MATH4326: Introduction to Fluid Dynamics

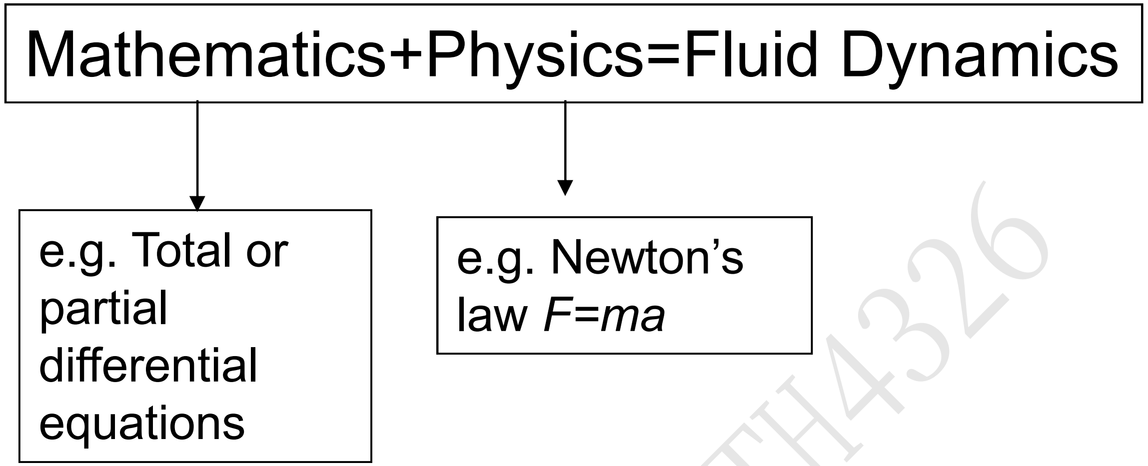
- 1. Develop an understanding of the core ideas and concepts of Fluid Dynamics.

- 2. Be able to recognize the power of abstraction and generalization, and to carry out investigative mathematical work with independent judgment.

- 3. Be able to apply rigorous, analytic, highly numerate approach to analyze and solve problems of fluid dynamics using combined physic and mathematic mean.

- 4. Be able to communicate problem solutions using correct fluid dynamic terminology and good English.

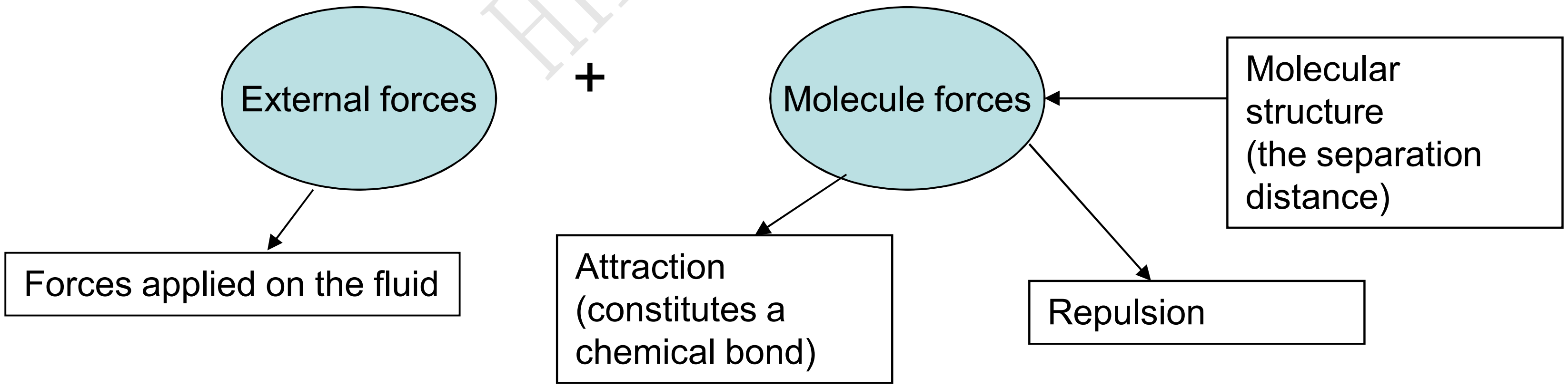
Chapter 1: The basic concepts in the fluid dynamics



1.1: The basic concepts in the fluid

Dynamics: (1) rigid bodies; (2) non-rigid bodies: (a) elasticity (solid elastic bodies, e.g. ice); (b) fluid (e.g. air, water).

Gross properties of fluids and forces:



A fluid is a substance which cannot resist a *shear force* or *stress* without moving as can a solid.

Liquid: hold together by intermolecular forces;
has volume but not shape;

Gas: molecules motion which collides with each other tending to disperse it; has no set volume or shape;

- Gases can be compressed much more readily than liquid when appreciable variations in pressure exist.

- Motions of fluid are accompanied by only slight variations in pressure, and hence *gases and liquids behave similarly*.

- The gross properties of fluids are directly related to their molecular structure and to the nature of the forces between the molecules.

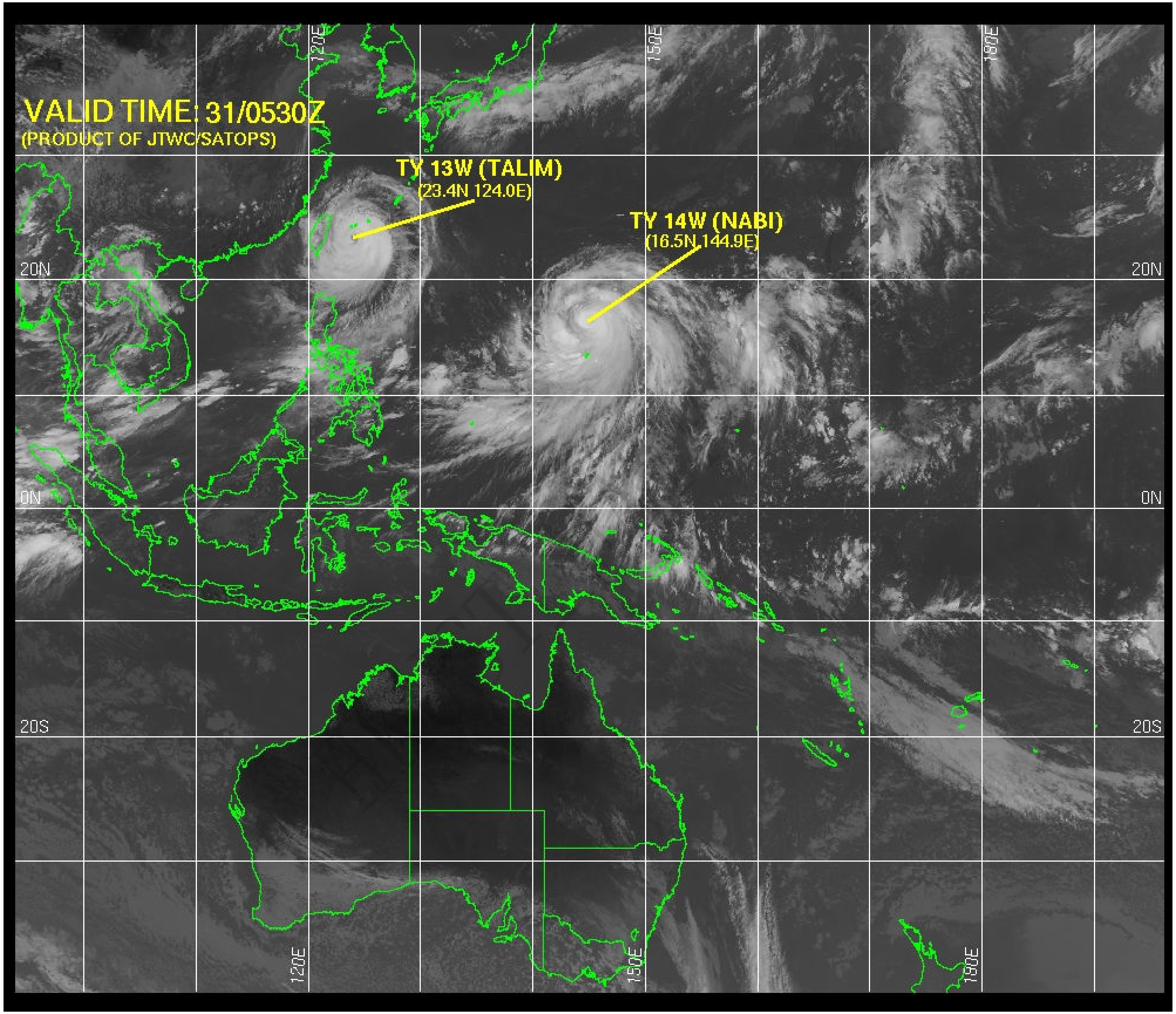
1.2: Application of fluid dynamics

Engineering:

Pumps, compressors, rocket engines, air over objects, aerodynamics, space engineering (aircraft, missiles and rockets), traffic control.

Sciences:

Meteorology, hydrology and oceanography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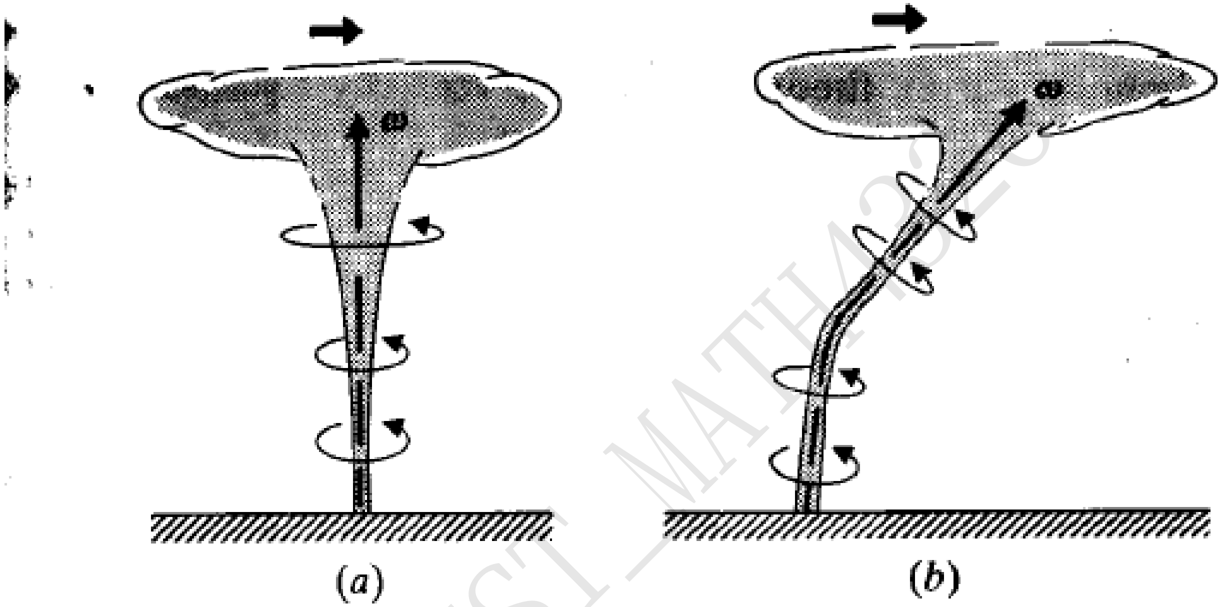


Fig. 5.5. The deformation of a tornado as the thunderclouds move overhead.

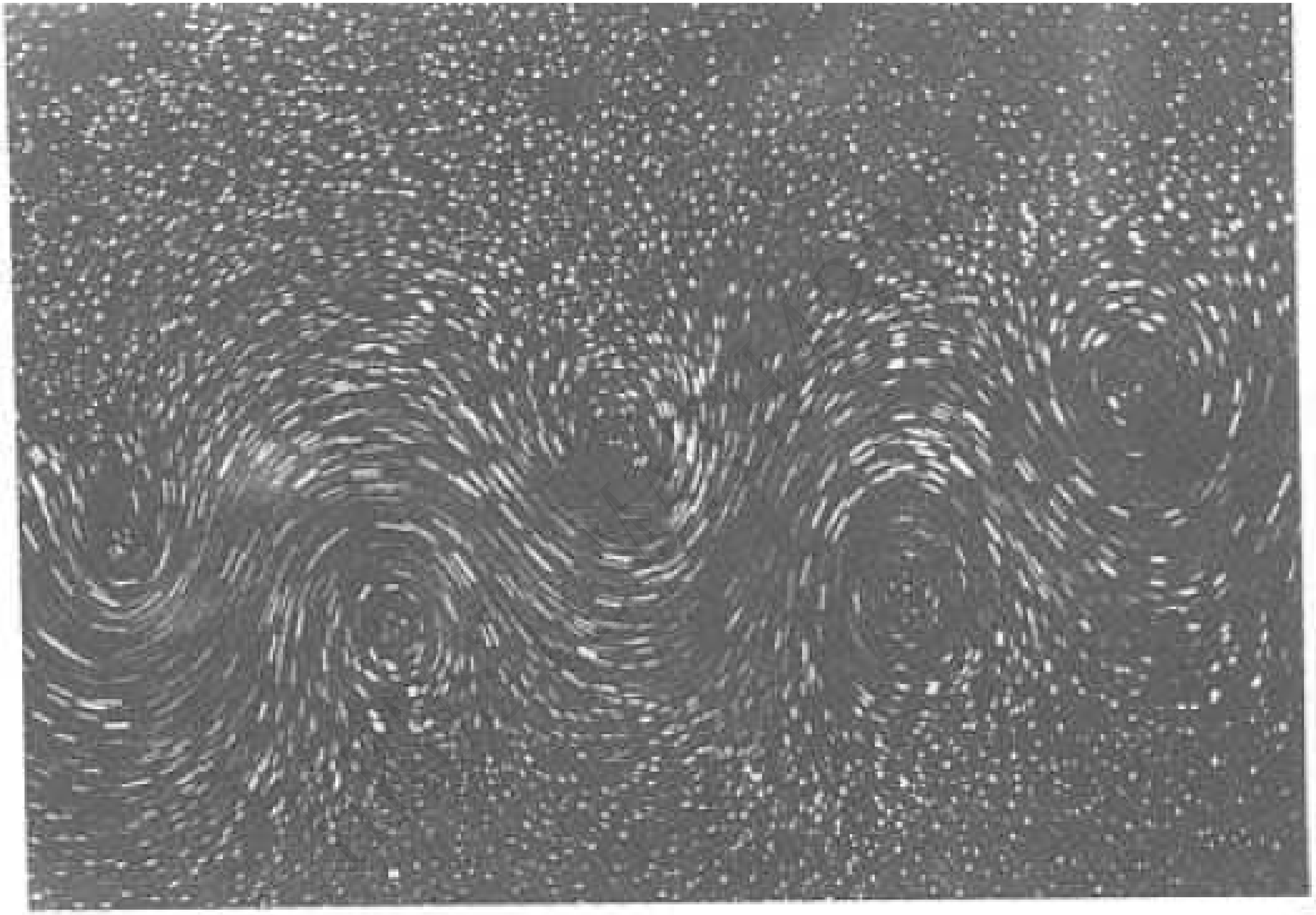
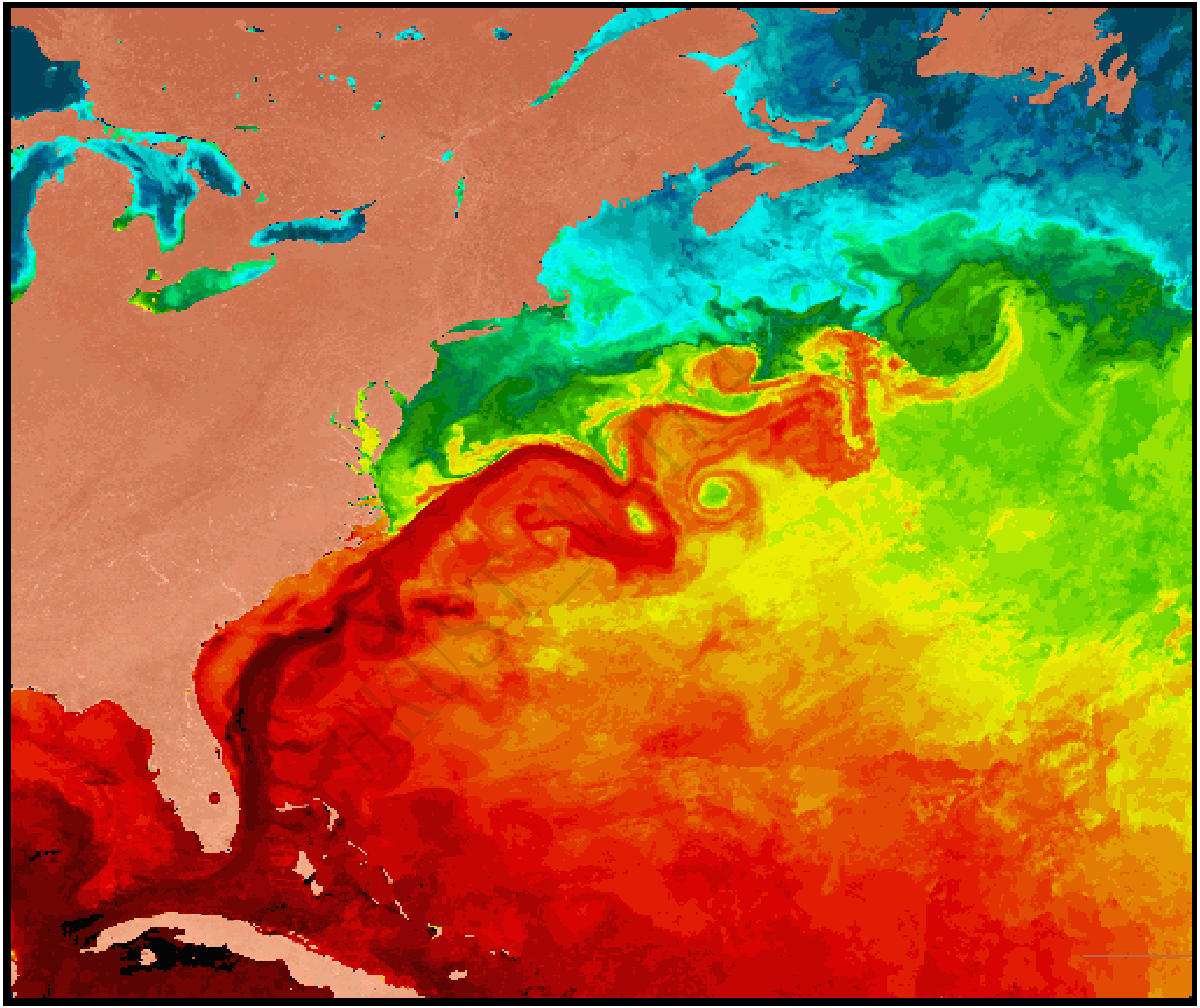


FIG. 3.7 Vortex street exhibited by motion of particles floating on water surface, through which cylinder has been drawn; Re = 200. From Ref. [380].



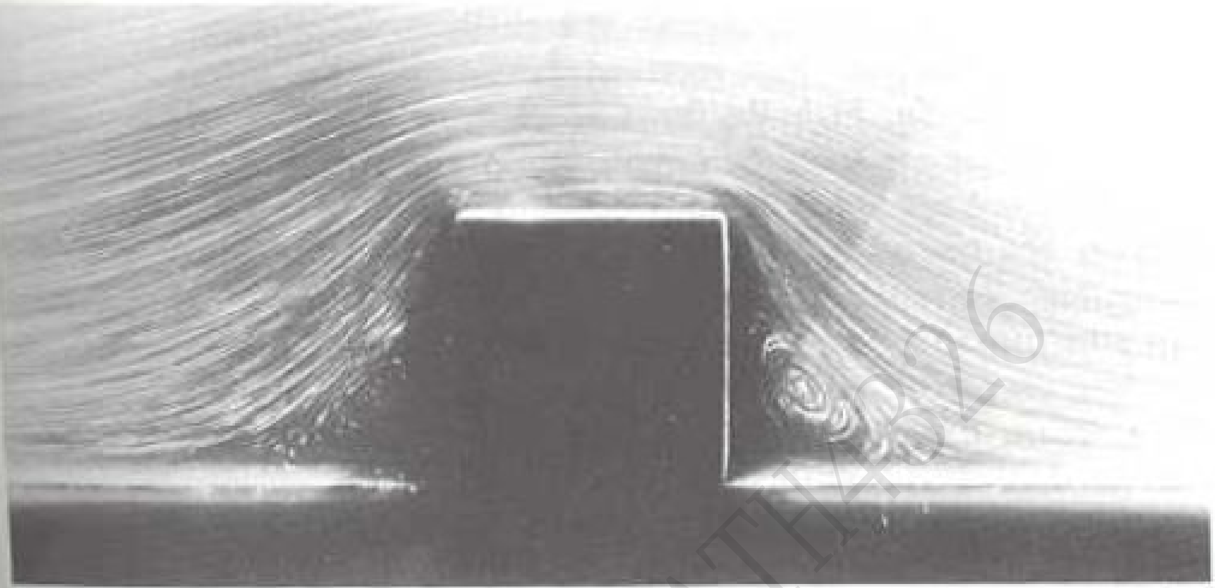


Fig. 12.1 Two-dimensional flow (shown by streaks produced by suspended aluminium powder) past a block on a wall at Re = 0.02. From Ref. [366].

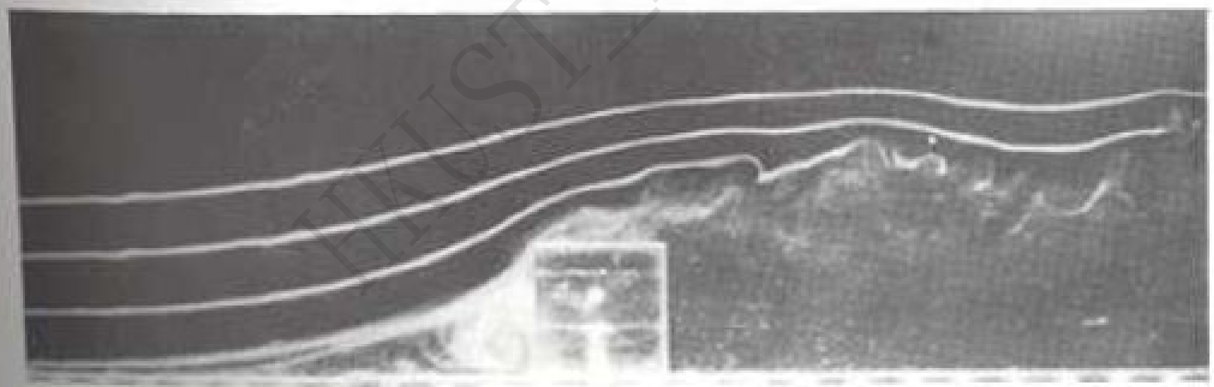


Fig. 12.2 Two-dimensional flow (shown by smoke) past a block on a wall at Re = 3300.

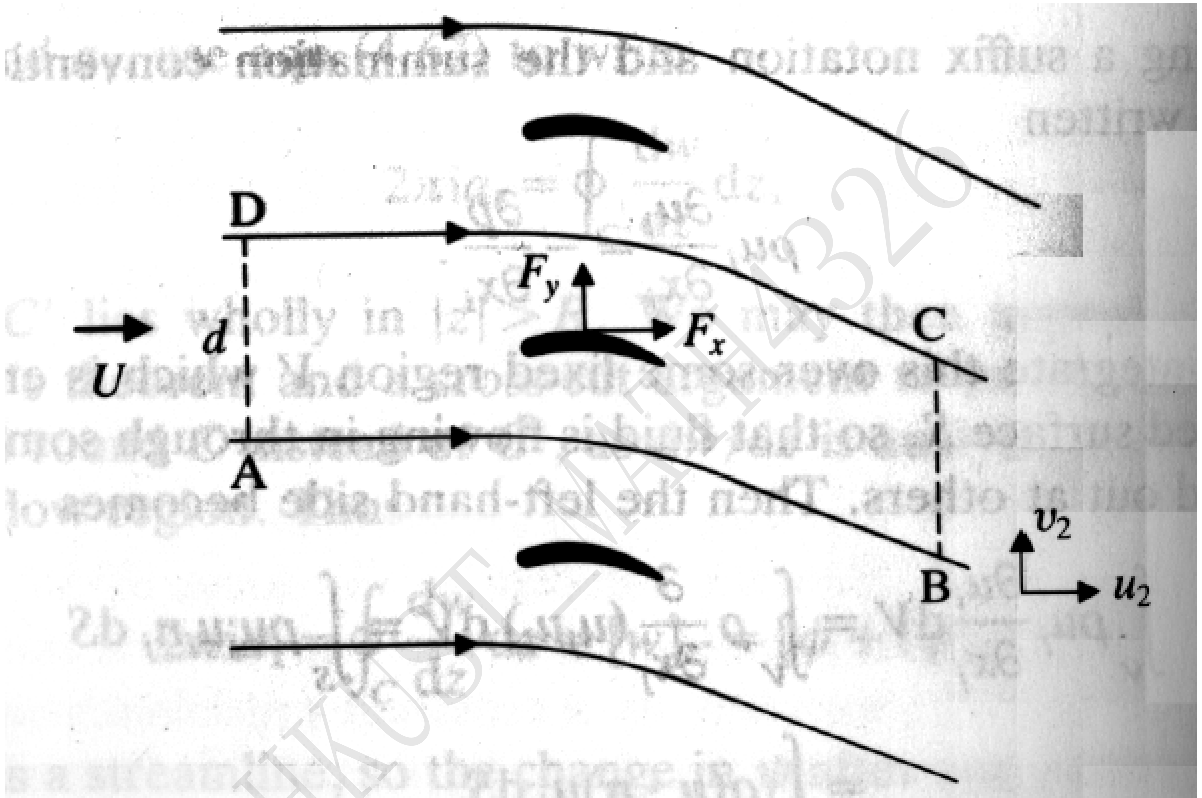


Fig. 4.10. Flow past a stack of aerofoils.

Course Content:

The basic concepts in the fluid dynamics

Application of fluid dynamics
Properties of fluids
Viscosity, friction and ideal flow
Laminar flow and turbulent flow
Compressible and incompressible flow
Subsonic and supersonic flow
Stratified and non-stratified flow

Equations of motion

Forces acting on a fluid
Total differentiation
Eulerian and Lagrangian coordinates
Euler Equations and Navier-Stoke equations
Continuity equation
Scaling parameters

Circulation and vorticity

Circulation, vorticity, Stoke theorem and vorticity equation
Examples of viscous flows
Kevin circulation theorem
The persistence of irrotational flow
The Prandtl-Batchelor Theorem

Waves
Properties of waves
Dispersion and group velocity
Simple wave types
The perturbation method
Simple wave types
  capillary waves, sound waves, shallow-water gravity waves
  hydraulic jumps and solitary waves
Aerofoil theory
Introduction
Velocity potential and stream function
Complex potential
Irrotation flow past a circular cylinder
Boundary layer theory
Viscous regions in high Reynolds number flow
The steady 2-D boundary layer equations
Rotating flows controlled by boundary layers
Boundary layer separation and attachment

1.3: Definitions:

Viscosity, Friction and Ideal Flow

- *Molecular Viscosity*: internal friction of fluid due to **molecular** motion, which causes it resist the tendency to flow. This comes to work when the scale of turbulence is

  < 1mm.

- *Viscous force*, i.e. friction depends on the type of fluid and physical configuration or flow pattern (including both molecular and turbulent viscous force. The magnitude of latter is much larger).

- If the viscous force is negligible, the flow is defined as *ideal flow* or *inviscid flow* in which friction is precisely zero.

- A fluid with very small viscosity may behave quite differently to a (hypothetical) fluid with no viscosity at all.

1.4: Laminar Flow and Turbulent Flow

- The terms laminar flow and purely viscous (molecular) flow are used synonymously to mean a fluid flow which flows in laminas or layers, as opposed to *turbulent flow* in which the velocity components have random turbulent fluctuations imposed upon their mean values.

- In general, increase the flow will change from laminar to turbulent.

- The effect of viscosity (molecular) are still present in turbulent flow, but they are masked by much strong turbulence.

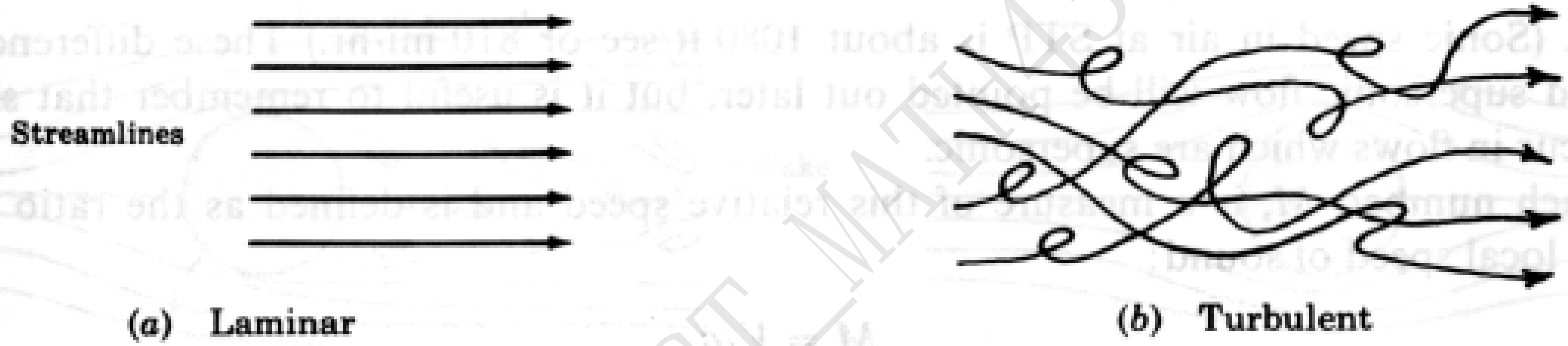


Fig. 1-3. **Laminar and turbulent flow. The lines indicate the paths of particles.**

1.5: Compressible and incompressible Flow

- In compressible flow, density (ρ, kg/m^3) of fluid changes with temperature and pressure, as opposed to incompressible flow in which the density remain constant following the motion.

- In most of problem, incompressible fluid assumption is adopted.

1.5: Subsonic and Supersonic Flow

- The flow velocities less than that of sound, subsonic flow, as opposed to flow involving velocities greater than that of sound, supersonic flow.
- Sound speed is 810mi/hr.
- There is a great distinction between the subsonic and supersonic flow.
- Measured by Mach number: $M=U/C_{o,}$,where U is flow speed and Co is sound speed.