Airplanes

Introductory Question

- As you ride in a jet airplane, the clouds are passing you at 600 mph. The air just in front of one of the huge jet engine intake ducts is traveling

A. much faster than 600 mph.
B. much slower than 600 mph.
C. about 600 mph.

Observations about Airplanes

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

6 Questions about Airplanes

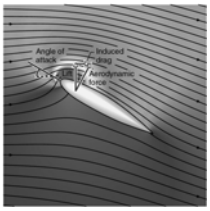
- How does an airplane support itself in the air?
- How does the airplane "lift off" the runway?
- Why does plane tilt up to rise, down to descend?
- Why are there different wing shapes?
- How does a plane turn?
- How does a plane propel itself through the air?

Question 1

- How does an airplane support itself in the air?
  - What pushes up on airplane to balance its weight?
  - What does it do with the momentum gravity gives it?

Using a Wing to Obtain Lift (part 1)

- As air flows under a wing,
  - air bends away from the wing
  - air's pressure rises, speed drops
- As air flows over the wing,
  - air bends toward the wing
  - air's pressure drops, speed rises



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Using a Wing to Obtain Lift (part 2)

- The wing experiences
  - a strong upward lift force
  - a small downstream drag force
- Wing pushes air down, air pushes wing up!
- Downward momentum is transferred from
  - the earth to the airplane by gravity
  - the airplane to the air by lift forces
  - from the air to the earth by pressure on the ground

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Question 2

- How does the airplane "lift off" the runway?
  - How does the pilot initiate the rise?
  - How is landing different from takeoff?

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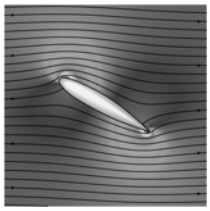
At Take-Off

- As a wing starts moving in air
  - the airflow is symmetric
  - and the wing experiences no lift
- However, this airflow is
  - unstable at trailing edge bend
  - and the wing sheds a vortex
- After the vortex leaves, the wing has lift



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Question 3

- Why does plane tilt up to rise, down to descend?
  - Does a plane always go in the direction it's pointed?
  - How can plane land if its nose is higher than its tail?

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Angle of Attack

- A wing's lift depends on
  - the shape of its airfoil
  - and on its angle of attack–its tilt relative to the wind
- Tilting an airplane's wings
  - changes the net force on the airplane
  - and can make the airplane accelerate up or down
  - but usually requires tilting the airplane's fuselage
- Plane's tilt controls lift, not direction of travel

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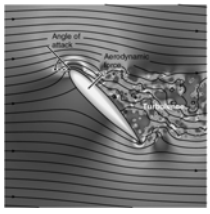
Limits to Lift: Stalling

- At too great an angle of attack,
  - Upper boundary layer stalls
  - Airstream detaches from wing
  - Lift nearly vanishes
  - Pressure drag appear
- Wing can't support plane
- Plane plummets abruptly



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Question 4

- Why are there different wing shapes?

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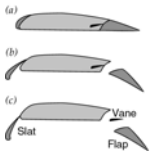
Wing Shape

- Asymmetric airfoils produce large lifts
  - well suited to low-speed flight
- Symmetric airfoils produce small lifts
  - well suited to high-speed flight
  - can fly inverted easily
- High-speed planes often change wing shape in flight



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Question 5

- How does a plane turn?

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Turning and Orientation

- Airplanes also use lift to accelerate to the side
- Three orientation controls:
  - Angle of attack controlled by elevators
  - Left-right tilt controlled by ailerons
  - Left-right rotation controlled by rudder
- Steering involves ailerons and rudder
- Elevation involves elevators and engine

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Question 6

- How does a plane propel itself through the air?
  - How does a plane maintain its forward momentum?

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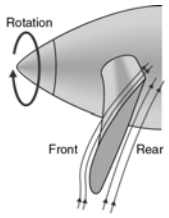
Propellers

- Propellers are spinning wings
  - They deflect air backward
  - Do work on air (add energy)
  - Pump air toward rear of plane
- Action-Reaction
  - They push the air backward
  - Air pushes them forward



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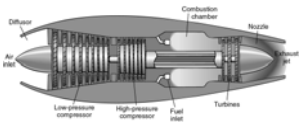
Jet Engines (Part 1)

- Jet engines pump air toward rear of plane
  - Engine consists of an oval "ball" with a complicated duct or passageway through it
  - Air inside the duct exchanges pressure and speed repeatedly
  - Engine adds energy to air inside the duct



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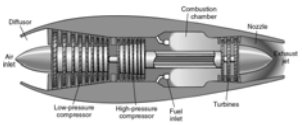
Jet Engines (Part 2)

- Air entering diffuser slows and its pressure rises
- Compressor does work on air
- Fuel is added to air and that mixture is burned
- Expanding exhaust gas does work on turbine
- As exhaust leaves nozzle it speeds up and pressure drops



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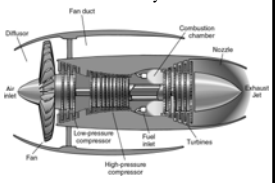
Jet Engines (Part 3)

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



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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