

Atwood's Machine

Objective:

- To determine the acceleration and final velocity of a masses in a pulley system.
- To determine the work done by friction in a pulley system.

Apparatus:

- | | |
|------------------------|---------------|
| • Clamp stand | • Weights |
| • Mounted light pulley | • Meter stick |
| • String | • Stopwatch |

Introduction and Theory:

Atwood's Machine consists of two masses connected by a string looped over a pulley. Applying Newton's second law to this system, we obtain the following equations.

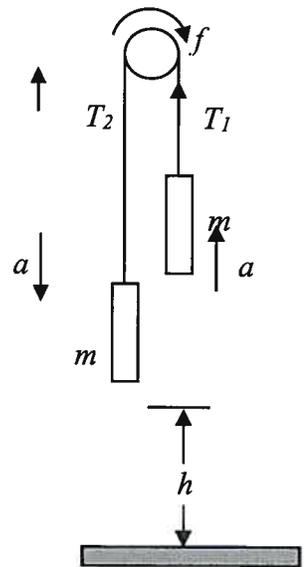
$$m_1 a = T_1 - m_1 g \quad (1)$$

$$-m_2 a = T_2 - m_2 g \quad (2)$$

$$T_2 = T_1 + f \quad (3)$$

If the friction in the bearing is negligible, then the combination of these two equations is:

$$a = \frac{(m_2 - m_1)}{(m_2 + m_1)} g \quad (4)$$



By measuring the time it takes for the masses, initially at rest, to travel a known distance, we can determine the experimental acceleration of the system (recall, $h = v_i t + \frac{1}{2} a t^2$). The calculated (by mass) and the experimental accelerations can then be compared.

On the other hand, as the masses move, the potential and kinetic energy in the system changes. The work done by all non-conservative forces (friction in this case) equals the change in mechanical (kinetic + potential) energy of the system. This last statement can be written as:

$$W_{nc} = (\sum KE_f + \sum PE_f) - (\sum KE_i + \sum PE_i) \quad (5)$$

where

$$KE = \frac{1}{2}mv^2 \quad (6)$$

and

$$PE = mgh \quad (7)$$

The final velocity (and therefore the kinetic energy) of this system can also be found by using the kinematic equations for constant acceleration:

$$v_f - v_i = at \quad (8)$$

and

$$h = v_i t + \frac{1}{2}at^2 \quad (9)$$

Since $v_i = 0$ at $t = 0$, equations (8) and (9) gives the final speed of the mass to be:

$$v_f = \frac{2h}{t} \quad (10)$$

Procedure:

1. Set one mass $m_1 = 150$ g on the floor and measure the distance, h , from the floor to the hanging mass $m_2 = 150$ g. (The two masses start out identical.)
2. Add 10 g to the hanging mass. Hold the hanging mass to stabilize the system so that is at rest.
3. Release the mass and measure the time it takes the hanging mass to hit the floor.
4. Repeat steps 1 – 3 for three total measurements.
5. Repeat steps 1 – 4 for 15, 20, 25, and 30 g added to m_2 .
6. For the last step (after adding 30 g), let the hanging mass drop to the floor, and count how many turns the pulley will undergo (N). Use fraction of a turn if necessary.

Data:

$h = \underline{1.4 \text{ m}}$

RLF

Trial	m_1 (kg)	m_2 (kg)	t_1 (s)	t_2 (s)	t_3 (s)	t_{avg} (s)
1	150	160	4.07	3.99	4.0	4.02
2	150	165	2.69	2.62	2.71	2.67
3	150	170	1.96	2.10	2.13	2.06
4	150	175	1.77	1.66	1.72	1.72
5	150	180	1.49	1.68	1.58	1.58

Calculations: (2 pts each)

Show your calculations for the mass difference of 30 g. Take note of the sign when calculating changes in energy.

1. Calculate the acceleration a_{mass} using Newton's Laws (equation 4).
2. Calculate the acceleration $a_{\text{kinematics}}$ and (equations 9).
3. Calculate the final velocity v_f using kinematics (equation 10)
4. Calculate the change in kinetic energy of both masses using kinematics.
5. Calculate the change in potential energy of both masses using kinematics.
6. Calculate the work done by friction.

Results:

$h = 1.14 \text{ m}$

$m_1 = 150 \text{ g}$

m_2 (g)	t_{avg} (s)	a_{mass} (m/s^2)	$a_{\text{kinematics}}$ (m/s^2)	% difference
160	4.02 s	.32 m/s^2	.14 m/s^2	76.59%
165	2.67	.47		
170	2.06	.61		
175	1.72	.75		
180	1.58	.89		

m_2 (g)	v_f (m/s)	ΔKE_1 (J)	ΔKE_2 (J)	ΔPE_1 (J)	ΔPE_2 (J)	W_f (J)
160	.567 m/s	.02411 J	.02572 J	1.676	-1.789	-.0617
165	.854					
170	1.11					
175	1.33					
180	1.44					

Questions: (3 points each)

1. Which was greater, a_{mass} or $a_{\text{kinematic}}$? How close were they?
2. What is the sign of W_f ? What is the significance of its sign?
3. Consider whether your answers to questions 1 and 2 consistent with one another. Based on the sign of W_f , do you expect a_{mass} or $a_{\text{kinematic}}$ to be greater? (Consider which assumptions went into the formula for calculating a_{mass} .)