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Section: ___________________ **Score:** ______________

Preparatory Physical Science (PHSC 001)
Experiment No. 5
Atwood Machine

Experiment Objectives: To study the relationship between force, mass, and acceleration using Atwood machine.

Methodology: The method consists of application of Newton's second law of motion for a system of two objects connected by a rope and to find the acceleration and the tension in the rope. Verification of the law of conservation of energy is also applied.

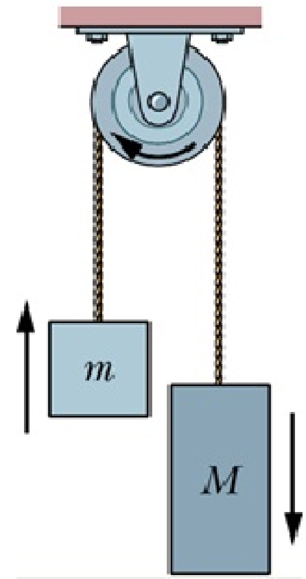

Fig.(5.1): Atwood Machine

Theory: Atwood machine shown in the simple drawing of Figure (5.1) was invented by George Atwood in 1784 to demonstrate the relationship between force, mass, and acceleration through the application of Newton's second law. It consists of two objects of masses M and m (with $M > m$), connected by an inextensible massless rope passes over an ideal massless and frictionless pulley.
When the masses are equal ($M = m$), then the system is in equilibrium and no motion will take place. If the two masses are close to each other in value, then the uniform acceleration of the two masses will be small and can be measured.

To derive the constant acceleration: Assume the rope is massless and inextensible; this requirement to insure that $a_1 = a_2 = a$. Assume, also, the pulley is a massless and frictionless; this will insure that $T_1 = T_2 = T$. The only forces acting on the two masses are the tension T and their weights or forces of gravity F_{gH}*(Heavy)*, and F_{gL}*(Light)*. A free body diagram is shown in Figure (5.2). To find the acceleration, we must investigate the forces acting on each individual mass separately. We should also follow a sign convention system.

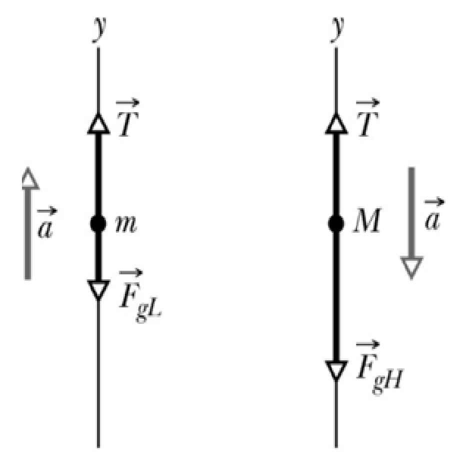

Fig.(5.2): Free body diagram of the forces acting on the two weights in Atwood machine.

Important: The student should realize that what causes the motion is a net force resulted from the difference between the weights of the two objects. Lets us analyze the motion of the two objects separately.

Object of mass *M*

Assume downward is positive. Apply Newton's second law:

$$F_{net} = Ma$$
$$Mg - T = Ma \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(5.1)}$$

Where ***T*** is the tension in the rope.

Object of mass *m*

Assume upward is positive. Apply Newton's second law

$$F_{net} = Ma$$
$$T - mg = Ma \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(5.2)}$$

Subtract equation (5.2) from equation (5.1) and get

$$a = \left(\frac{M-m}{M+m}\right) g \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(5.3)}$$

To derive the tension in the rope

It is left as an exercise to the student to prove that

$$T = \left(\frac{2mM}{M+m}\right) g \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(5.4)}$$

The students can use the machine to verify the law of conservation of energy, which can be stated as:

Energy before = Energy after

The process consists of allowing the heavy object to descents from a determined height with known gravitational potential energy. This energy will be converted to kinetic energy for the heavy object and work to lift up the light object upward. Therefore,

$$Mgh = \frac{1}{2}Mv^2 + mgh \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(5.5)}$$

Where v is the velocity of the heavy object.

Materials and equipment

- Single pulley
- Slotted weights
- 1 meter long metallic rod
- Supporting base
- A rope, 1 m long
- clamp

Procedure:

A. Determination of the acceleration

1. Set the machine up as shown in Figure (5.3). The rope must be long enough so that the two masses should be about 40 cm off the tabletop.
2. Start with 50 g masses on both weight holders. Total mass is 60 g on each side.
3. Keep the two objects (60 g each) on same sight level as shown in Figure (5.3). Lower the right side object a small distance downward and observe the system. Keep lowering until the object rests on the tabletop. Record your observation and data in Table 1.
4. Keep the two objects again on the same sight level shown in Figure (5.3). Add a total of 4grams to the object on the right side (1gram a time). Observe the motion of the system and record your data in Table 1
5. Remove the 4grams from the object on the right side. Add a 50g weight to the object on the left side and slowly let it settled on the tabletop (do not let it go by itself). The right object by now is moved upward (why?).

Figure (5.3): A simplified Atwood machine

6. With the left object on the tabletop and the right object is up, add few grams to the object on the right side (one gram a time) until the system start moving very slowly such that the right side object touches the tabletop. Record your data in Table 1.

Step	M (right side object) *gm*	m (left side object) *gm*	$\frac{M-m}{M+m}$	$a = (\frac{M-m}{M+m})g$ *m/sec^2*
3	60	60		
4				
5				

B. To prove conservation of energy

1. Start with 110g on each side of the rope.
2. Lower the left side object until it touches and settled on the tabletop.
3. Measure the distance between the right hand side object and the table top and record it in Table 2.
4. Add weights to the right side object one gram a time until it begins to descend downward slowly. Your partner should measure the time it takes the heavy object to settle on the tabletop.
5. Repeat step 4 and measure the time. Take the average. Find the speed. Record your data in Table 2.
6. When the heavy object moves down, the light object moves up the same distance moved by the heavy object. Record this distance in Table 2.
7. Apply Equation (5.5). Compare and explain.

Table2

step	*M* ***R.H.S***		*m* ***L.H.S***		*Time*			$velocity\ v = \frac{h}{t_{avg}}$ m/sec		
	Mass (kg)	h (m)	Mass (kg)	h (m)	t_1 (sec)	t_2 (sec)	t_{avg} (sec)	v_1	v_2	v_{avg}
1	0.110		0.110		0	0	0			
2	0.110		0.110	0	0	0	0			
3		0	0.110							

Calculations of part B

$Mgh =$ J

$\frac{1}{2}Mv^2 =$ J

$mgh =$ J

Questions

1. Derive Equation(5.4)

2. If M = 2.80.30 kg and m = 1.30 kg, what are

   (a) The magnitude of the system acceleration?

   (b) The tension in the rope?

3. Can you use this machine to determine “g” the acceleration due to gravity and how? Explain