

Question:

A smooth, gentle river is flowing past a cylindrical post. At the sides of the post, is the water level higher, lower, or equal to its level in the open river?

Aerodynamic Forces

- Drag Forces
 - Point directly downstream.
 - Caused by slowing the flow.
- Lift Forces
 - Point to right angles to flow.
 - Caused by deflecting the flow.

Drag Forces

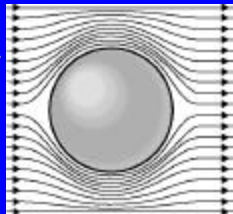
- Viscous drag
 - Caused by surface friction in a viscous fluid.
- Pressure drag
 - Caused by uneven slowing of fluid flow.
- Induced drag
 - Side effect of deflecting flow to obtain lift.

Lift Forces

- No separate types.
- Any deflection of fluid flow causes lift.
- Due to shape, tilt, and motion of object.

Perfect Flow

- Pressure rise in front.
- Pressure drop on side.
- Pressure rise in back.
- Only viscous drag.

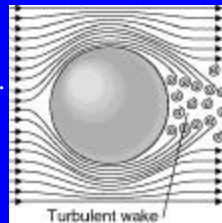


Onset of Turbulence

- Viscous drag slows flow near surface.
- Flowing into higher pressure slows flow.
- When flows stop, turbulence ensues.

Imperfect Flow – Slow

- Pressure rise in front.
- Pressure drop on side.
- Pressure wake in back.
- Large pressure drag.

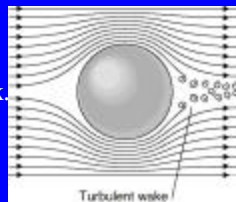


Boundary Layer

- Flow near surface is “boundary layer.”
- At low Reynolds number, boundary layer is laminar and slowed by viscous drag.
- At high Reynolds number ($>100,000$), boundary layer is turbulent and faster.

Imperfect Flow – Fast

- Pressure rise in front.
- Pressure drop on side.
- Pressure wake in back.
- Small pressure drag.

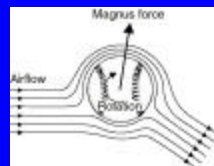


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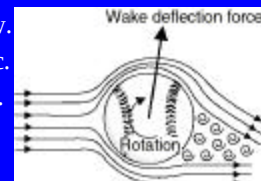
Spinning Balls

- Surface pulls flow.
- Flow faster on one side.
- Flow is deflected.
- Magnus lift force.



Spinning Balls

- Surface pulls flow.
- Wake asymmetric.
- Flow is deflected.
- Wake deflection lift force.



Wings

- Airflow slower under wing.
- Airflow faster over wing.
- Pressure imbalance lifts wing.

