Earth & Space Science

Exploration of Extreme Environments: Flight

Science and Mathematics
Education Research Group

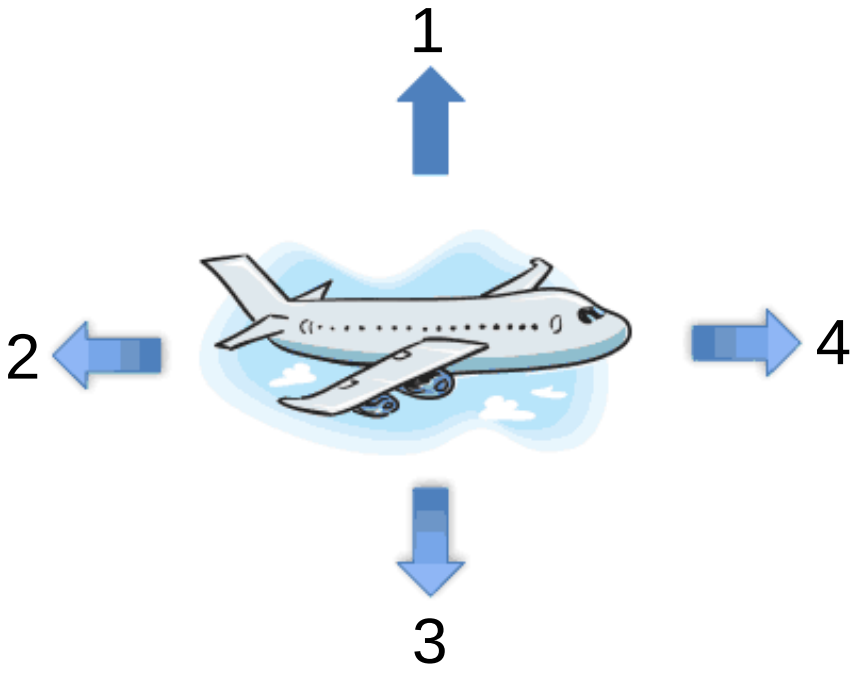
Supported by UBC Teaching and Learning Enhancement Fund 2012-2014

Flight

Flight I

Four forces act on a cruising airplane, each in a different direction.

Match each force with the direction in which it acts on a plane.



	1	2	3	4
A	gravity	drag	lift	thrust
B	lift	drag	gravity	thrust
C	gravity	thrust	lift	drag
D	lift	thrust	gravity	drag

Solution

Answer: B

Justification: The following four aerodynamic forces act on a plane in flight:

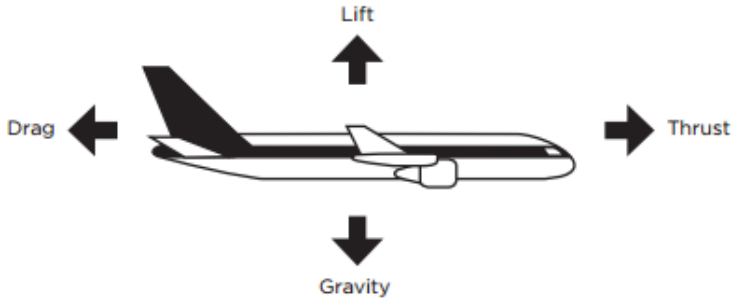
Lift – the force pulling the plane upwards

Gravity – the force pulling the plane down (also known as weight)

Thrust – the force pushing the plane forward

Drag – the force pushing the plane backward (air resistance)

These four forces are constantly working with and against each other while a plane is in flight.



Flight II

Which two forces must be **dominant** and outweigh the others in order for a plane to take off?

A. Gravity and thrust

B. Gravity and drag

C. Thrust and lift

D. Thrust and drag

E. Opposite forces must counterbalance each other

Press for hint

Forces are **counterbalanced** when they are <u>equal</u> and <u>opposite</u>.

Solution

Answer: C

Justification: For a plane to take off, the force of lift must be greater than the downward force of the earth's gravitational pull on the plane – essentially the plane's weight is keeping it on the ground.

Thrust from jet engines or propellers must be greater than the drag force acting on the plane.

For any plane to take flight, **thrust** and **lift** must be the two greatest forces acting on an airplane.

Solution Cont'd

Surprisingly, when an airplane is flying at a constant height and speed, the following is true:

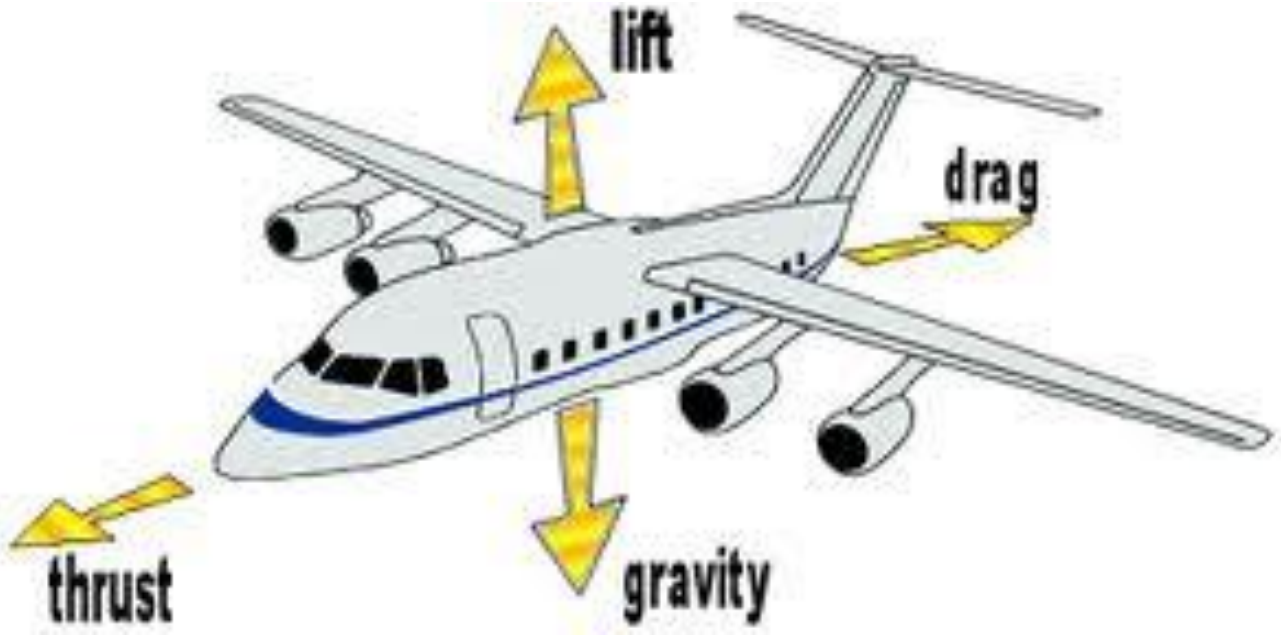
The force of thrust **exactly equals** the force of drag.

The force of lift **exactly equals** the force of gravity (or weight).

When two forces are **equal and opposite**, they are counterbalanced. See the following slide to learn more about counterbalanced forces.

Extend Your Learning: Vocabulary

Counterbalanced forces are two forces that are equal in magnitude (size) but opposite in direction. For example, if the opposing forces of lift and gravity were counterbalanced for a plane sitting on the tarmac, the plane would not be able to leave the ground.



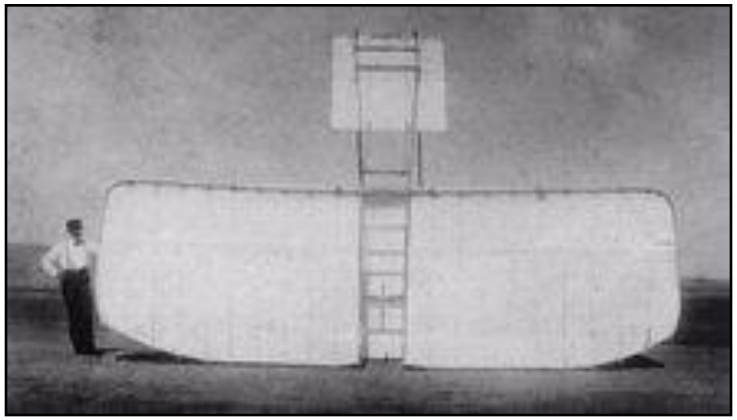
Extend Your Learning: Did You Know?

The Wright Brothers were the first people to experience flight by inventing airplanes. In the 1900s, ***The Glider*** was the first (of three) aircraft capable of flight. In 1901, a second glider was made – pictured to the right.

From these trials, the first plane to be mechanically powered and controlled was then invented. The Wright Brothers named it ***The Flyer***.

Click on the names to the right and explore more information about these two airplanes.

The Wright Glider



The* 1903 *Flyer

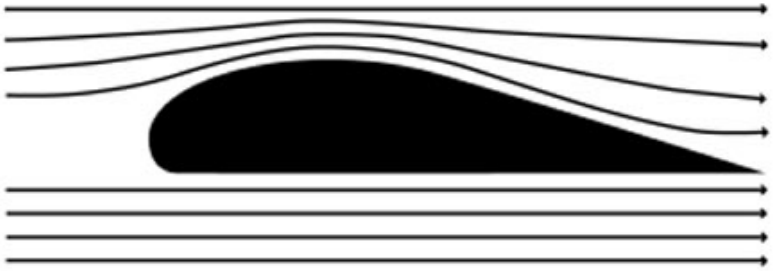
Flight III

Due to the shape of the wing (called an airfoil), air rushes over the top part of a wing faster than it moves across the bottom, flatter surface. The resulting pressure differences produce lift.

Which of the following diagrams accurately represents this principle?

A.

↑ Air speed = ↓ Pressure



↓ Air speed = ↑ Pressure

B.

↑ Air speed = ↑ Pressure

↓ Air speed = ↓ Pressure

Solution

Answer: A

Justification: Lift is the aerodynamic force that counteracts gravity and holds an airplane in the air. The wings are responsible for ensuring the lift force is greater than the gravitational pull of toward Earth.

Air is a fluid. This means that it can change velocity and speed to go faster or slower. When air moves around a wing, it goes either above or below the wing. The air travelling above the wing accelerates as it travels down the airfoil shape. Increased air speed results in lower pressure on top of the wing.

Solution cont'd

Below the wing, the opposite is true. Since the air speed is slower below the wing, pressure builds up here. It is this increased pressure under the wing that gives the plane lift.

The diagram below is an accurate representation of air speed and pressure above and below the wing of an airplane.

Bernoulli's Principle explains pressure increases below a wing in order to create

Extend Your Learning: Compare

The following images prove that nature has influenced how some technology is designed; in this case, an airplane's design!

Falcon

B-2 Stealth Bomber

Since a falcon is considered a predatory bird, do these photos give you an new appreciation for the term, ***birds of prey***?

Extend Your Learning: Experiment 1

There are a few ways to have a hands-on experience with Bernoulli's Principle

Materials	Two small strips of paper (approximately 5 cm by 20cm)
Procedure 1	• Place one strip of paper below your mouth • Blow air straight ahead
Procedure 2	• Hang two strips of paper parallel to each other, approximately 8 cm apart • Blow air in a straight line directly between the papers

What are your observations?

Extend Your Learning: Experiment 2

Materials

- 10-12 straight drinking straws
- 2 empty pop cans

Procedure

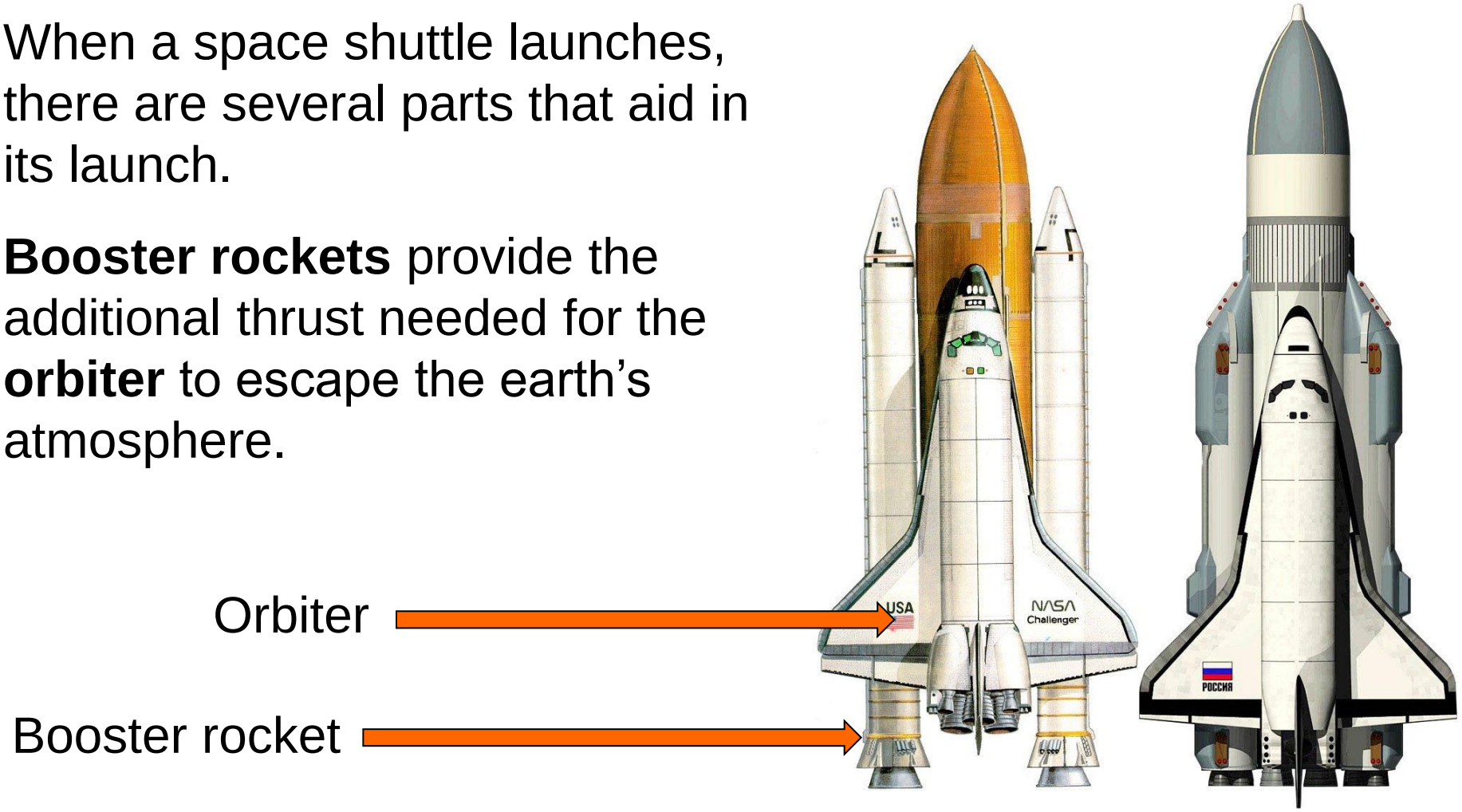
- Line up the straws, parallel to each other, approximately 1.5 cm apart on a flat surface
- Place the pop cans on the straws, about 8 cm apart
- Position your head so that you are level with the surface, and you can see between the cans
- Blow straight between the cans

What do you observe?

Flight IV

When a space shuttle launches, there are several parts that aid in its launch.

Booster rockets provide the additional thrust needed for the **orbiter** to escape the earth's atmosphere.



Flight IV Cont'd

What happens to booster rockets once they have used up all their fuel?

A. They stay attached and continue traveling with the orbiter
B. They remain attached to the launch pad after takeoff
C. They burn up in our atmosphere and disintegrate
D. They separate and descend on parachutes to land

Solution

Answer: D

Justification: Booster rockets (also called Solid Rocket Boosters, or SRBs) are required only for the first two minutes of launch. SRBs separate from the shuttle at an altitude of almost 45 kilometres. Once separated, they continue to travel upward (due to inertia) until they reach approximately 67 kilometres from the launch point on Earth.

Due to Earth's gravitational force, the SRBs then fall back through the atmosphere and are slowed down by a parachute system to prevent damage when they hit land. The rocket launch location is chosen to ensure SRBs will land in the ocean, away from humans.

Solution Cont'd

When objects travel from space back into the earth's atmosphere they will likely burn up and disintegrate due to friction. Because space is a vacuum, objects experience no drag when they travel through it. If an object in space travels close enough to Earth, it will get pulled in by Earth's gravity. This force of gravity, combined with the lack of drag causes these objects to travel at extremely high speeds. When objects travel from space into Earth's atmosphere, the friction they encounter travelling at such high speeds makes them catch fire.

Booster rockets do not escape Earth's atmosphere, so they do not experience enough friction for them to catch fire. If the booster rocket remained on the launch pad after take-off, they would only power the initial release of the rocket, which would not be able to leave the atmosphere.

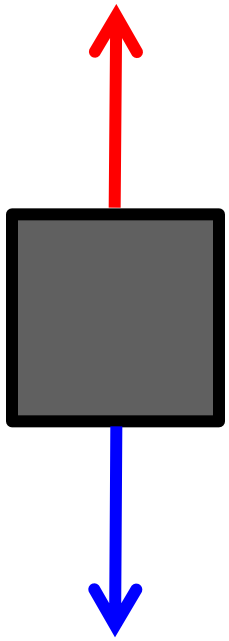
Extend Your Learning: Video

Title: Shuttle's Boosters Recovered in HD

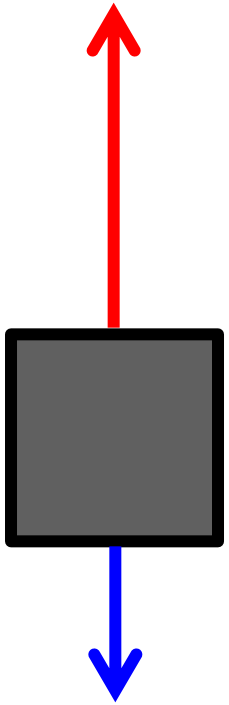
Flight V

Which diagram correctly represents the magnitude (size) of forces acting on a rocket immediately after it is launched?

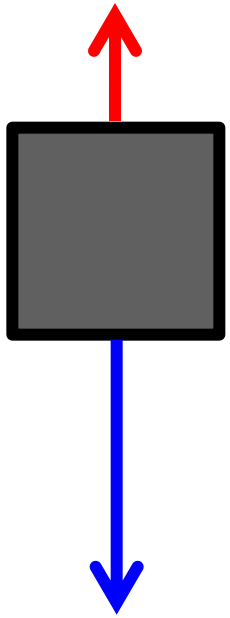
A.



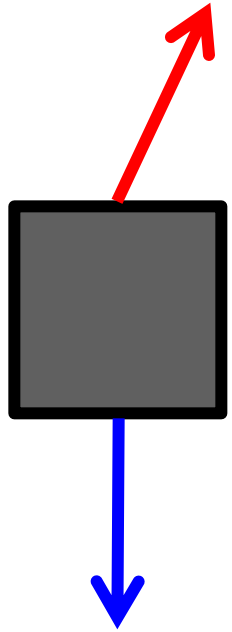
B.



C.



D.



Note: The grey square represents the rocket, the red arrow represents thrust and the blue arrow represents gravity (weight).

Solution

Answer: B

Justification: In order for a rocket to launch successfully, the thrust it experiences must be much greater than the force of gravity that it experiences.

Figure A: The two forces are equal;
the rocket will not be able to change speed.

Figure B: Thrust is greater than gravity (weight) and the rocket is able to take off.

Solution Cont'd

Figure C: Gravity (weight) is greater than thrust; the rocket will not move upward, and is unable to move down because it is positioned on the ground. The ground pushes up on the rocket with equal force, keeping objects from falling through the surface. If the rocket had been above the ground, it would fall.

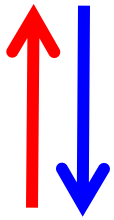
Figure D: The magnitudes (lengths) of both forces are equal, but the thrust force is acting on an angle; the rocket will move to the right.

Solution Cont'd

When two forces act on the same object, the **resultant force** is the sum of the two forces. The resultant force indicates the direction and speed of movement.

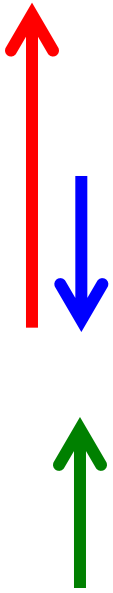
Below (in **green**) are the resultant forces for each of the scenarios in the question.

A.



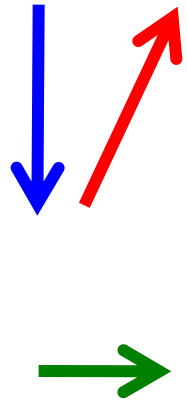
None – these two forces counterbalance each other

B.



C.

D.



Extend Your Learning: Take the Quiz

Title: Blastoff! The Big, Bad Space Launch System Quiz

Extend Your Learning: Video

Title: Discovery Launch Captured by Multiple Cameras