ÇANAKKALE ONSEKIZ MART UNIVERSITY

DEPARTMENT OF PHYSICS

GENERAL PHYSICS LABORATORY MANUAL AND WORKBOOK

EXPERIMENTS 3
NEWTON'S LAW'S OF MOTION:
APPLICATION WITH THE ATWOOD MACHINE

PURPOSE

The purpose of this experiment is to investigate the relationship between motion and its causes. In this experiment, Atwood's machine is arranged on an inclined air table to study Newton's second law of motion.

THEORY

To move an object that is initially at rest, we must apply a force on it. Force is a vector quantity and its SI unit is Newton (N).

The vector sum of several forces acting on an object is called their *resultant*. A resultant force is required to accelerate an object. Remember that acceleration is the rate of change of velocity. We know from experience that a resultant force must act on an object initially at rest to set it into motion and eventually the object speeds up. Similarly, a resultant force is required to slow down or stop an object that is already in motion. Certainly, we need to apply the resulting force on a moving object to change the direction of its motion. In all of these cases, the object accelerates (changes its velocity) under the action of the resultant force.

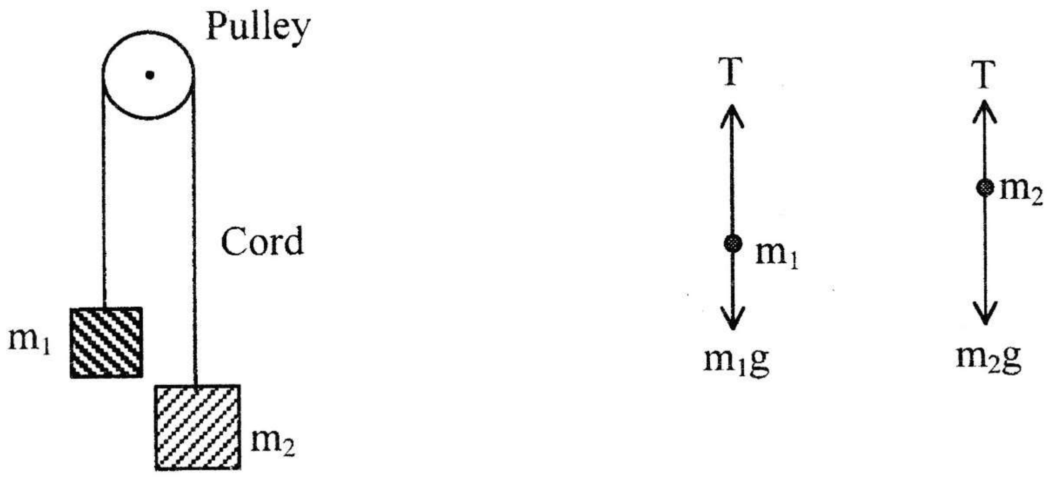
The acceleration of an object is directly proportional to the magnitude of the resultant force $\vec{F}$ exerted on it. When we doubled the force, the acceleration is also doubled. This means that the ratio of the magnitude of the force to the magnitude of the acceleration is constant. This ratio is called the mass m of the object. Therefore,

$$\mathbf{F} = m\mathbf{a} \tag{3.1}$$

This last relationship is called Newton's second law of motion. Note that both $\vec{F}$ and $\vec{a}$ are vectors and they are in the same direction. When several forces act on an object moving in the xy-plane, the components yields

$$\Sigma F_x = ma_x, \qquad \Sigma F_y = ma_y \tag{3.2}$$

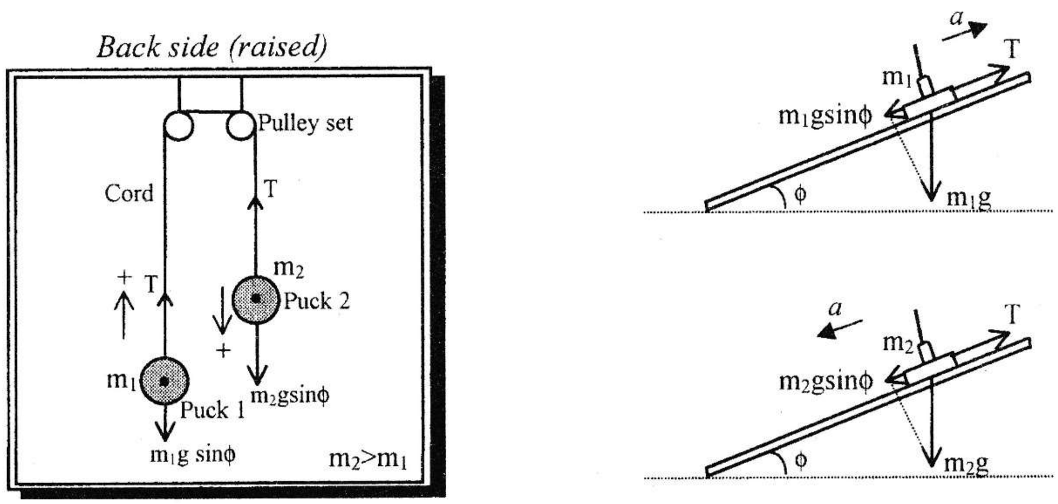
Elementary Atwood's Machine consists of two different masses m_1 and m_2 $(m_1 < m_2)$ connected by a cord passing through a pulley as shown in Figure 3.1a. When the system of two masses is released from rest, the heavier mass m_2 moves downward with constant acceleration and m_1 moves upward with the same acceleration. The forces acting on each of the masses are shown in Figure 3.1b. T is the tension in the cord. Since m_2 accelerates downwards, it experiences a resultant force in this direction, so $m_2g>T$. As for the mass m_1, $m_1g<T$.



(a) (b)

FIGURE 3.1 Atwood's machine. (a) The setup. (b) The forces acting on each puck.

The acceleration of the system is constant, and since both pucks start the motion from rest, the relation $y = \frac{1}{2}at^2$ holds. To make an elementary Atwood's machine on an inclined air table, the angle of inclination being ϕ, we set up the system shown in Figure 3.2a. Putting extra mass increases the mass of one of the pucks.



(a) (b)

FIGURE 3.2 The experimental setup of an Atwood's machine on an inclined air table.

The greater mass m_2 is shown in Figure 3.2b; the two forces along the inclined plane act on it. The tension T in the cord pulling upward and the component of its weight is $m_2g\sin\phi$. Since the mass accelerates downward, the tension T is smaller than $mg\sin\phi$, and hence the resultant force acting on mass m_2 is

$$m_2g\sin\phi - T = m_2a \quad (3.3)$$

$$T - m_1g\sin\phi = m_1a \quad (3.4)$$

Adding the two equations side by side and eliminating T, we find the acceleration

$$a = [(m_2 - m_1)g\sin\phi] / (m_1 + m_2) \quad (3.5)$$

Solving for the tension in the cord, we obtain

$$T = [2m_2m_1g\sin\phi\,] / (m_1 + m_2) \quad (3.6)$$

where *g* is the acceleration due to gravity ($=9.8 m/s^2$) and ϕ is the angle of inclination of the air table.

EQUIPMENT

An air table, pulleys, extra masses, wooden blocks, a cord, a ruler, millimetric graph paper.

PROCEDURE

This experiment is carried out on the inclined air table. First, level off the air table, then tilt it to an inclined position by raising its backside and placing a wooden block underneath it. Note that the angle of inclination is written on the wooden block.

1. Attach the pulley to the middle of the upper side of the air table and hang the cord with two masses at the ends of the pulleys as shown in Figure 3.2a. Note that the puck on the right has extra mass.
2. Put the puck on the left (with smaller mass) at the lowest position, and the other puck at the highest position. Activating only the pump (P), release the system from rest and observe the motion of the two pucks. Repeat this several times to get familiar with the motion.
3. Set the spark timer frequency. You may, however, change this to 10 Hz if your data was not convenient.
4. Repeat now by putting the two footswitches on top of each other and placing them simultaneously to produce the spark record for both pucks. Observe that the puck on the right goes down while the other goes up the incline.
5. Remove the datasheet and observe the dots produced on it. What kind of a trajectory do the pucks have? Do they have the same type of motion?
6. Starting from the first dot, number the dots produced by each puck on the datasheet as 0, 1, 2, 3, … etc., the first dot of each trajectory is to be taken as dot 0. Use this point as the reference point as zero position and zero time.
7. Taking the positive y-axis to be the direction of motion, measure the position and the time of five data points in each trajectory relative to dot 0, and fill in Table 3.1.
8. Use the data tabulated in Table 3.1 to plot the y versus t^2 graph for both of the masses m_1 and m_2. Draw the best and the worst lines, and find the acceleration from the slope of the graph.
9. Measure the masses m_1 and m_2. Using $\sin\phi$, m_1 and m_2 calculate the acceleration due to gravity.

ENGINEERING FACULTY
DEPARTMENT OF ENVIRONMENTAL ENGINEERING
Year: 2021-2022 Semester: Fall

Course Name: ENV-1021 – **General Physics Laboratory**

EXPERIMENT 3: NEWTON'S LAW'S OF MOTION:
APPLICATION WITH THE ATWOOD MACHINE EXPERIMENT REPORT

INSTRUCTOR'S NAME & TITLE:						SIGNATURE:		EXAM DATE:
STUDENT'S NAME/SURNAME: STUDENT ID #:						SIGNATURE:		EXAM DURATION:
Question								TOTAL POINT:
Point								
Prog. Outcomes	**PO1,2**							

REPORT OF
EXPERIMENTS 3
NEWTON'S LAW'S OF MOTION:
APPLICATION WITH THE ATWOOD MACHINE
Name-Surname:
Student No:
Group:
Laboratory and Examination Rules:

1- The most important thing in the laboratory is your safety. The dangers mostly result from a lack of knowledge of the equipment and procedures.
2- Personal safety rules must be obeyed with extreme discipline.
3- When you enter the laboratory never play with the equipment until it has been explained and the instructor has given permission.
4- Keep your experimental equipment and tabletop clean.
5- Report any accident to your instructor immediately.
6- Most of the equipment used in the laboratory is expensive and some of them are delicate. Even after you are familiar with the equipment, always have your experimental setup checked and approved by the instructor before putting it into operation.
7- If any of the equipment is broken or does not function properly, report it to the instructor.
8- Read and study the experiments before you come to the laboratory.
9- It is forbidden to share the questions and answers of this assignment on the internet or in another environment.
10- Students must answer the assignment by themselves. It is forbidden to do the assingment with others or to get help from others.
***11-* Write your name and surname and student number and sign your signature on the top right of each answer page.**

RESULTS AND DISCUSSION

1. Record the position and time measurements of five data points of the pucks m_1 and m_2 relative to dot 0 in Table 3.1.

TABLE 3.1.

Dot Number	$y \pm \Delta y$ (cm) (for m_1)	$y \pm \Delta y$ (cm) (for m_2)	$t \pm \Delta t$ (sec)	$t^2 \pm \Delta t^2$ (sec^2)
0				
1				
2				
3				
4				
5				

2. In the space below, show the details of the calculation of the errors Δt and Δt^2 in t and t^2 for any data point of the above table.
……………………………………………………………………………………………
……………………………………………………………………………………

3. Examine the dots on the datasheet and in the above table, what kind of motion does each puck have? Why?
……………………………………………………………………………………………
……………………………………………………………………………………

4. Can you say that both pucks have the same motion? Explain your answer.
……………………………………………………………………………………………
……………………………………………………………………………………

5. Draw y versus t^2 graph. Write down the slopes of the best and worst lines you found from the y versus t^2 graph with the correct number of significant figures.

M_b = ………………

M_w = ………………

$\boldsymbol{\Delta m = |m_b - m_w|} =$……………………….

6. Report below with the correct number of significant figures, the acceleration of the puck you found from the **y versus t^2** graph.
$a \pm \Delta a =$………………. cm/sec^2

7. Calculate the gravitational acceleration g, with the correct number of significant figures.
………………………………………………………………………………………
………………………………………………………………………………

8. Calculate the tension T in the cord. Report the result with the correct number of significant figures.
………………………………………………………………………………………
………………………………………………………………………………

9. Write down any comments related to the experiment, and/or elaborate on and discuss any points.
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