4. Two Dimensional Motions

INTRODUCTION

To understand motions in two-dimension, the following motions are analyzed.

1. Linear motion in constant velocity.
2. Linear motion in constant acceleration.
3. Collision of two objects.

I. LINEAR MOTION IN CONSTANT VELOCITY

PURPOSE

1. To measure the velocity of an object moving in constant velocity
2. To obtain the x and y components of its velocity and compute the vector sum
3. To learn how to use the video analysis system

THEORY

The velocity υ of motion in constant velocity is

$$\upsilon = \frac{s}{t}. \tag{1}$$

Therefore, the velocity of object can be obtained from the displacement s and the time t. Hence, the velocity is a vector that can be divided by the υ_x component and the υ_y component, as shown in *Fig. 1*.

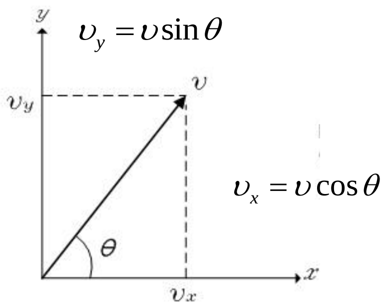

Fig. 1. x and y components of the velocity.

Thus, the velocity υ is,

$$\upsilon = \upsilon_x + \upsilon_y. \tag{2}$$

The amplitude of velocity can be obtained as follows:

$$\upsilon = \sqrt{\upsilon_x{}^2 + \upsilon_y{}^2}. \tag{3}$$

EQUIPMENT

1. Air table
2. Air blower
3. Motion recording camera and analysis program
4. Puck

Fig. 2. Air table.

Fig. 3. Air Blower.

PROCEDURE

1. Set the Air Table as shown in *Fig. 2*.

2. Connect the Air Blower shown in *Fig. 3* to the Air Table with the connecting hose and verify that the air is being supplied to the Air Table. Once this is confirmed, turn the switch off.

3. Run [PASCO Capstone], and double click [Movie] in the displays palette or drag & drop to the workbook page.

4. Click [Record Movie with Synced Data] in the workbook page, and select the connected camera.

5. Adjust the position of the camera to make the Air Table fill the screen.

6. Put a standard ruler on the Air Table and a puck on the Air Table.

7. Run the Air Blower to supply air to the Air Table. The air must be sufficient for the puck to move freely.

8. Click [Record] button and move the puck in diagonal direction, as shown in *Fig. 4*. Approximately 4~5 seconds are enough for recording

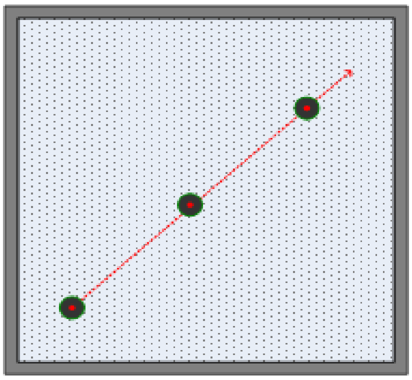

Fig. 4. Ideal motion of the puck in the linear motion experiment.

9. Click [Enter video analysis mode ] in the toolbar and enter the analysis mode. Select the starting frame to analyze using the Playback mode in the control palette.

10. Adjust the scale tool to match the scale of the ruler in the scene. When you right click the Calibration Tool or click [Properties > Calibration Tool], you can change the color, thickness and significant figures.

11. Set the position of the origin of the coordinates. It is convenient for the origin of the coordinates to be at the starting point. You can make the scale tool and coordinates invisible using the buttons ,  in the toolbar.

12. Tracking mode is activated by clicking anywhere in screen. From the second click, you can mark the position of the object. When you mark the position, "+" is marked, and the video goes to the next frame automatically.

13. After the tracking, double click [Graph] in the displays palette. Click [<Select Measurement>] at the x-axis, and click [Time (s)]. Click [<Select Measurement>] at y-axis, and click [Object # > x (m) or y (m)]. Click downward arrow right after [Apply selected curve fits to active data] in toolbar, and select appropriate fitting formula. You can also plot velocity, acceleration according to time.

14. You can measure distance or angle at [Distance Tool] or [Angle Tool] respectively in [Create Measurement Tool] in the toolbar in Movie panel.

II. LINEAR MOTION IN CONSTANT ACCELERATION

PURPOSE

To measure the acceleration of object moving on an inclined plane and obtain the gravitational acceleration.

THEORY

The acceleration of an object moving on an inclined plane is as follows:

$$s = \frac{1}{2}at^2. \tag{4}$$

Measure the drop time t to obtain the acceleration of the object.

$$a = \frac{2s}{t^2}. \tag{5}$$

The relationship between the acceleration of an object and the gravitational acceleration is as follows:

$$\begin{aligned} a &= g\sin\theta, \\ g &= \frac{a}{\sin\theta}. \end{aligned} \tag{6}$$

Obtain the acceleration of an object and use it to obtain the gravitational acceleration.

EQUIPMENT

1. Air table
2. Air blower
3. Motion recording camera and analysis program
4. Puck
5. Support Jack
6. Mass for puck

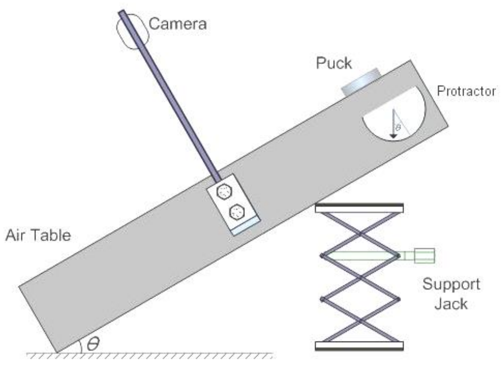

Fig. 5. Inclined air table with support jack.

PROCEDURE

1. Create an inclined Air Table using Support Jack as shown in *Fig. 1*. The incline angle can be 15~30 degrees.

2. Run [PASCO Capstone] and align the camera.

3. Place the puck in the initial position.

4. Supply air to the table and click [Record] button. Release the puck with initial x-direction velocity. Approximately 4~5 seconds are enough for recording

※ CAUTION ※

- Too much air can affect the experimental data by increasing the air friction.
- Lack of air can affect the experiment data by increasing the friction between the Air Table and the puck.

4. Enter video analysis mode, and track the puck after adjustment of scale bar and coordinate system.

5. After the tracking, double click [Graph] in the displays palette. Click [<Select Measurement>] at the x-axis, and click [Time (s)]. Click [<Select Measurement>] at y-axis, and click [Object # > x (m) or y (m)]. Click downward arrow right after [Apply selected curve fits to active data] in toolbar, and select appropriate fitting formula. You can also plot velocity, acceleration according to time.

6. Repeat the same experiment three times.

7. Change mass of the puck and repeat step (3~6).

8. Change the inclined angle and repeat step (3~6).

III. COLLISION OF TWO OBJECTS

PURPOSE

To understand a two-dimensional collision as well as the momentum and energy conservation.

THEORY

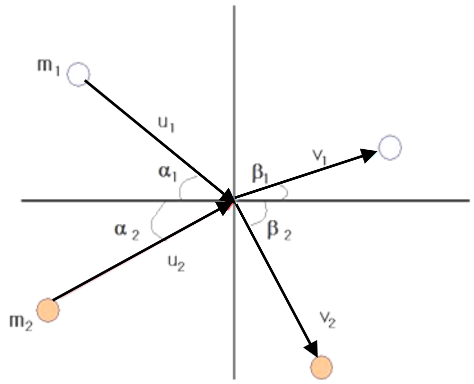

Fig. 6. Collision of two objects.

The momentum conservation is as follows:

$$m_1 u_1 \cos\alpha_1 + m_2 u_2 \cos\alpha_2 = m_1 \upsilon_1 \cos\beta_1 + m_2 \upsilon_2 \cos\beta_2, \tag{7}$$

$$-m_1 u_1 \sin\alpha_1 + m_2 u_2 \sin\alpha_2 = m_1 \upsilon_1 \sin\beta_1 - m_2 \upsilon_2 \sin\beta_2. \tag{8}$$

If it is an elastic collision, the kinetic energy is then conserved.

$$\frac{1}{2} m_1 u_1^{\,2} + \frac{1}{2} m_2 u_2^{\,2} = \frac{1}{2} m_1 \upsilon_1^{\,2} + \frac{1}{2} m_2 \upsilon_2^{\,2}. \tag{9}$$

If a puck collides with another puck with the same mass in rest, the formulas (7), (8), and (9) then become as follows, as $m_1 = m_2$ and $u_2 = 0$:

$$u_1 = \upsilon_1 \cos\beta_1 + \upsilon_2 \cos\beta_2, \tag{10}$$

(11)

$$0 = \upsilon_1 \sin \beta_1 + \upsilon_2 \sin \beta_2,$$

$$u_1^2 = \upsilon_1^2 + \upsilon_2^2. \tag{12}$$

The sum of the angles after the collision is

$\beta_1 + \beta_2 = \frac{\pi}{2}.$

EQUIPMENT

1. Air table
2. Air blower
3. Motion recording camera and analysis program
4. Puck
5. Support Jack
6. Mass for puck
7. Scale

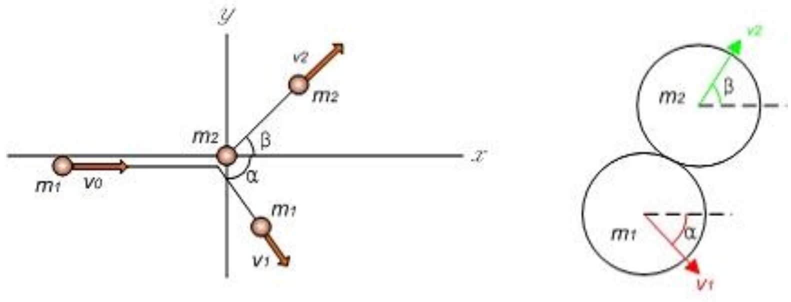

Fig. 6. Collision with a rest mass.

PROCEDURE

1. Run [PASCO Capstone] and align the camera.

2. Place the pucks with different color in the initial position.

3. Supply air to the table and click [Record] button. Move a puck in a certain direction and immediately move the other puck for collision to occur

※ CAUTION ※

- Too much air can affect the experimental data by increasing the air friction.
- Lack of air can affect the experiment data by increasing the friction between the Air Table and the puck.

4. Enter video analysis mode, and adjust scale bar and coordinate system.

5. To track more than 2 objects in single video, click [Create Tracked Object] in the toolbar. Click [Select Active Object] in the toolbar and activate first object. Select the

starting frame and track for first puck as before. Once you finished, return to the starting frame and click [Select Active Object] in the toolbar to switch to the second object. Repeat tracking for the second puck.

5. After the tracking, double click [Graph] in the displays palette. Click [<Select Measurement>] at the x-axis, and click [Time (s)]. Click [<Select Measurement>] at y-axis, and click [Object # > x (m) or y (m)]. To plot more than 2 data in single graph, click [Add new y-axis to active plot area] in the toolbar. Click [<Select Measurement>] at the second y-axis, and click [Object # > x (m) or y (m)]. You can also plot velocity, acceleration according to time.

6. Measure the masses of pucks using a scale.

7. Add a mass of unknown value to object 1 and repeat the experiment.

8. Calculate the mass of object 1 using the velocity before the collision and after the collision, the incident angles, the scattered angles, and the mass of object 2 obtained in step (12).

9. Measure the mass of object 1 and compare the result with result in step (14).