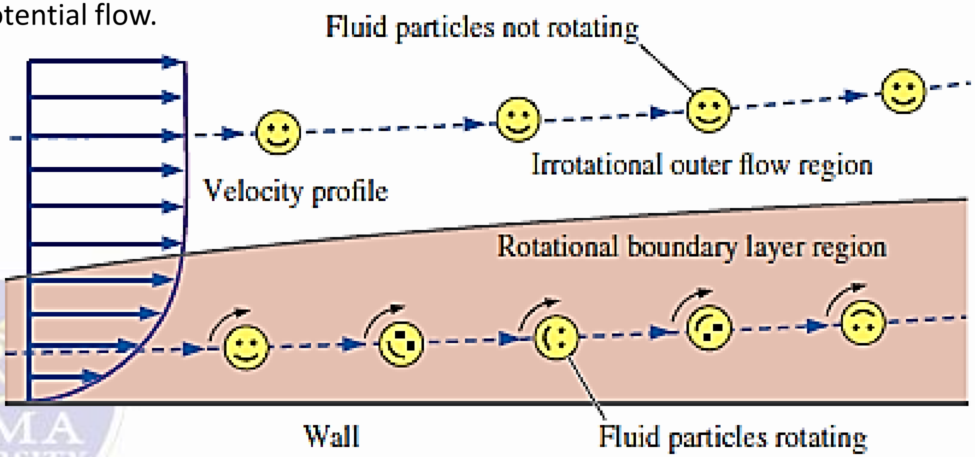
Fluid Properties

- Rotational flow. A flow is said to be rotational if the fluid particles while moving in the direction of flow rotate about their mass centres. Flow near the solid boundaries is rotational. Example. Motion of liquid in a rotating tank.
- Irrotational flow. A flow is said to be irrotational if the fluid particles while moving in the direction of flow do not rotate about their mass centres. Flow outside the boundary layer is generally considered irrotational.
- Example. Flow above a drain hole of a stationary tank or a wash basin.
- Note. If the flow is irrotational as well as steady, it is known as Potential flow.
- The difference between rotational and
- irrotational flow: fluid elements in a
- rotational region of the flow rotate, but
- those in an irrotational region of the
- flow do not.



Fluid Properties

- Laminar flow. A laminar flow is one in which paths taken by the individual particles do not cross one another and move along well defined paths (Fig.), This type of flow is also called stream-line flow or viscous flow. Examples.
- (i) Flow through a capillary tube.
- (ii) Flow of blood in veins and arteries.
- (iii) Ground water flow.
- Turbulent flow. A turbulent flow is that flow in which fluid particles move in a zig zag way (Fig). Example. High velocity flow in a conduit of large size. Nearly all fluid flow problems encountered in engineering practice have a turbulent character.
- Translational flow; The flow of low-viscosity fluids such as air at high velocities is typically turbulent. A flow that alternates between being laminar and turbulent is called transitional.

- Laminar, transitional, and turbulent flows over a flat plate.

Laminar and turbulent flows are characterised on the basis of Reynolds
For Reynolds number (Re) < 2000 ... flow in pipes is laminar.
For Reynolds number (Re) > 4000 ... flow in pipes is turbulent
For Re between 2000 and 4000 ... flow in pipes may be laminar or turbulent.

Fluid Properties

- A flow is classified as being compressible or incompressible, depending on the level of variation of density during flow.
- The densities of liquids are essentially constant, and thus the flow of liquids is typically incompressible. Therefore, liquids are usually referred to as incompressible substances

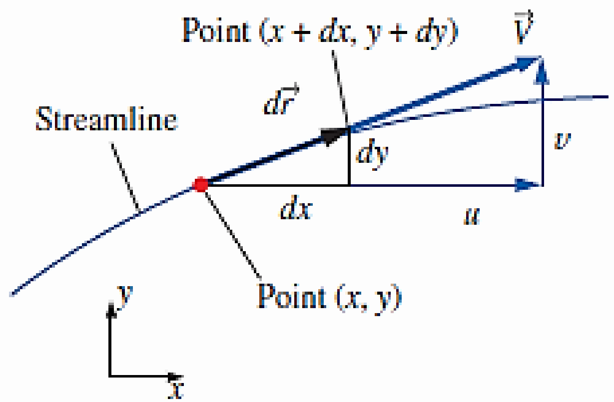
- Compressible flow. It is that type of flow in which the density (ρ) of the fluid changes from point to point (or in other words density is not constant for this flow).
- Mathematically: $\rho \neq$ constant.
- Example. Flow of gases through orifices, nozzles, gas turbines, etc.
- Incompressible flow. It is that type of flow in which density is constant for the fluid flow. Liquids are generally considered flowing incompressibly.
- Mathematically: $\rho =$ constant.
- Example. Subsonic aerodynamics.
- When analyzing rockets, spacecraft, and other systems that involve highspeed gas flows (Fig, the flow speed is often expressed in terms of
- the dimensionless Mach number defined as $$\text{Ma} = \frac{V}{c} = \frac{\text{Speed of flow}}{\text{Speed of sound}}$$

- where c is the speed of sound whose value is 346 m/s in air at room temperature at sea level. A flow is called sonic when Ma 5 1, subsonic when Ma , 1, supersonic when Ma . 1, and hypersonic when Ma .. 1.

TYPES OF FLOW LINES

- Streamlines:
- A streamline is a curve that is everywhere tangent to the instantaneous local velocity vector
- Streamlines are useful as indicators of the instantaneous direction of fluid motion throughout the flow field.
- Streamlines cannot be directly observed experimentally except in steady flow fields, in which they are coincident with pathlines and streaklines,
- Mathematically, however, we can write asimple expression for a streamline based on its definition.

Equation for a streamline: $$\frac{dr}{V} = \frac{dx}{u} = \frac{dy}{v} = \frac{dz}{w}$$

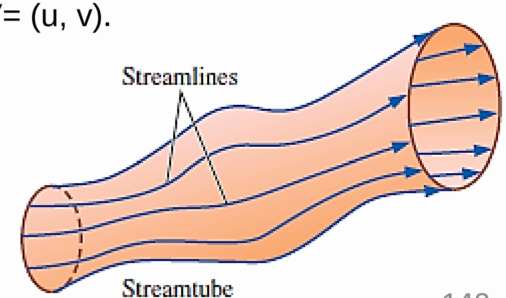


- where dr is the magnitude of dr and V is the speed, the magnitude of velocity vector V
- In two dimensions, (x, y), (u, v), the following differential equation is obtained:

Streamline in the xy-plane: $$\left(\frac{dy}{dx}\right)_{\text{along a streamline}} = \frac{v}{u}$$

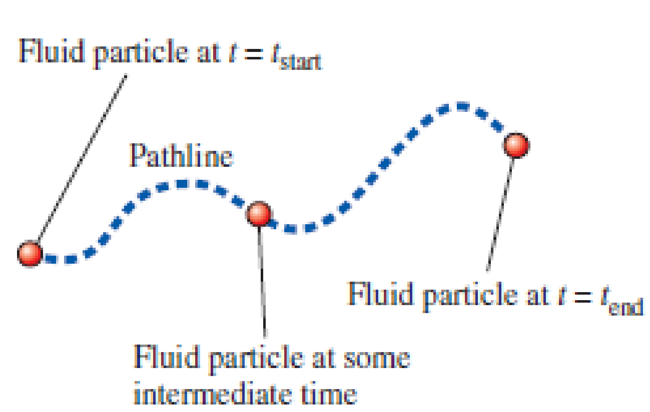
- Streamtube:
- A Streamtube consists of a bundle of streamlines (Fig.), much like
- a communications cable consists of a bundle of fiber-optic cables. Since
- streamlines are everywhere parallel to the local velocity, fluid cannot cross
- a streamline by definition. By extension, fluid within a streamtube must
- remain there and cannot cross the boundary of the streamtube. You must
- keep in mind that both streamlines and streamtubes are instantaneous quantities,
- defined at a particular instant in time according to the velocity field
- at that instant.

For two-dimensional flow in the xyplane, arc length dr= (dx, dy) along a streamline is everywhere tangent to the local instantaneous velocity vector V= (u, v).



Fluid Properties

- Path line
- A path line (Fig.) is the path followed by a fluid particle in motion. A path line shows the direction of particular particle as it moves ahead. In general, this is the curve in three-dimensional space. However, if the conditions are such that the flow is two-dimensional the curve becomes two-dimensional.
- A pathline is the actual path traveled by an individual fluid particle over sometime period.
- Pathlines are the easiest of the flow patterns to understand.
- A pathline is a Lagrangian concept in that we simply follow the path of an individual fluid
- particle as it moves around in the flow field



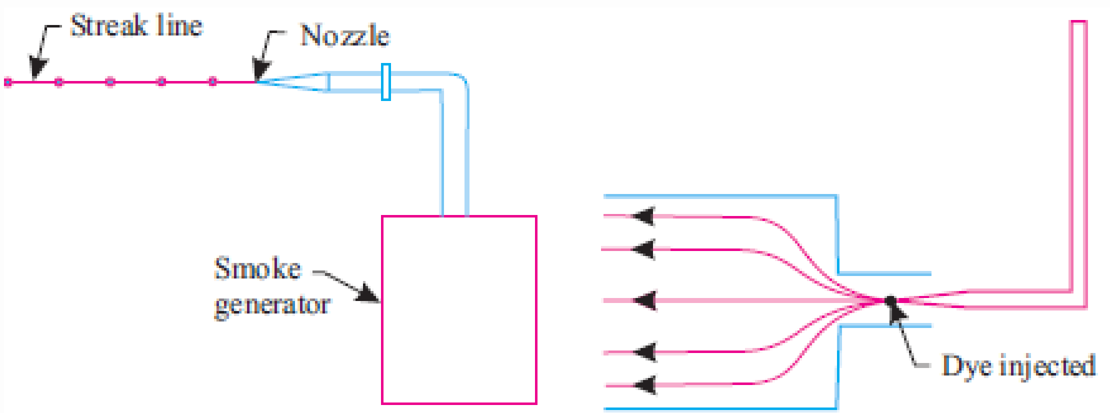
- Pathlines can also be calculated numerically for a known velocity field.
- Specifically, the location of the tracer particle is integrated over time from
- some starting location x_{start} and starting time t_{start} to some later time t.

Tracer particle location at time t: $$\vec{x} = \vec{x}_{start} + \int_{t_{start}}^{t} \vec{V}\, dt$$

- If the velocity field is steady, individual fluid particles follow streamlines. Thus, for steady flow, path lines are identical to streamlines.

Fluid Properties

- Streaklines
- A streakline is the locus of fluid particles that have passed sequentially through a prescribed point in the flow.
- Streaklines are the most common flow pattern generated in a physical experiment.
- The streak line is a curve which gives an instantaneous picture of the location of the fluid particles, which have passed through a given point
- Examples. (i) The path taken by smoke coming out of chimney (Fig.).
- (ii) In an experimental work to trace the motion of fluid particles, a colored dye may be injected into the flowing fluid and the resulting colored filament lines at a given location give the streak lines (Fig).



- A streakline is formed by continuous introduction of dye or smoke from a point in the f
- particles (1 through 8) were introduced sequentially