

# Airplanes

Turn off all electronic devices

## Observations about Airplanes

- Airplanes use the air to support themselves
- Airplanes need airspeed to stay aloft
- Airplanes seem to follow their nose, up or down
- Airplanes can rise only so quickly
- Airplane wings often change shape in flight
- Airplanes have various propulsion systems

## 6 Questions about Airplanes

1. How does an airplane support itself in the air?
2. How does the airplane "lift off" the runway?
3. Why does plane tilt up to rise; down to descend?
4. Why are there different wing shapes?
5. How does a plane turn?
6. How does a plane propel itself through the air?

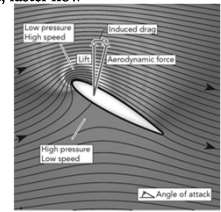
## Question 1

**Q:** How does an airplane support itself in the air?  
**A:** It deflects air downward; air pushes it upward

Air bends away from wing bottom—higher pressure, slower flow  
 Air bends toward wing top—lower pressure, faster flow

Wing and air push on one another

- ◊ Wing experiences upward pressure force
- ◊ Wing pushes air downward
- ◊ Wing transfers downward momentum to the air



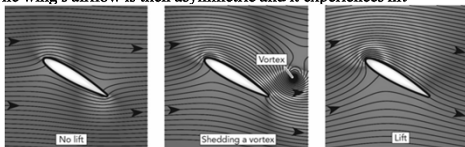
## Question 2

**Q:** How does the airplane "lift off" the runway?  
**A:** The airplane sheds a vortex and the air begins to lift it upward

The wing's initial airflow is symmetric and it experiences zero lift  
 Flow at the wing's trailing edge has a kink that blows away easily

The wing "sheds a vortex" from its trailing edge

The wing's airflow is then asymmetric and it experiences lift



## Question 3

**Q:** Why does plane tilt up to rise; down to descend?  
**A:** The wing's angle of attack affects its lift

A wing's lift depends primarily on three things:

- ◊ the shape of the wing's airfoil
- ◊ the wing's airspeed (the speed at which air passes the wing)
- ◊ the wing's angle of attack—its tilt relative to approaching air

Tilting an airplane's wings alters its angle of attack and its lift

- ◊ Can make the airplane accelerate up or down
- ◊ Usually requires tilting the airplane's fuselage

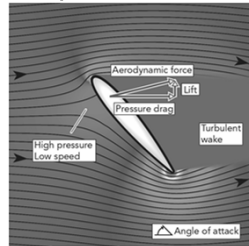
Plane's front-back tilt controls its lift, not its direction of travel

## Limits to Lift: Stalling

At too great an angle of attack,

- ◆ the upper boundary layer stalls
- ◆ the upper airstream detaches from the wing
- ◆ the lift decreases dramatically
- ◆ severe pressure drag appears

The plane plummets abruptly



## Question 4

Q: Why are there different wing shapes?

A: Airspeed and performance influence wing design

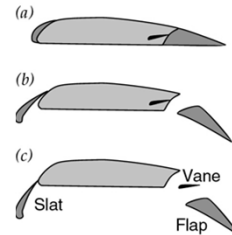
Asymmetric airfoils produce large lifts

- ◆ Are well suited to low-speed flight

Symmetric airfoils produce small lifts

- ◆ Are well suited to high-speed flight
- ◆ Allow plane to fly inverted easily

Some planes change wing shape in flight



## Question 5

Q: How does a plane turn?

A: It uses lift to accelerate in the direction of turn

Airplane has three orientation controls:

- ◆ Elevators control its angle of attack (raise or lower its nose)
- ◆ Ailerons control its left-right tilt (raise or lower its wingtips)
- ◆ Its rudder controls its left-right pointing (rotate its nose left or right)

Proper steering involves both ailerons and rudder

Elevation control involves both elevators and engine

## Question 6

Q: How does a plane propel itself through the air?

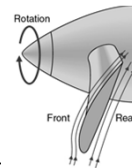
A: It pushes air backward with its props or engines

Propellers are spinning wings

- ◆ They push the air backward
- ◆ The air pushes them forward
- ◆ The plane obtains forward momentum from the air

Jet engines are ducts in which air is manipulated

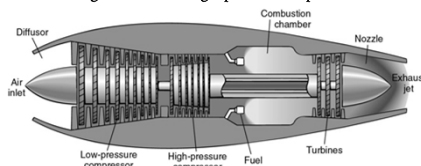
- ◆ They use diffusers to slow down incoming air
- ◆ They use combustion and fans to add energy to that air
- ◆ They use nozzles to speed up outgoing air
- ◆ The plane obtains forward momentum from the air



## Turbojet Engines

Jet engines push air toward the rear of the plane

- ◆ Air entering a diffuser exchanges speed for pressure
- ◆ A compressor does work on the air, increases the air's pressure
- ◆ Fuel is burned in that air, increasing the air's energy
- ◆ A turbine extracts work from the air, decreasing its pressure
- ◆ The air exiting a nozzle exchanges pressure for speed



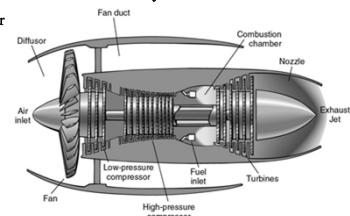
## Turbofan Engines

A turbojet engine obtains forward momentum by

- ◆ moving relatively little air
- ◆ giving that air too much energy

A turbofan engine obtains forward momentum by

- ◆ moving much more air
- ◆ giving air less energy



## Summary about Airplanes

Airplanes use lift to support themselves  
Propulsion overcomes induced drag  
Speed and angle of attack affect altitude  
Extreme angle of attack causes stalling  
Propellers do work on passing airstream  
Jet engines do work on slowed airstream