Simulated Lab (Newton's Second Law)

Newton's Second Law tells us that a force is required to cause an object to accelerate, and the larger the mass of the object, the larger the force must be to reach a given acceleration. In this simulated lab, we will explore the relationship amongst the force, mass, and acceleration of an object. Additionally, we will continue to use regression analysis to examine the data.

Procedure

1. Start Virtual Physics and select Newton's Second Law from the list of assignments. The lab will open in the Mechanics laboratory.

2. The laboratory will be set up with a ball on a table. Attached to the ball is a rocket used to push the ball across the table. There is no friction. In this experiment, you will collect position and velocity data as the ball moves across the table. Then you will make velocity vs time graphs.

3. Click on the red Recording button to start recording data in the Lab Book. Start the ball rolling by clicking on the Force button. Observe what happens as the ball rolls across the table. The force is set to 10 N and the mass of the ball is 2 kg. The experiment will stop automatically when the ball has reached the end of the table. A link will appear in the Lab Book containing the position and velocity versus time data of the ball rolling across the table. Click next to the link to label the link with the force and mass.

4. Click the Reset button to reset the experiment back to the beginning. Use the Parameters Palette to change the rocket force and repeat Step 3 for **two more** different forces. Record the forces in the table below.

5. Now observe what happens to the ball's speed and acceleration when you change the mass. Click the Reset button to reset the experiment back to the beginning. Use the Parameters Palette to change the mass of the ball. Make sure the Force is set to 10 N, and repeat Step 3 for **three** different masses. Do not change the force for these experiments. Record the masses in the table.

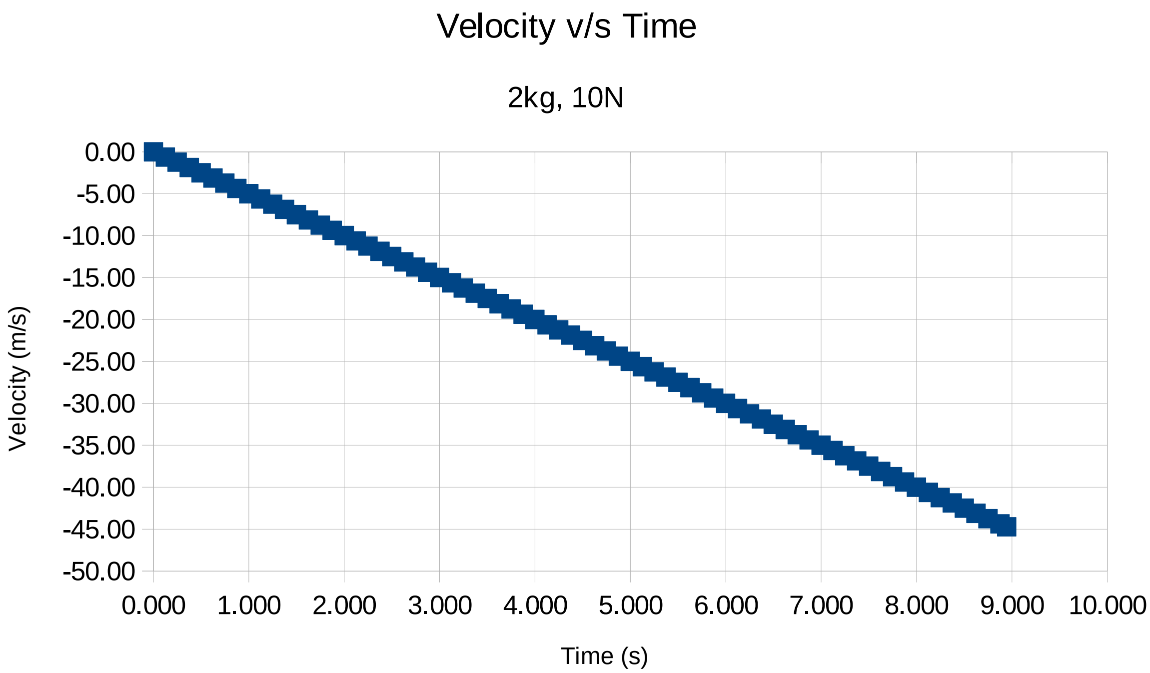
6. Open each of the links and record the final velocity and the time it took to reach that velocity in the table. Note: record the time when the ball first reaches the end of the ramp—there may be other data points after that, but just take the time when it reaches the end.

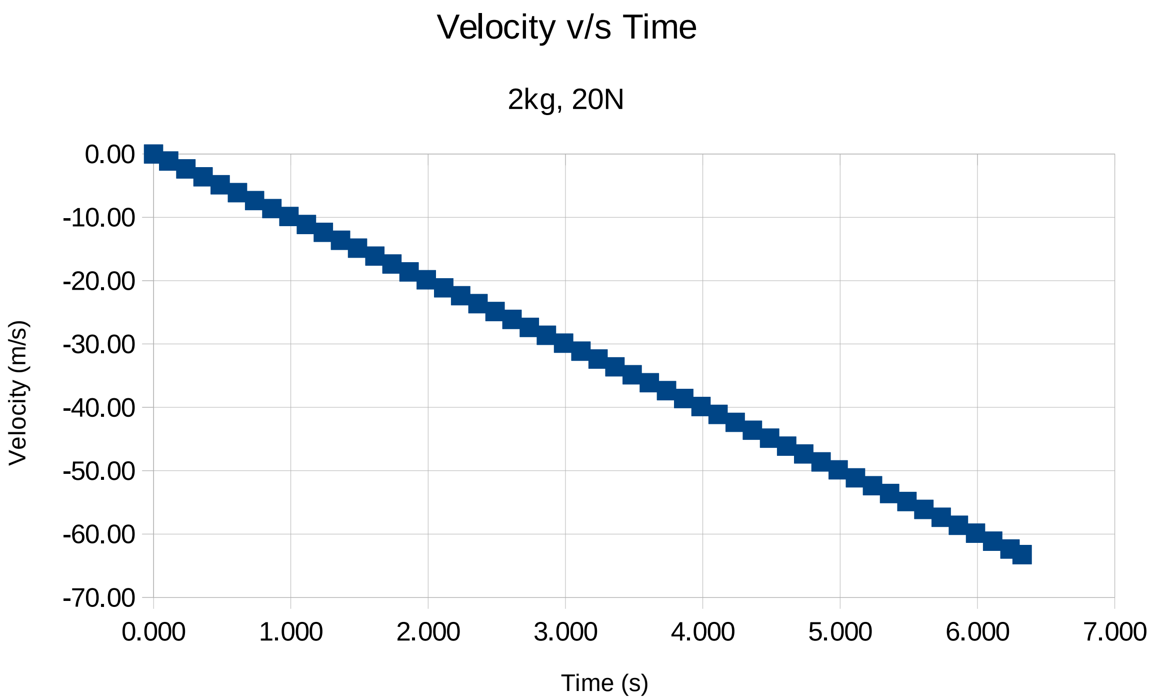
7. Fill out the table below with the Force, mass, time to reach the end of the table, and final velocity.

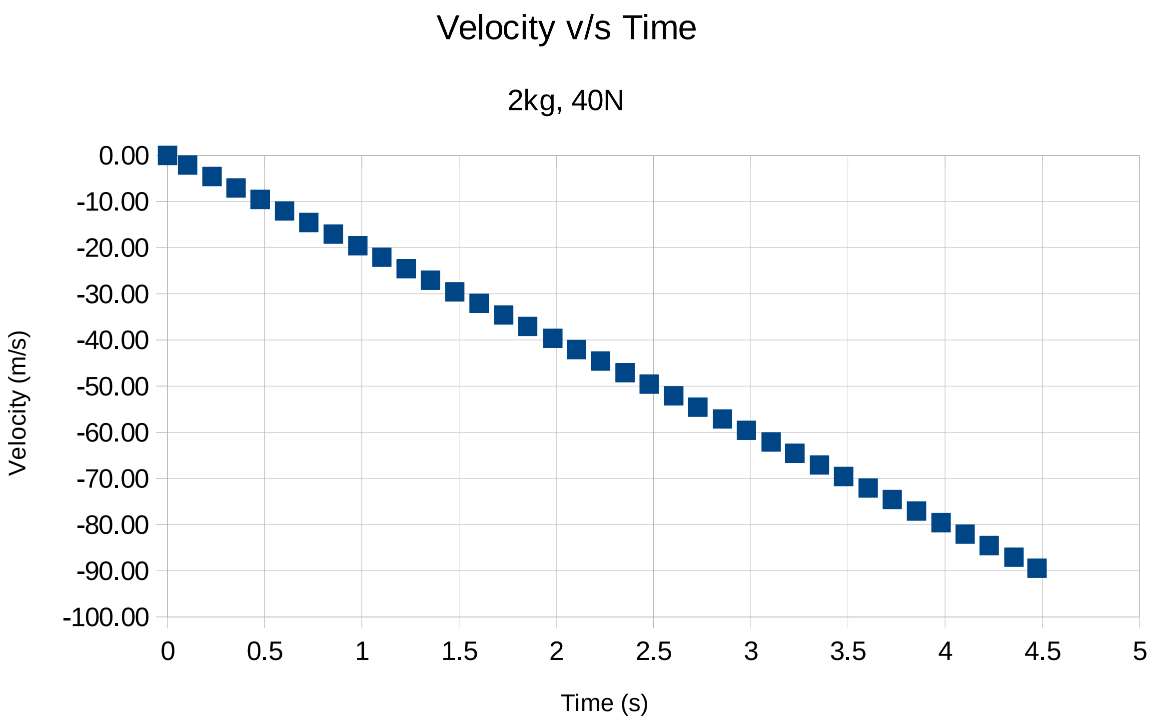
Force (N)	Mass (kg)	Time (s)	Final Velocity (m/s)
10	2	8.945	-44.721
20	2	6.325	-63.246
40	2	4.473	-89.443
10	1	6.391	-63.750
10	2	8.945	-44.721
10	4	12.650	-31.623

Data Analysis and Questions

1. For the first three data sets (3 different forces), plot the velocity vs. time graph in excel. The velocity should be on the vertical axis, while the time is on the horizontal axis. Make sure all the proper titles and units are displayed.


Velocity v/s Time
2kg, 10N
Velocity (m/s)
0.00
-5.00
-10.00
-15.00
-20.00
-25.00
-30.00
-35.00
-40.00
-45.00
-50.00
0.000
1.000
2.000
3.000
4.000
5.000
6.000
7.000
8.000
9.000
10.000
Time (s)


Velocity v/s Time
2kg, 20N
Velocity (m/s)
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
-60.00
-70.00
0.000
1.000
2.000
3.000
4.000
5.000
6.000
7.000
Time (s)



2. What is different about each of the graphs? How can you interpret the change in each graph?

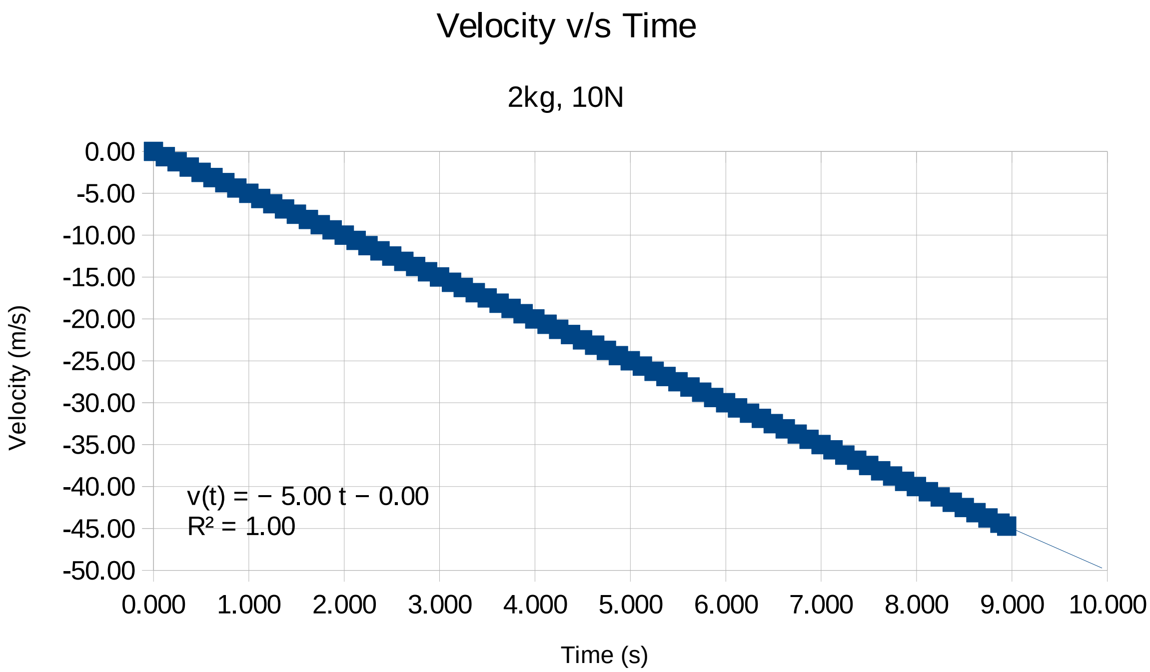
The graphs have different slopes, increasing in absolute value as more Force is applied to the object.

3. What kinematic equation should we fit this graph to, if we want to determine the acceleration of each run?

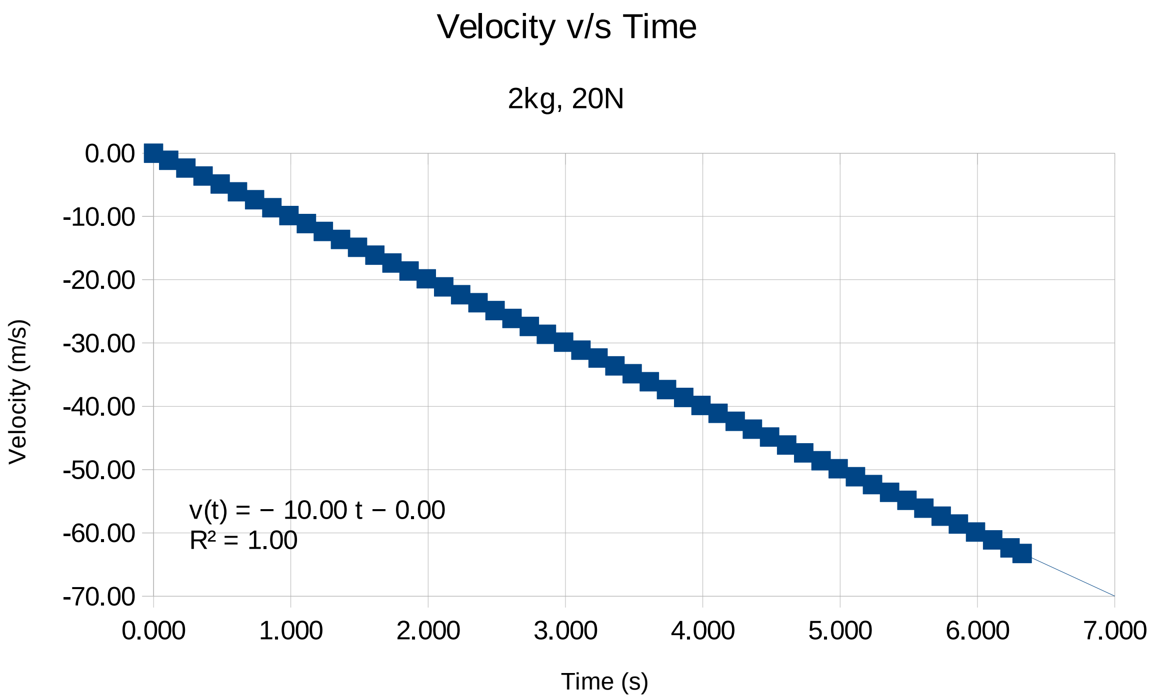
We can use Newton's 1st equation of motion: $v = u + at$

4. Fit the graph and determine the acceleration for each of the three runs. Paste the graph below and make sure it has the

proper titles, units, trendlines, equation of the line of best fit, and the R-squared value.

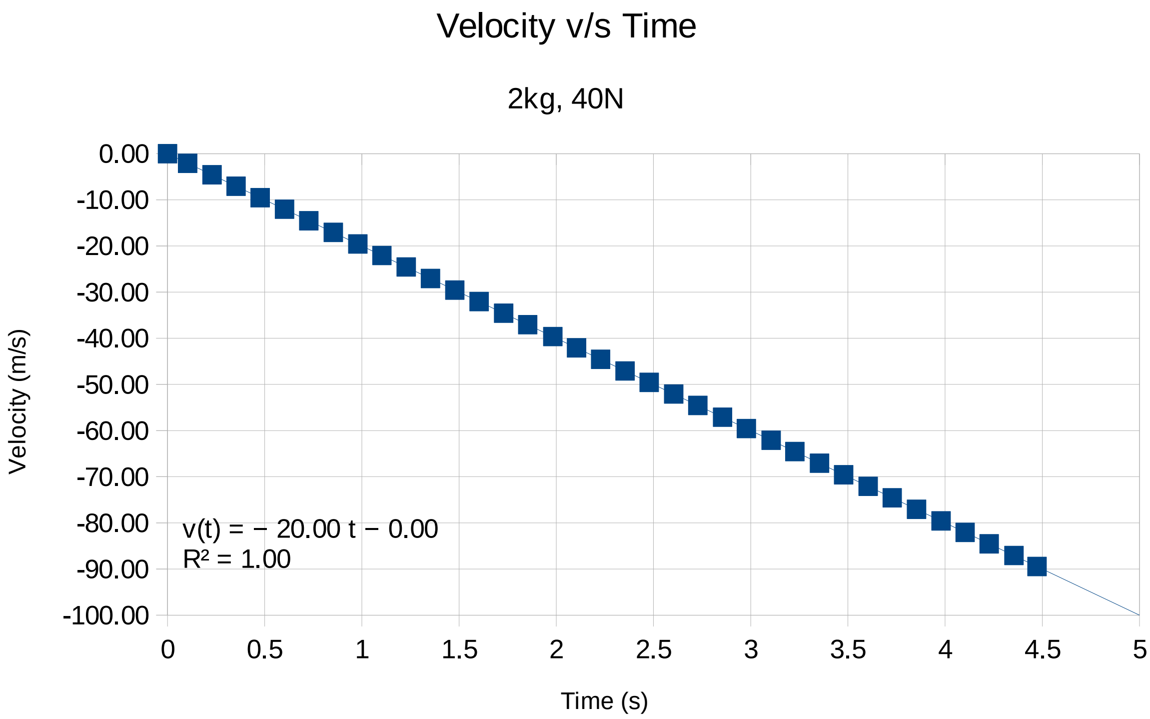


$a = -5 m/s^2$



Velocity v/s Time
2kg, 20N
Velocity (m/s)
Time (s)
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
-60.00
-70.00
0.000
1.000
2.000
3.000
4.000
5.000
6.000
7.000
v(t) = − 10.00 t − 0.00
R² = 1.00

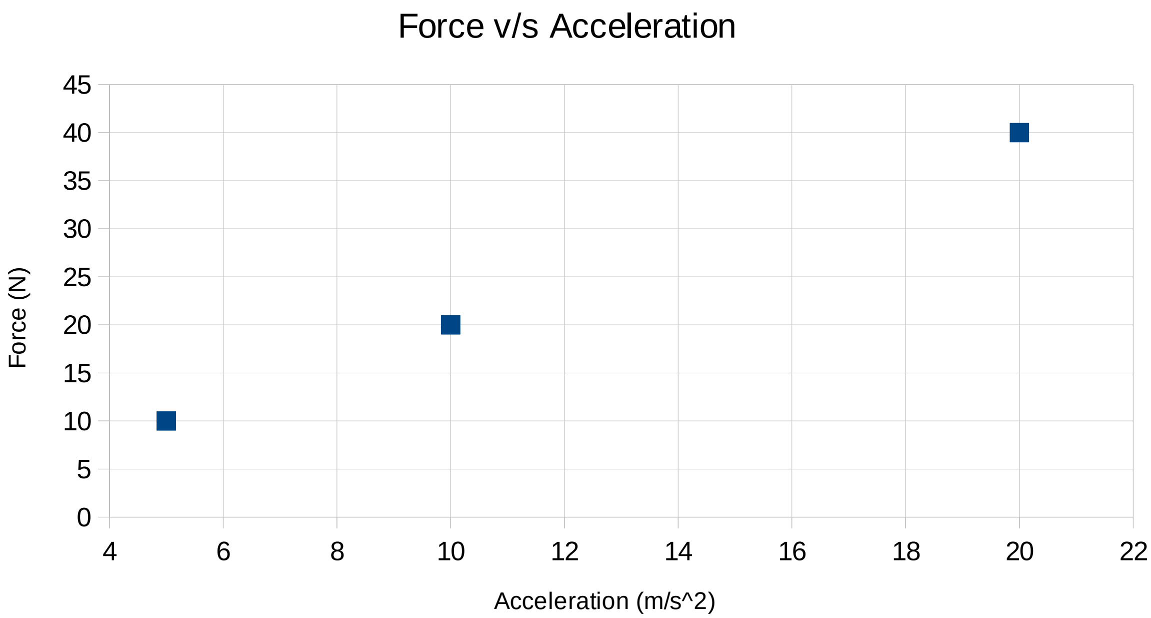
$a = -10 m/s^2$



Velocity v/s Time
2kg, 40N
Velocity (m/s)
Time (s)
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
-60.00
-70.00
-80.00
-90.00
-100.00
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
v(t) = − 20.00 t − 0.00
R² = 1.00

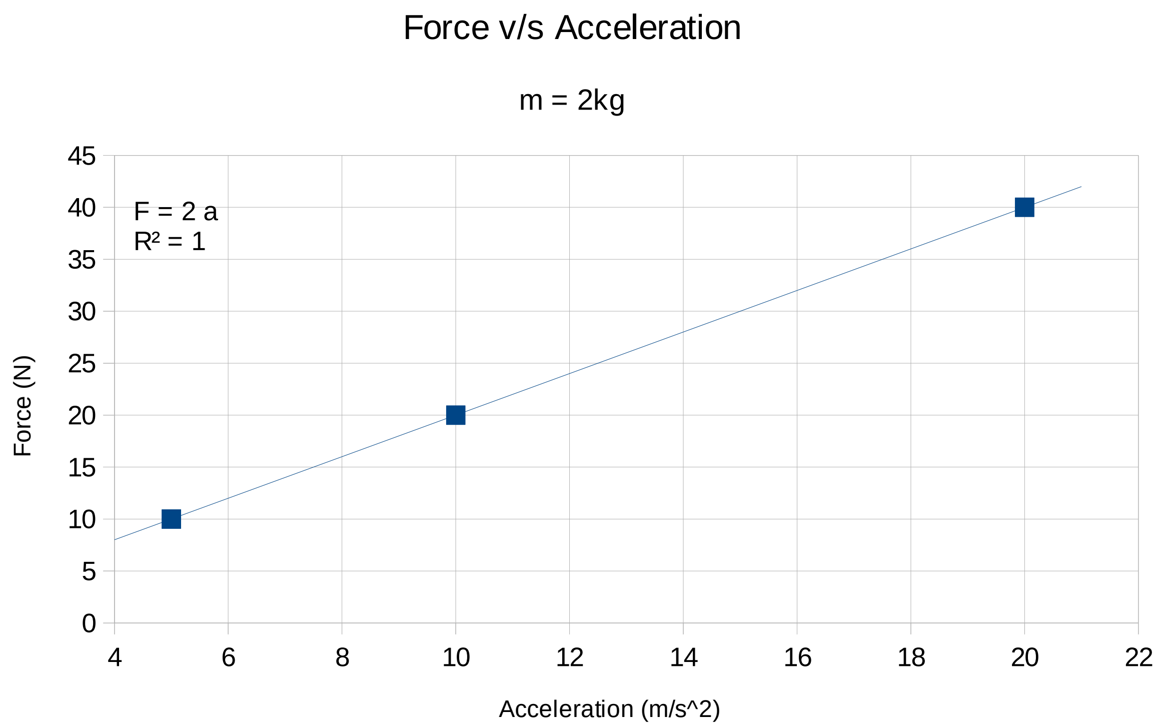
$a = -20 m/s^2$

5. Now that you have the acceleration of the object for each of the applied forces, plot the force vs. acceleration graph with force on the vertical axis and acceleration on the horizontal axis. Make sure the graphs have the proper titles and units.



6. What kind of trend does this plot present? (linear, quadratic, exponential, etc.) Compare your answer to Newton's Second Law $(F = ma)$. Do they agree with one another?

The graph is linear.

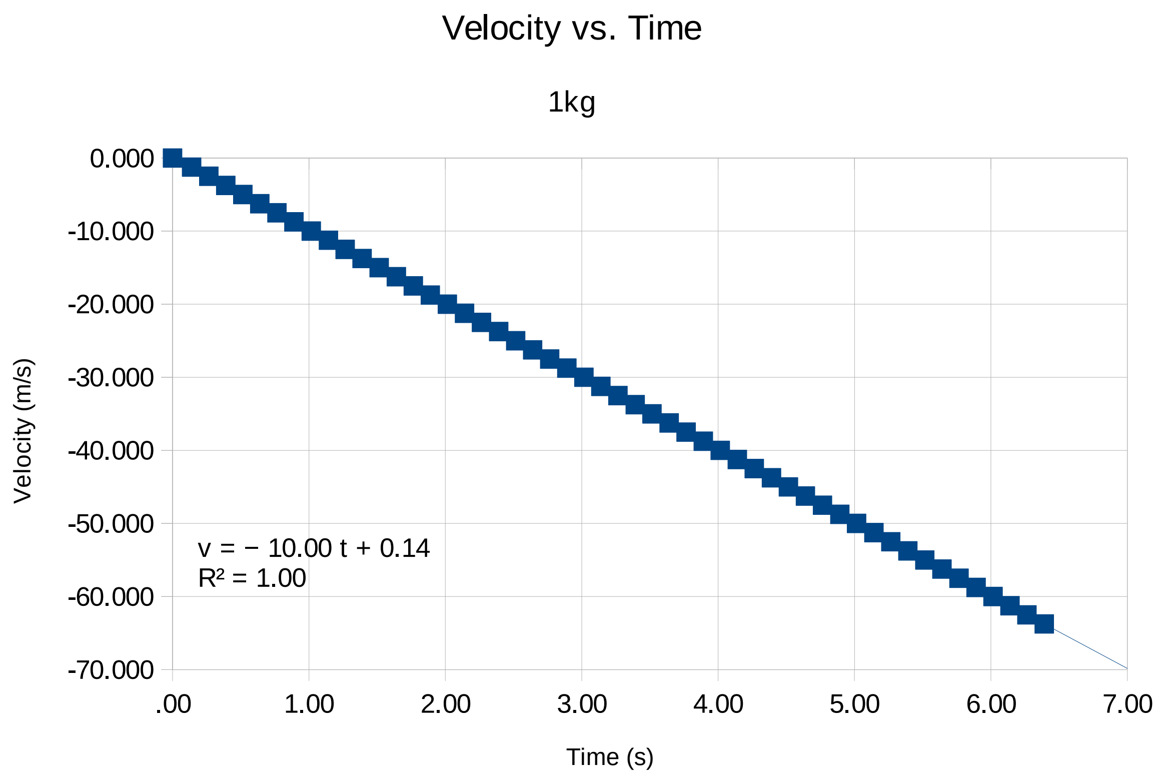


It agrees well with Newton's Second law.

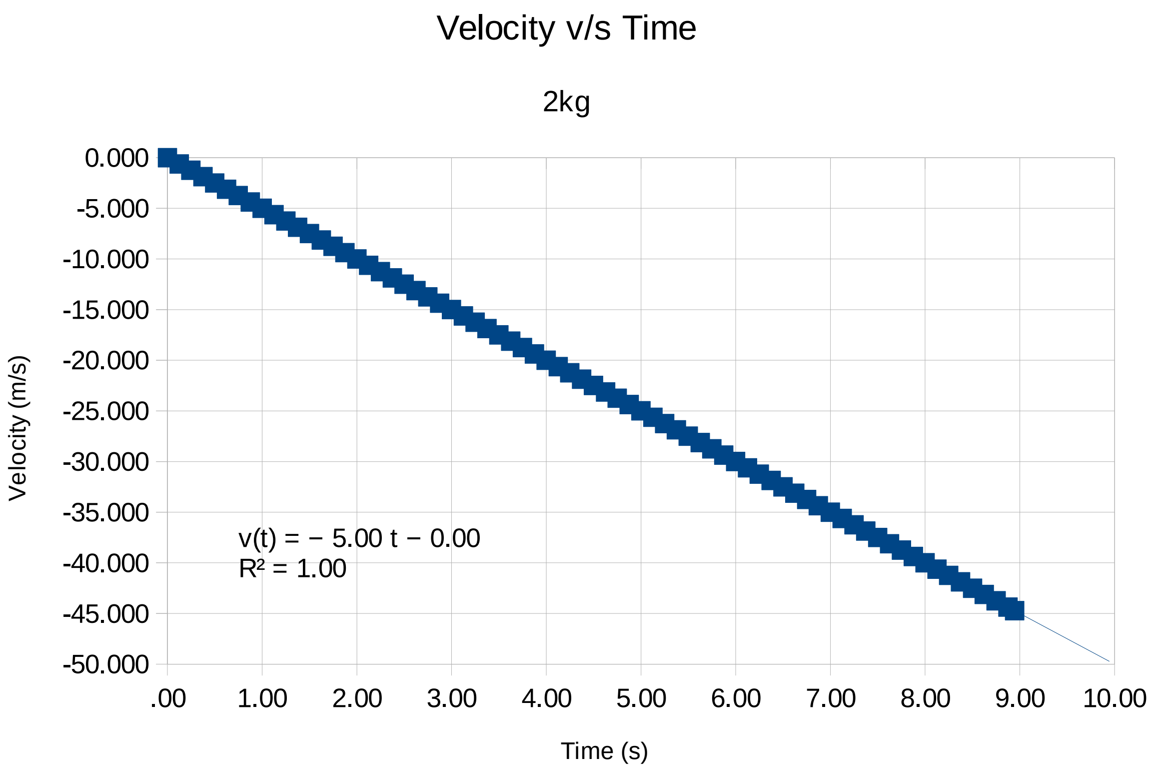
7. Fit to the trend mentioned in your answer above and determine the mass of the object. Does this agree with the settings used in the experiment?

The trend line predicts the mass to be 2kg, which agrees with the settings used in the experiment.

8. Now plot and fit the velocity vs. time graphs for each of the three runs with different masses. Determine the acceleration of each of the runs. Make sure each of the graphs have the correct titles, units, trendlines, equation of the line of best fit, and the R-squared value. Paste the graphs below.

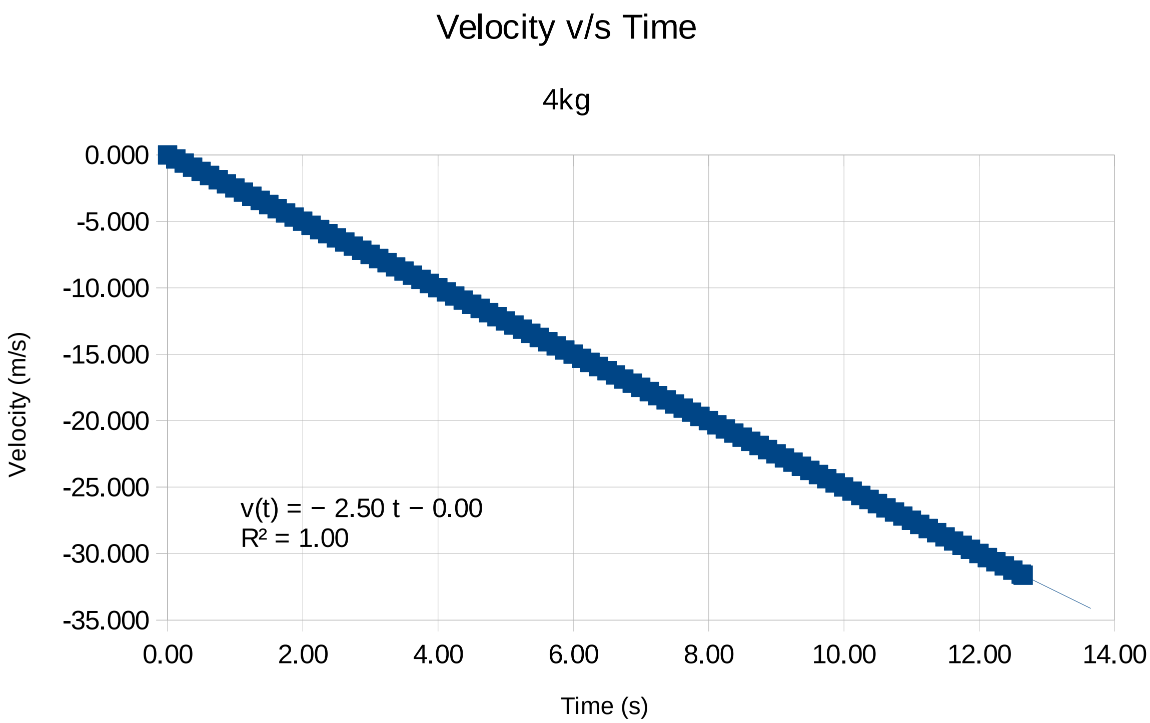

Velocity vs. Time
1kg
0.000
-10.000
-20.000
-30.000
-40.000
-50.000
-60.000
-70.000
Velocity (m/s)
v = − 10.00 t + 0.14
R² = 1.00
.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
Time (s)

$a = 10.00 m/s^2$



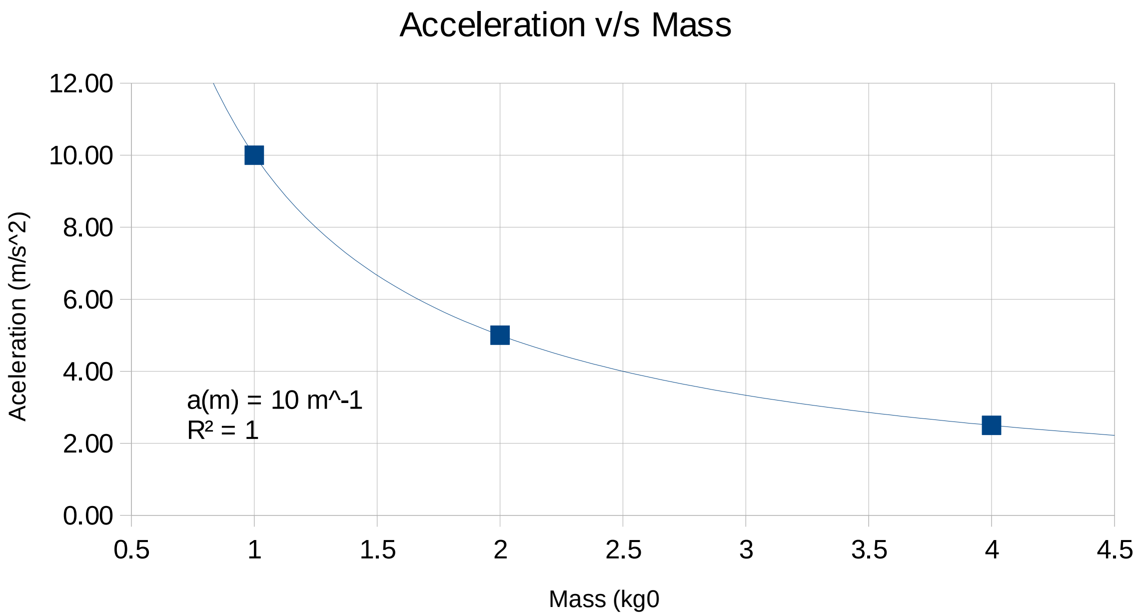
Velocity v/s Time
2kg
0.000
-5.000
-10.000
-15.000
-20.000
-25.000
-30.000
-35.000
-40.000
-45.000
-50.000
Velocity (m/s)
v(t) = − 5.00 t − 0.00
R² = 1.00
.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Time (s)

$a = 5.00 m/s^2$



$a = 2.50 m/s^2$

9. Now plot the mass vs. acceleration, where the acceleration is on the vertical axis and the mass is on the horizontal axis. What can you conclude about the acceleration as the mass is increased? Does this agree with Newton’s Second Law?



We can conclude that as mass increases the acceleration dereases, this agrees with Newton's second law.