ScienceCube

Atwood's Machine

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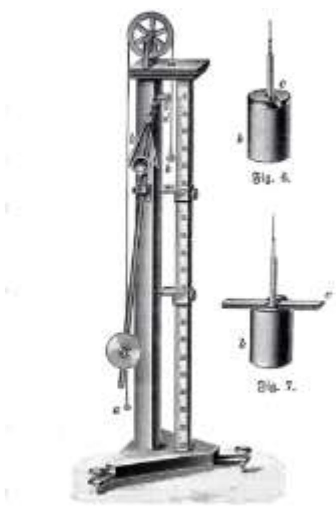
1. **Measuring the acceleration of an Atwood machine using a photogate and explaining it.**
2. **Explaining the relationship between mass and acceleration through the Atwood machine.**

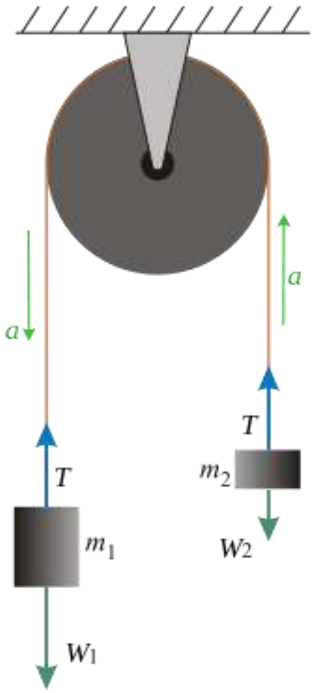
Fundamental Concept

1. **Atwood's Machine**

The Atwood machine was invented by Atwood in 1784. By using a lightweight pulley with low friction, if you attach equal masses M on both sides of the pulley and add a small mass m to one side, the entire system will move with an acceleration of $m/(2M+m)$ times the gravitational acceleration. By adjusting M and m, you can control the speed of the motion as needed. After starting the motion, if you remove m, the system will move at a constant velocity, allowing the acceleration to be measured.



2. Uniformly Accelerated Motion Equation



By analyzing the forces, the acceleration equation can be derived. Assuming the mass and elasticity of the string and the mass of the pulley can be ignored, the forces to consider are the tension T and the weights of the two masses ($W1$ and $W2$). To determine the acceleration, it is necessary to identify the forces acting on each mass. Using Newton's second law (assuming $m1>m2$), a set of simultaneous equations can be established to solve for acceleration a. We assume the positive direction for $m1$ is downward, and for $m2$, it is upward. The weights of $m1$ and $m2$ are $W1=m1g$ and $W2=m2g$, respectively.

$$m_1 g - T = m_1 a$$

$$T - m_2 = m_2 a$$

$$m_1 g - m_2 g = m_1 a + m_2 a$$

$$\mathrm{a} = \frac{m_1 - m_2}{m_1 + m_2} g$$

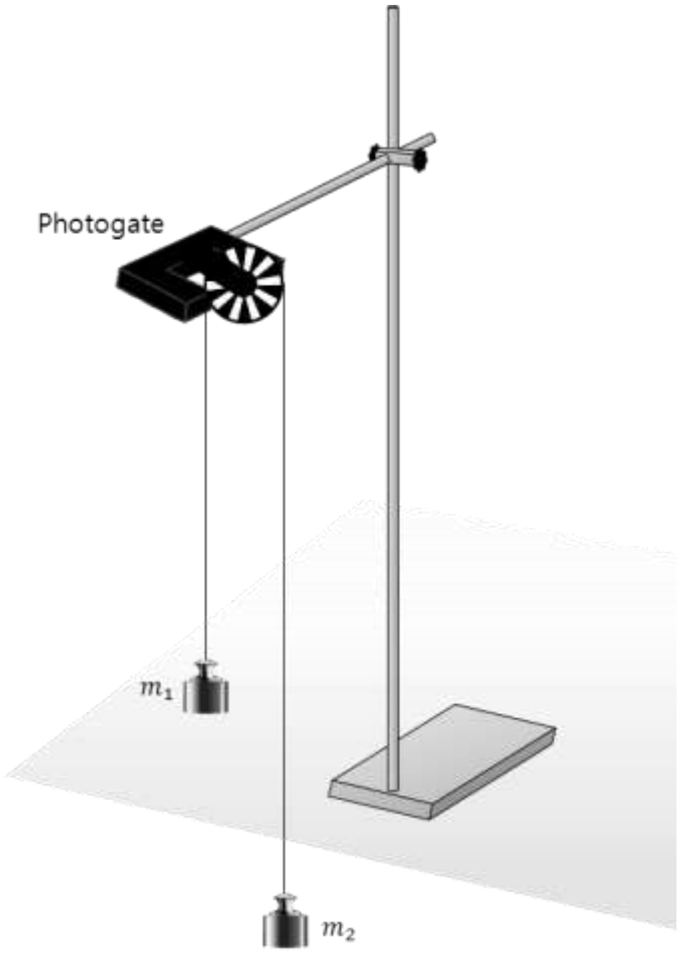
Experiment

Materials Needed

Interface, Science# program (smart device), Photogate, Set of weights (100g x 4, 30g x 3, 20g x 2, 10g x 1), String, Sensor rod, Pulley

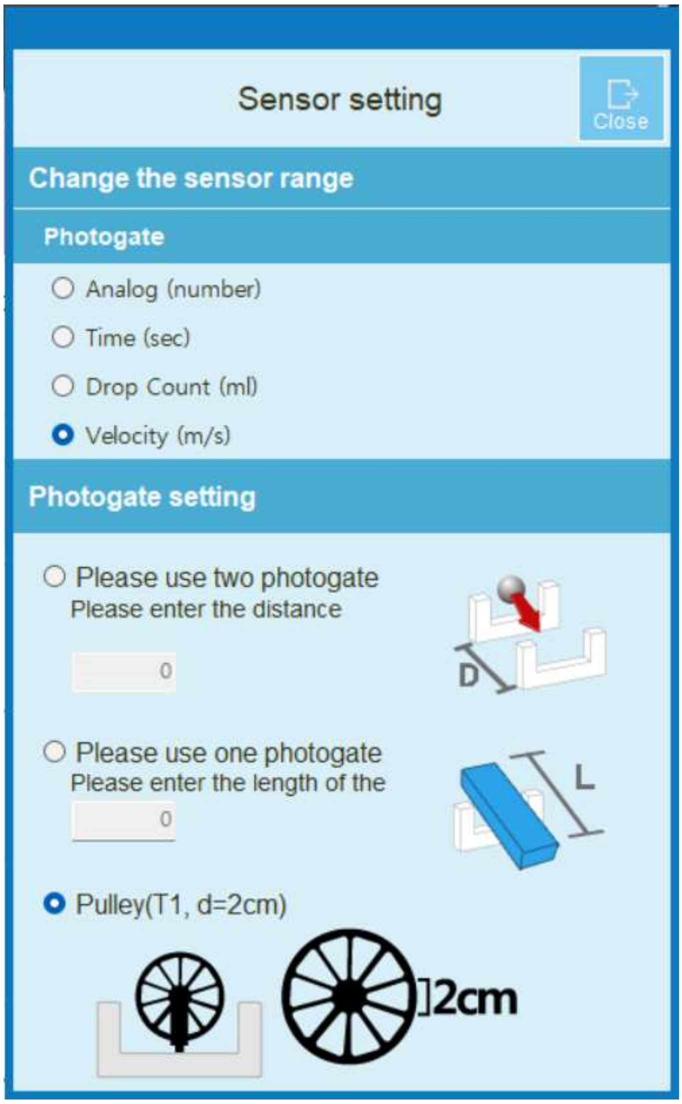
Experimental Setup

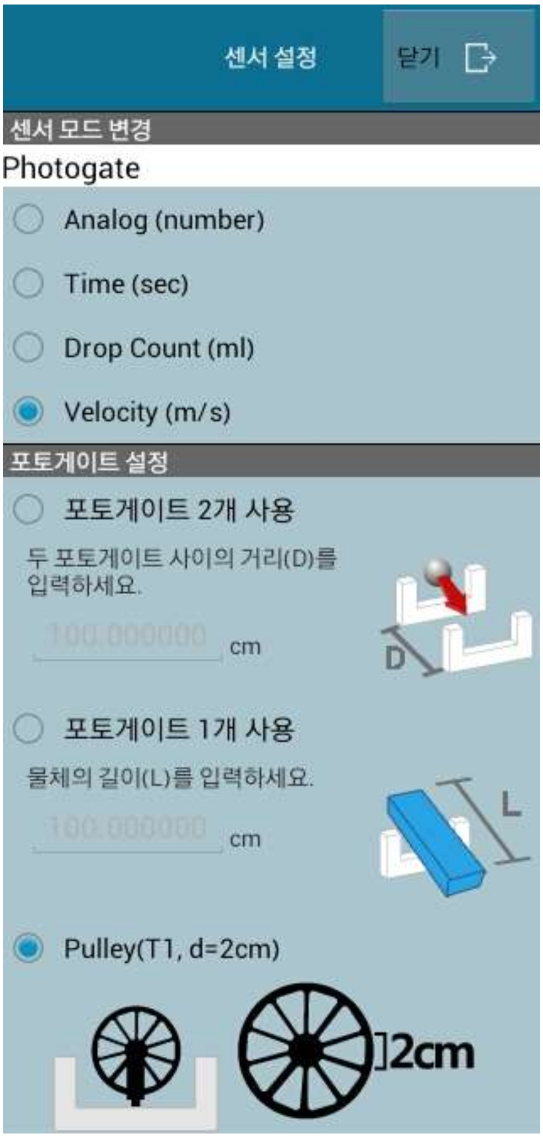
1. Using the photogate, set up the Atwood machine as shown in the diagram and install it at the edge of the table.
2. Attach weights $m1=200g$ and $m2=200g$ to maintain a total mass of 400g.



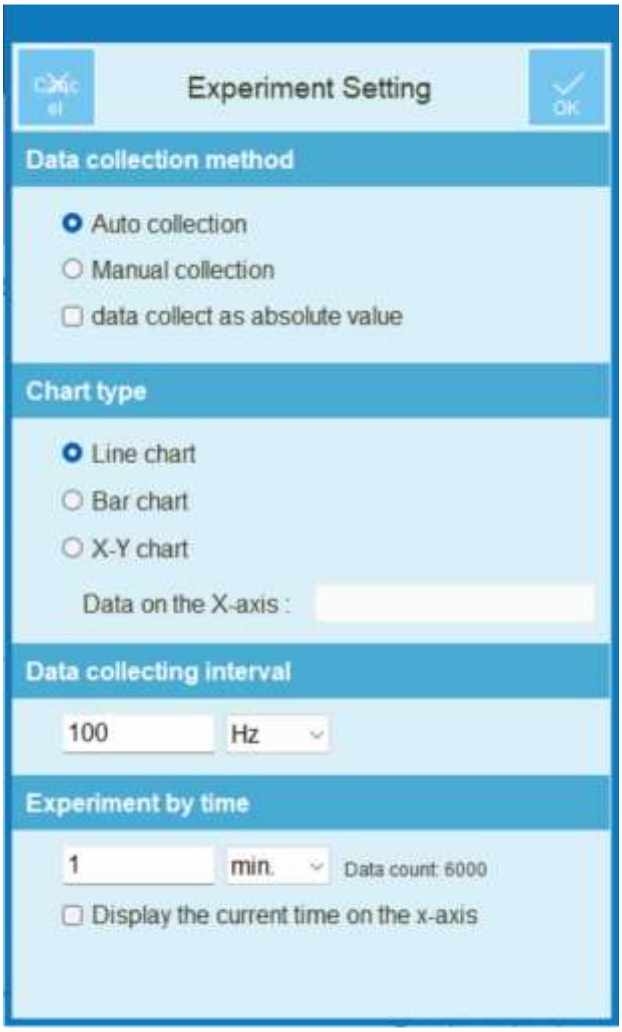
Interface Setup

1. Run Science#.
2. Connect the photogate to the interface.
3. Press the button to change the sensor mode to Velocity (m/s) and set the photogate to Pulley (T1, d=2cm).



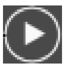
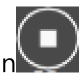


4. Press  to set up the experimental environment as shown below or press  for automatic setup.

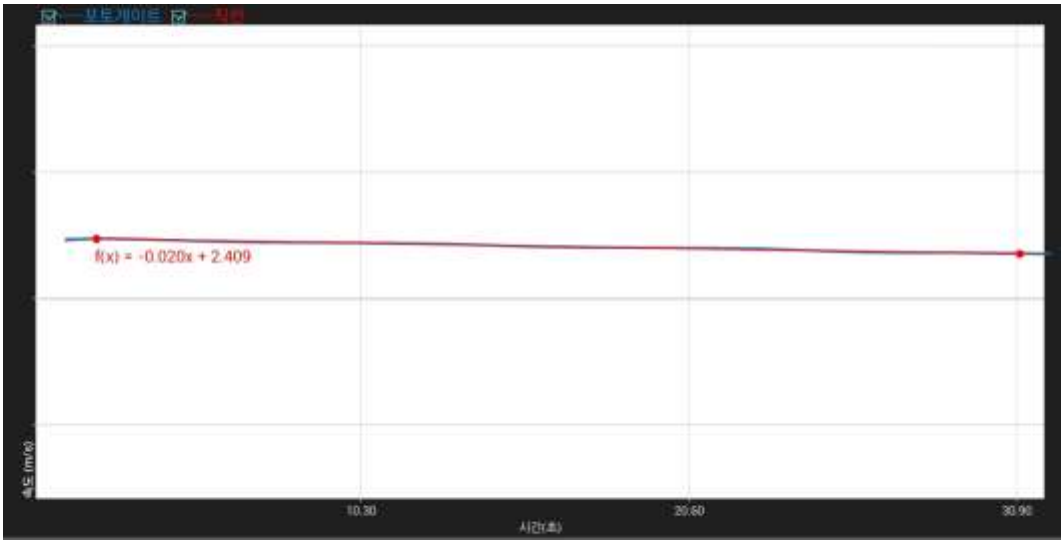


Data Collection

[Maintaining Total Mass of 400g]

1. Press the button  to start data colletion.
2. Gently pull one side of the weight to initiate motion.
3. Once the motion of the weights stops, press the button  to stop data collection..
4. Press [Analyze] - [Linear fit: f(x) = Ax + B] to analyze and record the acceleration A

   Example)



5. Attach weights $m1$=210g and $m2$=190g to maintain a total mass of 400g but with different masses on each side.
6. Determine and record acceleration A using the same method as #1 to #4.
7. Attach weights $m1$=220g and $m2$=180g to maintain a total mass of 400g but with different masses on each side.
8. Determine and record acceleration A using the same method as #1 to #4..

[Maintaining Mass Difference of 20g]

9. Attach weights $m1$=160g and $m2$=140g and determine and record acceleration A using the same method as #1 to #4.
10. Add 20g weights to both $m1$ and $m2$ to maintain a mass difference of 20g and determine and record acceleration A using the same method as #1 to #4.
11. Perform and record three experiments by increasing the masses by 20g each..

Data Analysis

Recording Data

[Maintaining Total Mass of 400g]

1. The total mass is maintained at 400g, and the Atwood machine was operated by varying the masses on each side. Record the mass of each weight and the acceleration obtained from the analysis in the table below.

Category	m1 (kg)	m2 (kg)	Mass Difference (kg)	Acceleration (m/s^2)
1				
2				
3				

[Maintaining Mass Difference of 20g]

2. To maintain a mass difference of 20g, the same mass was continuously added to both sides of the Atwood machine. Record the mass of the weights and the analyzed acceleration in the table below.

Category	m1 (kg)	m2 (kg)	Total Mass (kg)	Acceleration (m/s^2)
1				
2				
3				

Data Application

1. Describe the motion when the masses on both sides were equal. Record and explain the acceleration at that time.

2. When the total weight of the masses was kept constant, but the mass was shifted to create a difference, describe the motion and explain how the acceleration changed with the mass difference.

3. Explain how the acceleration changed as the total mass increased while maintaining a 20g mass difference, along with the reason.

4. The following is the formula for calculating acceleration according to Newton's second law. Use this to calculate the theoretical acceleration for each mass and compare it with the actual experimental data..

$$a = \frac{m_1 - m_2}{m_1 + m_2} g$$

case		Experimental Acceleration (m/s^2)	Theoretical Acceleration (m/s^2)	Error (m/s^2)
m1	m2			


Report
(For Teachers)


Report
(For Students)