

Four forces on an airplane

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TOP: An airplane pictured on June 30, 2016. Courtesy of Pexels. BOTTOM: Four forces on an airplane. Courtesy of NASA.

A force may be thought of as a push or pull in one direction. A force is a vector quantity, which is a type of measurement that refers to both a direction and a magnitude. Magnitude is the measure of how strong the force is. When describing forces, we need to state both their magnitude and their direction.

The forces that act on an airplane in flight are weight, lift, drag and thrust.

Weight

Weight is one of the four forces on an airplane in flight. This force is always directed toward the center of the earth. The magnitude of the weight depends on the mass of all the airplane's parts, plus the amount of fuel, plus any payload on board (people, baggage, etc.). The weight is distributed throughout the airplane. But we can often simplify the picture, and imagine all that mass acting at one single point. This single point is called the center of gravity. It won't always be located at the exact center of the airplane, but will be closer to where the most weight is concentrated.

Two major problems must be addressed before the plane can fly. First, the weight of the object has to be met by an opposing force, which lifts the object. Second, the object in flight has to be kept under control. During flight, an airplane's weight constantly changes as the aircraft consumes fuel, which moves the plane's center of gravity. To keep the airplane balanced, the pilot must constantly adjust the controls.

Lift

Airplanes produce an opposite force called lift to overcome the weight force. Lift is created by the motion of the airplane through the air. It is an aerodynamic force, which is a force exerted on an object by the air through which the object is moving. "Aero" means air, and "dynamic" means motion.

Lift is directed upward from the direction of flight. Its magnitude depends on the aircraft's shape, size and velocity, which is the speed in a given direction. As with weight, each part of the aircraft contributes to the aircraft lift force. Most of the lift is generated by the wings. Aircraft lift acts through a single point called the center of pressure. The center of pressure is an imaginary point, just like the center of gravity. But while the center of gravity is the point where most mass is concentrated, the center of pressure is where the most pressure is concentrated.

The lift force is important for solving the problem of control in an aircraft. It helps the pilot control the three ways in which a plane can move, which are roll, pitch and yaw. A plane pitches when it turns up or down and yaws when it turns left or right. The third direction in which an aircraft moves is by rolling on itself, or rocking from side to side.

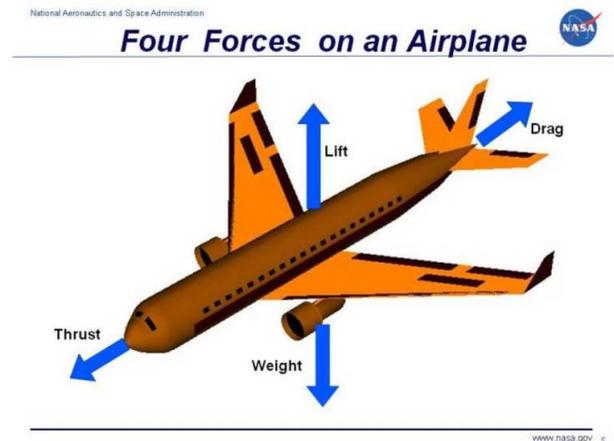
Drag

As the airplane moves through the air, there is another aerodynamic force present. The air the plane is flying through resists the motion of the aircraft. The resistance force is called drag. Drag is directed against the flight direction. Some elements that affect the magnitude of the drag force are the shape of the aircraft, the "stickiness" of the air and the velocity. Like lift, drag acts through the aircraft's center of pressure.

Thrust

Since drag is what pulls the aircraft back, another force is needed to move it forward. Airplanes are able to generate a force called thrust. The magnitude of the thrust depends on many different factors, including the type of engine, the number of engines and the throttle, which is used to control the engines' power.

For jet engines, thrust results from the hot gas rushing out of a piece of equipment called the nozzle. As explained by Newton's Third Law of Motion, every action has an equal and opposite reaction. This means that when hot gas goes out the back of the aircraft, it generates an equal and opposite force. This force is the thrust, which pushes toward the front. This means that the direction of thrust is the opposite direction from the hot gas.



Balance

The motion of the airplane through the air depends on the strength and direction of the forces described above. If the forces are balanced, the aircraft cruises at constant velocity. If the forces are unbalanced, the aircraft accelerates in the direction of whichever force has the greatest magnitude.

The main job of the engine is not to lift the airplane, but to act against the drag of the airplane. Only the airplane's wings are doing the lifting. Some aircraft called gliders have no engines at all, but still fly just fine. Paper airplanes are the most obvious example, but there are many kinds of gliders. For example, during re-entry and landing, the space shuttle is a glider: The rocket engines are used only to launch the shuttle into space.

Quiz

- 1 Why does an airplane's weight change during the course of a flight?
- (A) People get up and walk around in the aisles of the airplane.
 - (B) Baggage shifts in the cargo space below the airplane.
 - (C) Fuel is burned while running the engines of the airplane.
 - (D) The angle of the nose of the airplane changes during the flight.
- 2 Which statement would be most important to include in a summary of the article?
- (A) Thrust in a jet occurs in the opposite direction from hot gas.
 - (B) Drag is an aerodynamic force that is affected by the "stickiness" of the air.
 - (C) The movement of airplanes is governed by four forces: weight, thrust, drag, and lift.
 - (D) Unbalanced forces on an airplane may cause the plane to accelerate in one direction.
- 3 If drag is reduced, what would most likely happen?
- (A) No change will happen.
 - (B) Lift will increase.
 - (C) Weight will increase.
 - (D) Thrust will decrease.
- 4 Which two of the following selections from the article include central ideas of the article?
1. *A force may be thought of as a push or pull in one direction.*
 2. *A force is a vector quantity, which is a type of measurement that refers to both a direction and a magnitude.*
 3. *Weight is one of the four forces on an airplane in flight. This force is always directed toward the center of the earth.*
 4. *The motion of the airplane through the air depends on the strength and direction of the forces described above.*
- (A) 1 and 2
 - (B) 2 and 3
 - (C) 3 and 4
 - (D) 1 and 4
- 5 Airplane wings have flaps on them that move up and down, changing the surface area and shape of the wing. What force(s) does this change?
1. *thrust*
 2. *lift*
 3. *drag*
- (A) 2 only
 - (B) 1 and 2
 - (C) 2 and 3
 - (D) 1, 2, and 3

6 Read the paragraph from the section "Weight."

Two major problems must be addressed before the plane can fly. First, the weight of the object has to be met by an opposing force, which lifts the object. Second, the object in flight has to be kept under control. During flight, an airplane's weight constantly changes as the aircraft consumes fuel, which moves the plane's center of gravity. To keep the airplane balanced, the pilot must constantly adjust the controls.

Which two words would BEST replace "problems" and "addressed" in the first sentence?

- (A) issues; dealt with
- (B) concerns; attacked
- (C) complications; discussed
- (D) challenges; questioned

7 How are thrust and lift related?

- (A) The greater the thrust, the faster the air moves over the wings, generating lift.
- (B) The greater the lift, the stronger the force of gravity pulling the plane downward.
- (C) They are opposing forces that both act on an airplane.
- (D) Thrust and lift are not directly related.

8 Read the following paragraph from the section "Drag."

As the airplane moves through the air, there is another aerodynamic force present. The air the plane is flying through resists the motion of the aircraft. The resistance force is called drag. Drag is directed against the flight direction. Some elements that affect the magnitude of the drag force are the shape of the aircraft, the "stickiness" of the air and the velocity. Like lift, drag acts through the aircraft's center of pressure.

Which of the following phrases provides context clues to the meaning of the word "resistance"?

- (A) the motion of the aircraft
- (B) directed against the flight direction
- (C) some elements that affect the magnitude
- (D) through the aircraft's center of pressure