

# 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

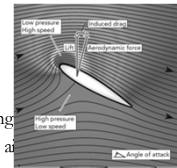
1. How does an airplane support itself in the air?
2. How does the airplane “lift off” the runway?
3. Why does plane tilt up to rise; down to descend?
4. Why are there different wing shapes?
5. How does a plane turn?
6. How does a plane propel itself through the air?

## 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
  - Air pressure rises, speed drops
- Air bends toward wing top
  - Air pressure drops, speed rises
- There is an upward pressure force on the wing
- Wing transfers downward momentum to the air

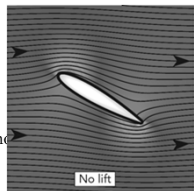


## Question 2

Q: How does the airplane “lift off” the runway?

A: The airplane sheds a vortex and is lifted upward

- As wing starts moving in air
  - the airflow is symmetric
  - and the wing experiences no lift
- Trailing edge kink is unstable
  - and the wing sheds a vortex
- After the vortex leaves, the wing experiences lift



## Question 3

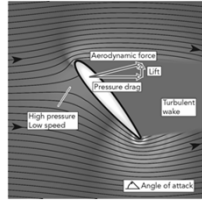
Q: Why does plane tilt up to rise; down to descend?

A: The wing’s angle of attack affects its lift

- A wing’s lift depends on
  - the shape of its airfoil
  - its angle of attack—its tilt relative to approaching air
- Tilting an airplane’s wings affects lift
  - Can make the airplane accelerate up or down
  - Usually requires tilting the airplane’s fuselage
- Plane’s tilt controls lift, not direction of travel

### Limits to Lift: Stalling

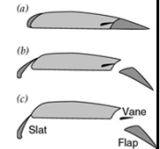
- At too great an angle of attack,
  - the upper boundary layer stalls,
  - the airstream detaches from wing,
  - the lift decreases dramatically,
  - and severe pressure drag appears
- Plane plummets abruptly



### 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

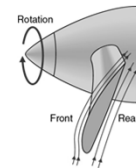
Q: How does a plane turn?  
 A: It uses lift to accelerate in the direction of turn

- Airplane has three orientation controls:
  - Its angle of attack is controlled by elevators
  - Its left-right tilt is controlled by ailerons
  - Its left-right rotation is controlled by rudder
- Steering involves ailerons and rudder
- Elevation involves elevators and engine

### Question 6

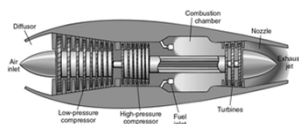
Q: How does a plane propel itself through the air?  
 A: It pushes air backward with its props or engines

- Propellers are spinning wings
  - They deflect air backward,
  - do work on air (add energy),
  - and pump air toward rear of plane
- Jet engines are ducted air pumps
  - Confine the air and pump it toward rear of plane



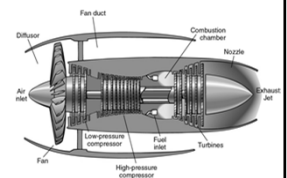
### Turbojet Engines

- Jet engines pump air toward rear of plane
  - Air entering duct diffuser exchanges speed for pressure
  - A compressor does work on air, increases its pressure
  - Fuel is burned in that air, increasing air's energy
  - A turbine extracts work from air, decreasing its pressure
  - Air exiting duct nozzle exchanges pressure for speed



### Turbofan Engines

- Turbojet obtains forward momentum by
  - moving relatively little air
  - and giving that air too much energy
- Turbofan obtains forward momentum by
  - moving much more air
  - giving that 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