference is_________________ for the Atwood machine same as the theory says. Thus, we can say that Newton's second law is _______________.

2.10 Resources:

For further understanding, students may go through the following resources:

- **Fundamental of Physics (10th Edition):** Newton's second law of motion (Chapter 5, page 98-109).
- **Video Links:**
  - Newton's second law: https://www.youtube.com/watch?v=xzA6IBWUEDE
  - Atwood Machine: https://www.youtube.com/watch?v=a0KVxh8iPP4