Experiment 6. Atwood Machine

Diluting gravity so that the time of fall can be measured more accurately.

Objective:

To study motion under gravity and to determine the value of g, the acceleration due to gravity by using an Atwood machine.

Apparatus:

An Atwood machine (Fig. 2), a timer, weights.

Theory:

Consider the two masses M_1 and M_2, attached to the ends of a light string passing over the light smooth pulleys as shown in Fig. 1. Mass M_1 is greater than M_2. When the masses are released, M_1 will descend with an acceleration 'a' and M_2 will ascend with the same acceleration 'a'. The tension T in the string is the same throughout its length.

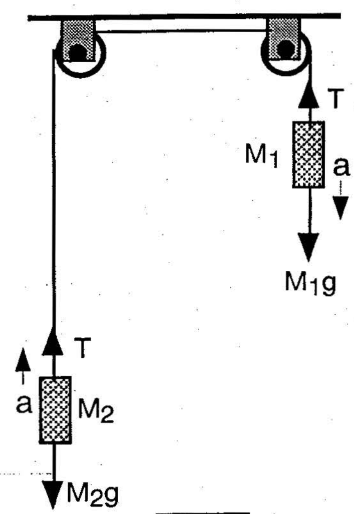

Fig. 1

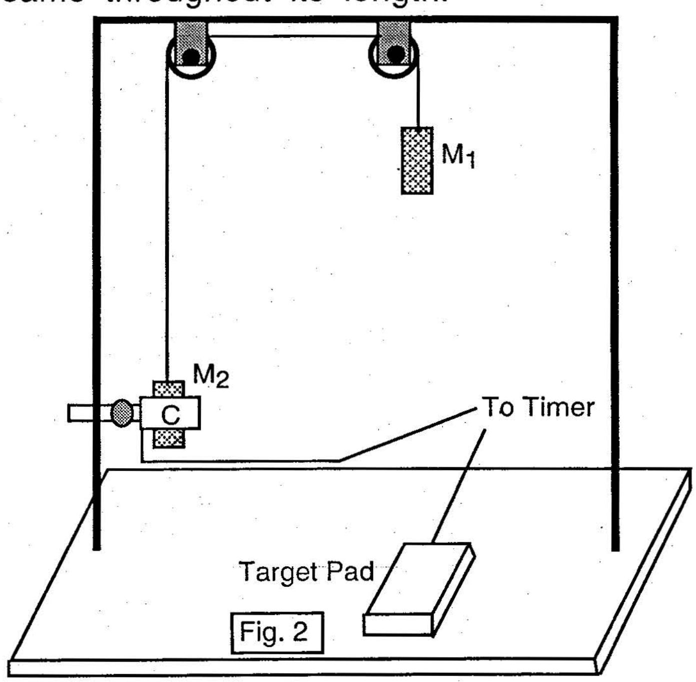

Fig. 2

By applying Newton's second law of motion to mass M_1,

Resultant of external forces acting on M_1 = (Mass M_1)(acceleration of M_1).

Or $\quad T - M_1\, g = - M_1\, a \qquad (1)$

Note that the acceleration of M_1 is downward and hence the negative sign.

Similarly, for the motion of M_1,

$$T - M_2\, g = M_2\, a \qquad (2)$$

By subtracting Eq. (1) from Eq. (2),

$$M_1 g - M_2 g = M_1 a + M_2 a.$$

Or $$a = \frac{M_1 - M_2}{M_1 + M_2} g = \frac{\Delta M}{\Sigma M} g \qquad (3)$$

Here $\Delta M = M_1 - M_2$ = difference between the masses, and

$\Sigma M = M_1 + M_2$ = sum of the masses.

Note that the weights of the hangers must be considered in calculating ΔM and ΣM.

Eq. (3) indicates that if ΣM is kept constant,

$a \propto \Delta M$.

Thus a graph between a and ΔM will be a straight line and the value of g can be computed from the graph.

Further, Eq. (3) indicates that if ΔM is kept constant,

$a \propto \frac{1}{\Sigma M}$.

Thus a graph between a and $\frac{1}{\Sigma M}$ will be a straight line.

The value of g can be computed from the slope of the a versus $\frac{1}{\Sigma M}$ graph.

Procedure:

1. Study the working of the Atwood machine apparatus (Fig. 2) carefully. The masses M_1 and M_2 are tied at the ends of a light string passing over two smooth light pulleys. The lighter mass M_2 is held by a clamp C while the heavier mass M_1 hangs free. The timer should be reset before releasing the mass M_2. As soon as the mass M_2 is released, the timer starts. Mass M_2 rises and mass M_1 falls. When mass M_1 hits the target pad, the timer stops. Thus the time of fall of M_1 is measured.
2. Practice operating the apparatus a few times. Clamp mass M_2 such that its bottom is in level with the lower edge of the clamp C. Reset the timer and release the system so that mass M_1 falls on the target pad. Record the time of fall. Repeat the process a few times until you get consistent values of the time of fall.
3. Clamp mass M_2 such that its bottom is in level with the lower edge of the clamp C. Hold the meter stick vertically such that its one end rests on the target pad and read the position of the bottom of mass M_1. Thus

determine the distance of fall which is the height of the bottom of mass M_1 above the target pad.

4. Keeping ΣM constant, find the times of fall for five or six different values of ΔM. Measure the time of fall three times for each value of ΔM.
5. Keeping ΔM constant, find the times of fall for five or six different values of ΣM. Measure the time of fall three times for each value of ΣM.

Sample set of masses to be clamped on the left and right cylinders for the two pars of the experiment are given below:

Note that masses M_1 and M_2 consist of masses clamped on the left and right cylinders.

Let mass of the right cylinder $= C_1$
mass clamped on the right cylinder $= m_1$
mass of the left cylinder $= C_2$
mass clamped on the left cylinder $= m_2$
Thus mass $M_1 = m_1 + C_1$
and mass $M_2 = m_2 + C_2$

ΣM = constant				ΔM = constant		
No.	m_1 (kg)	m_2 (kg)		No.	m_1 (kg)	m_2 (kg)
1	0.095	0		1	0.02	0
2	0.085	0.01		2	0.03	0.01
3	0.075	0.02		3	0.04	0.02
4	0.065	0.03		4	0.05	0.03
5	0.055	0.04		5	0.06	0.04

Make tables similar to the above examples with suitable values of m_1 and m_2 for use in steps 4 and 5 of the procedure.

Use mks units in this experiment.

York College of The City University of New York

Physics I Name:

Experiment No. 6: Pre-Lab Questionnaire

The following data were obtained in an Atwood machine experiment:

Distance of fall = 0.455 m

M_1	M_2	Time of fall (sec)		
		R_1	R_2	R_3
0.20 kg	0.10 kg	0.535	0.539	0.932

1. Explain why the third reading R_3 should be discarded or repeated?

2. On repeating the experiment, R_3 was found to be 0.531 sec. Find the average value of time of fall.

3. Find the value of acceleration 'a' from the above data.

4. Calculate the value of 'g' from the above data.

Experiment No. 6

Name: Marks:

Partner: Remarks:

Section:

Date Submitted:

Title:

Objective:

Theory/Formulas:

Data Sheet

Mass of the right cylinder, C_1 =

Mass of the left cylinder, C_2 =

Distance of fall, D =

Least count of the timer =

ΣM = constant:

Note that small m's (m_1 and m_2) represent masses on the cylinders.

$\Sigma M = m_1 + C_1 + m_2 + C_2 =$

In the following table, $\Delta M = m_1 + C_1 - m_2 - C_2$.

No.	m_1 (kg)	m_2 (kg)	ΔM (kg)	Time of fall, T (second)			Average T	$a = \frac{2D}{T^2}$
				R_1	R_2	R_3		

Plot a graph between ΔM and a. Choose 2 points on the graph, find the values of ΔM and a for the 2 points and calculate the value of g from the slope of the graph by applying Eq. (3).

Percent error in the experimental value of g =

ΔM = constant:

Note that small m's (m_1 and m_2) represent masses on the cylinders.

$\Delta M = m_1 + C_1 - m_2 - C_2 =$

In the following table, $\Sigma M = m_1 + C_1 + m_2 + C_2$.

No.	m_1 (kg)	m_2 (kg)	ΣM (kg)	$\frac{1}{\Sigma M}$	Time of fall, T (second)			Average T	$a = \frac{2D}{T^2}$
					R_1	R_2	R_3		

Plot a graph between $\frac{1}{\Sigma M}$ and a.

Choose 2 points on the graph, find the values of $\frac{1}{\Sigma M}$ and a for the 2 points and calculate the value of g from the slope of the graph by applying Eq. (3).

Percent error in the experimental value of g =

Experiment No. 6: Questions

1. Draw the free body diagrams of M_1 and M_2, indicating the forces acting on them.

2. What is the resultant force acting on M_1 in observation number 2 of the first table?

3. Is the magnitude of the resultant force acting on M_1 equal to the magnitude of the resultant force acting on M_2? Explain your answer.