Experiment 4. Inclined Plane

Galileo's experiments that revealed important secrets of nature performed with modern technology

Objective: To study the motion of a glider along an inclined plane and to determine the acceleration due to gravity.

Apparatus: An air track, a glider with a flag, photogates, CHAMP interface and a personal computer.

In a photogate (Fig. 1), a beam of infrared light emitted by a light emitting diode (LED) is sent to a solid state infrared detector. Changes in the light level at the detector change the voltage levels in the control circuits which turn the timers in the computer on and off.

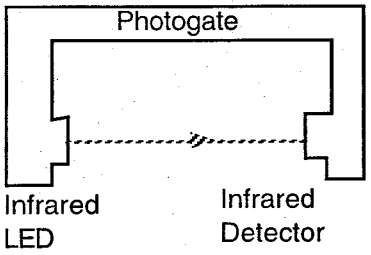

Fig. 1

In the double gate (B) mode, when an object such as a flag on the glider passes through gate 1 and through gate 2 (Fig. 5), time t_1 is the time during which gate 1 is blocked, time t_2 is the time taken by the object in going from gate 1 to gate 2 and time t_3 is the time during which gate 2 is blocked.

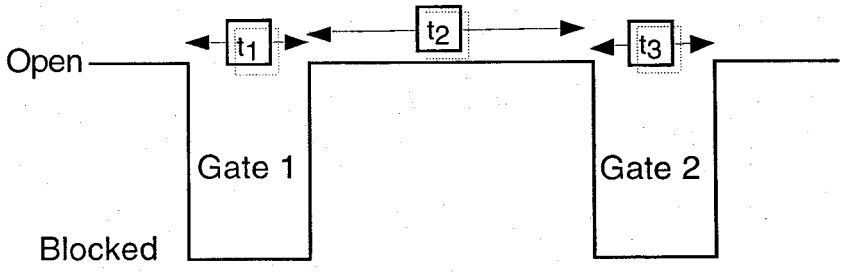

Fig. 2

Theory:

Consider a glider on a smooth inclined plane (shown in Fig. 3). The cart glides on a cushion of air and so friction is minimized. Thus the external forces acting on the block are its weight mg and the normal force F_N applied by the plane. The component of the weight perpendicular to the plane is mg cos θ, which balances the normal force F_N. Thus the resultant force on the glider is equal to the component of mg along the plane, that is mg sin θ. Finally, according to Newton's second law, the acceleration of

the glider along the plane is given by

$$a = \frac{mg \sin\theta}{m} = g \sin\theta. \qquad (1)$$

Thus by determining the acceleration 'a' and angle θ, the acceleration due to gravity g can be calculated.

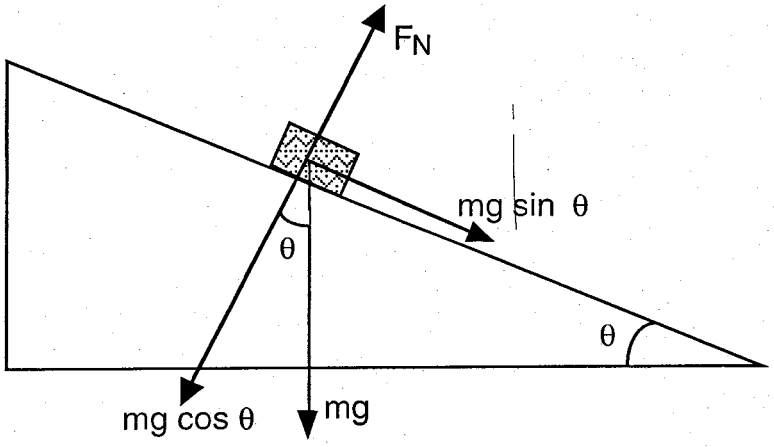

Fig. 3

Now let the velocity of the glider at gate 1 = v_1
and the velocity of the glider at gate 2 = v_2
Further let the separation between the gates = s
Then the third kinematic equation gives

$$v_2^2 = v_1^2 + 2\,a\,s. \qquad (2)$$

By measuring v_2, v_1 and s, one can calculate the acceleration 'a'.

Procedure:

1. Measure the height (h) and length (ℓ) of the inclined plane at two points.

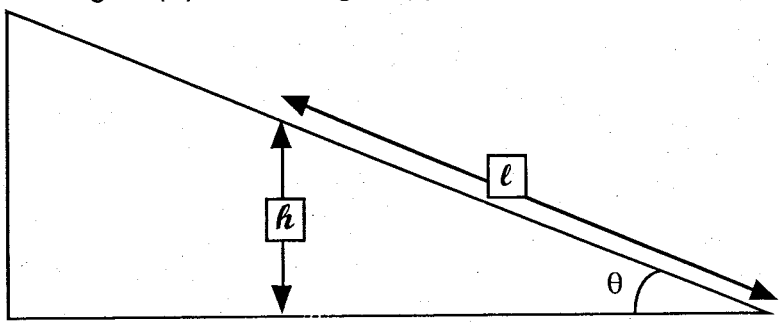

Fig. 4

2. Measure the length of the flag twice.
   Place the two photogates at suitable positions. Place gate 1 at a convenient position near the top of the inclined plane and gate 2 about 25 cm down the plane from gate 1.
3. Turn on the CHAMP and then the computer.

(Always make sure that CHAMP interface is connected and turned on before switching on the computer. Also the computer should be switched off before turning off the CHAMP.)

At the prompt

C:TPACK>

enter TP

You will see 'TIMEPACK' on the screen among other things.

Press any key and you will see

You will see 'HIT ENTER TO ACCEPT', etc. on the screen.

Press the enter key.

You will see 'PLEASE ENTER PASSWORD'.

Enter PASS as the password.

4. You will see the menu containing:

A: Single gate timer	H: Frequency Timer
B: Double gate timer	- - - - -
C: Time between gates	- - - - -
D: Pendulum timer	- - - - -
E: Motion timer	L: Data Analysis
F: Collision timer	M: Test photogates
- - - - -	N: Exit Timepack

Enter M

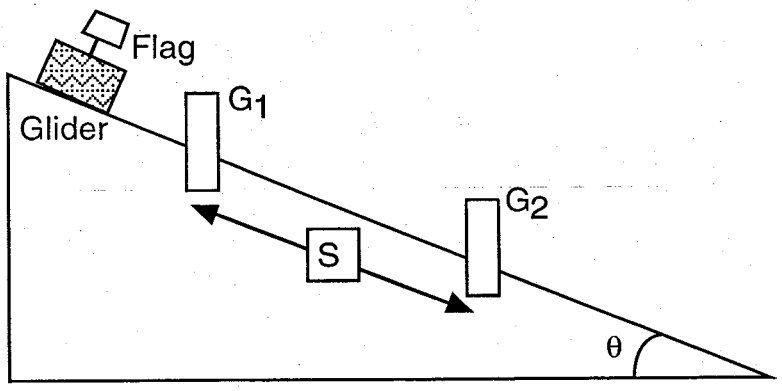

Fig. 5

Move the glider until photogate 1 changes from open to blocked. This gives the position of gate 1. Record the position of gate 1 in meters. Now move the glider until photogate 2 changes. This gives the position of gate 2. Record the position of gate 2 in meters.

The difference between the positions of the two gates gives s.

Press any key to return to the main menu.

5. To measure times, select "B: Double gate timer"
   Turn on the air flow.
   Release the glider five times. Make sure that the glider is released from the same point each time. Make sure that the glider does not bounce up along the plane up to the second gate.
   Now press any key to terminate data collection.
   A table containing
   Run # Time #1 Time #2 Time #3
   and their averages (AVG) and standard deviations (STD) will be displayed on the screen. Examine the data for consistency.
6. To analyze the data, press any key to go to data analysis menu.
   You will see the menu containing:

A: Display Data Table	E: Edit Timing Data
B: Print Data Table	- - - - -
C: Analyze Timing Data	H: Repeat Experiment
D: Graph Timing Data	I: Return To Main Menu

   Enter C to select "C: Analyze Timing Data"
   Enter length of flag in m (meter).
7. A table containing velocity #1 velocity #2 acceleration
   and their averages will be displayed on the screen.
   Examine the data for consistency.
   If all five trials have consistent values, you need not edit the data.
   If all five trials have inconsistent values, you should repeat steps 5, 6 and 7.
   If one or two trials contain inconsistent values, edit the data.
8. To edit, press any key to return to the previous menu (Data Analysis Menu). Enter E: EDIT TIMING DATA
   The screen will give directions to edit the data. Move the cursor to the line which contains the data to be deleted and press enter. An asterisk (*) will appear next to the data to be omitted. Press ESC and follow the directions on the screen to return to the data analysis menu. Copy average values of the velocities and acceleration.
9. Repeat steps 4-8 by changing the positions of the photogates and take 5 or 6 sets of readings with different values of s. Move photogate 1 down by about 2 cm and photogate 2 by about 7 or 8 cm.
10. Plot a graph between s and $(v_2^2 - v_1^2)$ and find 'a' from the slope of the graph.
    Use mks units in this experiment.

York College of The City University of New York

Physics I Name:

Experiment No. 4: Pre-Lab Questionnaire

1. Briefly explain the working of a photogate.

2. If in Fig. 2, ℓ = 86 cm and h = 17 cm, find the value of sin θ. If the value of 'a' given by the CHAMP is 1.93 m/s^2, calculate g.

3. If the CHAMP gives v_1 = 1.2 m/s, v_2 = 1.7 m/s and the separation between the two gates is 0.4 m, find 'a'.

Experiment No. 4

Name: Marks:

Partner: Remarks:

Section:

Date Submitted:

Title:

Objective:

Theory/Formulas:

Data Sheet

Measure all lengths in meters.

Determination of sin θ:

Height (h)		
Length (ℓ)		
sin θ		

Average sin θ =

Length of the flag: Reading 1 = ; Reading 2 =

Average length of the flag, L =

Caution: Release the glider from the same point in each reading.

Readings for acceleration:

No.	Position of gate 1 r_1	Position of gate 2 r_2	s= r2-r1	Average			a [formula (2)]
				v_1	v_2	a(CHAMP)	

Average 'a' (CHAMP) = g =

Average 'a' (formula) = g =

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Data for graph:

No.	$s = r_2 - r_1$	$v_2^2 - v_1^2$

Plot a graph between s and $v_2^2 - v_1^2$ and find 'a' from the slope of the graph.

'a' (graph) = g =

Conclusions & Remarks:

Experiment No. 4: Questions

1. What is the advantage of determining 'g' by using the inclined plane rather than by free fall?

2. Does the acceleration of the glider depend on the angle of inclination of the plane? Does the value of 'g' depend on the angle of inclination of the plane? Explain.

3. Is the velocity of the glider at the second photogate greater than that at the first photogate? What about the acceleration?

4. How will the results of the experiment change if a heavier glider is used?