Basic knowledge

Fundamentals of hydrodynamics

Hydrodynamics is concerned with the study and description of fluids in motion. The main emphasis is the teaching of the conservation laws of mass, energy and momentum.

Flowing fluids possess kinetic energy. This energy can be converted into potential energy (pressure, height) and vice versa.

Typical keywords include Bernoulli's equation, continuity equation and conservation of momentum. For ease of understanding, it is mostly steady states of incompressible fluids that are considered.

Other topics within hydrodynamics

- pipe flow (laminar/turbulent)
- methods of flow rate measurement
- open-channel flow
- flow around bodies
- turbomachines
- flow of compressible fluids

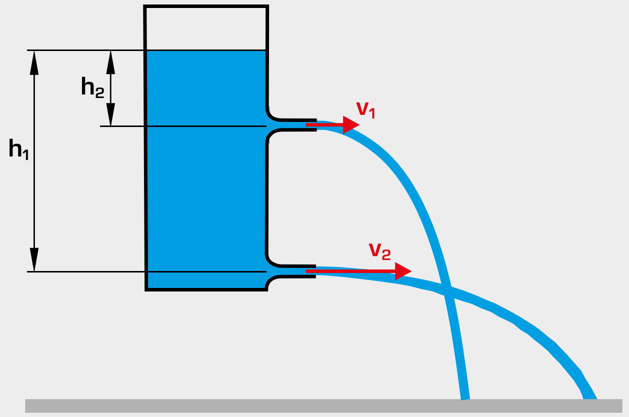
Flow from a tank

The flow from a tank can be regarded as both steady and transient. In the steady case the fill level, and thus the width of the jet, remains constant (e.g. discharge under a weir). The outlet velocity **v** only depends on the head **h** and is calculated according to Torricelli's law.

$$v = \sqrt{2gh}$$

v velocity, **g** gravitational acceleration,
h distance between discharge and water level

When the tank is emptying during the discharge process, it is in what is referred to as the transient state.

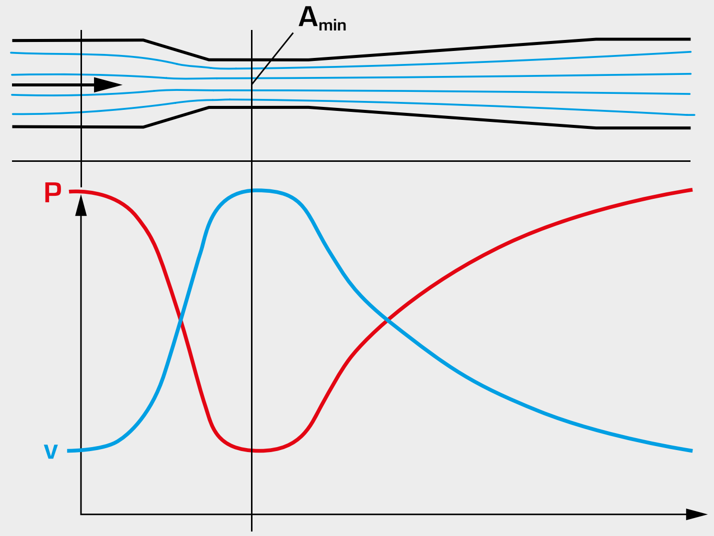


h head, distance between discharge and water level, **v** velocity

Venturi nozzle

The velocity of the flowing fluid is at its greatest at the narrowest cross-section (**continuity equation** A·v = const). Bernoulli discovered that a part of the pressure energy is converted into kinetic energy. When velocity increases it therefore results in a drop in pressure, so that the lowest pressure occurs in the narrowest cross-section. **Bernoulli's equation** states that the energy of a frictionlessly flowing, incompressible fluid is constant.

Applications include water jet pumps, carburettors, flow measurement

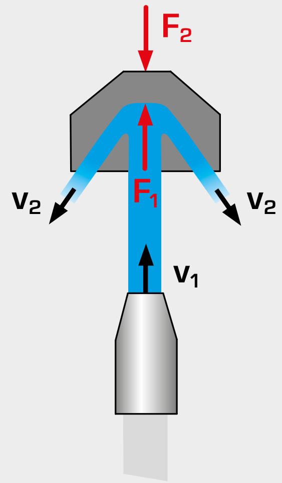


velocity, static pressure curve

Jet forces

If the flow velocity changes then the momentum of a fluid changes according to the magnitude and/or direction. This results in forces that, for example, could drive a free jet turbine or a water vehicle.

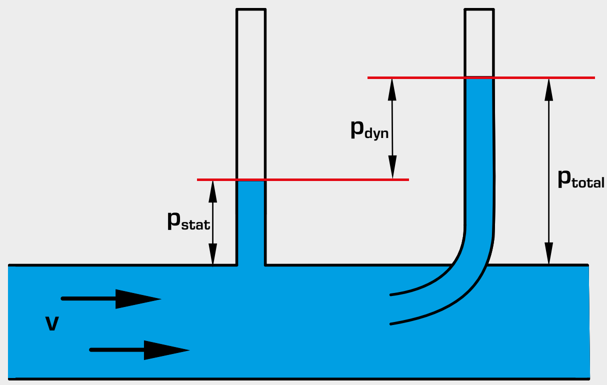
These forces can be easily demonstrated and measured when the jet hits the wall and is deflected.



F_1 jet force, F_2 reaction force,
v_1 jet velocity, v_2 velocity after deflection

Pressure in a flowing fluid

The energy of the flowing fluid is determined by pressure, velocity and density. The total pressure is made up of a static and a dynamic component. The dynamic component grows quadratically as the flow velocity increases. A flowing fluid can contain potential, kinetic and pressure energy. In the ideal case the total energy is conserved. In this case, the proportions may vary, so for example pressure energy is converted into kinetic energy.



v velocity, p_{stat} static pressure, p_{dyn} dynamic pressure,
p_{total} total pressure

Vortex formation

Vortices occur when, within a fluid, a portion of the fluid flows more quickly than the rest of the fluid. This results in a velocity gradient within the fluid. Energy is dissipated in vortices.

Free vortices (potential vortex, e.g. whirlpool) are formed during discharge from a tank, for example. With free vortices all fluid particles move in concentric circular paths without rotating around their own axis. Free vortices are formed solely by hydrodynamic forces.

Forced vortices are rotational and are formed by external forces, such as a stirrer.