ACTIVITY FIVE-A
NEWTON'S SECOND LAW: THE ATWOOD MACHINE

PURPOSE

For this experiment, the Motion Visualizer (MV) is used to capture the motion of two masses which are suspended above the ground and connected by fishing line. The fishing line is draped over two pulleys. The overall goal of this activity is for students to gain an understanding of the relationship between force, mass and acceleration. Students will use the data collected to determine the tension in the fishing line. This will be accomplished by examining the change in acceleration that occurs when the system is not in equilibrium.

After this activity, students should be able to do the following:

√ Use Newton's Second Law of Motion to determine the acceleration of a system.

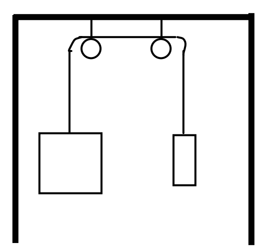
√ Use Newton's Second Law of Motion to determine the tension in a system.

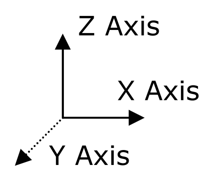
SOFTWARE SET-UP

This is a 1D, two-object experiment with vertical motion. The distance from camera lens to plane of motion was set to 2.0 meters and the camera angle was set to -5°. With this set-up, the software displays the vertical motion on the Z-axis.

MATERIALS

- Computer with MV software and hardware.
- Video camera with tripod.
- Angle measuring device.
- Tape measure or meter stick.
- Fishing line and paperclips.
- Suspension device.
- Various hanging masses.
- Two pulleys.
- Two clamps.

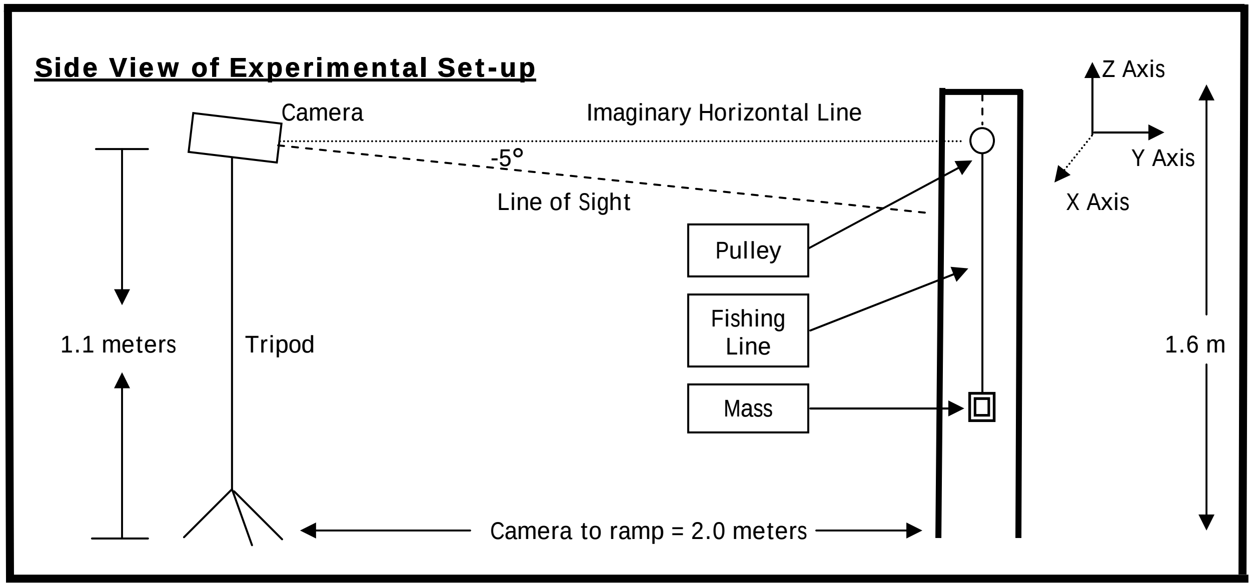


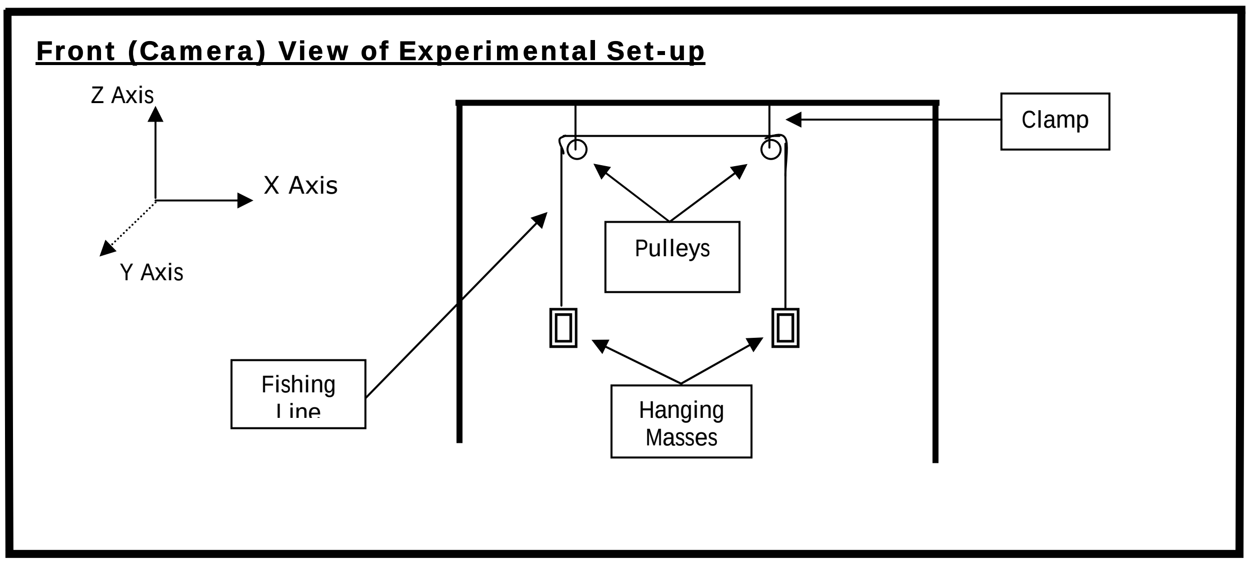


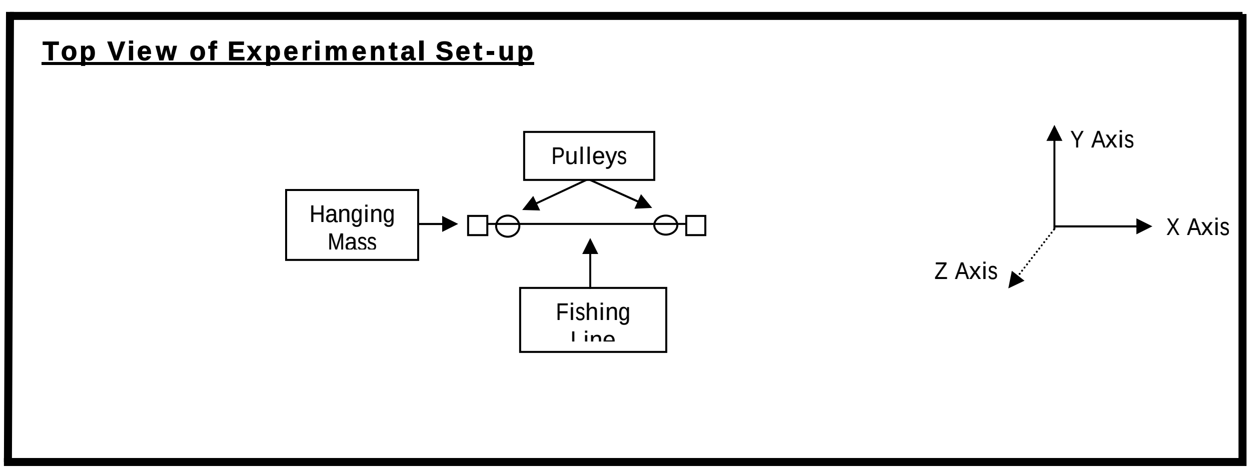
PROCEDURE

1. Clamp pulleys vertically to a support beam.
2. Attach one paperclip to each end of a 1 meter long fishing wire line.
3. Attach a large mass to one paperclip and a small mass to the other paperclip.
4. Adjust the view finder of video camera to capture entire range of motion.
5. Use angle finder to determine camera angle. Enter this value in computer.
6. Measure distance from camera lens to plane of motion. Enter this value in computer.
7. Elevate large mass to starting position.
8. Run experiment.

Written by Michael Quinlan. Michael is a Physics teacher at Newton North High School, Newton, Massachusetts







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DATA COLLECTION, PRESENTATION AND ANALYSIS GUIDELINES

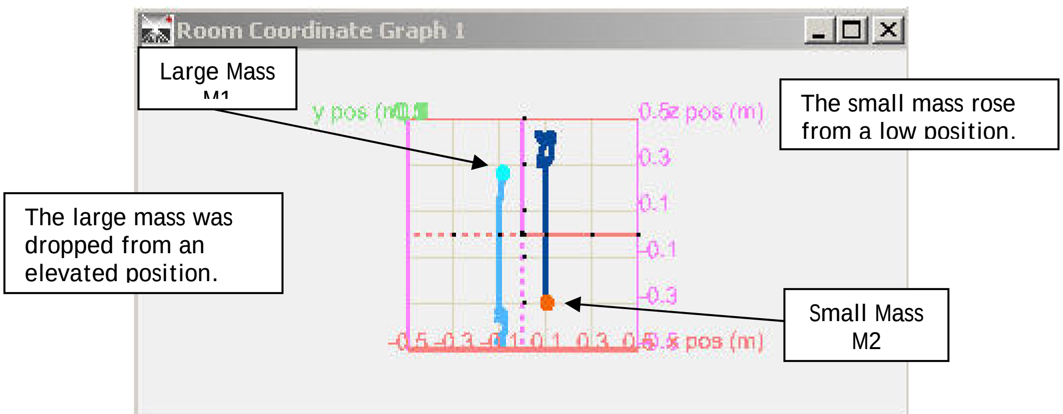
In this activity, a fishing line, which was draped over two pulleys, connected two different sized hanging masses together. The larger hanging caused the entire system to accelerate. Since the hanging masses are connected by a string, they move as one unit. Therefore, the acceleration experienced by the one hanging mass will be the same as the acceleration experienced by the other. [Friction, pulley mass and moment of inertia have been ignored.] The following scenario was analyzed:

The larger hanging mass remained constant while the smaller hanging mass changed.

- **Large hanging mass = 200g.**
- **Small hanging masses = 10g, 20g, 50g and 100g.**

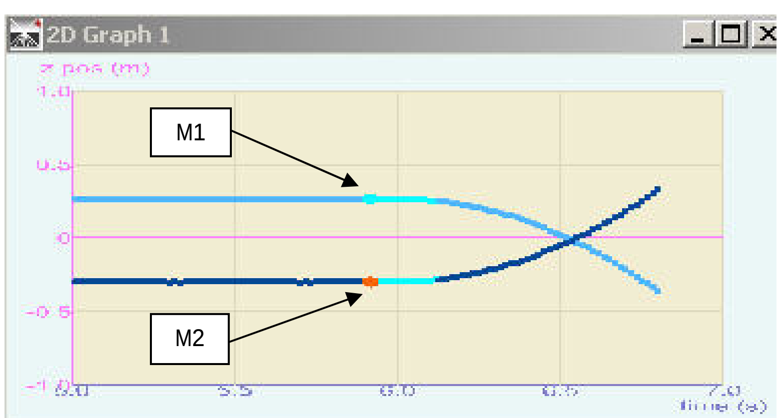
The following graphs and analyses are here to provide ideas about how the data can be used with students.

1. **<u>Room Coordinate Graphs</u>**: Images that show the actual path of the object in the X direction from various perspectives.
   - **<u>Front (Camera) view</u>** – This view shows the motion of the cart from the camera's perspective.



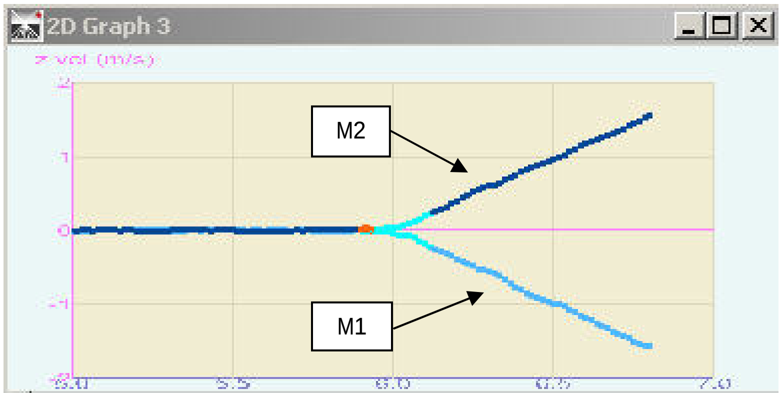
2. **<u>Z Position v. Time Graphs</u>**: Graphical interpretation of the masses' displacement in the Z-direction.

Z Position v. Time Graph: [M1 = 200 g and M2 = 100 g]



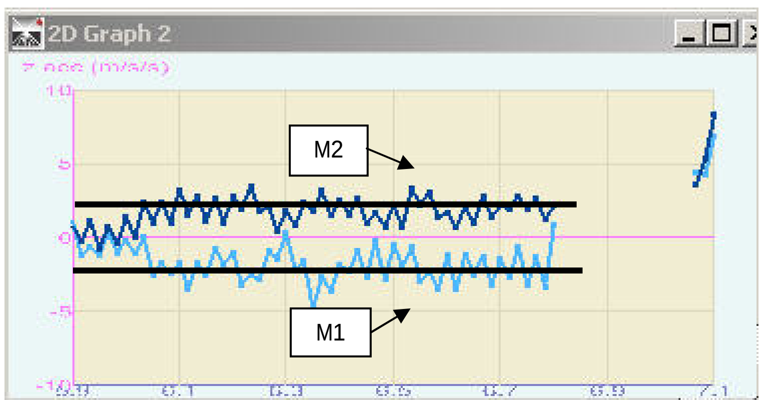
3. **Z Velocity v. Time Graphs**: Graphical interpretations of the masses' velocity in the Z direction.

Z Velocity v. Time Graph: [M1 = 200 g and M2 = 100 g]



4. **Z Acceleration v. Time Graphs**: Graphical interpretations of the masses' acceleration in the Z direction.

Z Acceleration v. Time Graphs: [M1 = 200 g and M2 = 100 g]



When the 200 gram hanging mass is released, it supplies the force that accelerates the 100 gram hanging mass. If friction effects and the masses of the string and pulley are ignored, then the approximate average acceleration of the system is given by the above graph.

Average Acceleration	**m / sec^2**
M1	-3.0
M2	+3.0

The acceleration values shown on the above graph can be verified by applying Newton's 2nd Law of Motion [F_{net} = ma] to the system.

$$F_{net} = mA$$

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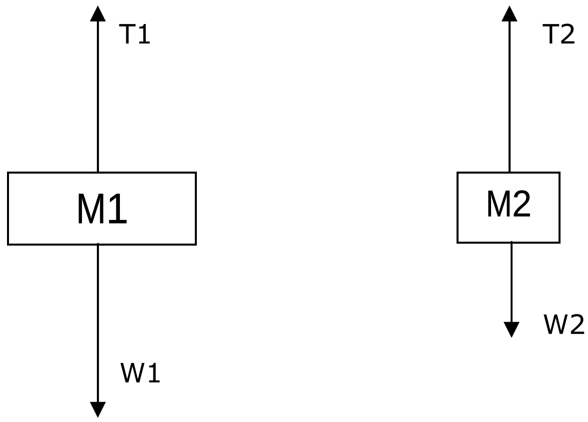
The system includes two masses, so the first step is draw a force diagrams for each hanging mass.



Forces are only acting in the Z direction, so Newton's 2nd Law is written to reflect this.

$$F1_{net} = M1A_z$$

$$F2_{net} = M2A_z$$

The right side accelerates down and the left side accelerates up. The direction of the acceleration, for each case, determines the positive direction.

For M1, Down is +.

$F1_{ne}t = -T1 + W1$

$- T1 + W1 = M1A_Z$

$W1 = (M1) * \text{"g"}$

$W1 = (0.2\ kg) * 9.81\ m/sec^2$

$W1 = 1.96\ N$

$- T1 = M1A_z - W1$

$- T1 = (0.2\ kg)\ (A_z) - 1.96\ N$

$T1 = - (0.2\ kg)\ (A_z) + 1.96\ N$

For M2, Up is +.

$F2_{net} = T2 - W2$

$T2 - W2 = M2A_Z$

$W2 = (M2) * \text{"g"}$

$W2 = (0.1\ kg) * 9.81\ m/sec^2$

$W2 = 0.98\ N$

$T2 = W2 + M2A_z$

$T2 = 0.98\ N + (0.1\ kg)\ (A_z)$

$T2 = 0.98\ N + (0.1\ kg)\ (A_z)$

The tension in the rope is the same, so T1 = T2.

$-0.2\ kg\ (A_z) + 1.96\ N = 0.98\ N + (0.1\ kg)\ (A_z)$

$0.98\ N = (0.3\ kg)\ (A_z)$

$(A_z) = 3.27\ m/sec^2$

Error Analysis: $(3.0 - 3.27)\ 3.27 * 100 = 8.3\ \%$

EXTENSIONS

- Collect data for various combinations of hanging masses.

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