

FLUID DYNAMICS

The study of the movement of fluids:

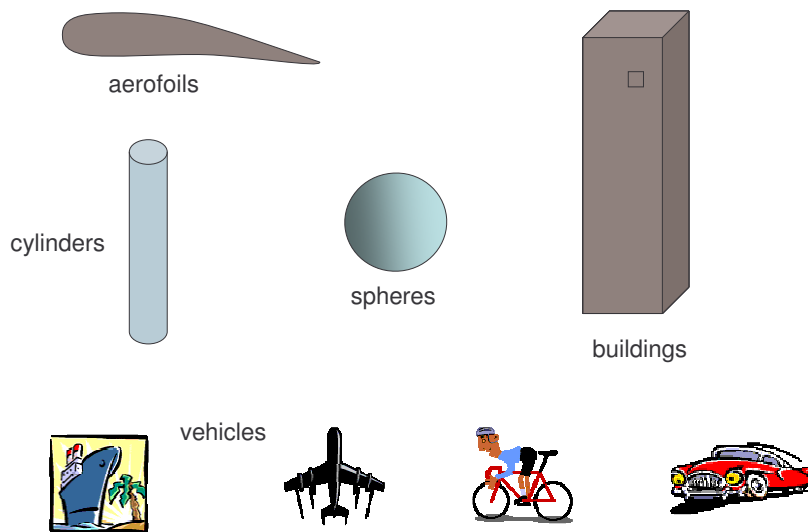
Fluid Dynamics covers a very wide range of topics and applications, from the **natural** movement of fluids (tides, wind, rivers, convection currents, etc.) to the **forced** flow of fluids (lubrication, pipe flow, aerodynamics, gas dynamics, naval architecture, pumps, turbines, power jets, etc.)

We shall study a sub-set of some of these topics.

A broad classification of fluid dynamics is to categorise fluid flow as **external** or **internal**.

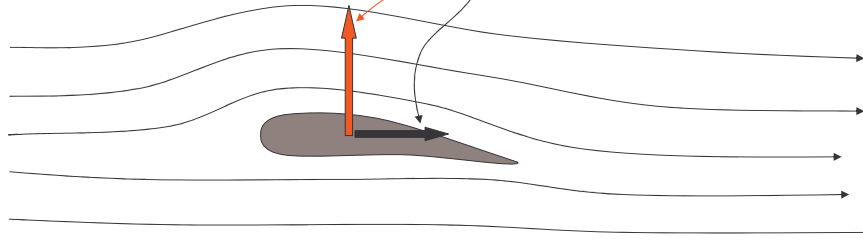
EXTERNAL FLUID FLOW

This is typically flow **around** solid bodies. In many cases the fluid can flow around a body in a fairly unrestricted way – and in the case of gas flow it can often be treated as incompressible flow. (e.g. in low speed aerodynamics).



With external flow we are often interested in the pressure distribution around the body and the forces that the fluid exerts on it. These forces are often referred to as 'lift' forces (at right-angles to the oncoming flow) or 'drag' forces (parallel to the oncoming flow). They are particularly important when we have to provide an engine or propulsive device to overcome the drag – since the smaller we can make the drag the faster we can go, or we can minimise the power requirements for a given speed.

We often visualise external flow by means of stream lines which show how the fluid 'streams' around a body.



INTERNAL FLUID FLOW

This is typically flow **inside** channels or tubes. It is typically classified as either open channel flow or closed channel flow.

Open channel flow is concerned with the flow of liquids in open channels such as rivers, open drains, weirs, gutters, etc. – it often concerns civil engineering projects such as rainwater run-off, canals, navigable waterways, flood defences, etc.

It is characterised by the liquid having a 'free surface'.

Closed channel flow is concerned with the flow of liquid or gases in closed conduits such as in pipes, oil galleries, gas mains, water mains, oil pipelines, air-conditioning ducts etc. This type of flow often concerns mechanical engineering – since incorrect pipe sizes, or incorrect design, can lead to excessive pumping power or restricted flow rates.

It is normally assumed that the fluid completely fills the tube or closed channel.



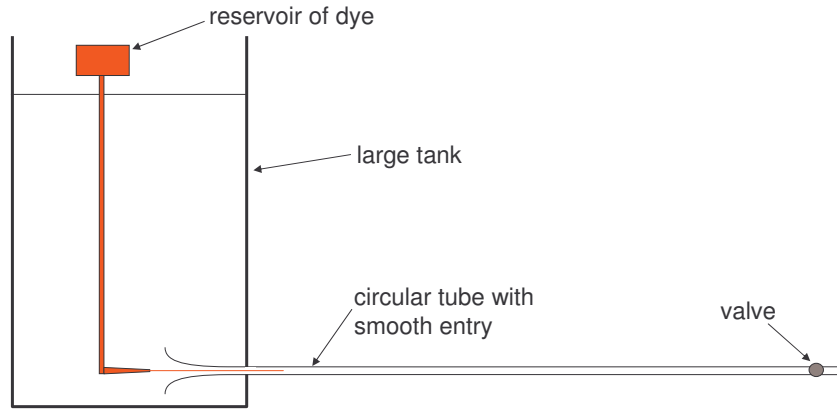
TYPES of FLUID FLOW

Fluid flow occurs in two fundamental ways:

Laminar flow, or

Turbulent flow

These are best illustrated by the experiments of Osborne Reynolds (1842-1912)



Reynolds found that provided the fluid velocity in the tube remained below a certain limit the dye stream remained intact.



However, once the fluid velocity in the tube exceeded a certain value the dye stream broke up and dissipated. This occurred no matter how still the liquid was at the beginning or no matter how still the tube was kept.



The velocity at which this occurred also depended on the diameter of the tube (d) and on the fluid's kinematic viscosity (ν). It was found that when the ratio $\frac{vd}{\nu}$ exceeded a value of ~ 2300 , the fluid flow always 'broke up' and became turbulent.

The ratio $\frac{vd}{\nu}$ is known as **Reynold's Number** and is an important determining parameter of whether fluid flow is smooth, unbroken **laminar** flow, or broken, quasi-unstable **turbulent** flow in any given situation.

Turbulent flow occurs because within a fluid there are two forces tending to determine the motion of the fluid particles. Viscous forces (the property of fluid particles sticking to each other) tend to 'damp down' random movement, whereas momentum forces (related to the mass and velocity of the particles) tend to increase random movement. When the ratio of momentum to viscous forces exceeds a certain value the motion of the fluid particles becomes random (although the particles still have an overall average velocity).

$$\text{kinematic viscosity} = \frac{\text{dynamic viscosity}}{\text{density}}$$

$$\nu = \frac{\mu}{\rho}$$

Therefore Reynold's Number can also be written: $\frac{\rho vd}{\mu}$

Whether a fluid flow is laminar or turbulent significantly affects the way in which we have to deal with it.