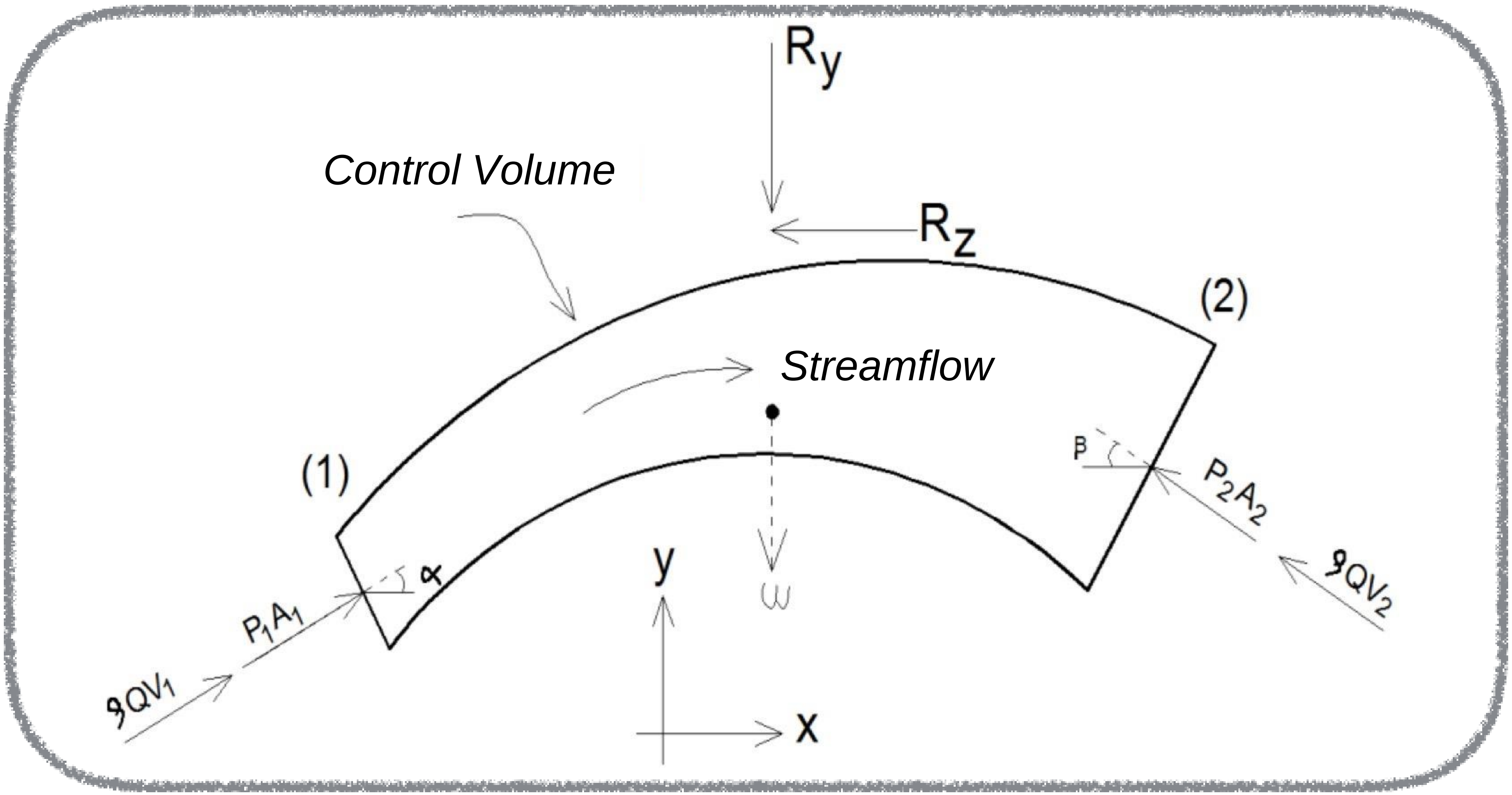
Fluid Mechanics

Abdusselam Altunkaynak

Flow in Elbow:

Let's analyze the force acting on the elbow of a pipe. Let there be an elbow of a pile on the horizontal plane as given in the figure.



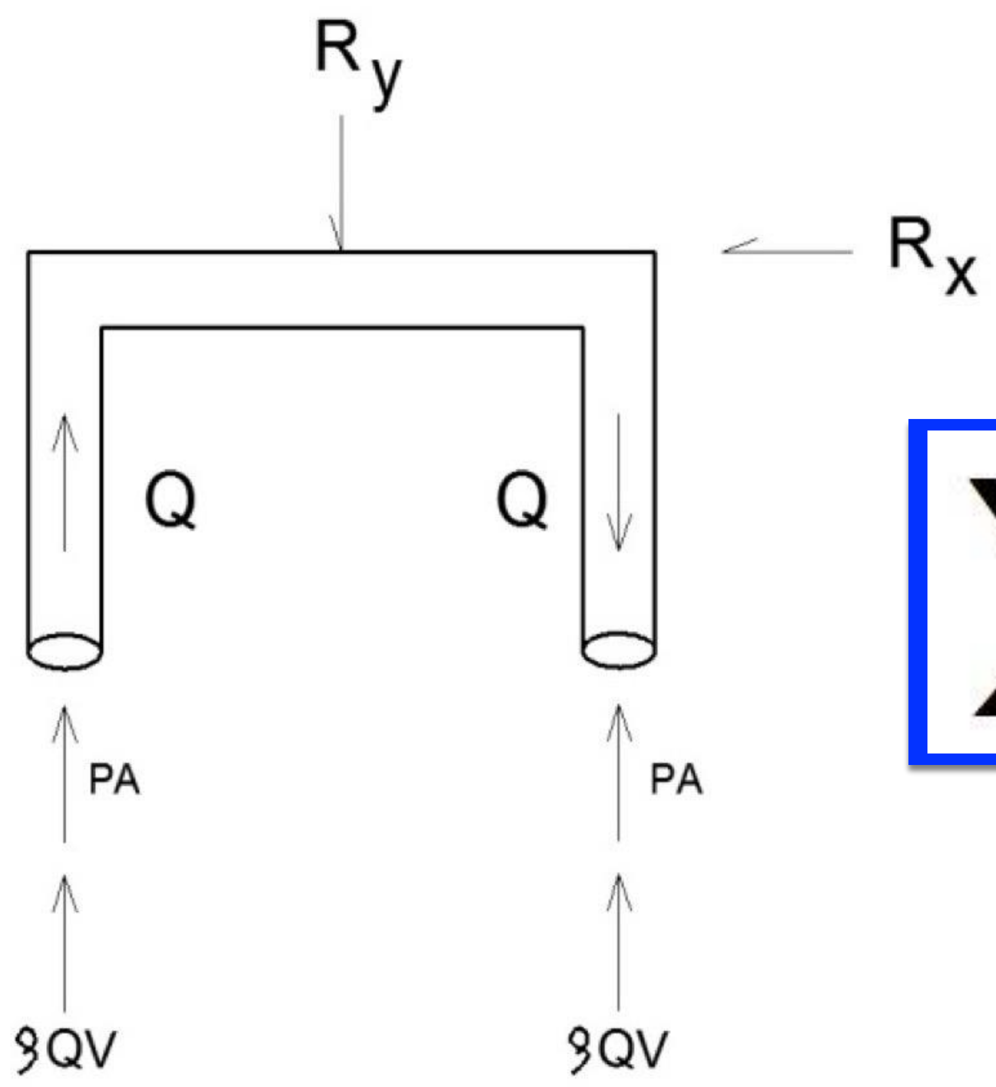
*Let the fluid be **ideal** and the flow be **permanent***

Let Rx and Ry be the x and y components of the force exerted by the wall of the pipe on the fluid found in the control volume

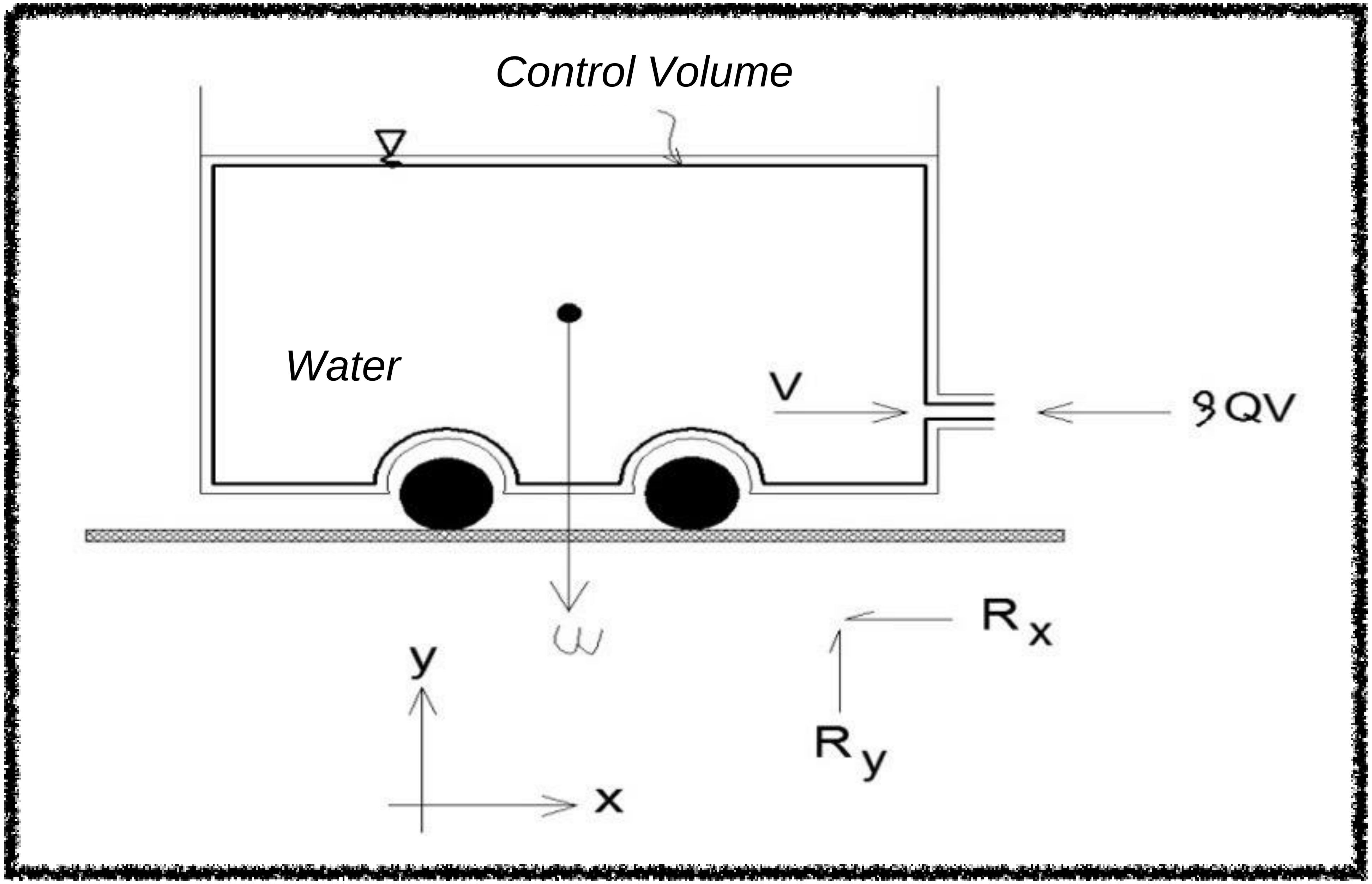
Rx and ***Ry*** are equal in magnitude and opposite in direction

Accordingly

$$\sum F_y = 0$$



$$\sum F_x = 0$$



$$\sum F_x = 0$$

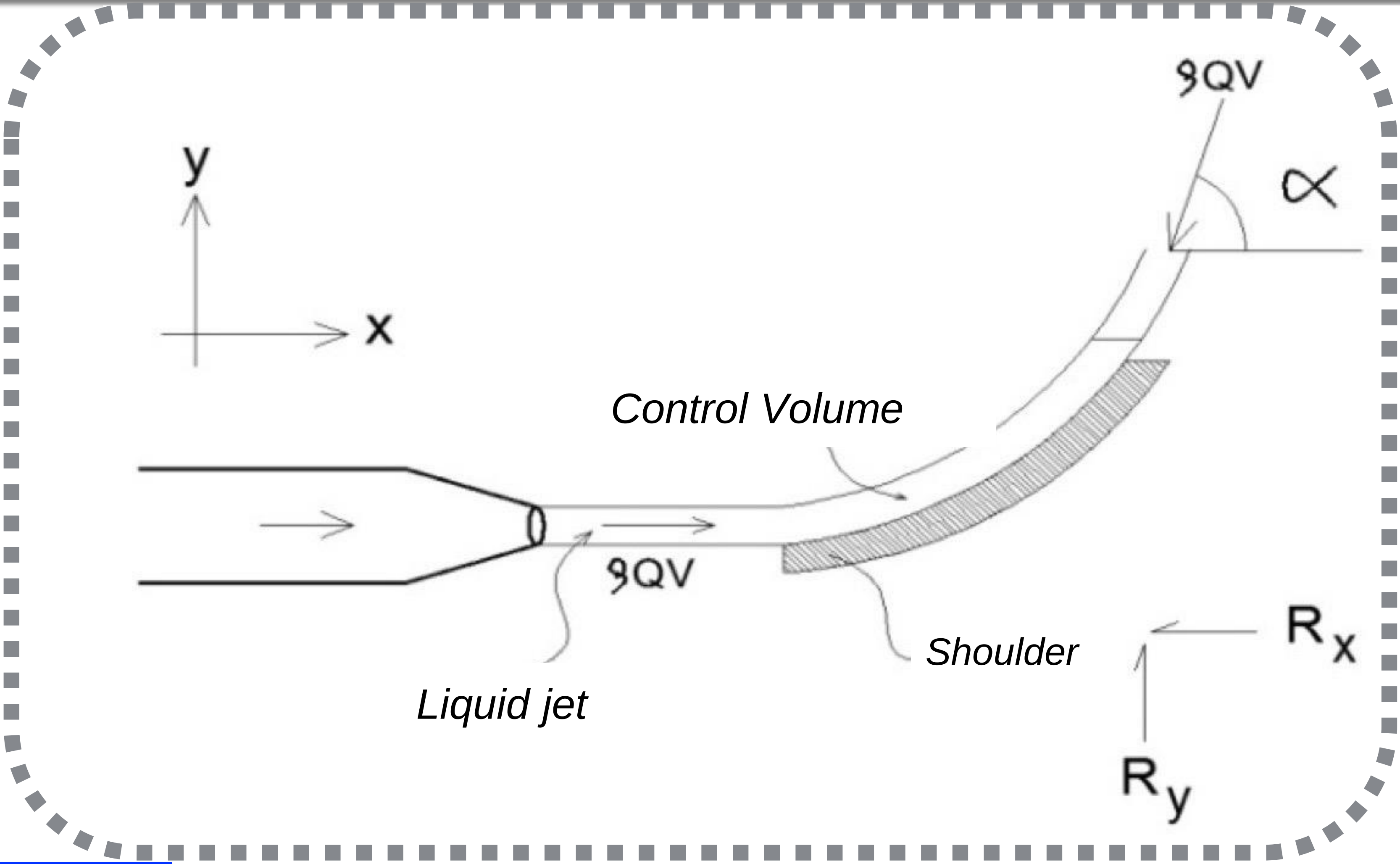
$$\sum F_y = 0$$

$$R_x = -\rho.Q.v$$

$$R_y = w$$

The effect of liquid jet on a wing:

*Let's assume that the wing is on a horizontal plane,the fluid is **ideal** and the flow is **permanent**.*



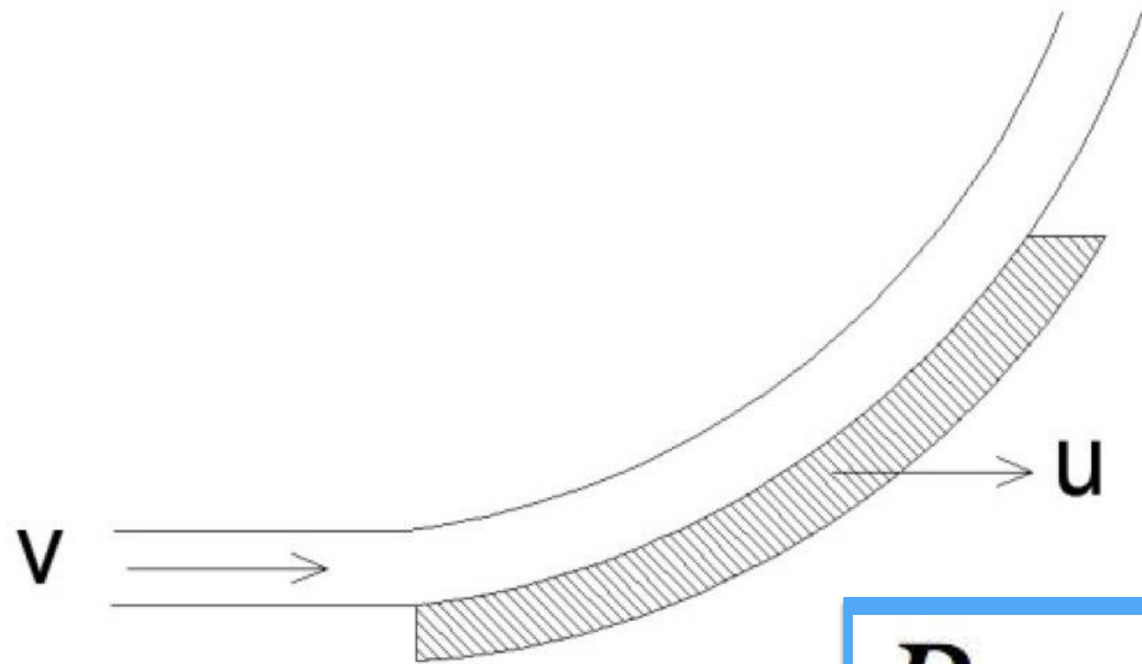
$$\sum F_x = 0$$

$$\sum F_y = 0$$

$$R_x = \rho.Q.v(1-\cos\alpha)$$

$$R_y = \rho.Q.v\sin\alpha$$

If the wing moves with velocity 'u' in the jet direction:



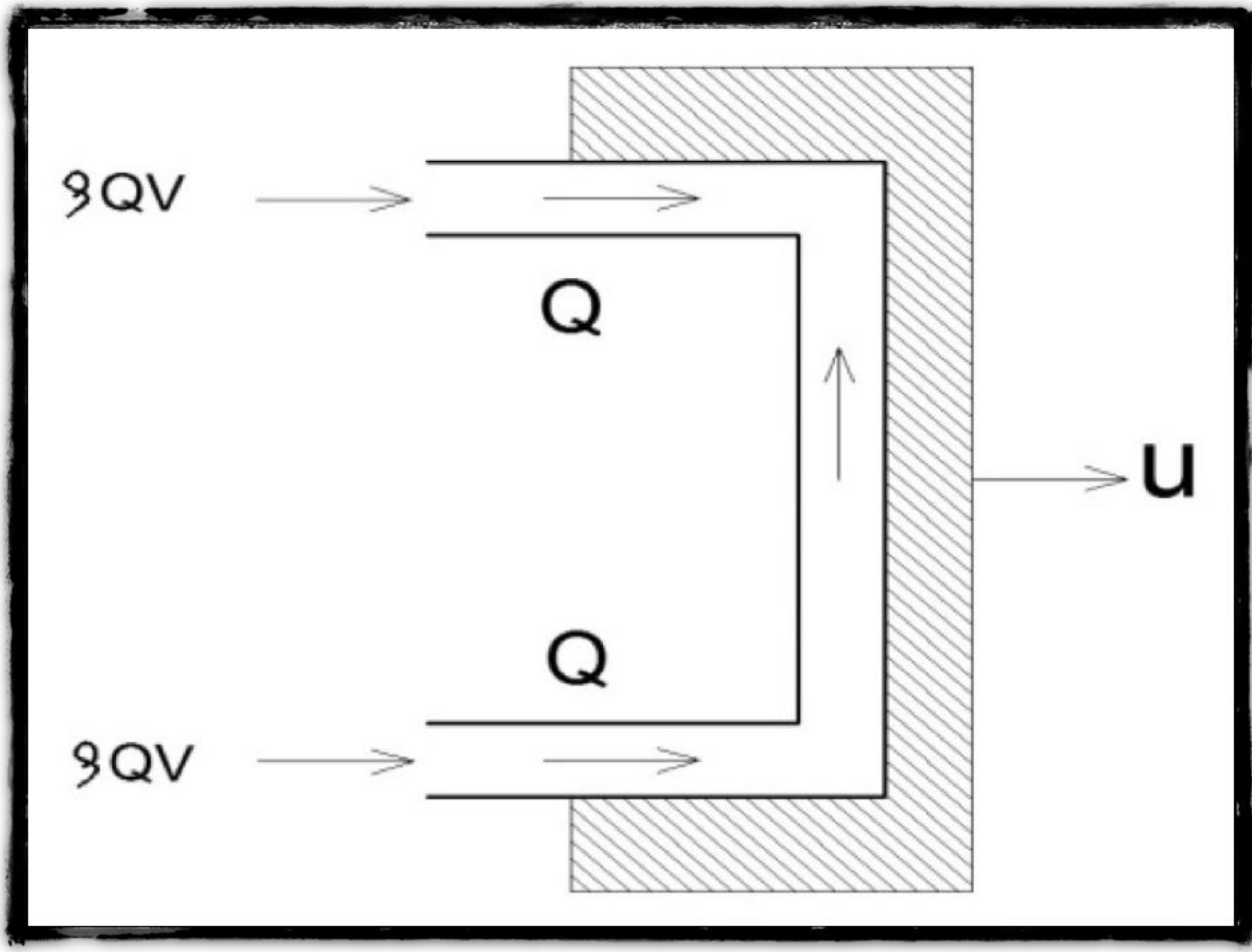
$$R_y = \rho.Q.(v-u)\sin\alpha$$

$$R_x = \rho.Q.(v-u)(1-\cos\alpha)$$

If $\alpha = 180^o$

$$R_x = 2\rho.Q.(v-u)$$

$$R_y = 0$$


ϱQV
Q
Q
ϱQV
u

For $u = 0$

$$\sum F_x = 0$$

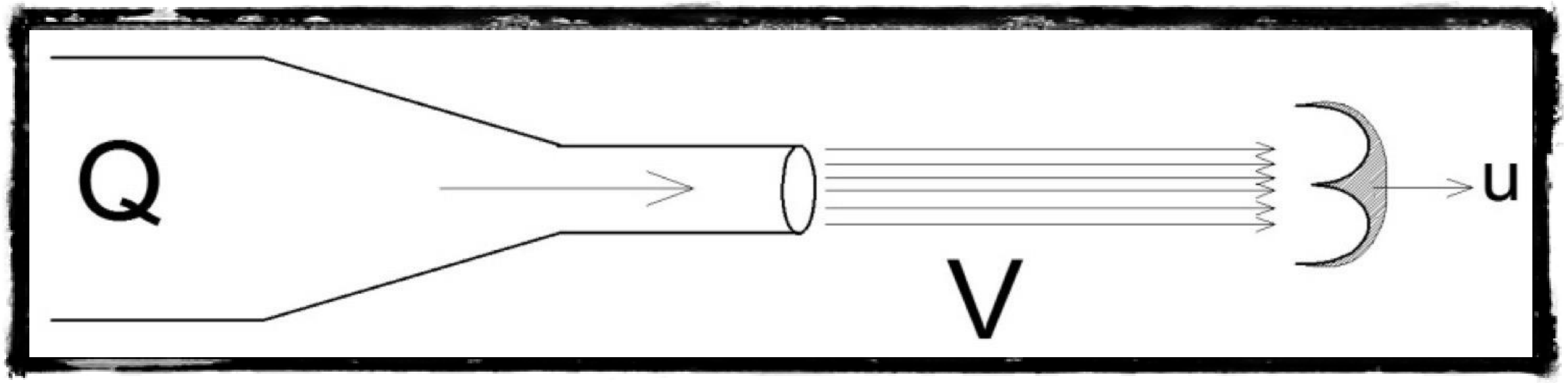
$$R_x = 2\rho.Q.v$$

If it moves with u

$$R_x = 2\rho.Q.(v - u)$$

$$\sum F_y = 0$$

$$R_y = 0$$



$$\sum F_x = 0$$

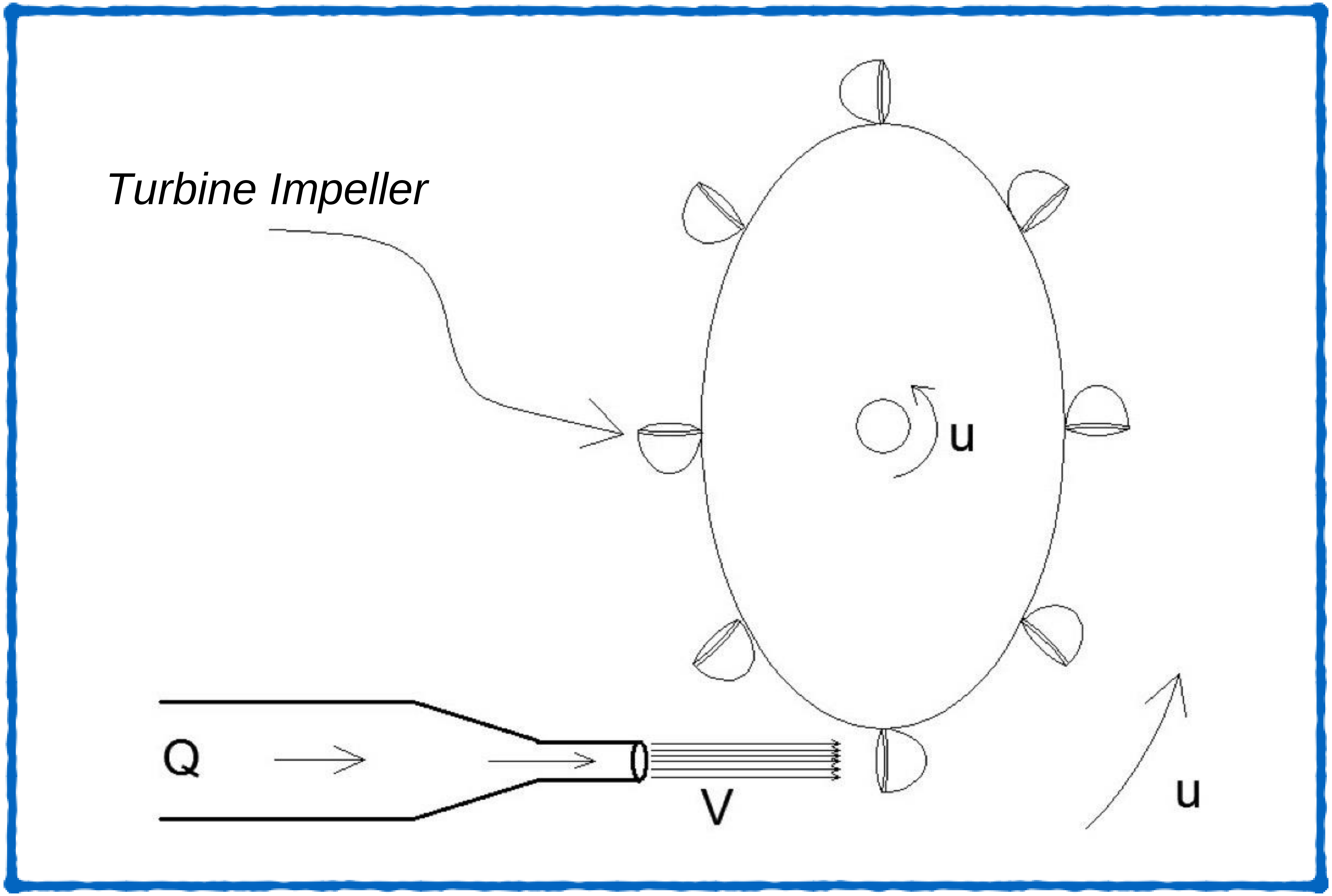
$$R_x = 2\rho.Q.v$$

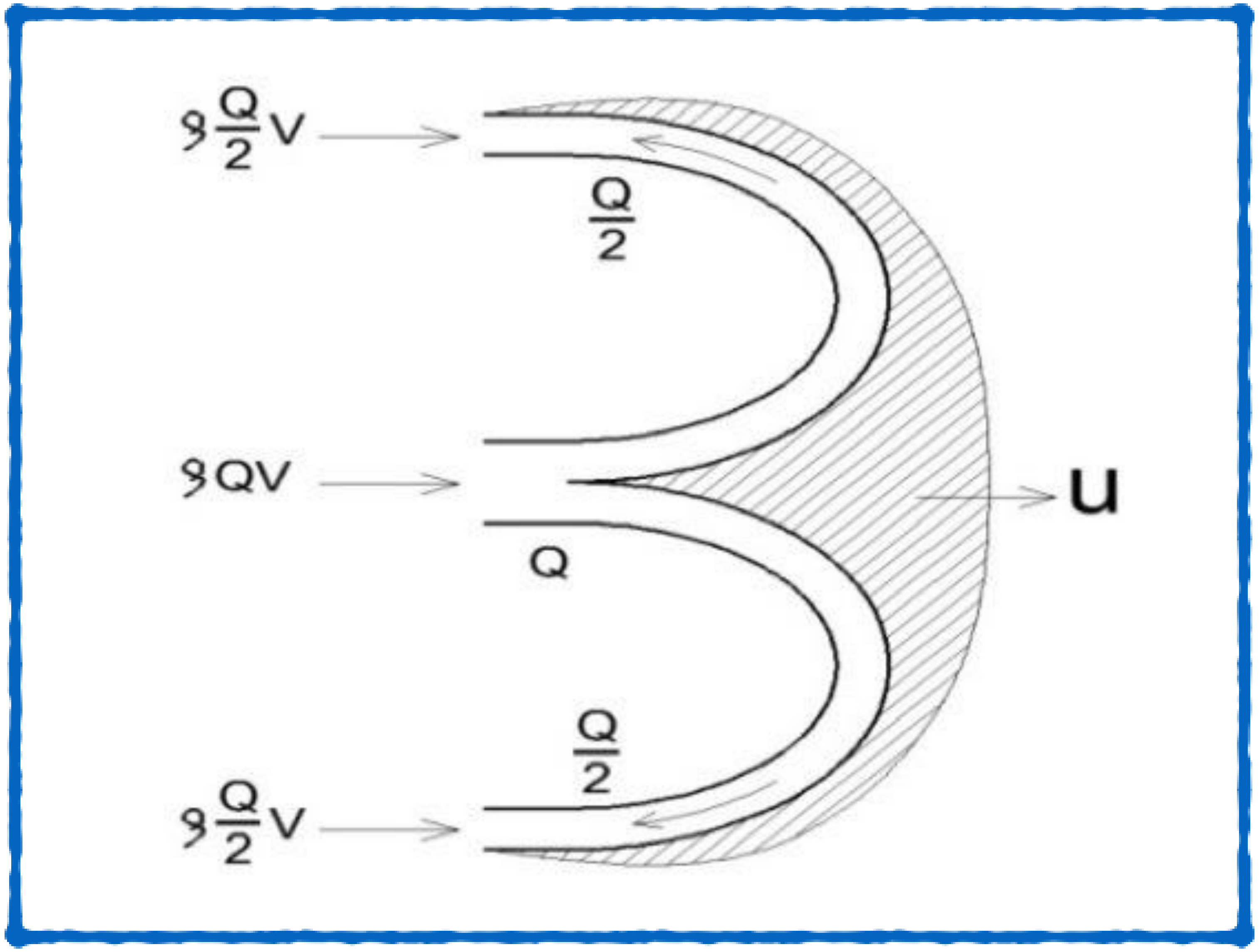
$$\sum F_y = 0$$

$$R_y = 0$$

Pelton Turbine

Here, we want to determine the forces acting on the blades of the turbine.





$$\sum F_x = 0$$

$$\sum F_y = 0$$

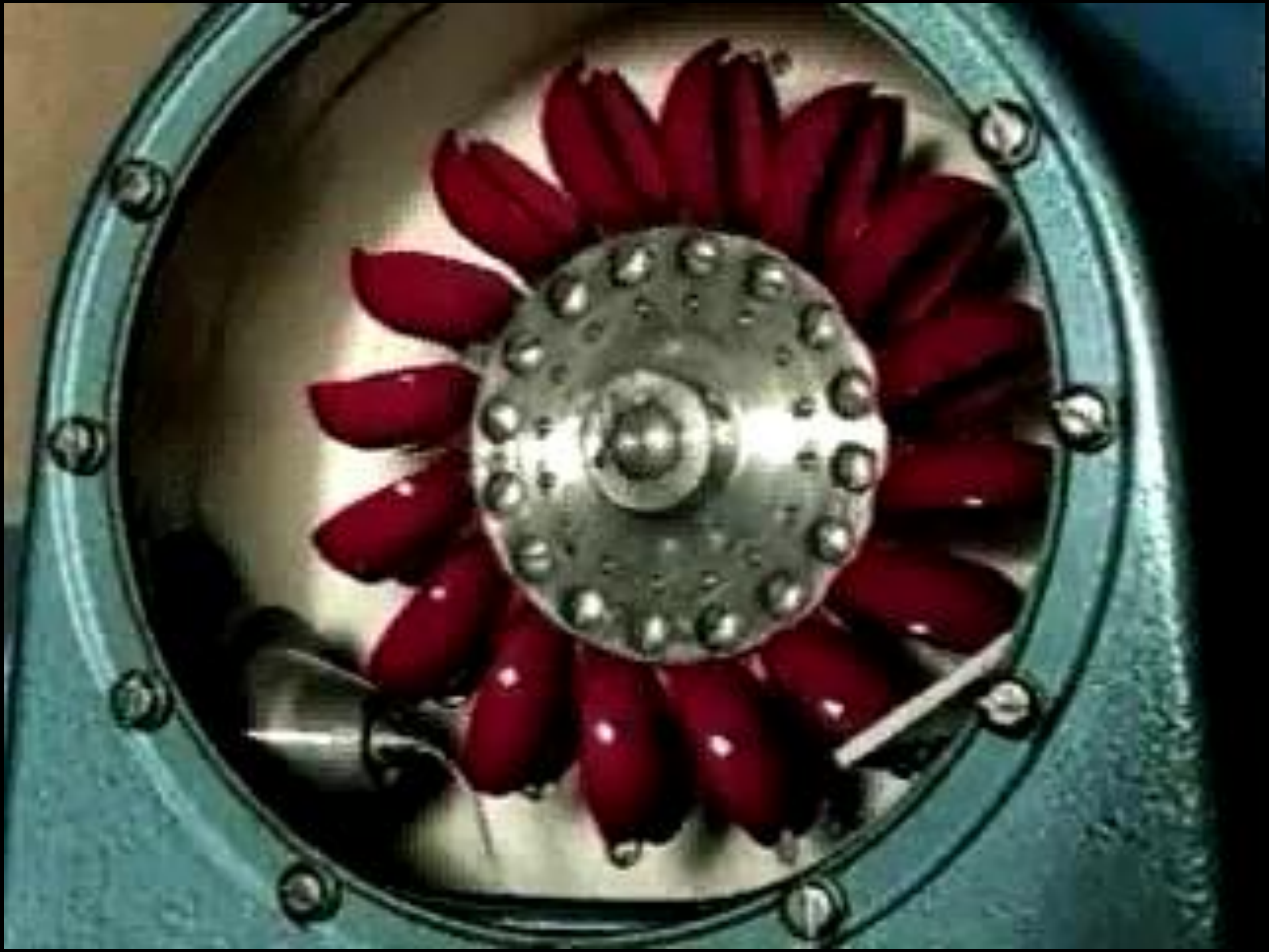
If we take u in to consideration instead of v,

$$R_x = \rho.Q.v$$

$$R_x = \rho.Q.(v-u)$$

$$R_y = 0$$

A Pelton wheel turbine is a device used to generate power by extracting energy from flowing water.



Energy of the water is converted into the output energy of the turbine

If the power transferred to the blades of the turbine is P, taking that power is defined as the work done per unit time

$$P = FU$$

where

$$F = R_x$$

In order to maximize power

$$\frac{\partial P}{\partial u} = 0$$

$$P = \gamma . Q . H$$

1. One Dimensional Flows of Real Fluids

As opposed to ideal fluids, in real fluids

$$\mu \neq 0\,,\ \tau \neq 0$$

So →

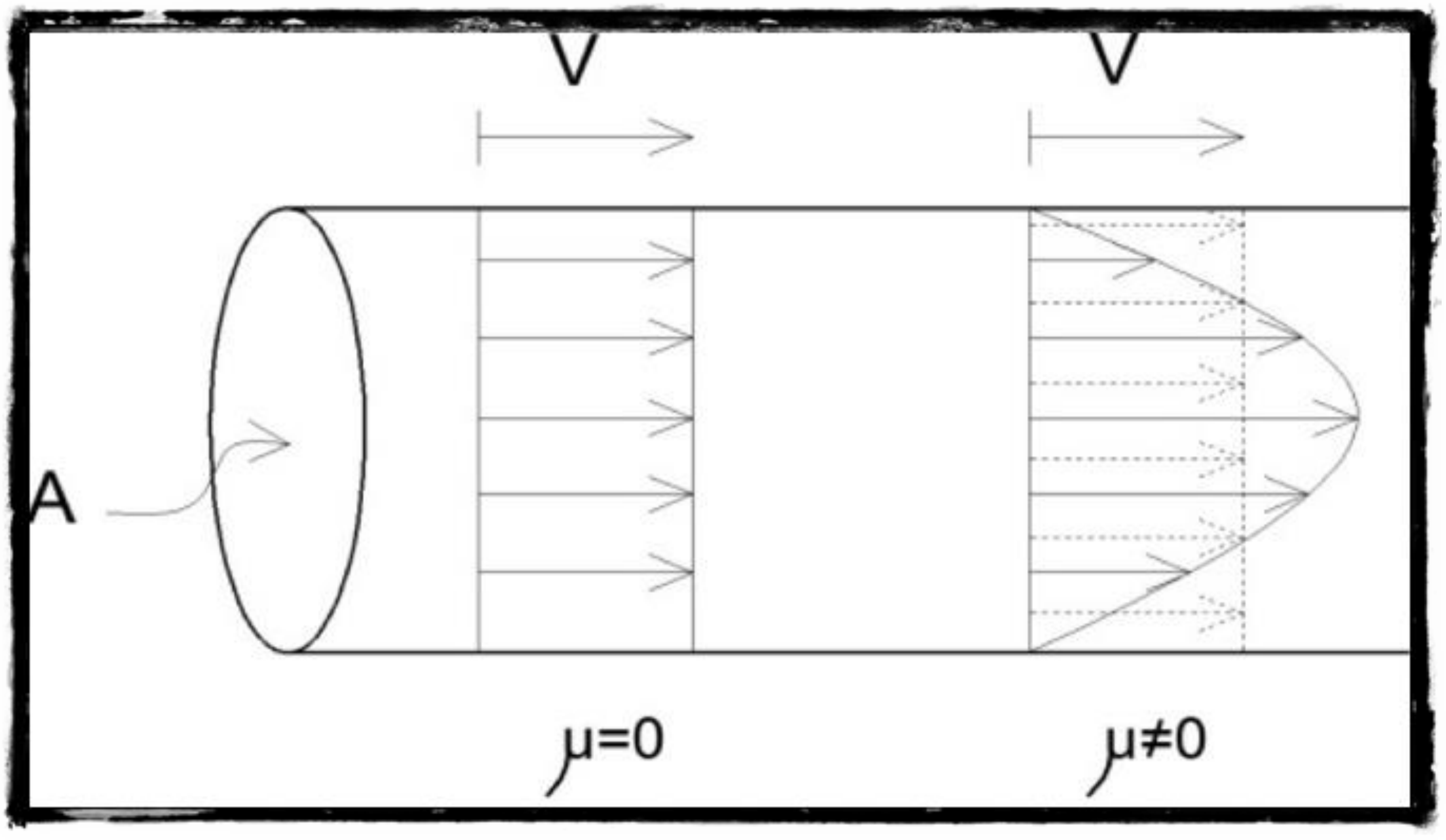
$$ds \neq 0\,,\ h_k \neq 0$$

Basic equations:

1. Continuity equation

In its general form continuity equation

$$u_1 . dA_1 = u_2 . dA_2$$



Here, is the mean cross-sectional velocity

$$V = \frac{1}{A}\int_A u.dA$$

It is the velocity which is used to determine the discharge, Q, when multiplied by the cross-sectional area, A, of the channel.

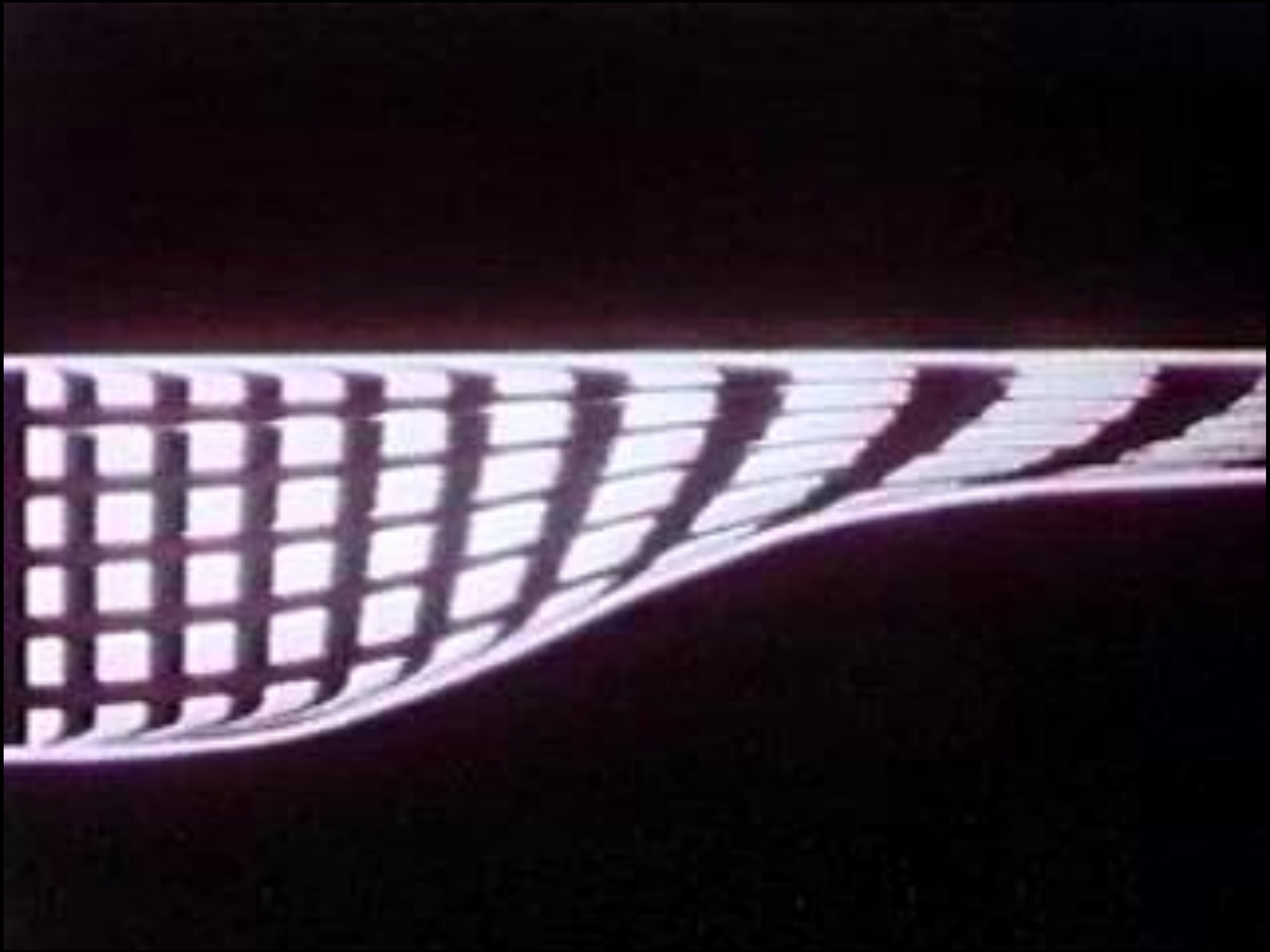
$$Q = V_1.A_1 = V_2.A_2$$

This is the continuity equation of real fluids.

It should not be forgotten that

V is the mean velocity over the cross-sectional area of the channel.

By the ***continuity equation***, for an incompressible flow, the average velocity is inversely proportional to the cross-sectional area of the flow.



Energy equation

In its general form, this equation is given as:

$$u_1.dA_1.z_1 + \frac{p_1}{\gamma}.u_1.dA_1 + \int dA_1.\frac{u_1^3}{2g} = u_2.dA_2.z_2 + \frac{p_2}{\gamma}.u_2.dA_2 + \int dA_2.\frac{u_2^3}{2g} + \frac{1}{\gamma}\frac{dS}{dt}$$

$$\sum F_n = m.a$$

$$Z_A + \frac{P_A}{\gamma} = Z_B + \frac{P_B}{\gamma} = Z_i + \frac{P_i}{\gamma} = \text{constant}$$

This was to analyze the piezometric distribution at a cross-sectional area of a pipe located at a certain height above a datum.

The analysis shows that the piezometric distribution along the same cross-section does not change.

Coming back to our ***energy equation*** again, since we are dealing with ***real fluids***, we need to have a ***mean velocity for the cross-section***.

If we introduce a dimensionless parameter given as:

$$\alpha_1 = \frac{\int u_1^3 dA_1}{v_1^2 \int u_1 . dA_1}$$

$$\alpha_2 = \frac{\int u_2^3 dA_2}{v_2^2 \int u_2 . dA_2}$$

$$z_1 + \frac{p_1}{\gamma} + \frac{\alpha_1 . v_1^2}{2g} = z_2 + \frac{p_2}{\gamma} + \frac{\alpha_2 . v_2^2}{2g} + h_k$$

This is the ***energy equation for one dimensional real fluids.*** *If there were no head loss, i.e.*

T*he equation will reduce to* ***Bernoulli's equation*** *explained in previous sections*
and are called ***Kinetic correction factors****.*

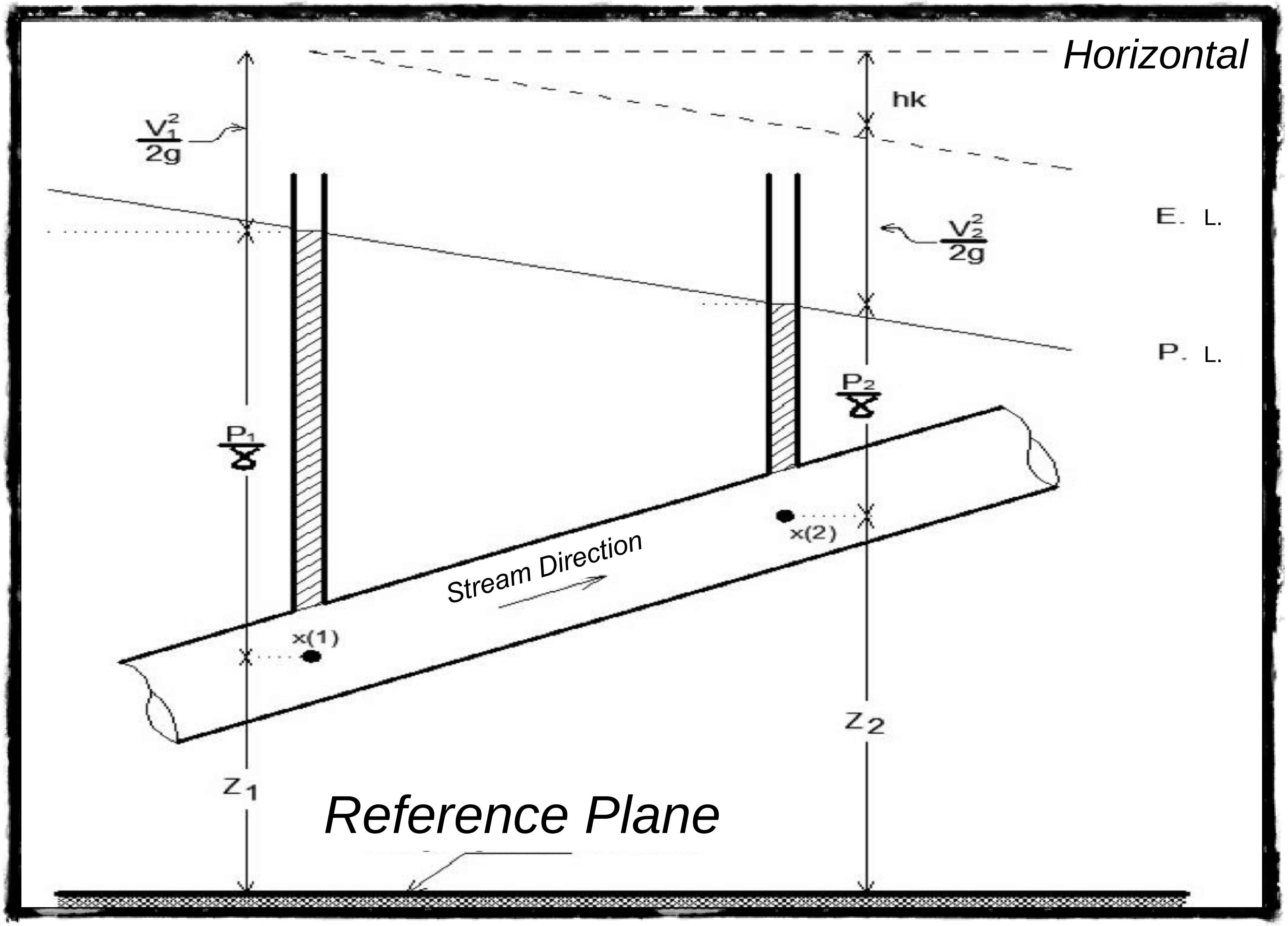
These factors are always greater than 1

Because of the velocity distribution in practice, they have values very close to 1 (ranging from 1.02-1.03). Because of this, approximately, they are taken as 1 and,

therefore, the ***energy equation*** *becomes:*

$$z_1 + \frac{p_1}{\gamma} + \frac{v_1^2}{2g} = z_2 + \frac{p_2}{\gamma} + \frac{v_2^2}{2g} + h_k$$

We can show the meaning of this equation using the figure



$$h_k = \frac{f}{D} \cdot \frac{v^2}{2g} \cdot L$$

V is the mean velocity and it is constant, D is pipe diameter and L is the distance between the points considered in the analysis.

*If the pipe did not have a **constant diameter**, would not be linear.*

This equation is called

Weisbach's head loss equation

and it shows that the head loss is linear for the given condition.

Impulse-Momentum equation

Recall that we developed the general form of this equation given as follows.

$$\vec{F} = (\rho_2 . u_2 . dA_2)\vec{u}_2 - (\rho_1 . u_1 . dA_1)\vec{u}_1$$

In real fluids, we need to have a ***mean cross-sectional velocity.***

For the same reason given earlier for ,
let's introduce another *dimensionless parameter* :

$$\beta_1 = \frac{\int u_1^2 dA_1}{v_1 \int u_1 . dA_1}$$

$$\beta_2 = \frac{\int u_2^2 dA_2}{v_2 \int u_2 . dA_2}$$

β_1 **and** β_2

↓

Momentum correction factors

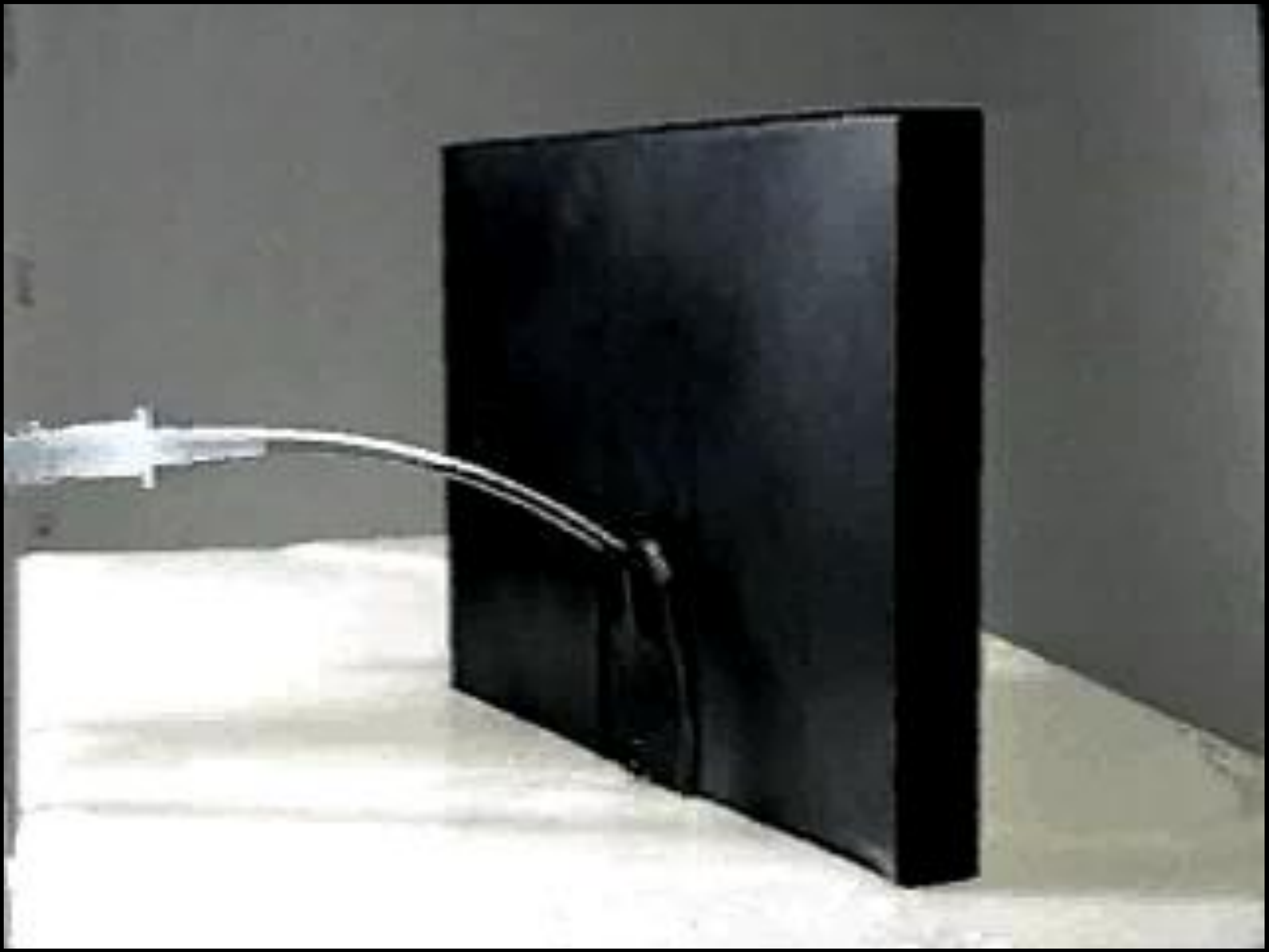
However, in practice, they are taken as 1:

the equation becomes

$$\vec{F} = \rho.Q(V_2 - (V_1))$$

Here again, it should be remembered that V is the mean cross-sectional velocity.

A jet of fluid deflected by an object puts a force on the object.



This force is the result of the change of momentum of the fluid and can happen even though the speed (magnitude of velocity) remains constant.

A horizontal momentum flux of water is created when the garden hose is turned on. A corresponding reaction force acts on the garden hose, pushing it backwards.

Work must be done on the device shown to turn it over because the system gains potential energy as the heavy (dark) liquid is raised above the light (clear) liquid. This potential energy is converted into kinetic energy