The Atwood Machine - Explanation

The Atwood machine was constructed to demonstrate and verify certain laws of motion under laboratory conditions. The machine is named for the man who invented and constructed it, the Reverend George Atwood. The Atwood machine consists essentially of two masses suspended from a string over a pulley and is used to show the state of constant acceleration experienced by both masses when the masses do not equal each other. Today, any machine constructed in a similar way for this purpose is still called an Atwood Machine, and machines of this type are still commonly used in teaching to demonstrate certain laws of physics.

By applying Newton's second law of motion, it can be calculated that when the two masses suspended by a string over a pulley are unequal, acceleration will result as the larger mass falls down and the smaller mass is pulled up and that this acceleration will be constant for both masses. This is what would take place under ideal conditions and does not take into account friction or the tendency of any string or wire to stretch. Both of these factors can be calculated and factored into any measured observations of any demonstration of this law using an Atwood machine.

The basic construction of an Atwood machine is simple. A vertical stand with a pulley mounted on an arm allows the two masses to be suspended from the pulley by a single string. The pulley can be mounted in any fashion, as long as the strings hang vertically, but in the original version and in most other machines of this type, the pulley is mounted so that its axle rests on and is surrounded by as many as four other wheels, in an attempt to reduce friction as much as possible. Any version of Atwood's machine will also have the means to measure the distance traveled by each mass during the demonstration or experiment.

The machine provides a way for students and scientists to confirm through demonstration and to better understand Newton's second law of motion and other principles of physics and mechanics. The two masses to be hung from the ends of the string, for example, will not move on their own as long as they are equal. Changing one of the masses so that they are not equal will result in one accelerating upward and the other downward, both at an equal and constant rate which does not change regardless of the size of either of the two masses. A very large mass and a very small mass will both accelerate at the same constant rate as two masses that differ only slightly, and this machine allows this fact to be demonstrated under laboratory conditions[2].

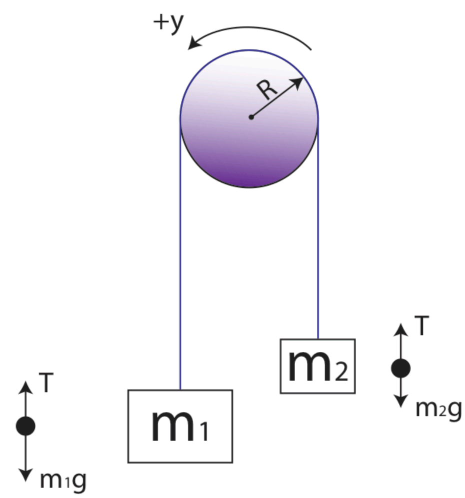
Citations:

1. “Atwood Machines.” APlusPhysics.com. 2015. 30 June 2015. http://www.aplusphysics.com/courses/honors/dynamics/Atwood.html#.

2. “What is an Atwood Machine?” WiseGeek.com. 2015. 30 June 2015. http://www.wisegeek.com/what-is-the-atwood-machine.htm.

Question: Two masses, m_1 and m_2, are hanging by a massless string from a frictionless pulley. If m_1 is greater than m_2, determine the acceleration of the two masses when released from rest.

Answer: First, identify a direction as positive. Since you can easily observe that m_1 will accelerate downward and m_2 will accelerate upward, since $m_1 > m_2$, call the direction of motion around the pulley and down toward m1 the positive y direction. Then, you can create free body diagrams for both object m_1 and m_2, as shown to the right:



Using this diagram, write Newton's 2nd Law equations for both objects, taking care to note the positive y direction:

$$m_1 g - T = m_1 a \;(1)$$
$$T - m_2 g = m_2 a (2)$$

Next, combine the equations and eliminate T by solving for T in equation (2) and substituting in for T in equation (1).

$$T - m_2 g = m_2 a (2)$$
$$T = m_2 g + m_2 a \qquad (2b)$$
$$m_1 g - m_2 g - m_2 a = m_1 a \quad (1+2b)$$

Finally, solve for the acceleration of the system[1].

$$m_1 g - m_2 g - m_2 a = m_1 a \quad (1+2b)$$
$$m_1 g - m_2 g = m_1 a + m_2 a$$
$$g(m_1 - m_2) = a(m_1 + m_2)$$
$$a = g\frac{(m_1 - m_2)}{(m_1 + m_2)}$$