Newton's Second Law of Motion for Planes

Sir Isaac Newton was a prominent scholar of the late 1600s and early 1700s. He was interested in various subjects, including math, astronomy, physics, and theology. Some of his significant accomplishments include inventing the first reflecting telescope, identifying gravity as a universal force, developing the generalized binomial theorem, and serving in Parliament. He also wrote three fundamental laws of motion, which are the foundation of classical mechanics.

Law #1: An object at rest remains at rest unless acted upon by an outside force.

Law #2: When the forces acting on an object are not balanced, the acceleration of that object is dependent on the net force acting on the object and the object's mass.

Law #3: When one object interacts with an object with force, there is an equal and opposite reaction from the second object.

This activity is based on the second law of motion, which you will apply to airplanes flying above your school.

Exercises

| Reg # | Model | First Observation | | Second Observation | | weight |
		Speed (knots)	Time	Speed (mph)	Time	

1. When your teacher pauses the screen, collect all the data on the left-hand side of the dark line.
2. Go to flightaware.com
3. Put the call sign of a flight into the Search by Flight # box. This should take you to the plane which was flying in your location. Scroll down the page until you see the graph (located immediately beneath the map). In the top right corner, you will see the speed in mph. IMPORTANT: Both observations need to be at the same altitude. If the altitude is just a little different, it is okay. However, if there is a significant difference, wait a little while to see if the plane returns to its original altitude. Then, collect that data and record the time.
4. Continue collecting the second observation data for all planes.

5. To find the plane's weight, place the model into the google search box. Select a webpage that has the information you need. It would be best to record the maximum weight at takeoff in the box. While this is not entirely accurate, it is close enough for our purposes.

Conversions

The data you collected above needs to be converted before it can be used in the equation. The required conversion factors are listed below. However, you may need to use more than one of these factors to convert a piece of data to the required form.
1. To convert knots to mph, multiply the number of knots by 1.15
2. To convert weight to mass

    m = weight (N)/acceleration of gravity
    acceleration of gravity = 9.8 m/s^2

3. To convert miles to meters, multiply the number of miles by 1609.34
4. To convert pounds to Newtons, multiply the number of pounds by 4.448
5. To convert hours to seconds, multiply the number of hours by 3600

Use the instructions above to convert your data. Record all converted units in the table below.
1. Convert the speeds from the first observation from knots to m/s.
2. Convert the speeds from the second observation from mph to m/s.
3. Convert the weights to mass.
4. Lastly, you need the change in time for the force calculation, but this must be in seconds. So, determine how many minutes passed and convert that to seconds.

Reg #	Model	First Observation Speed (m/s)	Second Observation Speed (m/s)	Mass (kg)	Change in time (s)

Calculating the Force

According to Newton's Second Law of Motion, the force acting on a moving object can be determined by multiplying the object's mass by acceleration.   F = m * a
Before calculating the force, let's take a moment and consider what this force represents. On a plane, there are forces in two directions, the horizontal or x and the vertical or y. In the horizontal, there are two forces, drag, and thrust. Drag is the force that acts in opposition to

thrust. It pushes the plane backward and is caused by friction and differences in air pressure. Thrust is the force that moves an aircraft in a forward direction and is created by the engines. In the vertical, there are also two forces. The force of gravity is pulling the plane back to Earth. Acting in opposition to gravity is lift which is the force pushing up on the bottom of the aircraft. This force is created by air pressure pushing up on the bottom of the wings.

If a plane is flying at a constant elevation, the lift and gravity forces cancel each other out. That is why you were instructed to collect data for the second time when the altitude was the same as the first data point, which leaves drag and thrust. As long as the plane moves in a forward direction, the thrust force is larger than the drag force. Therefore, in the calculations below, the F represents the thrust.

Now you need to calculate the amount of force present for each of the planes.

$$F = m * a$$

F = force
m = mass
a = acceleration

You converted the plane's weight to mass above, but you don't have a number for acceleration. However, acceleration is just the change in velocity over the change in time. We will use speed instead of velocity, but these two values are not quite the same. Velocity is a vector, meaning there is a direction associated with the value. That is the only difference between speed and velocity, so since direction doesn't factor into the force equation, we can ignore it for the calculation. Just remember to indicate which direction the force is traveling in your answer. Use the following equation and calculate the force associated with each plane. Place your answers in the table below.

$$F = m * ((v_1 - v_0)/(t_1 - t_0))$$

F = force
M = mass
v_1 = velocity from the second data point
v_0 = velocity from the first data point
Remember, we are using speed for velocity
t_1 = time from the second data point
t_0 = time from the first data point

Reg #	Model	Force (N)

Back to Where We Started

Now you know the thrust force that was acting on each of the planes in your area. Let's finish this activity by remembering how we got this information.

1. How were you able to track airplanes in your area? Your answer should be a short essay that includes both what happened in your classroom and on the plane. Be sure to mention not only the hardware but how it works.