Elevator Dynamics Lab - Samhitha Bodangi

Question: Does observing the apparent weight of different masses in an elevator provide a way to calculate the acceleration? **Hypothesis:** Observing the apparent weight of different masses in an elevator can provide a way to calculate the acceleration at the minimum and maximum points of the apparent weight.

Introduction

A weighing scale measures the normal force applied to an object rather than the actual mass. The normal force is the perpendicular force exerted by a surface to balance the downward force of gravity on the object.

When the object is stationary, the gravitational force and the normal force are equal, which would read the "normal weight" of the object. However, if the object is standing on a scale that accelerates vertically, the scale would read a different weight depending on the direction of the acceleration. This weight is commonly known as apparent weight.

1 Strategy

1. Three rocks with different masses were put on a scale in an elevator
2. The change in apparent weight was filmed as the rock was going down the elevator from floor four to the first floor
3. Using iMovie, the change in apparent weight was recorded to the nearest millisecond
4. The time and apparent weight were graphed in Excel and the acceleration was calculated

2 Data

After collecting the data and creating graphs for each rock, it was clear that the elevator had different accelerations at different times. The different accelerations must be calculated individually. However, the data presents a consistent acceleration pattern:

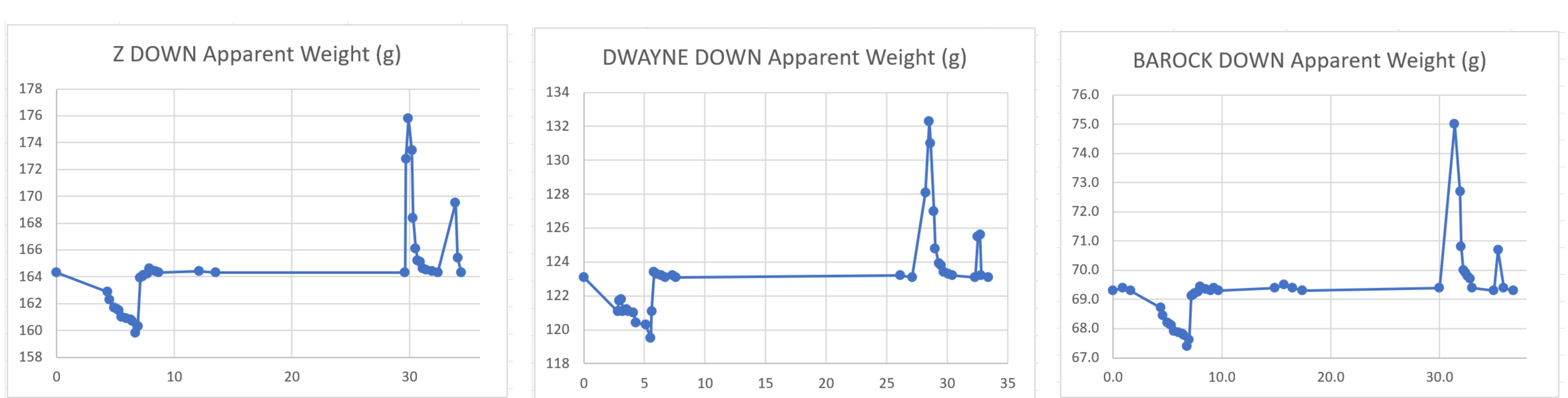


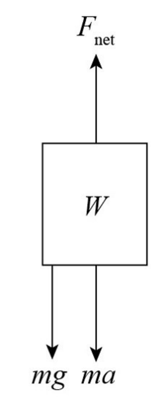
Figure 1: Graphs of Each Rock Side-by-Side Comparison

By looking at these graphs, the path of the elevator becomes clear. Initially, the elevator goes above the fourth floor (evident as the apparent weight becomes lower than the initial weight), then it travels down (weight increases from the minimum point), travels down at a constant velocity (straight line indicates zero acceleration), and then goes down, up, down, up (spikes) until the door opens to the first floor.

3 Results

Based on the graphs, it is clear that the path of the elevator has multiple stages. The apparent weight at rest can be considered as the mass of the rocks. The straight line is when the acceleration is zero, or when the velocity is constant. Therefore, the minimum and the maximum accelerations can be found by looking at the minimum and maximum apparent weights.

Finding Acceleration



Defining Variables	
F_n	Normal Force
mg	Gravity
ma	Net Force

Figure 2: Free-Body-Diagram of Rock (F) in Elevator and its variables

The free-body diagram in Figure 2 shows the forces acting on the rocks as the elevator moves. The normal force is the ground of the elevator pushing upwards. The mg is the force of gravity pushing down on the rock, and the ma is the force resulting from the acceleration of the elevator.

From this free-body diagram, an equation can be made to find the acceleration. Because the normal force is equal to the sum of forces perpendicular to the surface, the normal force is equal to:

$$F_n = mg + ma \tag{1}$$

Isolating ma gives the final equation:

$$F_n - mg = ma \tag{2}$$

Based on the graphs from Figure 1, the initial mass was recorded at the mass of the rocks at the start of the elevator trip. The minimum and maximum masses were recorded from the lowest and highest peaks on the graph. Table 1 has the initial, minimum, and maximum apparent masses.

Rocks	Initial	Minimum	Maximum
Z	164.3 g	159.8 g	175.8 g
Dwayne	123.1 g	119.5 g	132.3 g
Barock	69.3 g	67.4 g	75.0 g

Table 1: Significant Data

Using equation (2), the maximum and minimum accelerations can be found. The normal force is equal to the apparent mass multiplied by 0.0098 (to get the force in Newtons). The final variable to solve for is the acceleration. For example, below is an example equation to find the minimum acceleration for rock Z:

$$159.8 \cdot 0.0098 - 164.3 \cdot 0.0098 = 0.1643 \cdot a \tag{3}$$

Below is the table with the final calculated accelerations for each rock with the average acceleration.

Rocks	Minimum Acceleration	Maximum Acceleration
Z	-0.2684 m/s^2	0.6859 m/s^2
Dwayne	-0.2866 m/s^2	0.7324 m/s^2
Barock	-0.2687 m/s^2	0.80601 m/s^2
Average	-02746 m/s^2	0.7415 m/s^2

Table 2: Final Calculated Accelerations

4 Analysis

Clearly, the acceleration can be accurately found by observing the apparent weights of the rocks. By deriving an equation from a free-body diagram, the minimum and maximum accelerations can be found. To calculate the percent error, the average acceleration was found and used as the actual value. The highest percent errors were 4.37% and 8.71% for the minimum and maximum accelerations respectively. The error may be due to a few different reasons. It could be because of the weight distribution in the elevator. Additionally, it could be because of a delay in the scale updating, which could have led to inaccurate apparent weights.