



T.C

SAKARYA UNIVERSITY

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PHYSICS LABORATORY-I

(MECHANICS)

SAKARYA 2022

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ISSUES TO BE CONSIDERED ABOUT LABORATORY STUDY

The activities to be done in the laboratory during the experimentation process are listed below.

- 1) The students in the experimental groups will take their measurements in order and make their calculations separately, in addition to helping each other.
- 2) Before coming to the laboratory, the experiment on the subject will be read, and if necessary, the relevant books will be studied. If the responsible lecturer understands that you have entered the experiment without being prepared, he may remove you from the laboratory. If there is no opportunity to make up for the experiment, you will be deemed not to have made that experiment.
- 3) Do not touch instruments and devices when entering the laboratory. Only use the tools that have been introduced to you, after waiting for the officer to arrive and getting his or her permission and advice.
- 4) When you come to the laboratory, be sure to bring graph paper with you.
- 5) After setting up the experiment, have it checked and then start working.
- 6) Do not speak loudly while experimenting in the laboratory.
- 7) Do not disturb your other friends during your studies.
- 8) When coming to the laboratory, always turn off your mobile phones (do not turn them on during the experiment either).
- 9) Before the experiment, listen carefully to the explanations made by the officer and apply them as necessary.
- 10) Use tools carefully and with care. Do not forget that any damage to the tools will be covered by you financially.
- 11) After you have finished your experiment, leave your table absolutely clean and as you received it.
- 12) Obtain sufficient information before the experiment by reading the resources you have.
- 13) There is an 80% attendance requirement to the laboratory. Therefore, show the necessary sensitivity to the continuation.

PREPARATION OF THE EXPERIMENT REPORT:

After the experiment is done in the laboratory and the data is taken, the report of the experiment will be prepared and delivered to the lecturer of the course. The points to be considered while preparing the report are listed below.

- On the first page of the report you will prepare (in the middle), write the name of the experiment, the number of the experiment, your name, surname, number, which education you are in and your group. Do not write anything else on this page. The title will be centered and the preparation of the report will be as follows.
- Experiment name: Write the name of the experiment written on the experiment sheet.
- Purpose of the experiment: Write in your own words what you aimed for in your experiment.
- Theory of the experiment: Write the theory of your experiment using different source books.
- Conducting the experiment: First of all, write down how you set up the experiment scheme, the tools you used and how you took the measurements, and then make your calculations.
- If there is a graph that needs to be drawn, draw your graph precisely using millimetric paper.
- Result, differences calculation and interpretation: Interpret your experiment by calculating the differences about the size you calculated in this part of the experiment.
- Reports will be written by hand, computer printouts will not be accepted.

ERRORS AND CALCULATIONS

When an error occurs in an experiment, the numerical results of the measurements appear unexpectedly. The limits of some errors are easy to find. But sometimes they are insignificant. Since the purpose of this laboratory is not to obtain definitive results, detailed statistical results are not expected. Despite everything, experimentation is a good and healthy method to understand the reliability of the result reached. For this purpose, a brief introduction is made to evaluate the most common errors. Errors are divided into two groups as systematic errors and random errors. It is difficult to distinguish between errors when errors of a measured magnitude are a combination of errors of both types.

Systematic Errors:

Such errors are caused by the devices used in the experiment or by the observer. Device errors; consists of the system itself and the device used. Usually this error is a fixed error that affects measurements made in the same way. For example, a poorly adjusted air table can cause such an error.

Errors caused by the observer are called “personal errors”. Misreading the scale, carelessness and inability to use tools are examples of such errors. Systematic errors can be minimized by reviewing the results and repositioning the test instruments appropriately.

Incidental Errors:

Incidental errors arise from uncontrolled fluctuations in the system. Signs are unknown. It is impossible to make any corrections. However, before specifying the value of a quantity to be measured, the magnitude of the random error can be estimated.

If we make many measurements for a quantity, we can consider the average value as the best result. The distribution formed by the measurements gives us a measure of uncertainty or experimental error.

Let x_1, x_2, \dots, x_n be the results of measurements made for a quantity. In this case,

$$\bar{x} = (x_1 + x_2 + \dots + x_n) / n$$

gives the average of these measurements. The deviation of a single measurement from its mean values \bar{x} is expressed as

$$d_i = x_i - \bar{x} \quad (i = 1, 2, 3, \dots, n)$$

The “root mean square root” value of the deviation is called the standard deviation, and it is expressed as

$$\sigma = \sqrt{(d_1^2 + d_2^2 + \dots + d_n^2) / (n - 1)}$$

Standard error of the mean; it depends on the distribution of measurements and is a measure of whether the mean is within the margin of error. If n measurements were made for a quantity;

$$\alpha = \frac{\sigma}{\sqrt{n}}$$

expression can be written. Thus, it is shown as the average. For some experiments it may not be possible to make multiple measurements. In this case, it is necessary to estimate the largest possible error. For example, let's say we use a ruler to measure length. If the smallest scale on

the ruler is 1 mm, the largest possible error is about 0.5 mm. So, if you measured anything as x and it's the largest possible error Δx , The true value of x is somewhere between $x + \Delta x$ and $x - \Delta x$.

Error Calculation for Multivariable Functions:

If we can determine the error in measuring a quantity; for another variable dependent on this quantity, calculating the value of the resulting error would be an easy task. For example; If we measure x with the largest possible error Δx , then the largest error in a function r ($r = f(x)$) relative to x , we can easily calculate it using the equation

$$\Delta r = |f(x + \Delta x) - f(x)| \quad (1)$$

If the result is dependent on variables x, y and z with the largest possible errors such as $\Delta x, \Delta y$ and Δz , $r = f(x, y, z)$ and

$$\Delta r = |f(x + \Delta x, y, z) - f(x, y, z)| + |f(x, y + \Delta y, z) - f(x, y, z)| + |f(x, y, z + \Delta z) - f(x, y, z)| \quad (2)$$

Some error formulas for composite results are given below. Here it is assumed that the x and y measurements have Δx and Δy errors, respectively.

Collection:

If it is in the form of $r = x + y$, the largest possible error in r can be calculated with the help of the formula $\Delta r = \Delta x + \Delta y$. This result can be obtained using equations (1) and (2).

Extraction: If $r = x - y$ is of the form, the largest possible error in r can be calculated with the help of formula $\Delta r = \Delta x + \Delta y$. Because mistakes do not annihilate each other, they are added on top of each other.

Impact: If $r = xy$, it is possible $\Delta r = (\Delta x)y + x(\Delta y)$.

If both sides of the above formula are multiplied by $1/r$

$$\frac{\Delta r}{r} = \frac{(\Delta x)y}{xy} + \frac{x(\Delta y)}{xy}$$

$$\frac{\Delta r}{r} = \frac{\Delta x}{x} + \frac{\Delta y}{y}$$

equation is obtained. It should be noted here that the result should be expressed as $r + \Delta r$. It is wrong to express it as $r + \Delta r / r$.

Exponential: n 'nin herhangi bir sayı olması şartı ile $r = x^n$ ise r 'deki bağıl hata

Relative error in r if $r = x^n$, provided n is any number

$$\frac{\Delta r}{r} = n \frac{\Delta x}{x}$$

can be found using the formula.

Trigonometric functions: If $r = \sin x$, the greatest possible error in r is in the form

$$\Delta r = \sin(x + \Delta x) - \sin x.$$

If the above operations are simplified, they become quite simple. For example, equation (2) can be expressed as

$$\Delta r = \left| \frac{\Delta f}{\Delta x} \Delta x \right| + \left| \frac{\Delta f}{\Delta y} \Delta y \right| + \left| \frac{\Delta f}{\Delta z} \Delta z \right| \quad \text{in this way.}$$

In scientific studies, root mean square error is used instead of the greatest possible error. For this reason, scientific studies

$$\Delta r = \sqrt{\left(\frac{\Delta f}{\Delta x} \Delta x \right)^2 + \left(\frac{\Delta f}{\Delta y} \Delta y \right)^2 + \left(\frac{\Delta f}{\Delta z} \Delta z \right)^2} \quad \text{equality is used.}$$

ABOUT THE AIR DESK EXPERIMENT SETUP

The Air Table Experiment Arrangement mainly consists of the following elements:

- 1- A glass plate that provides a hard and flat surface on which the discs can move freely.
- 2- Three adjustable legs that allow the air table to be adjusted horizontally,
- 3- An air pump that provides the continuous air supply needed to create a thin air cushion under the discs.

- 4- An arc generator providing the timing function (“Sparktimer”).

The compressed air supplied by the air pump is sent to the discs by passing through latex hoses and is ejected through a series of small holes near the center at the bottom of the discs, creating a thin air cushion on which the discs can float freely.

The Arc Generator (you can also call it the “Arc Timer”) is connected to the electrode in the center of each disc by a cable and a thin chain enclosed in latex tubing that carries air to the discs. The high voltage generated periodically by the Arc Generator creates an arc between the electrode of the disc and the conductive carbon paper placed on the glass plate. Each of the periodically occurring arcs leaves a black spot on the surface of the "white" paper, which is placed on the conductive carbon paper while the experiments are being carried out, on the carbon paper contacting surface. Each black dot indicates the position of the disc at the time of the arc.

HORIZONTAL ADJUSTMENT OF THE AIR DESK

Adjusting the horizontality of the Air Table (“leveling”) is important. If it is desired to measure the acceleration of a mass under the influence of a certain force, the force acting on the mass must be accurately determined. If the table is inclined even at a small angle, the force of gravity will act and the movement of the disc will be caused by a different force acting on its mass. The level adjustment of the Air Table is done as follows:

1. Place a disc in the middle of the glass plate and start the air pump. If the table is not horizontal, the disc will move in the tilt direction.
- 2.a. Adjust the two legs at the front of the table to eliminate the sideways tilt. When you see that the disc is no longer moving sideways, the sideways tilt will be corrected.
- b. Adjust the back leg of the table to eliminate any forward or backward tilt. When the disc no longer moves forward or backward, this tilt will also be eliminated and the table will be brought to a horizontal position.

TURNING THE AIR DESK TO THE INCLINED PLANE

The Air Table can also be used to study movements in the inclined plane. In experiments where the glass table is used as an inclined plane, the back of the table is raised by placing

wooden blocks under the foot at the back of the air table. Wooden blocks prepared for this purpose are among the accessories of the air table.

When the Air Table is used as an inclined plane, the value of its angle with the horizontal is important. The value of this angle is found with the help of the following equation.

$$\sin \theta = \frac{h_2 - h_1}{L}$$

In this equation, h_1 is height of the front leg of the table, h_2 is height of the back of the table, L is the side length of the table (see Figure 1).

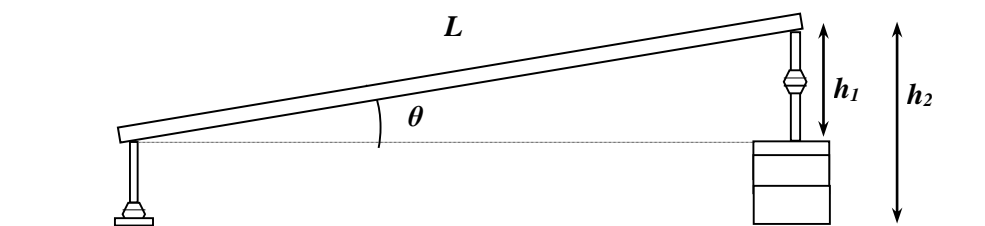


Figure 1. Inclined plane condition of the air table.

TIME ADJUSTMENT OF ARC GENERATOR

Timing the Arc Generator, or adjusting the arc generation rate, allows to determine the time dimension of the measurements in your experiments, as it means adjusting the times between points to be obtained in the experiments. The arc generation rate of the device is adjusted by the Frequency Adjustment Knob on the front panel as the number of arcs produced in one second (Hertz).

In an experiment involving velocity measurements, if we want the time between two successive points to be, for example, 50 ms, so that the arc generator produces an arc every 50 ms, in other words, if we want the period of the arcs to be 50 ms (0.050 seconds), then the device ($1:0.05 =$) We have to make it produce 20 arcs. In that case, we need to set the frequency setting of the device to produce 20 arcs per second, that is, to 20 Hz.

With a similar approach, we can adjust the frequency setting to 10 Hz so that the device works to produce 10 arcs in one second, so there is a 0.1 second (1:10 =) time between two arcs - or two consecutive points on our test paper. The following table summarizes this relationship between the frequency setting of the arc generator and the timing of the experimental points.

Frequency Setting, f , (Hz) = Arc Generation Rate (arc/s) (s^{-1})	Arc Period, $1/f$, (s) = Time Between Two Points (s)
10	0.1
20	0.05
40	0.025
50	0.02
100	0.01

In our experiments, we can easily determine the velocities of the disks by measuring the distances between the points that represent the positions of the disk centers - and the times between them are known. For example, in an experiment with the frequency setting of the arc generator at 10 Hz, if the distance between two points was measured 3 mm (0.3 cm), the velocity of the disk (0.3 cm / 0.01 s) would be calculated as 30 cm/s.

In order for the velocities you will use in the experiments to be suitable velocities, that will facilitate the evaluation of your data, it will be useful to do a few trials before you start taking measurements. You can do such a trial run by following the steps below, and you can decide on the disk velocities that will be suitable for your experiment and what the most appropriate arc frequency should be for it:

1. Place a sheet of conductive carbon paper on top of the glass tray of the air table and a sheet of recording paper on top of it. (Since you will use a single disc in this trial run, fold the corner of the recording paper in one corner of the table and put the disc on this folded piece. This disc will not be able to move due to the folded paper underneath, but since the electrode in the center of the disc will come into contact with the conductive carbon paper, the arc traces we desire will be obtained. will not be prevented.)
2. While holding the piece of thick plastic tube (“handle”) on the disc you will use in the experiment, start the air pump and then slowly push the disc forward. Evaluate the time it takes the disc to reach the opposite side of the platter. You can find the time between two points (two arcs) by dividing this time you have determined (as approximately 10 points will usually be needed in experiments where linear motion is examined) by 10,

and you can select the closest frequency setting corresponding to this time from the frequency settings on the arc timer.

OPERATING THE AIR DESK EXPERIMENT SETUP

1. Place conductive carbon paper on the glass tray of the Air Table, and on top of that the “white” paper on which the records will be processed.
2. Start the air pump and release the discs in the center of the table. Examine the movement of the discs; Check whether the table is horizontal by observing its right-left and back-and-forth movements. If necessary, adjust as described in the previous section to make it horizontal.
3. Turn on the arc generator and set the frequency to 10 Hz. (Remember that with this setting, the device will produce 10 arcs per second, so the time between two successive arcs will be 0.1 seconds.)
4. Prepare to depress the arc generator control pedal by holding the discs by their “handles” close to the front edge of the table and about 30 to 40 cm apart.
5. Release the discs by pushing them slowly so that they collide in the center of the table as much as possible and immediately depress the control pedal of the arc generator. After the discs collide, keep depressing the pedal until they are close to the edge of the table. (Take your foot off the pedal before the discs hit the sides and bounce back, and you'll avoid mixing up the arc traces of the discs hitting the sides of the table and returning back before and after the collision.)

Studies with a Single Disc

In some experiments only one disc will be used. Motion under a constant force in an inclined plane, motion in orbits, angular motion of a suspended mass can be studied by experiments with a single disk. Note that in these experiments with a single disc, the second disc must also rest on the carbon paper on the glass tray. Both discs must be on conductive carbon paper in order for the high voltage to return. Otherwise, the high voltage produced by the arc generator may cause the circuits of the device to burn out.

UNIT PREFIXES

Factor (Power)	SI Prefix	SI Symbol	Example
10^{12}	tera-	T	Terahertz (THz)
10^9	giga-	G	Gigahertz (GHz)
10^6	mega-	M	Megahertz (MHz)
10^3	kilo-	k	kilovolt (kV)
10^{-2}	centi-	c	centimeter(cm)
10^{-3}	milli-	m	milliampere (mA)
10^{-6}	micro-	μ	microvolt (μ V)
10^{-9}	nano-	n	nanosecond (ns)
10^{-12}	pico-	p	picofarad (pF)

UNITS

Physical Quantity	MKSA Unit	CGS Unit
Length	meter (m)	centimeter (cm)= 10^{-2} m
Mass	kilogram (kg)	gram (g) = 10^{-3} kg
Time	second (s)	second(s)
Force	Newton (N) = kg.m/s ²	dyne = 10^{-5} N
Energy	Joule (J) = N.m	erg = 10^{-7} J
Power	Watt (W) =J/s	erg/s = 10^{-7} W
Electric charge	Coulomb (C)	statcoulomb = $10^{-9}/2.998$ C
Electric current	Amper (A) = C/s	abamper = 10 A
Electric potential	Volt (V) = J/C	statvolt = 2.998×10^2 V
Electric field	Volt/meter or Newton/Coulomb	
Magnetic field (B)	Weber/meter ² (Wb/m ²)	gauss = 10^{-4} Wb/m ²
Resistance	Ohm (Ω) = volt/ampere	
Capacitance	Farad (F) = coulomb/volt	
Inductance	Henry (H) = volt.second/ampere	

WARNING:

Never operate the Arc Generator when both discs are not on carbon paper together.

EXPERIMENT -1

MOTION IN ONE DIMENSION: POSITION, VELOCITY AND ACCELERATION

Aim:

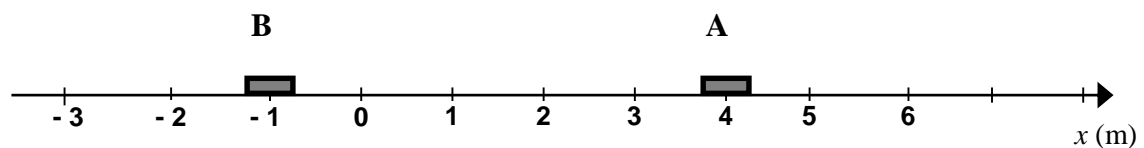
The purpose of this experiment is to examine the motion of an object moving on an inclined plane, and the relationships between its velocity and acceleration.

Tools and Equipment:

Air Table Experiment Setup, Data Paper, Ruler, millimeter paper

Basic knowledge:

To study the motion of an object moving along a straight line, an axis is usually defined in the direction of motion.



The arrowhead at one end of the axis indicates the positive direction of movement. To locate the object, we must first define any reference point as the origin (start point) “O”.

The position of the object is written as a signed number. The pointer indicates where the object is located (orientation) relative to the origin, and the number indicates its distance from the origin.

In the figure above, we see that the positions of A and B are $x_A = +4\text{ m}$ and $x_B = -1\text{ m}$, respectively.

The displacement of an object in a given time interval is defined as the difference between the object's final and initial positions: $x_A = x_S - x_i$

Velocity is defined as the rate at which displacement occurs and can be viewed as the slope of the position-time curve.

$$\text{Average Velocity; } \quad \bar{v} = \frac{\Delta x}{\Delta t} \quad \text{Instantaneous velocity; } \quad v = \frac{dx}{dt}$$

Acceleration is the rate at which velocity changes in a given time interval; is given as the ratio of the change in velocity to the time interval during which it occurs:

$$\text{Average Acceleration; } \quad \bar{a} = \frac{\Delta v}{\Delta t} \quad \text{Instantaneous Acceleration; } \quad a = \frac{dv}{dt}$$

So acceleration can be found by measuring the slope of the velocity-time curve.

Also, the equations describing uniformly varying linear motion are:

$$V = V_0 \pm at$$

$$x = V_0t \pm \frac{1}{2}at^2$$

$$V^2 = V_0^2 \pm 2ax$$

In equations; V_0 represents the initial velocity, a acceleration, V and x represent the velocity at the end of time t and the distance traveled during this time, respectively. If a stationary object starts motion at $t=0$ and continuously increases its velocity with constant acceleration, the motion of this object is called the first velocity less uniformly accelerating motion. In cases where $V_0=0$, the above equations are;

$$V = at$$

$$x = \frac{1}{2}at^2$$

$$V^2 = 2ax$$

Here is the second equation can be written in the form;

$$\frac{x}{t^2} = \frac{a}{2}$$

This equation shows that the slope of the graph of change of position over time squared ($x-t^2$) is equal to half of the acceleration of motion.

Experimental Procedure:

1. First, carefully adjust the feet to bring the air table to a horizontal position.
2. Place a block under the rear foot to tilt the air table as shown in Figure 1 below.
3. Measure the h and d distances shown in Figure 1.

$h = \dots\dots\dots\text{cm}$

$d = \dots\dots\dots\text{cm}$

4. Put the conductive carbon paper first, and then your data paper on the glass plate of the air table.

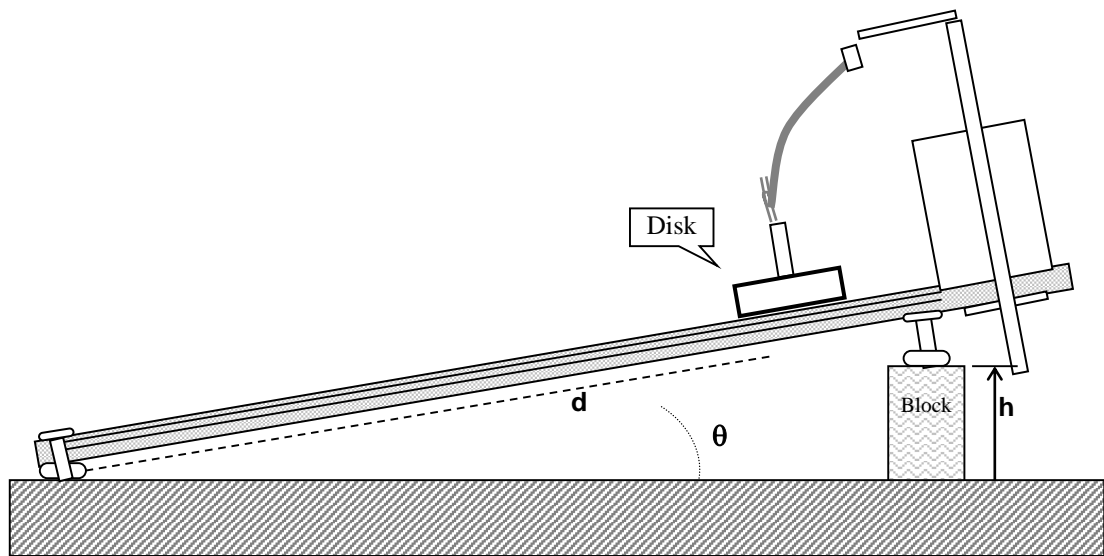


Figure 1 Air table in inclined plane

5. Put one of the discs in one corner of the glass plate and place a folded piece of paper under it so that it stays still.
6. Set the frequency of the arc generator to $f=10$ Hz.
7. Keep the pedals depressed until the disc comes down, activating the air pump and arc generator and measure the position of the disc as a function of time.
8. Lift your data sheet off the air table. Review your points and number them 0, 1, 2, Measure the distances of the first six points from point 0 and determine the time for each point. Write these distance and time data in Table 1 below.

Table 1. Position and time values of the movement

Point No.	X_n	t_n
0		
1		
2		
3		
4		
5		

Measurement and Calculations:

From the obtained data, the theoretical and experimental value of the acceleration of the motion will be found.

1. Calculate the theoretical acceleration. The acceleration of the disk on an inclined plane as in Figure 1, g being the acceleration of gravity, it is calculated with the formula,

$$a = g \sin \theta = \frac{gh}{d} \quad (g=980 \text{ cm/s}^2)$$

2. Using the data recorded in Table 1, fill in the blanks in Table 2.

Table 2

Point No	X_n	t_n	X_{n+1}	X_{n-1}	t_{n+1}	t_{n-1}	v_n
0				---		---?.....
1							
2							
3							
4							
5			---		---		---

3. Calculate the " V_n " values using the formula " $V_n = \frac{X_{n+1} - X_{n-1}}{t_{n+1} - t_{n-1}}$ ", and place them in the table.
4. Using the data recorded in Table 2, draw a position-time ($x-t$) graph on millimetric paper.
5. Using the data recorded in Table 2, draw a velocity-time ($V-t$) graph on millimetric paper.
6. Find the experimental acceleration of the mobile from the slope of the velocity-time graph. ($a_{\text{experimental}}$)
7. Calculate the % error for acceleration. (% error = $\frac{|\text{Experimental value} - \text{Theoretical value}|}{\text{Theoretical value}} \times 100$)

EXPERIMENT -2

MOTION IN TWO DIMENSIONS

Aim:

To examine the concepts of position, speed and acceleration in two-dimensional motion (oblique throw).

Tools and Equipment:

Air Table Experiment Setup, ruler, millimeter paper.

Basic knowledge:

Two numbers are required to indicate the position of an object in a plane. One method is to use the rectangular coordinate system.

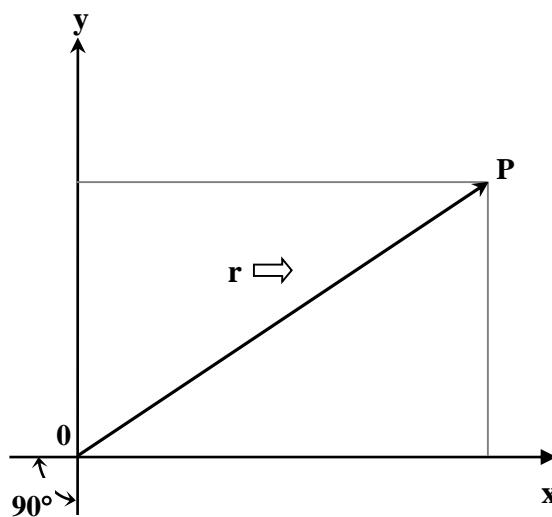


Figure 1

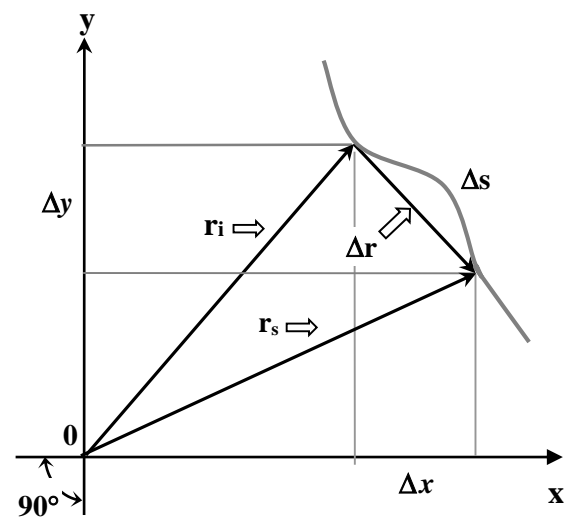


Figure 2

The position of point P in Figure 1 can be given relative to the two components of the position vector $\mathbf{r} = (x, y)$. The x-component is the projection of “ $\Delta \vec{r} = \vec{r}_s - \vec{r}_i$ ” on the x-axis. The sign of this component indicates whether the projection is in the same direction (+) or in the opposite direction (-) as the axis.

The curve ‘ $i - s$ ’ in Figure 2 represents the path followed by an object in the time interval Δt . \vec{r}_i is the position vector at the beginning and \vec{r}_s is the position vector at the end of this time interval. $\Delta \vec{r} = \vec{r}_s - \vec{r}_i$ is the displacement vector has $\Delta \mathbf{x} = \mathbf{x}_s - \mathbf{x}_i$ and $\Delta \mathbf{y} = \mathbf{y}_s - \mathbf{y}_i$ components. The distance traveled by the object is a scalar quantity equal to the length of the arc Δs .

Accordingly, the average and instantaneous velocity vectors of a motion;

$$\text{Average velocity} \equiv \bar{v}_{ort} = \left(\frac{\Delta x}{\Delta t}, \frac{\Delta y}{\Delta t} \right)$$

$$\text{Instantaneous velocity} \equiv \bar{v} = \left(\frac{dx}{dt}, \frac{dy}{dt} \right)$$

Speed, which is a scalar quantity, is expressed by the equations;

$$\text{Average speed} \equiv v_{avg} = \frac{\Delta s}{\Delta t}$$

$$\text{Instantaneous speed} \equiv v = \frac{ds}{dt}$$

This speed v is the magnitude or length of the \bar{v} velocity vector and is divided into velocity components.

$$v = (v_x^2 + v_y^2)^{1/2}$$

is associated with the expression. For the acceleration,

$$\text{average acceleration} \equiv \bar{a}_{ort} = \frac{\Delta \bar{v}}{\Delta t} = \left(\frac{\Delta v_x}{\Delta t}, \frac{\Delta v_y}{\Delta t} \right)$$

$$\text{Instantaneous acceleration} \equiv \bar{a} = \frac{dv}{dt} = \left(\frac{dv_x}{dt}, \frac{dv_y}{dt} \right)$$

Experimental Procedure:

1. First, carefully adjust the feet of the air table to make it horizontal.
2. Place a block under the rear foot to tilt the air table
3. Measure the h and d distances defined in Experiment 1.
 h=.....cm d=.....cm
4. Put the conductive carbon paper first, and then your data paper on the glass plate of the air table.
5. Put one of the discs in one corner of the glass plate and place a folded piece of paper under it so that it stays still.
6. Set the frequency of the arc generator to $f=10$ Hz.
7. Position the disc thrower near one of the corners on the underside of the air table, at an angle of $\alpha=60^\circ$ to the horizontal. Try a few shots by turning on the air pump. Repeat your sighting shots, adjusting the disc shooter until you get the best trajectory.

8. As soon as you throw the disc using the disc thrower, depress the control pedals of the arc generator and air pump and keep them pressed until the disc completes its trajectory and reaches the bottom edge.
9. Once you have marked the starting side of your paper, lift it off the glass tray and inspect the arc marks. Check if the dots are clear and in sufficient number. If the recording is not sufficient, repeat your experiment.

Measurement and Calculations:

1. Identify the vertical and horizontal axes on your recording paper.
2. Select the arc trace closest to the beginning of the parabolic curve describing the orbit of the disk and clearly visible as the starting point (zero point). Using a miter and referencing the vertical direction line, draw the vertical y -axis and horizontal x -axis through the starting point you selected.
3. Measure the distance from the x - and y -axes of each point on the trajectory using the miter. The distance of each point from the x -axis will be the y -coordinate of that point, and the distance from the y -axis will be the x -coordinate. Record these values in Table 1.

Table 1

Point No	X_n	Y_n	t_n	V_{xn}	V_{yn}	V_n
0					---	
1						
2						
3						
4						
5						

4. Calculate the y components of the velocity of the disc as it passes through each point using the equation $V_{yn} = \frac{Y_{n+1} - Y_{n-1}}{t_{n+1} - t_{n-1}}$ and record them in the table.
5. Using the data in Table 1, draw an $x - t$ graph on millimetric paper and verify that the motion made by the mover along the x axis is a constant velocity motion. Find the horizontal velocity value (V_{xn}) of the moving (same at each point) from the slope of the graph you have drawn and record it in the table.
6. Calculate the resultant speed (V_n) of the object as it passes through each point using the Pythagorean relation and record it in the table.
7. Determine the first velocity component V_{y0} , which cannot be found with the formula, using the equation $V_{y0} = V_{x0} \tan \alpha$.
8. Using the data in Table 1, draw the graph $V_y - t$ on millimetric paper and find the acceleration of the motion in the y direction from the slope of the graph.
9. Calculate the error between the experimental acceleration value you found and the theoretical acceleration value.

EXPERIMENT NO: 3 NEWTON'S LAWS OF MOTION

Purpose:

To determine the functional dependence between acceleration, force, and mass in one-dimensional motion.

Tools and Equipment:

Air Table Experiment Setup.

Basic knowledge:

In order to move an object that is initially at rest, a force must be applied to it. Force is a vector quantity and its SI unit is the Newton (N). The vector sum of several forces acting on an object is called the resultant of these forces. A resultant force is required to accelerate an object. Remember that acceleration is the rate of change in velocity. We know from experience that in order to move an initially stationary body, a resultant force must act on it. As a result, the object accelerates. Similarly, a resultant force is required to slow down or stop an object that is already in motion. Undoubtedly, in order to change the direction of motion of a moving object, a resultant force must be applied to it. In all these cases, the body 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 acting on it. When this force is doubled, the acceleration doubles as well. This means that the ratio of the magnitude of the force to the magnitude of the acceleration is a constant. This ratio is called the mass of the object (m).

So we can write $\vec{m} = \vec{F} / \vec{a}$ or $\vec{F} = m\vec{a}$. This relationship is known as Newton's Second Law of Motion. Notice that both \vec{a} and \vec{F} are vectors, and that these vectors point in the same direction. When a few forces act on an object moving in the xy -plane, using the components method, $\Sigma F_x = ma_x$, $\Sigma F_y = ma_y$, where ΣF_x is the x components of the forces, ΣF_y is the y components of the forces.

Atwood Machine

A simple Atwood Machine consists of two masses m_1 and m_2 ($m_2 > m_1$) connected by a rope passing through a pulley as shown in Figure 1.a below. When this two-mass system is released while at rest, the heavier mass m_2 moves downwards with constant acceleration, while the mass m_1 moves upwards with the same acceleration. The forces acting on each mass are shown in Figure 1.b. T is the tension in the rope. The downward acceleration of m_2 indicates that it is subjected to a resultant force in this direction and that $m_2g > T$. For the same reason, it turns out that for mass m_1 , $m_1g < T$.

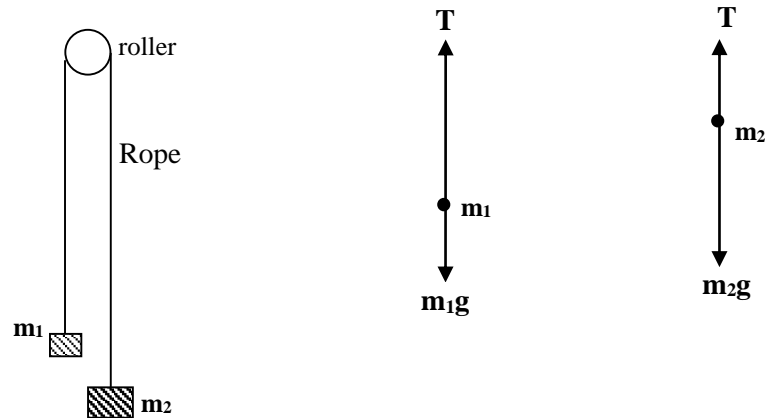
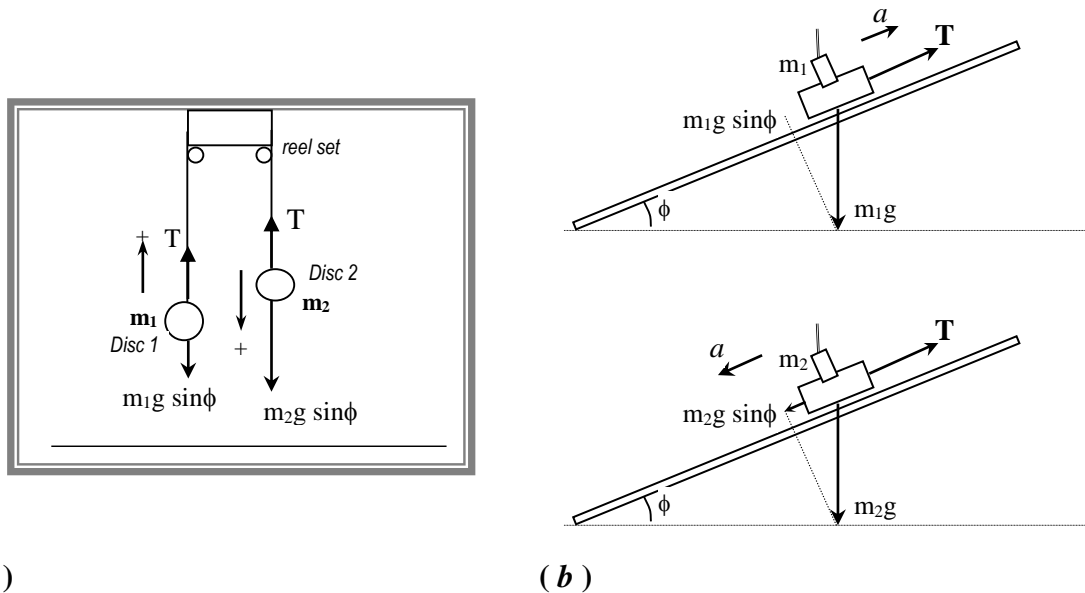


Figure 1: The Atwood Machine. (a) Setup. (b) Forces acting on the two masses.

Since the acceleration a of the system is constant, and both masses start to move while at rest, we can easily see that the relation $y = \frac{1}{2}at^2$ holds. In order to make a simple Atwood Machine on an air table with inclination angle ϕ , the system is set up as in Figure 2.a. Here, the two masses in the machine are replaced by the two discs of the air table. By placing additional masses on one of the discs, the mass of that disc is increased.



(a)

(b)

Figure 2: Experimental setup of an Atwood Machine on an Inclined Air Table.

As shown in Figure 2.b, two forces act on the larger mass m_2 on the inclined plane: the pulling force T in the rope, which pulls it upwards, and the component of the weight of the m_2 mass ($m_2g \sin \phi$). Since this mass is accelerated downwards, the pulling force T is less than $m_2g \sin \phi$; therefore, we can write the following equation for the resultant force acting on the mass m_2 :

$$m_2g \sin \phi - T = m_2a$$

With the same approximation, we can see that the resultant force acting on mass m_1 is

$$T - m_1 g \sin \phi = m_1 a$$

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

$$a = \frac{(m_2 - m_1)g \sin \phi}{m_1 + m_2}$$

Using this value of a, we get

$$T = \frac{2m_2 m_1 g \sin \phi}{m_1 + m_2}$$

for the pulling force in the rope.

Recall that in these equations, g is the acceleration of gravity ($=9.8 \text{ m/s}^2 = 10 \text{ m/s}^2$) and ϕ is the angle of inclination of the air table.

Experimental Procedure:

1. First, carefully adjust the feet of the air table to make it horizontal.
2. Place a block under the rear foot to tilt the air table.
3. Measure the distances h and d defined in Experiment 1.

$h = \dots\dots\dots \text{cm}$

$d = \dots\dots\dots \text{cm}$

4. Put the conductive carbon paper first, and then your data paper on the glass plate of the air table.
5. Set the frequency of the arc generator to $f=10 \text{ Hz}$.
6. Attach your pulley set to the center of the top edge of the glass tray. Pass the rope you have tied to the discs through the pulleys as shown in Figure 2.a. Note that there are additional masses on the right disc (m_2).
7. Put the left (smaller) disc (m_1) on the table in the lowest position and the other disc in the highest position. By simply operating the air pump, release the system and observe the movement of the two discs. To be able to recognize this movement, repeat this experiment several times, and on the last time, activate the arc generator while releasing the discs.
8. Remove your recording paper from the tray and review the recorded arc traces. Check what kind of path the discs follow and whether both discs make the same kind of movement.

Measurement and Calculations:

1. Starting from the first point, number the dots left by the two discs as 0, 1, 2, ..., n on the recording sheet. (The first point of each disc's path will be point 0. Use this point as reference point for zero position and zero time). Considering the positive y-axis as the direction of motion, measure the position and time of the five data points on both paths of the discs relative to the 0 point and record your measurements in Table 1 below.

Table 1

Nokta No	<i>m₁ kütlesi</i>			<i>m₂ kütlesi</i>		
	<i>Y_n(cm)</i>	<i>t_n(sn)</i>	<i>t_n²(sn²)</i>	<i>Y_n(cm)</i>	<i>t_n(sn)</i>	<i>t_n²(sn²)</i>
0						
1						
2						
3						
4						
5						

2. Using the data you recorded in Table 1, determine the accelerations of the discs (a_1 , a_2) from the slope of the graph by plotting $y - t^2$ graphs for both m_1 and m_2 masses separately on millimetric paper. The arithmetic mean of the a_1 , a_2 values you find will give the experimental acceleration value.
3. Calculate the experimental gravitational acceleration using the experimental acceleration value you found. Calculate the error between the value you found and the theoretical value of the gravitational acceleration.
4. Calculate the tensile force (using the experimental value of the gravitational acceleration) on the string.

EXPERIMENT NO: 4 COLLISIONS AND CONSERVATION OF LINEAR MOMENTUM

Purpose:

To study the conservation of linear momentum and energy in elastic and inelastic collision types in an isolated system and the motion of the center of mass of a two-disc system before and after the collision.

Tools and Equipment:

Air Table Experiment Setup.

Basic knowledge:

The linear momentum (\vec{P}) of a body is defined as the product of its mass and its velocity:

$$\vec{P} = m\vec{v} \quad (1)$$

Therefore, an object at rest will have zero linear momentum. Again, as can be seen from the above definition, an object of constant mass will have a constant momentum as long as its velocity does not change (hereinafter, linear momentum will be referred to as momentum for short). However, we know that the velocity of an object changes only when a net external force \vec{F}_d is applied to it. This means that the momentum of an object will only change when that object is subjected to a net external force. This fact can also be seen from Newton's second law. We know that for a constant mass object, Newton's second law is

$$\vec{F}_d = m\vec{a} = m \frac{d\vec{v}}{dt} \quad (2)$$

When mass (m) is constant, we can write it as

$$\vec{F}_d = \frac{d(m\vec{v})}{dt} = \frac{d\vec{P}}{dt} \quad (3)$$

The above equation means that if no net force acts on an object, the momentum of the object will be conserved, or the momentum of the object is constant against time.

In other words, if $\vec{F}_d = \mathbf{0}$,

$$\frac{d\vec{P}}{dt} = \mathbf{0} \quad (4)$$

or

$$\vec{P} = \text{constant} \quad (5)$$

is inferred.

Here, constant means that the momentum will not change with time, i.e. the object will always have the same momentum. This result above can be generalized to a N-particle system consisting of fixed masses m_1, m_2, \dots, m_N .

The total momentum of this system of particles at any instant is defined as

$$\vec{P}_t = \vec{P}_1 + \vec{P}_2 + \dots + \vec{P}_N \quad (6)$$

where $\vec{P}_1 = m_1\vec{v}_1, \vec{P}_2 = m_2\vec{v}_2, \dots, \vec{P}_N = m_N\vec{v}_N$

It is clear that the sum in the above equation is not an algebraic but a vectorial sum.

In this case, Equation (3), generalizes to

$$\vec{F}_d = \frac{d\vec{P}_t}{dt} = \frac{d}{dt}(\vec{P}_1 + \vec{P}_2 + \dots + \vec{P}_N) \quad (7)$$

Here \vec{F}_d means a net force outside of this system of particles (any force other than the forces that the particles of the system exert on each other (from interparticle forces)).

This force can be a force such as friction force, gravitational force,

Thus, if no such net external force acts on this system of particles, the total momentum of the system will be conserved:

$$\frac{d\vec{P}_t}{dt} = \frac{d}{dt}(\vec{P}_1 + \vec{P}_2 + \dots + \vec{P}_N) = 0 \quad (8)$$

or

$$\vec{P}_t = \vec{P}_1 + \vec{P}_2 + \dots + \vec{P}_N = \text{sabit} \quad (9)$$

Thus, a system of particles, or an isolated system, under no net external force, will have the same total momentum at any instant in time, regardless of any collision (interaction) between the particles. In this experiment, you will study the conservation of momentum of a system of two discs moving on a horizontal air table. Since the air table is horizontal and friction is almost completely eliminated, no net external force will act on the discs placed on it.

Therefore, we expect the total momentum of the discs to be conserved. In the experiment, the discs will collide and their total momentum before and after the collision will be measured and compared. The general shape of the points you need to achieve on your data sheet will be as shown in Figure 1 below:

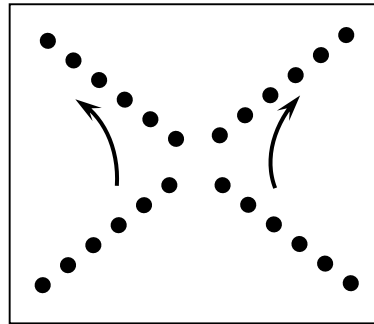


Figure 1. Data points in elastic collision of two discs on a horizontal air table.

The velocities of the two discs will be v_A and v_B before the collision and v_A' and v_B' after the collision. Since this is an isolated system, the total momentum will be conserved and at any instant; With

$$P_t = \text{sabit} \quad (10)$$

and hence $P_A = m_A v_A$, $P_B = m_B v_B, \dots$,

$$P_A + P_B = P_A' + P_B' \quad (11)$$

relations will hold. Since the masses of the discs are the same, the above relation can be reduced to the following equation:

$$\vec{v}_A + \vec{v}_B = \vec{v}_A' + \vec{v}_B' \quad (12)$$

The sum in Equation 12 is also vectorial, and how to find this sum geometrically is explained below:

Even in a completely "inelastic" (fully inelastic) collision, momentum will be conserved, since the system is still an isolated system. In such a collision, the two discs will stick together and form a single object of mass $2m$, moving with velocity v' . The points on the data sheet will be similar to Figure 2 below.

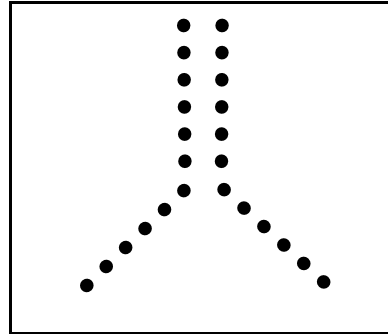


Figure 2. Data points in a purely inelastic collision of two discs on a horizontal air table.

The conservation of momentum during collision can be represented as follows:

$$\mathbf{P}_A + \mathbf{P}_B = \mathbf{P}' \quad (13)$$

or

$$v_A + v_B = 2v' \quad (14)$$

Another concept that we will recognize and examine in this experiment is the concept of Center of Mass (CM). You can predict that the CM of a homogeneous cube or sphere will be at the geometric center of these symmetrical bodies. You can also guess that the pin seen in Figure 3.c will be at the midpoint of the stick connecting the two balls of the CM. Likewise, the center of mass of two identical homogeneous spheres will be at the midpoint of a line joining their centers (Figure 3.d). If one of the spheres were heavier, the CM would slide towards the heavier sphere as seen in Figure 3.e. The amount of this shift is determined by how much mass M is heavier than mass m . It will be clear from the examples above that it is possible to predict the position of the CM for some symmetric mass distributions. For example, it is not difficult to predict that the CM of the two-disc system of this experiment will be located at the midpoint of the line joining their centers.

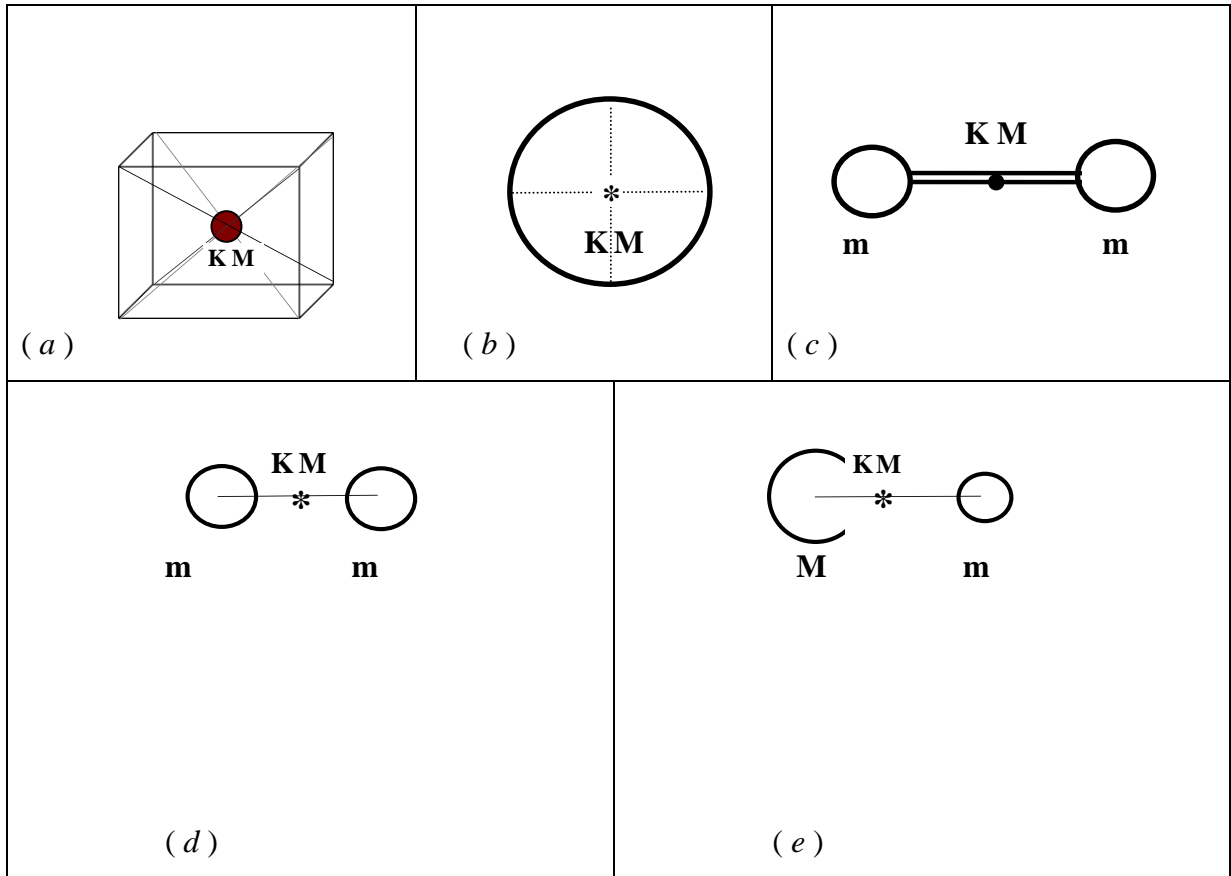


Figure 3. Centers of mass of some symmetric homogeneous bodies.

For more general mass distributions, the definition of CM cannot be as simple as in the examples above. The position vector \vec{R} of the center of mass of a system of particles consisting of masses m_1, m_2, \dots, m_N whose position vectors are $\vec{r}_1, \vec{r}_2, \dots, \vec{r}_N$ respectively, is defined as follows (see Figure 4):

$$\vec{R} = \frac{m_1\vec{r}_1 + m_2\vec{r}_2 + \dots + m_N\vec{r}_N}{m_1 + m_2 + \dots + m_N} \quad (15)$$

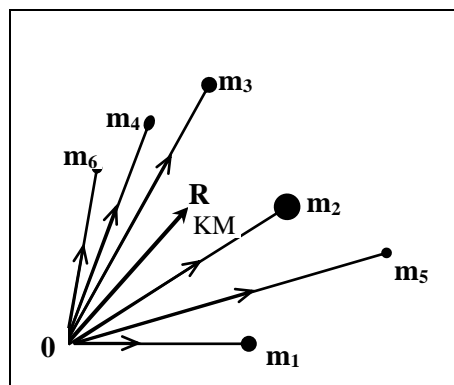


Figure 4. \vec{R} center of mass of a distribution of masses.

As the particles change their position over time, the position of the CM will also change. The rate at which the position vector \vec{R} of CM changes can be thought of as the rate of CM:

$$\vec{V}_{CM} = \frac{d\vec{R}}{dt} \quad (16)$$

In the case where the masses are constant, by taking the derivative of both sides of Equation 15 with respect to time,

$$\vec{V}_{CM} = \frac{m_1\vec{v}_1 + m_2\vec{v}_2 + \dots + m_N\vec{v}_N}{m_1 + m_2 + \dots + m_N} \quad (17)$$

is obtained.

Also for our two-disc system,

$$\vec{R} = \frac{m\vec{r}_A + m\vec{r}_B}{m + m} \quad (18)$$

and since the masses of the discs are the same,

$$\vec{R} = \frac{\vec{r}_A + \vec{r}_B}{2} \quad (19)$$

is found. Accordingly, the velocity of CM will be

$$\vec{V}_{CM} = \frac{\vec{v}_A + \vec{v}_B}{2} \quad (20)$$

We can draw important conclusions from the above equation. First, notice that the denominator of the right-hand side of the equation is a constant (compare this equation with Equation 12) due to conservation of momentum for the two-disc system on the horizontal air table. The fact that this denominator is constant indicates that the velocity of CM is constant for this case. In other words, the CM is moving with a constant velocity (“Constant velocity” means constant in both magnitude and direction). Thus, for an isolated system in which the total momentum is conserved, the center of mass of the system always moves along a straight line with constant velocity. Moreover, for the system we will examine in this experiment, at any instant, the velocity of the CM is half the vectorial sum of the velocities of the discs.

Therefore, we can write the equations

$$\vec{V}_{KM} = \frac{\vec{v}_A + \vec{v}_B}{2} = \vec{V}'_{KM} = \frac{\vec{v}'_A + \vec{v}'_B}{2} \quad (21)$$

for the velocities before and after the collision in our two-disc system.

Kinetic energy

In this experiment, we will also investigate the conservation of kinetic energy of the discs during collision. Recall the definition of the kinetic energy K of a body of mass m and linear velocity v :

$$K = \frac{1}{2} m v^2 \quad (24)$$

Therefore, the total kinetic energies of the two-disc system before and after an elastic collision are; it should be

$$K = \frac{1}{2} m v_A^2 + \frac{1}{2} m v_B^2 \quad K' = \frac{1}{2} m v_A'^2 + \frac{1}{2} m v_B'^2$$

(Since kinetic energy is a scalar quantity, the sums in these equations are algebraic sums.) In a purely inelastic collision, where two discs stick together during the collision and become a single body with mass $2m$ and velocity \bar{v}' , the total kinetic energy after the collision will be

$$K' = \frac{1}{2}(2m)v'^2 = mv'^2 \quad (27)$$

While in an elastic collision kinetic energy is nearly conserved ($K = K'$), in a purely inelastic collision, by definition, it is not. Loss of kinetic energy,

$$\text{Fractional loss} = \frac{K - K'}{K} \quad \text{Percent loss} = \% \frac{K - K'}{K} \times 100$$

we can define as.

Experimental Procedure:

1. First, carefully adjust the feet of the air table to make it horizontal.
2. Put the conductive carbon paper first, and then your data paper on the glass plate of the air table.
3. Set the frequency of the arc generator to $f=10$ Hz.
4. At first, with only the air pump running, try pushing the two discs diagonally against each other to collide somewhere in the middle of the table. Do not push discs too slowly or too fast. Repeat these sighting shots until you manage to get a good skirmish.
5. Start the arc generator as soon as you push and release the discs to collide in the middle of the air table, as you did in your experiments. Continue to run the arc generator until both discs have completed their movement.
6. After removing your recording paper from the tray and putting in a new paper, tighten the "Velcro" tapes around both discs. Take care that the lower edges of the tapes do not touch the data sheet.
7. Practice first by simply turning on the air pump, pushing and dropping the discs diagonally towards each other so that the two discs collide near the center of the table and stick together, continuing the motion. Take care that the discs do not rotate after the collision.
8. Start the arc generator as soon as you push and release the discs to collide in the middle of the air table, as you did in your experiments. Continue to run the arc generator until the discs have finished moving.
9. Stop the air pump; Lift your Recording paper off the tray by turning off the arc generator.

Measurement and Calculations:

The analysis part of the experiment will be done in two separate parts. In Part A, the data received when elastic collision occurs (the discs collide and separate) will be analyzed. In Part B, the data of the inelastic collision using "Velcro" tapes will be examined.

Part A:

1. Review the traces taken in the first part of the experiment, similar to those in the example in Figure 1. Mark the paths the discs took before the collision as **A** and **B**, and the ones after the collision as **A'** and **B'**.
2. Number the points the discs leave on each path as 0, 1, 2, . . . , n (You don't need to start from the first point).
3. Find the velocities of each disc before (v_A, v_B) and after (v_A', v_B') collision by measuring the length of two or three gaps on both disc paths and dividing by the respective time slots.
4. Comment on the conservation of momentum by finding the vector sums of $\vec{v}_A + \vec{v}_B$ and $\vec{v}_A' + \vec{v}_B'$. For example, to find the sum of $\vec{v}_A + \vec{v}_B$, extend paths A and B until they intersect; then, starting from the point of intersection, draw vectors in the directions \vec{v}_A and \vec{v}_B with lengths proportional to the magnitudes of these velocities (For example, to show a velocity of 10 cm/s, you can draw a 1 cm long vector). After drawing the velocity vectors, find the resultant velocity vectors by closing the vector parallelograms.
5. Identify points that occur simultaneously before and after the collision. Connect both points formed at the same time with a line. Determine the position of CM on the line connecting each pair of points. This way you will get a record of how the position of the CM changed during the collision. Using this record, find the CM's velocities before and after the collision.
6. Find and compare the kinetic energies of the two discs before and after the collision.

Part B:

1. Review the traces taken in the second part of the experiment that are similar to the example in Figure 2. Mark the paths that the discs followed before the collision as **A** and **B**, and the common path after the collision as **AB**.
2. Find the velocities of each disc before collision (v_A, v_B) and the joint (v_{AB}) velocity at the end using the method in Part A.
3. Comment on the conservation of momentum using the vector sum $\vec{v}_A + \vec{v}_B$ and the velocity \vec{v}_{AB} .
4. Identify the points that occur simultaneously before and after the collision. Connect both points formed at the same time with a line. Determine the position of KM on the line connecting each pair of points. This way you will get a record of how the position of the KM changed during the collision. Using this record, find the KM's velocities before and after the collision.
5. Find and compare the kinetic energies of the two discs before and after the collision.
6. Find the total kinetic energies of the discs before and after the collision, calculate the fractional loss and percent fractional loss.

EXPERIMENT NO -5 ROTATIONAL MOTION

Purpose:

To study the dynamics of a disc rotating around an axis passing through its center of mass, to find the angular velocity, angular acceleration and moment of inertia of this disc.

Tools and Equipment:

Air Table Experiment Setup.

Basic knowledge:

A rigid body is defined as a body whose shape is not distorted or for which the distances between all pairs of particles are constant. A rigid body rotating about a fixed axis has a moment of inertia depending on its mass distribution. The same body can have different moments of inertia for different axes of rotation. A force must be applied to rotate a rigid body about a fixed axis. The turning effect of this applied force is called torque or moment. The torque of the applied force depends on the magnitude of that force and the force arm. The vertical distance between the axis of rotation and the direction line of the applied force is called the force arm. If a net torque acts on a rigid body capable of rotating freely about a fixed axis, that object gains an angular acceleration.

$$\tau = I\alpha \quad (1)$$

Here I is the moment of inertia, τ is the torque, α is the angular acceleration. Let's attach a disc of mass M and radius R to the top of the inclined air table. This disc can rotate freely, free of friction, about an axis passing through the center of mass and perpendicular to the surface of the inclined air table. Let's wrap a rope around this disc and tie another disc of mass m to the free end of the rope. Thus, we set up a two-disc system. When we release this system, while the disc of mass m accelerates downwards, the disc of mass M begins to rotate.

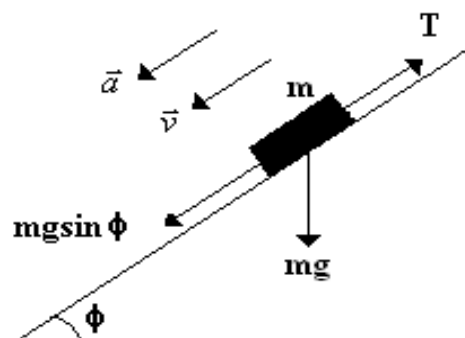


Figure 1

The forces acting on the disc of mass m are shown in Figure 1. Calculate

$$mg \sin \phi - T = ma \quad (2)$$

using Newton's second law of motion. Here ϕ is the slope of the air table and T is the tension in the rope. The torque acting on the mass M is

$$\tau = RT = I\alpha \quad (3)$$

α is the angular acceleration of the disc of mass M and depends on the linear acceleration of the disc of mass m by the relation

$$a = R\alpha \quad (4)$$

The moment of inertia of the disc of mass M is

$$I = \frac{MR^2}{2} \quad (5)$$

Angular acceleration and tension force using equations (2), (3), (4) and (5), respectively,

$$\alpha = \frac{2m(g \sin \phi - a)}{MR} \quad (6)$$

and

$$T = m(g \sin \phi - a) = \frac{MR\alpha}{2} \quad (7)$$

is obtained as.

If the disc of mass M starts to move with angular velocity w_0 at time $t_1 = 0$ and accelerates with a constant angular acceleration, then at time $t_2 = t$ its angular velocity will be

$$w = w_0 + \alpha t \quad (8)$$

Also, using equation (6), its angular velocity;

$$w = w_0 + \frac{2m(g \sin \phi - a)t}{MR} \quad (9)$$

we can also express it as.

If the initial angular velocity of the disc with mass M is zero ($w_0 = 0$); becomes

$$w = \alpha t = \frac{2m(g \sin \phi - a)t}{MR} \quad (10)$$

A disc of mass M has a kinetic energy due to its rotational motion. A disc of mass m has both kinetic and potential energy. The total kinetic energy of the system is written as:

$$K = \frac{1}{2}mv^2 + \frac{1}{2}Iw^2 \quad (11)$$

The relation between the linear velocity of the mass m and the angular velocity of the disc of mass M is;

$$v = R\omega \quad (12)$$

If the system is initially at rest, there is only potential energy in the system immediately. Let be the total energy of the system. If the initial position of the disc of mass m is accepted as the reference point for the potential energy, it will be the initial total energy of the system. The kinetic energy of both discs increases as mass m goes down and loses potential energy. Suppose mass m travels d on an inclined air table. The total energy at this point

$$-mgd \sin \phi + \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 = 0 \quad (13)$$

Experimental Procedure:

1. First, carefully adjust the feet of the air table to make it horizontal.
2. Place a block under the rear foot to tilt the air table.
3. Calculate the sine of the slope angle ($\sin\phi$) by measuring the distances h and d defined in Experiment 1.

$h = \dots\dots\dots \text{cm}$

$d = \dots\dots\dots \text{cm}$

$\sin\phi = \dots\dots\dots$

4. Put the conductive carbon paper first, and then your data paper on the glass plate of the air table.
5. Set the frequency of the arc generator to $f=10$ Hz.
6. Place the reel of mass M on the top of the inclined air table so that it can rotate freely around the center of mass and wind the rope around it. Tie one of the mass discs to the free end of this rope and set it to remain motionless in the top position on the inclined air table. Put the other disc in one corner of the glass plate and place a folded piece of paper under it so it stays still.
7. By operating the air pump and the arc generator at the same time, observe that the disc descends and the M -mass pulley rotates as well.

Measurement and Calculations:

1. Take out the test paper and examine the traces of the mass m . What is the type of motion of the mass m ?
2. Determine the position of the traces by taking the direction of the movement as the positive y direction. Then record the location of each track and the time it took for mass m to reach that location in Table 1.

Table 1

<i>Point No</i>	<i>y</i>	<i>t</i>	<i>t</i> ²
0			
1			
2			
3			
4			
5			

3. Using the data in the table, plot the location versus time squared graph. Calculate the linear acceleration of motion using the slope of this graph.

4. Measure the radius (R) of the disc. After finding the angle ϕ that the air table makes with the horizontal, calculate the angular acceleration (α) using equation (6). Calculate the angular acceleration again using equation (4) and compare the values you found.
5. Calculate the tension force in the rope from equation (7).
6. Calculate the moment of inertia of the disc of mass M in two ways using both equation (3) and equation (5). Then compare these two values.
7. Show that the total energy is conserved using equation (13).