STEM: On The Fly!
Student Activity

Name ________________

Class ________________

Open the TI-Nspire document *STEM_On_The_Fly.tns.*

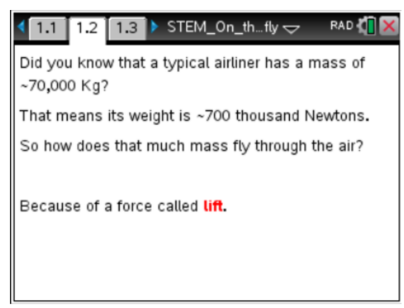
In this activity, you will explore the math and science behind how airplanes fly. You will also gain some insight into what academic path you should take to become a pilot. Simulations will allow you to experience the parts of the plane that control lift and thrust.

Meet Alex Livingston and Adam Schindall

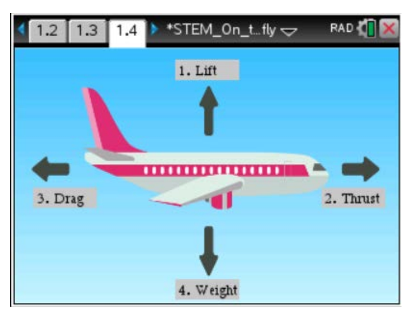
Alex is a high school student and pilot in training. He is a member of the Civil Air Patrol and has flown gliders and single prop planes. Alex is considering a career in aviation as a commercial airline pilot. Recently Alex made a trip to Dallas to tour a major airline carrier. He spoke with a commercial airline pilot named Adam Schindall.

Schindall is known as a ***check airman***. A check airman is responsible for working with newer pilots to train them and evaluate their skills in a flight simulator before they become actual commercial airline pilots. Adam has thousands of hours of flight experience. Adam explained that a strong foundation in math and science is essential for any student considering a career in aviation as a pilot.

Move to pages 1.2 to 1.4 on the handheld.



1. This page introduces the idea that something as heavy as an airplane can actually lift into the air and fly long distances through a process called, **lift**.



2. Pages 1.3 and 1.4 explore the four forces associated with an airplane; lift, thrust, drag, and weight. Lift and thrust achieve upward and forward motion while drag and weight resist upward and forward motion. On page 1.4, select the terms to explore the four forces of flight.

Question 1.

Which of the following *best* describes the interaction between drag and thrust?

A. Drag and thrust are additive, both contributing to the forward motion of the plane.

B. Drag is air resistance which is counter force to thrust.

Question 2.

In which of the following situations is drag *most* useful?

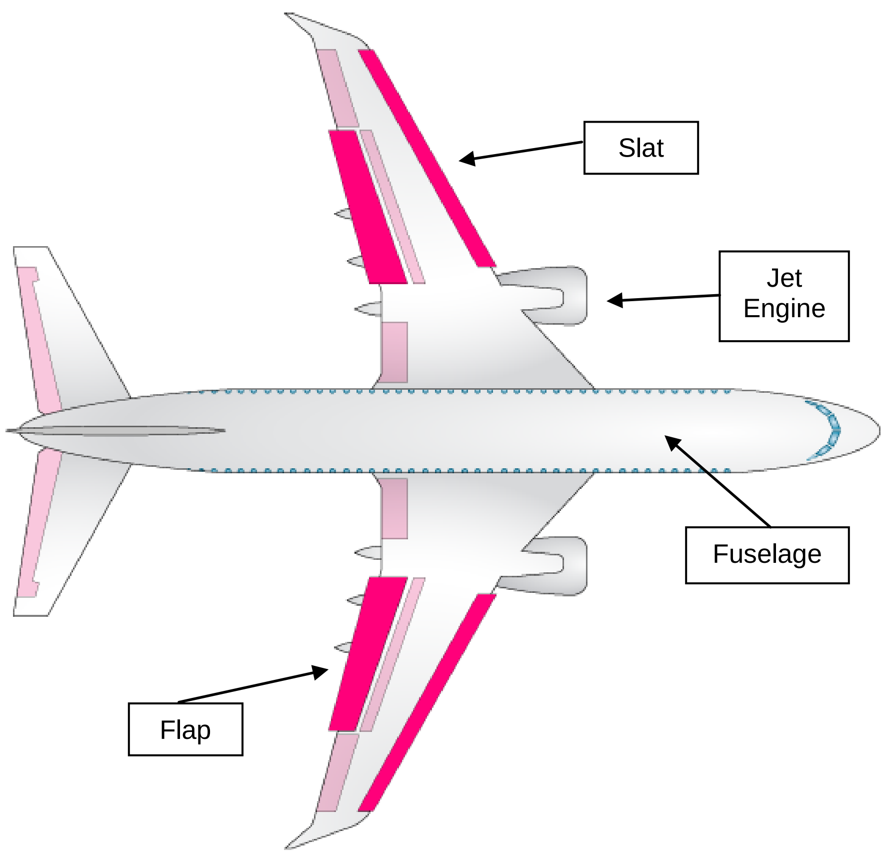
A. Drag is most useful during takeoff

B. Drag contributes most during the cruising phase of the flight

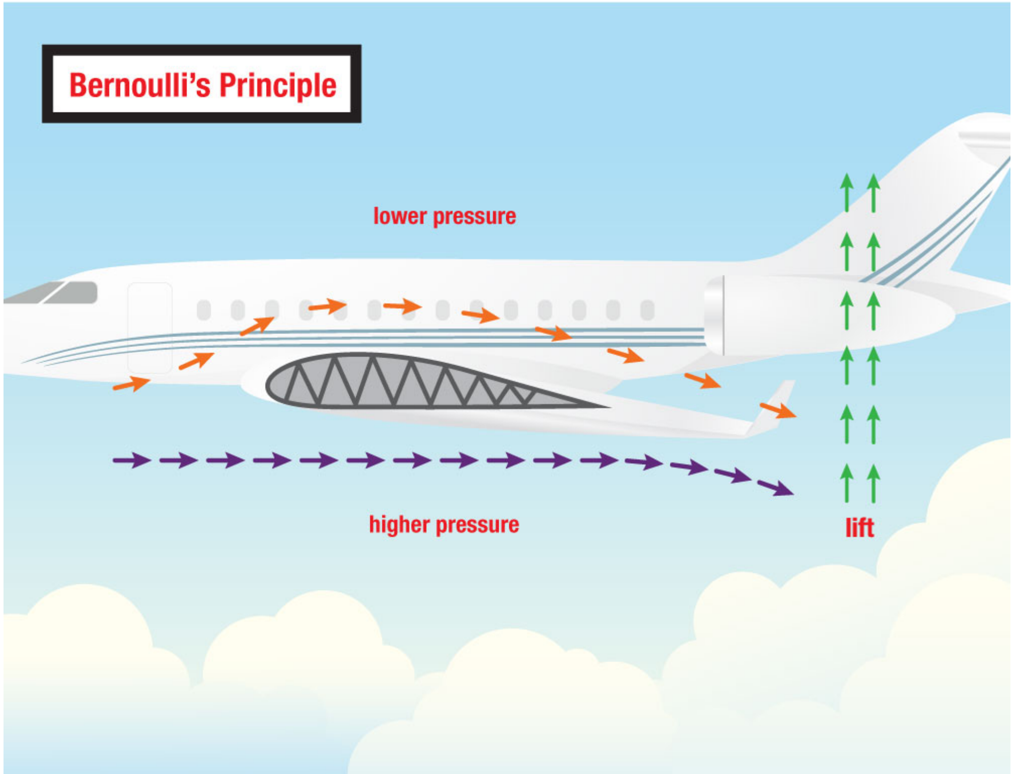
C. Drag helps to slow the plane down during the landing portion of the flight

How wings create lift

3. Planes control lift by increasing or decreasing thrust and/or changing the amount of surface area of the wings. In order to change the surface area of the wings, the pilot can deploy the slats and flaps. Slats are the long thin extensions on the leading edge of the wing. Flaps are the shorter, wider extensions on the trailing edge of the wing.



4. One of the mechanisms behind a plane lifting into the sky is based on **Bernoulli's principle**. Bernoulli discovered that as a fluid's velocity increases, that fluid's pressure on the surrounding area decreases. So, in the case of airplanes, the fluid is air. Because the shape of the top of the wing is more curved as compared to the shape of the bottom of the wing, air above the wing has a tendency to move faster as compared to the air below the wing. As a result of the differences in air speed between the top and bottom of the wing, there is also a resulting difference in air pressure. There is less pressure above the wing than below the wing resulting in the plane being pushed up from the bottom of the wing. We call this phenomenon **lift**.

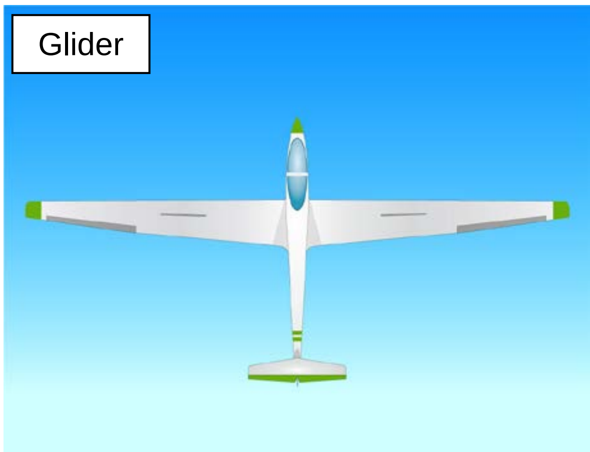


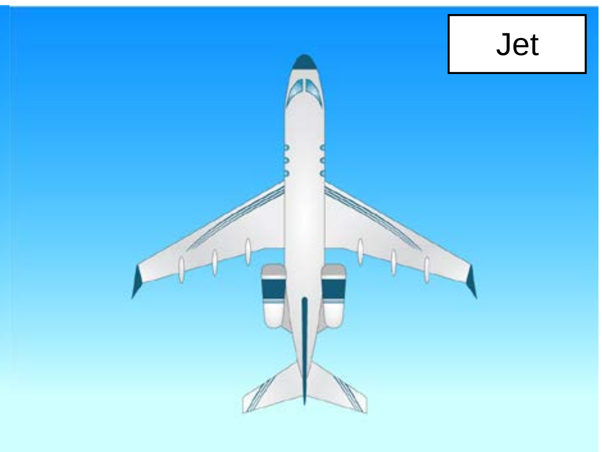
Note –**Newton's third law of motion**, which explains how every action has an equal but opposite reaction, also plays a role in lift since the air hitting the bottom of the wing, when the wing is as at an angle relative to the plane's motion, will push against that wing resulting in lift. The combination of air pressure differences above and below the wing and Newton's third law of motion cause the air at the trailing edge of the wing to move at a slight angle downward. We call this motion of the air at the trailing edge "**downwash**".

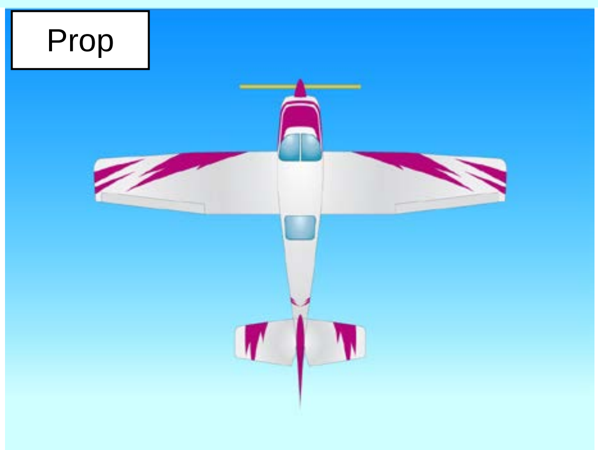
**Misconception Alert!* - In some representations of Bernoulli's principle, it is implied that two air molecules that are split between the top and bottom of the wing will end at the same location at the trailing edge with the top air molecule having to move faster because of a longer distance due to the curvature of the top portion of the wing. This "equal transit theory" has been shown to be incorrect. The top air molecule moves much faster than the bottom due to several variables and will find the trailing edge much sooner than the bottom air molecule.*

Not all planes are equal:

5. All planes have wings but not all wings are the same. Smaller planes, such as gliders, require long narrow wings to interact with more air. Smaller powered planes like single-propeller or “prop” planes have shorter wider wings. Planes with a lot of thrust, such as jets, don’t require really long wings. There is an obvious relationship between thrust and wing area.







Question 3.

Since gliders don’t have engines, how might they achieve enough thrust to generate lift?

Question 4.

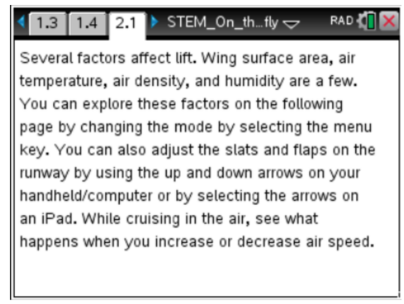
Complete the following sentence: As air velocity increases, air pressure _________________________.

Question 5.

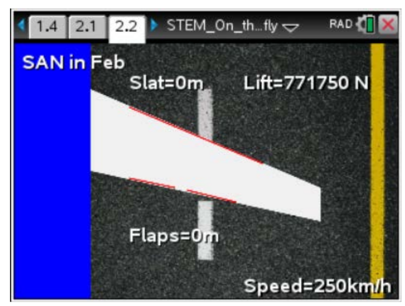
Which of the following are primary mechanisms for lift?

- **A.** Bernoulli's Principle
- **B.** Gravity
- **C.** Newton's third law of motion
- **D.** All of the above

Move to pages 2.1 to 2.2 on the handheld.



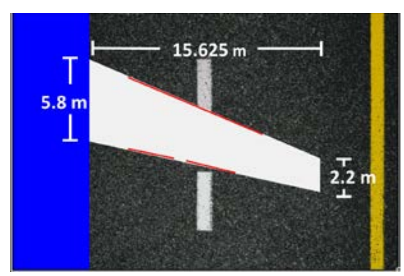
6. These pages explore what happens to the force of lift when the slats and flaps are deployed. You can also explore the differences in lift when the plane takes off from different airports in different weather conditions.



7. On page 2.2 there are three different modes for you to explore. Use the menu to change between modes. Press the up/down arrows to extend/retract the flaps and slats. The flaps and slats are parallelograms with the height equal to the extension. The width of the slat is 12.5 meters and the width of each of the flaps is 5 meters.

Question 6.

Use the diagram to the right to compute the area of one wing of the airliner. All the units are in meters and the wing is a trapezoid. Report your answer in square meters.



Question 7.

Set the mode to SAN (San Diego) and determine the total area of both wings for each position of the flaps and slats, and fill out the table with the correct area and corresponding lift.

Base Area one wing (m^2)	Slat Area one wing (m^2)	Flaps Area one wing (m^2)	Total Area one wing (m^2)	Total Area both wings (m^2)	Lift (N)	$\frac{\Delta L}{\Delta A}$
	0	0				----

Question 8.

How much does the total area of both wings change between row 1 and row 2 of the table? How much does lift change?

Question 9.

How much does the total area of both wings change between row 3 and row 4 of the table? How much does lift change?

Question 10.

Calculate the change in lift with respect to change in area for each row of the table $\frac{\Delta L}{\Delta A} = \frac{L_2 - L_1}{A_2 - A_1}$. What do you notice about the rate of change of lift with respect to area, $\frac{\Delta L}{\Delta A}$, among the rows of the table?

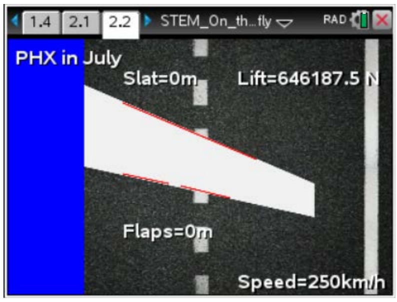
Question 11.

What does this mean about the relationship between lift and area?

Question 12.

Write an equation that could be used to determine the lift for this aircraft during takeoff in San Diego, given a certain wing area and a velocity of 250 $\frac{km}{h}$.

Question 13.



Use the menu to change the takeoff mode to Phoenix, AZ. During the summer in Phoenix the air can reach extreme temperatures. When temperature rises, air density decreases which changes the relationship between lift and surface area.

Complete the table below for the lift vs. area relationship for an extremely hot day in Phoenix. Use the same area values as the previous table since this is the same plane.

Total Area both wings (m^2)	Lift (N)	$\frac{\Delta L}{\Delta A}$

Question 14.

How is the relationship between area of the wings and lift different than in San Diego?

Question 15.

In the given conditions, does it require more area to generate the same lift in Phoenix or San Diego assuming the same takeoff velocity?

Question 16.

Use the menu to change to cruising mode. At cruising speeds, a pilot would not extend the flaps or slats, however, often the velocity can change, and this effects the lift generated. Use the up and down arrow to change the velocity and note the relationship between velocity and lift.

Velocity ($\frac{km}{h}$)	Lift (N)	$\frac{\Delta L}{\Delta V}$

Question 17.

How much does the velocity change between row 1 and row 2 of the table? How much does lift change?

Question 18.

How much does the velocity change between row 3 and row 4 of the table? How much does lift change?

Question 19.

What do you notice about the rate of change of lift with respect to velocity, $\frac{\Delta L}{\Delta V}$, from row to row in the table?

Question 20.

What does this mean about the relationship between lift and velocity?

Question 21.

How is the relationship between lift and velocity different than the relationship between lift and area?

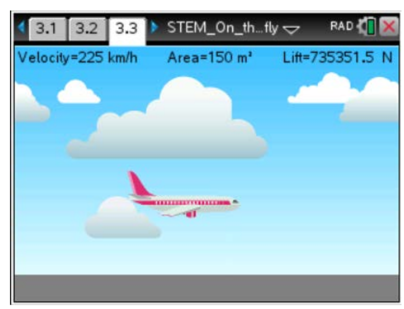
Question 22.

Use the lift equation to show why the relationship between lift and area you found in part () makes sense, assuming all the other variables remain constant. The lift equation is $L = C_L \frac{\rho * V^2}{2} A$ where C_L is the coefficient for lift of the wing, ρ, is the air density in $\frac{kg}{m^3}$, V, is velocity in $\frac{m}{s}$, and A is the surface area of the wing in m^2.

Question 23.

Using the lift equation and the assumption that all the other variables remain constant, explain why your answer makes sense for the relationship between lift and velocity.

Move to page 3.1 to 4.2.



8. These pages allow you to fly a plane using velocity and the surface area of the wing variables. Try to change these variables to a point where the plane will lift-off and fly.

Going Further

Research and explore other parts of an airplane such as the ailerons, spoilers, rudder, and elevators which help with movements such as yaw, pitch, and roll. In addition, identify 2 additional careers in aviation outside of being a pilot.