Fluid Mechanics

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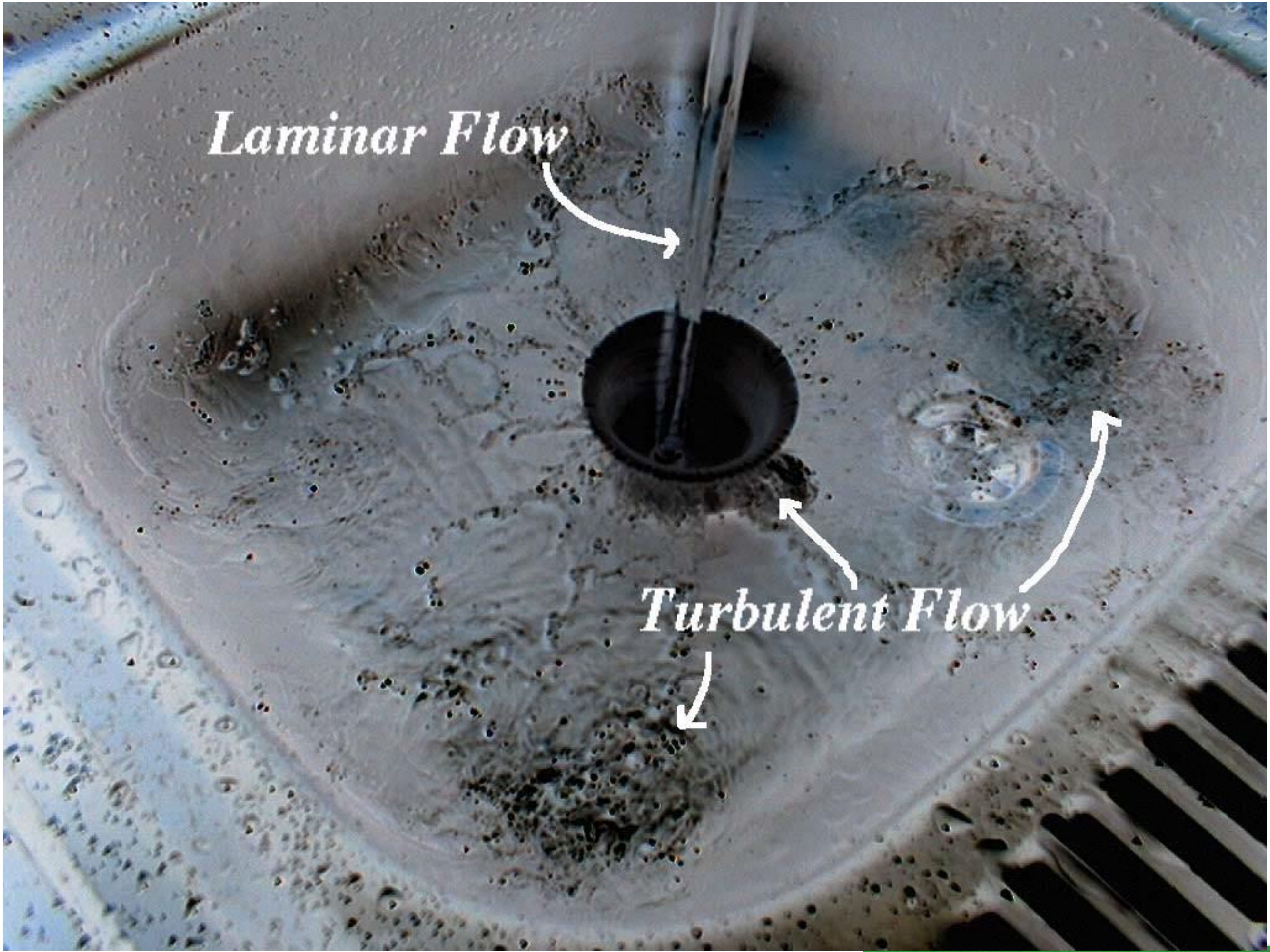
One dimensional flow in real fluids Laminar and Turbulent Flows

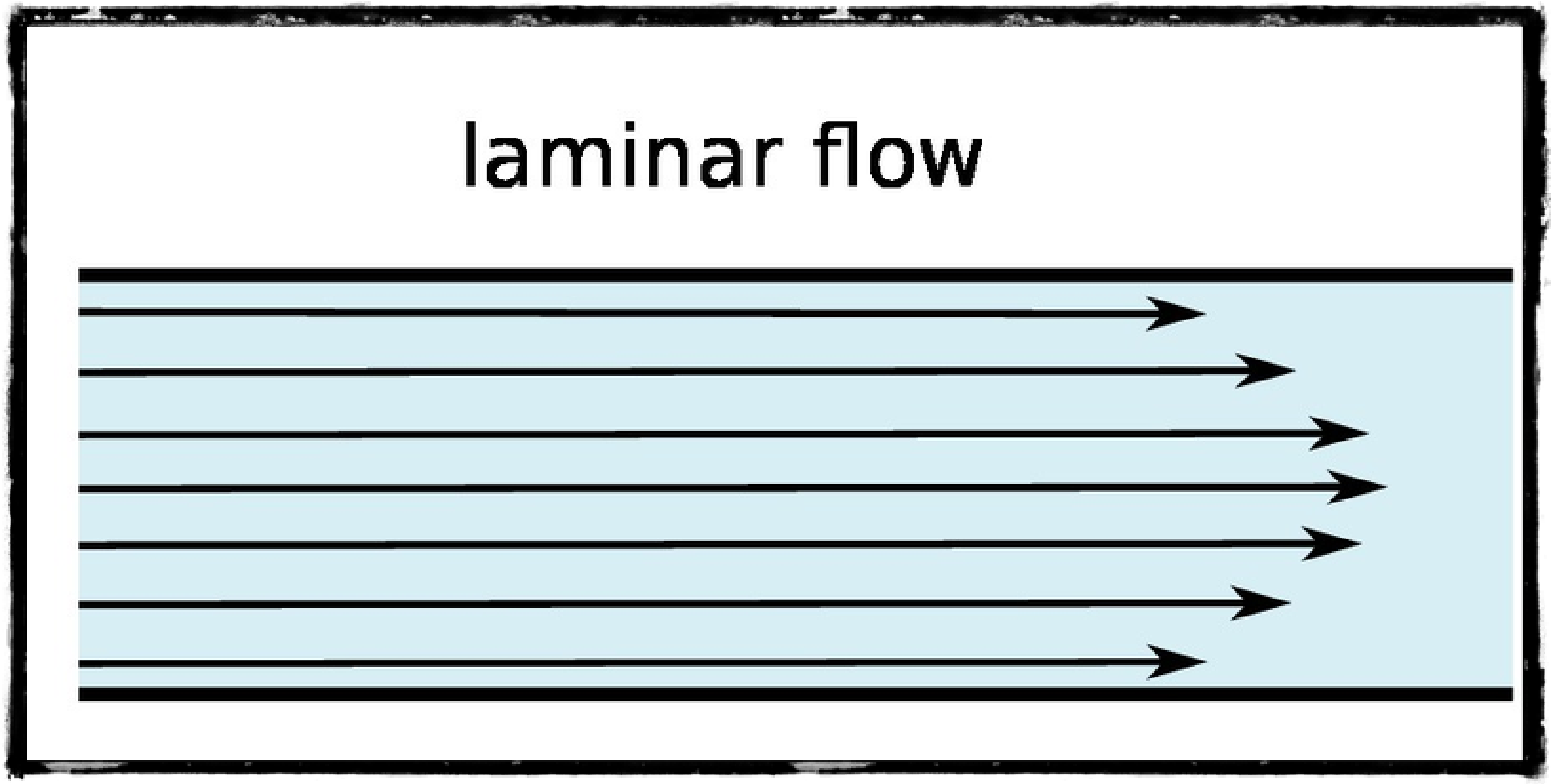
*The flow of fluids is divided in to two groups as **laminar** and **turbulent***

The first person to identify these two different flow types for the first time is Reynolds


Laminar Flow
Turbulent Flow

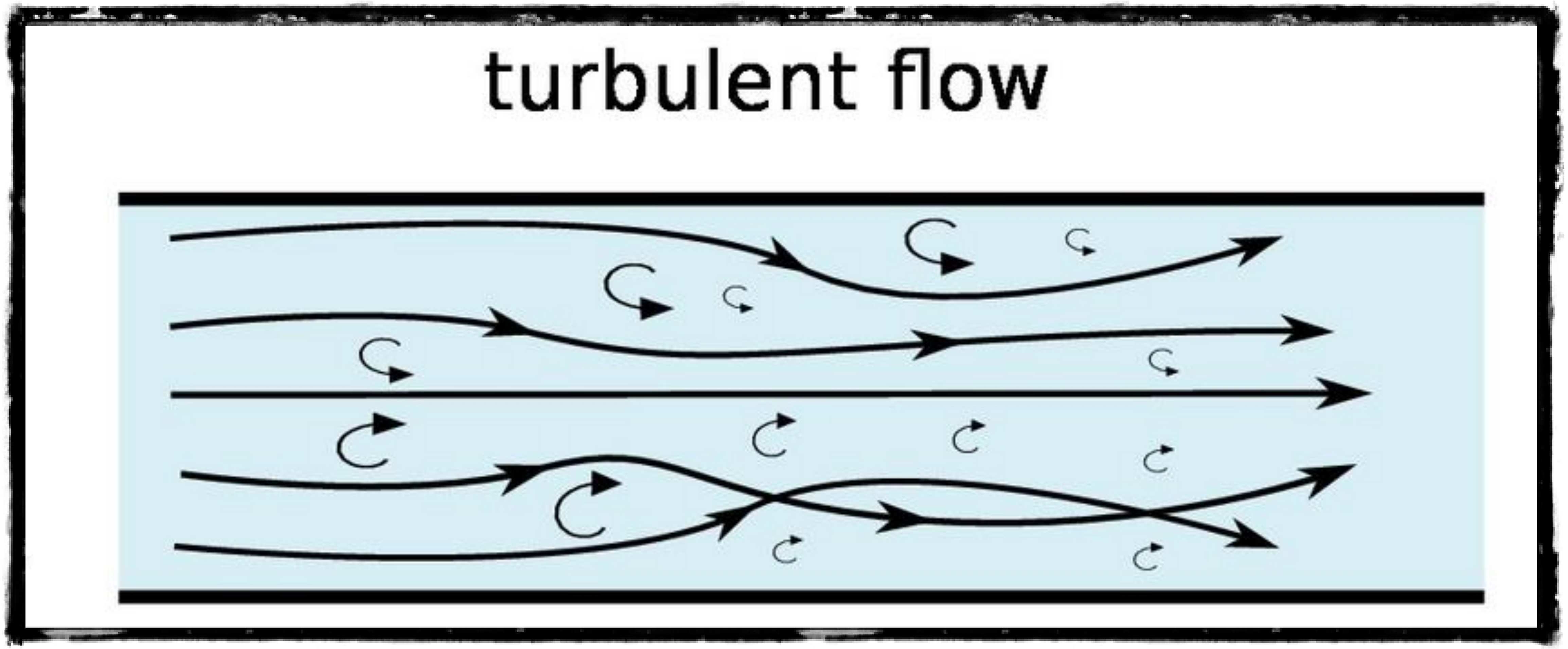
Laminar flows *are flows in which there is* ***no exchange of momentum or energy*** *of flow between layers of flow.*

Layers of flow are ***independent*** *from each other.*



Turbulent flows are flows, as opposed to laminar flows, where **there is exchange of momentum or energy** of flow between layers of flow

Because of this exchange, the flow velocity distribution is close to the distribution on uniform flows

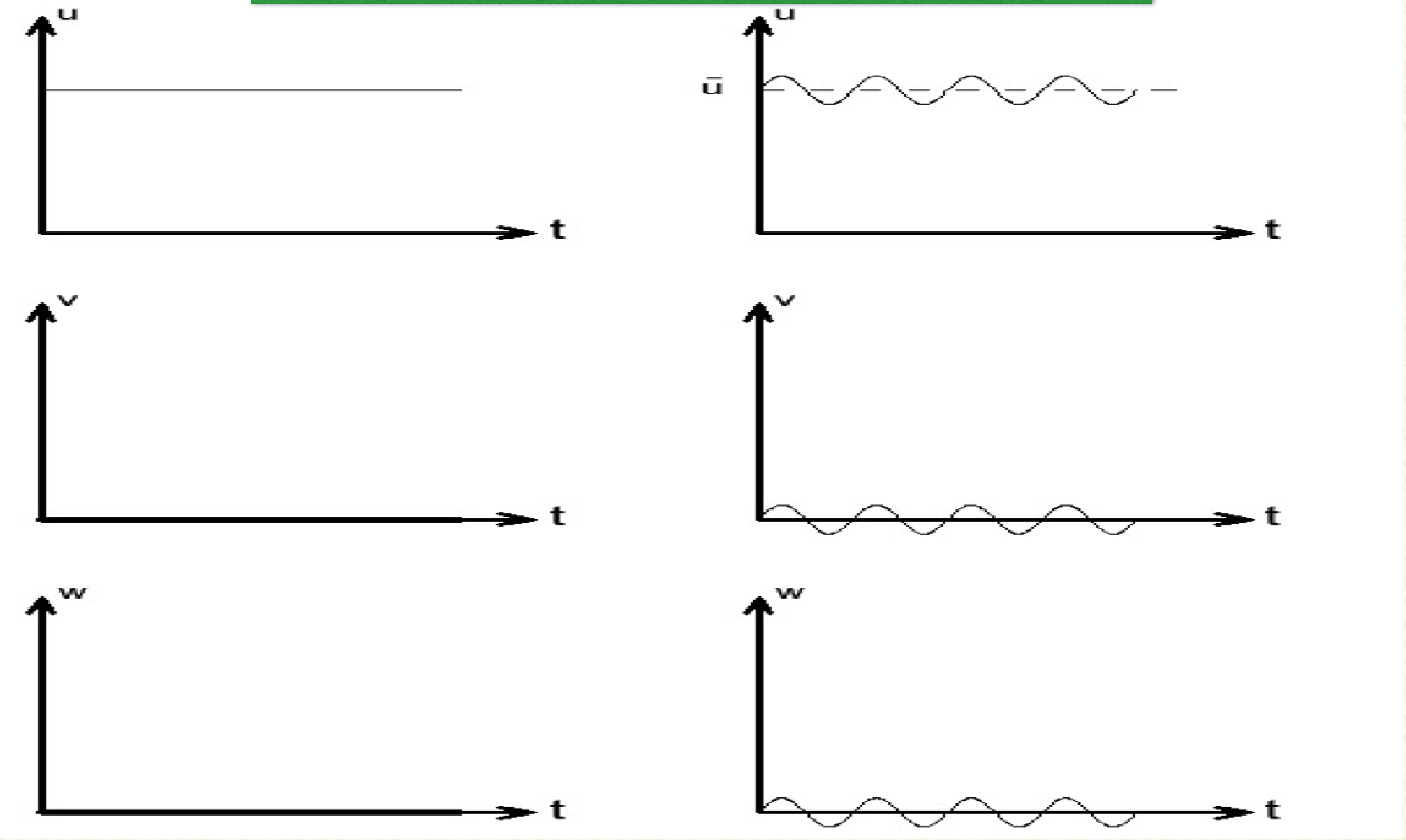


This usually happens in fluids having **high velocities**

If the velocity at a point in one dimensional flow is measured continously and if it is drawn graphically

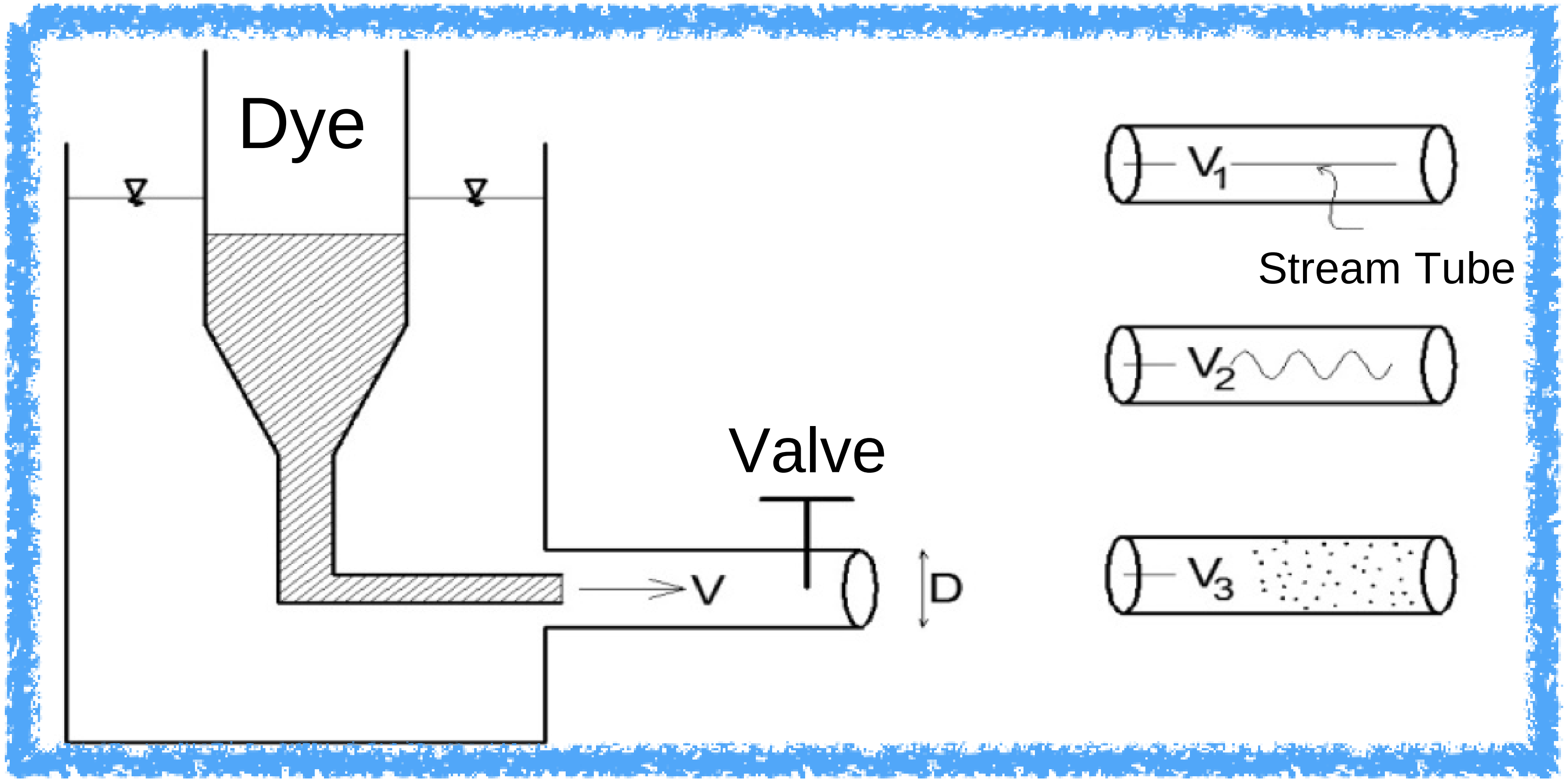
one can get the following graphics from ***laminar*** *and* ***turbulent*** *flow conditions*

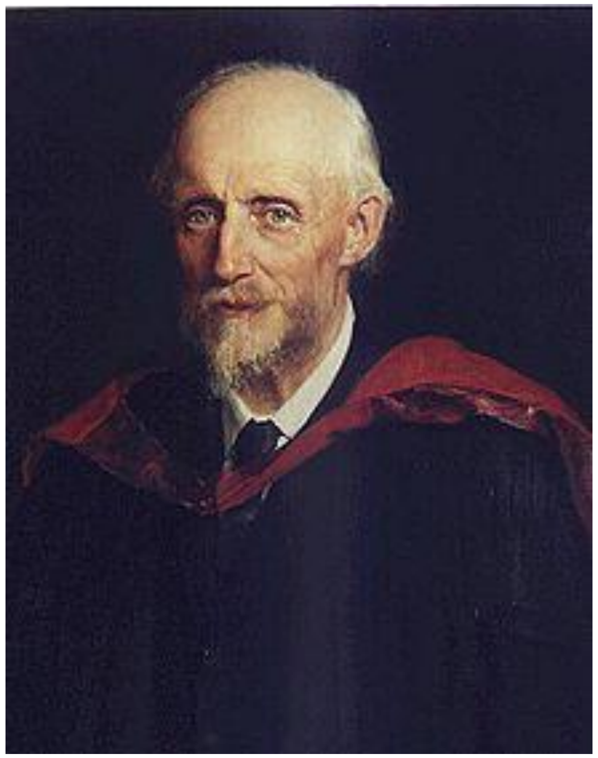
Let the flow be in the x-direction.



Examples of Turbulent Flows

Reynolds's Number Experiment





1842-1919

Reynolds *undertook an experiment and as a result proposed a number called* ***Reynolds's number (R_e)***

$$R_e = \frac{\rho . v . D}{\mu}$$

$$\text{Since } \vartheta = \frac{\mu}{\rho}$$

$$R_e = \frac{v . D}{\vartheta}$$

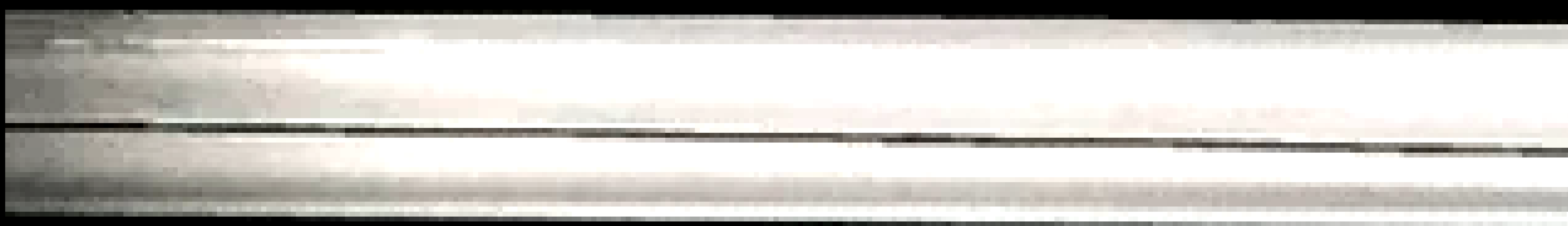
Based on the results of the experiment, Reynolds grouped flows into groups using R_e.

If $R_e < 2000$, the flow is called Laminar flow

If $2000 < R_e < 2500$, the flow is called Transition flow

If $R_e > 2500$, the flow is called Turbulent flow

Experiment in Reynolds Tank



Laminar Transient Turbulent Flows

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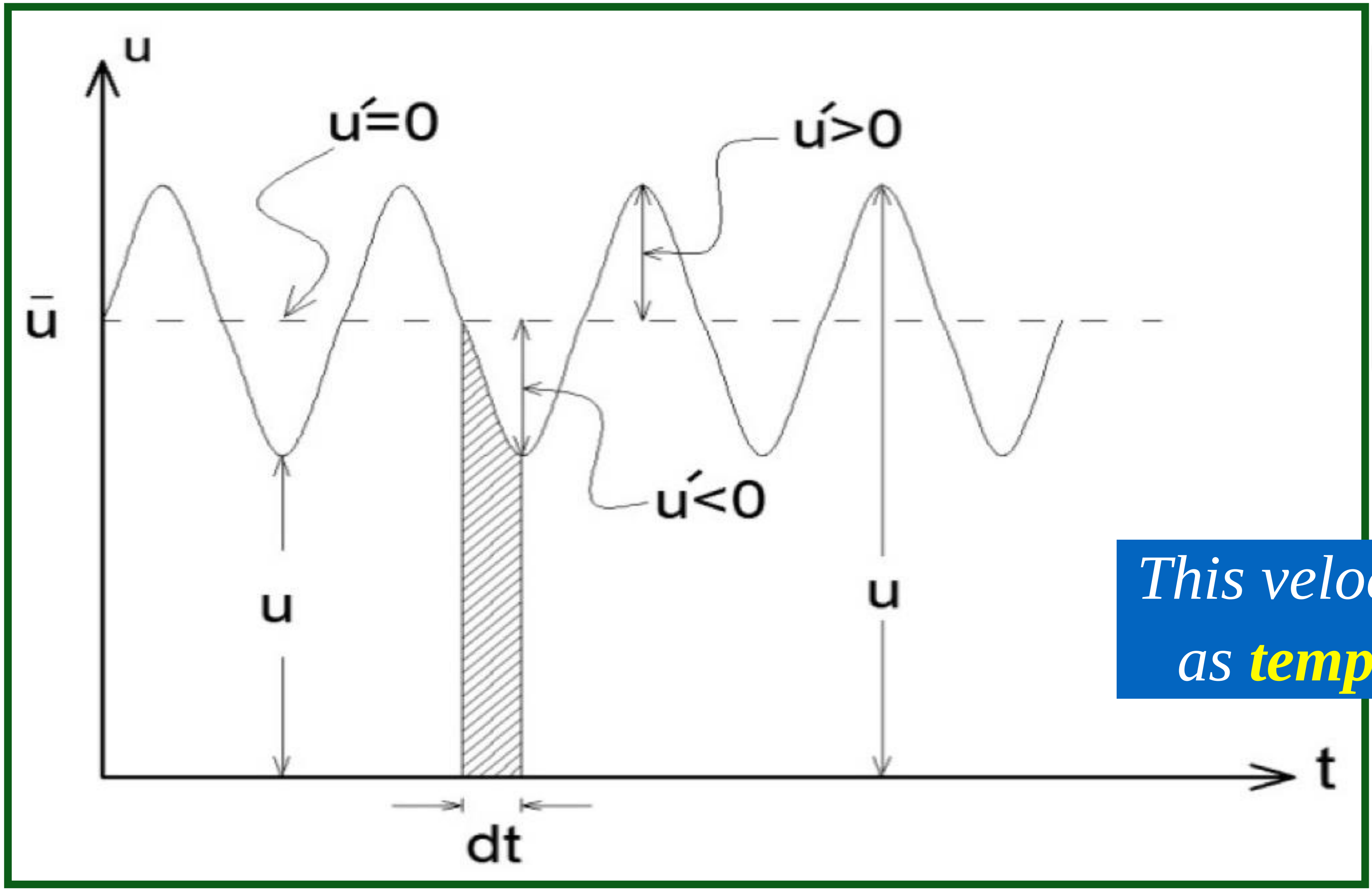
Turbulent *flows can be considered as permanent flows if* *temporal mean velocity* *variations are taken into consideration.*

Let's say we have a time series of velocity as given in the following figure.



$$\overline{U} = \frac{1}{T}\int_0^T u.dt$$

This velocity is what is known as ***temporal mean velocity***

We know that

$$U' = \frac{1}{T}\int_0^T u'.dt = 0$$

In the same manner

$$U' = W' = 0$$

We can write the instantaneous velocities in terms of their temporal mean velocity and the corresponding velocity fluctuation as follows :

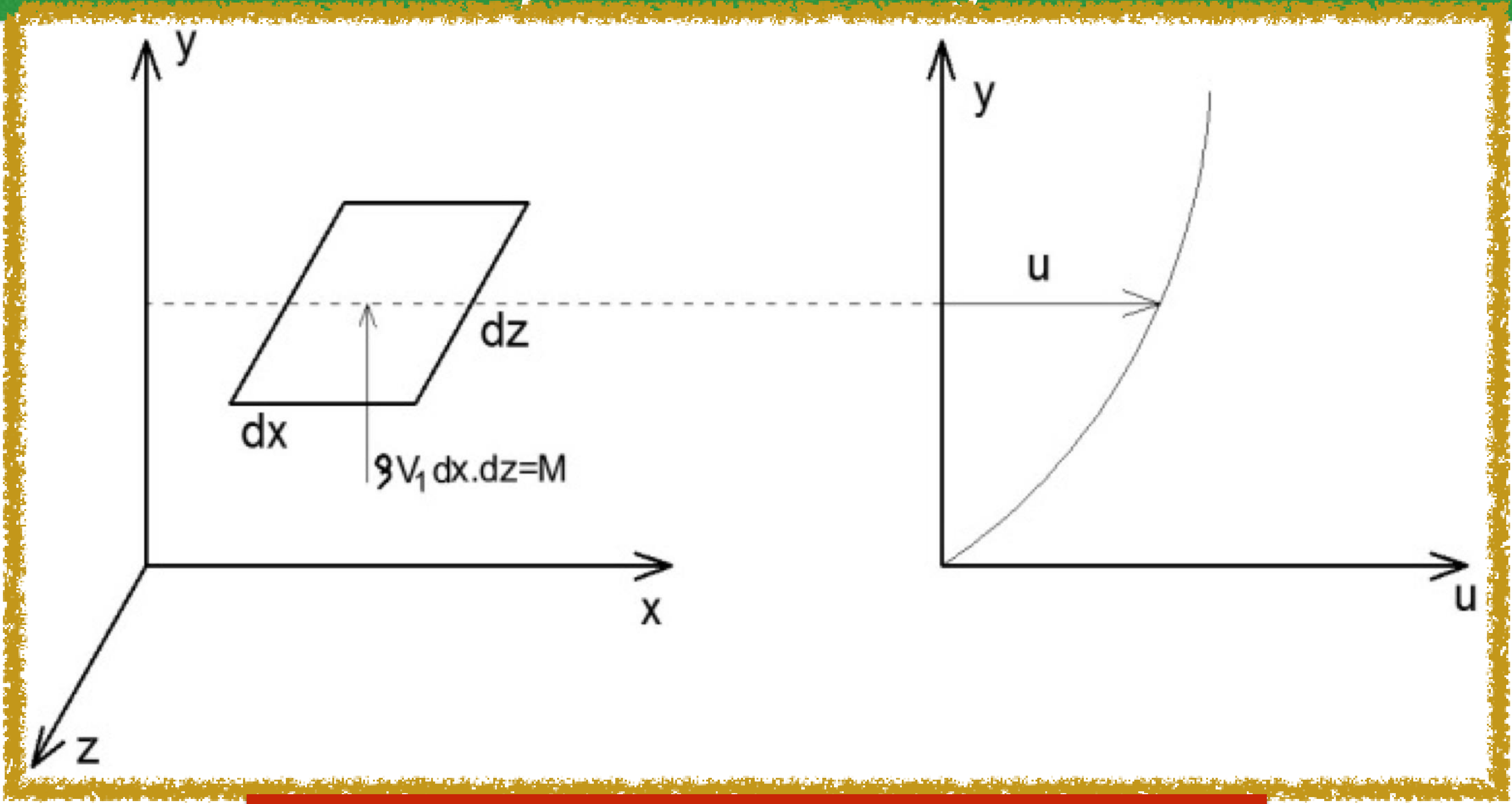
$$u = \bar{u} + u'$$

$$v = \bar{v} + v'$$

$$w = \bar{w} + w'$$

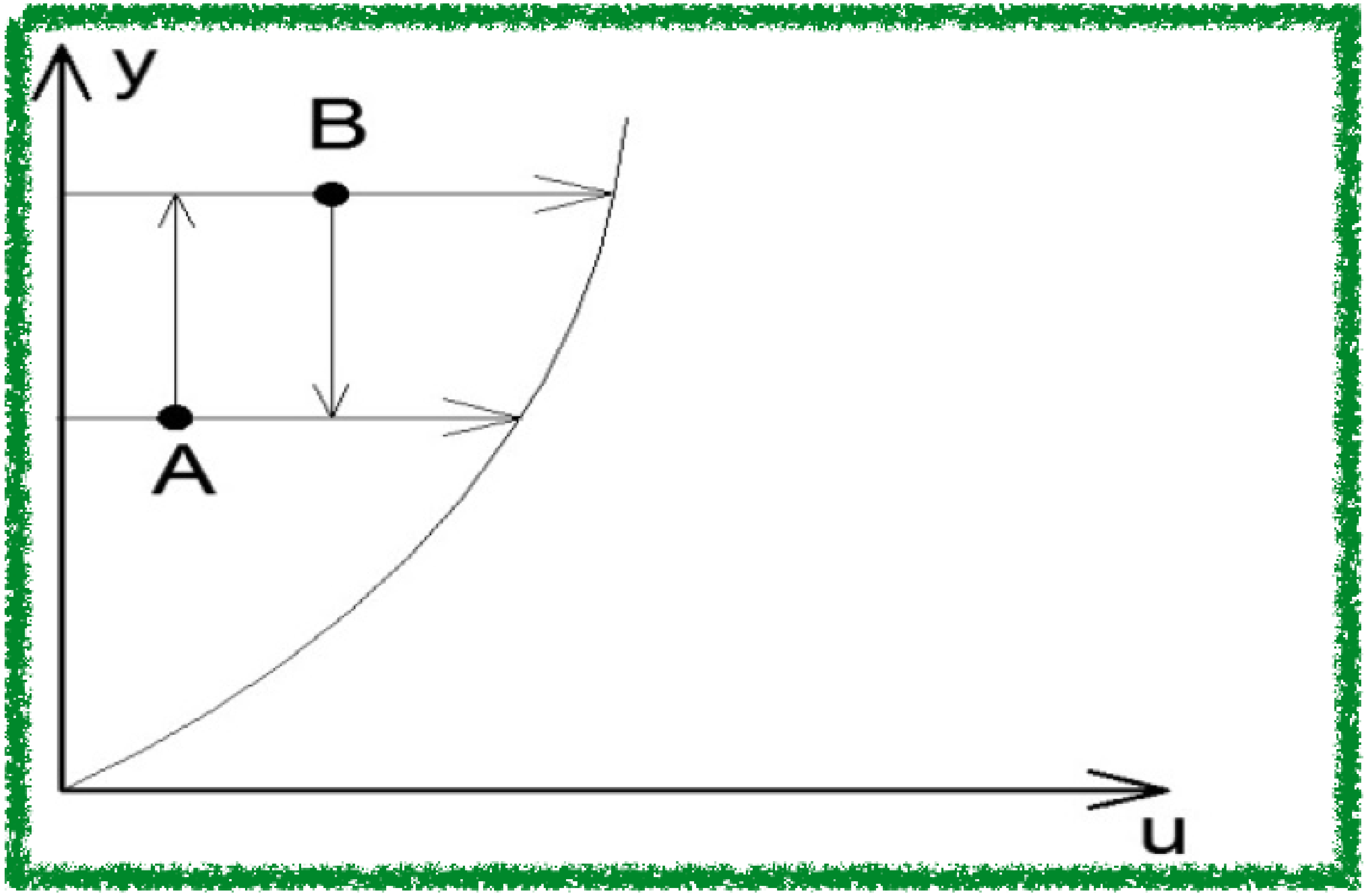
Turbulent Shear Stress (Reynolds Stress)

Let's consider an area along x-z plane given on x-y plane as depicted on the figure



$$\bar{\tau} = -\rho.\overline{u}'.\overline{v}'$$

The (-) sign is introduced in the equation to obtain a positive value of the mean shear stress because the product is always negative



A. If $v' < 0\,,\ u' > 0$

B. If $v' > 0\,,\ u' < 0$

If we take the absolute values,

$$|u'| = |v'| = l\frac{du}{dy}$$

$$l = \chi \cdot y$$

$$\chi$$

Prandtl length *of path.*

Von Karman's constant

its value is equal to 0.4

$$\bar{\tau} = \mu_T \cdot \frac{du}{dy}$$

This is the

turbulent shear stress equation

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μ_T → ***Turbulent viscosity* or *Eddy viscosity***

Therefore, in real fluids, the total shear stress is the sum of the **turbulent** and **laminar** shear stresses

$$\tau_{Tot} = \tau_T + \tau_l$$

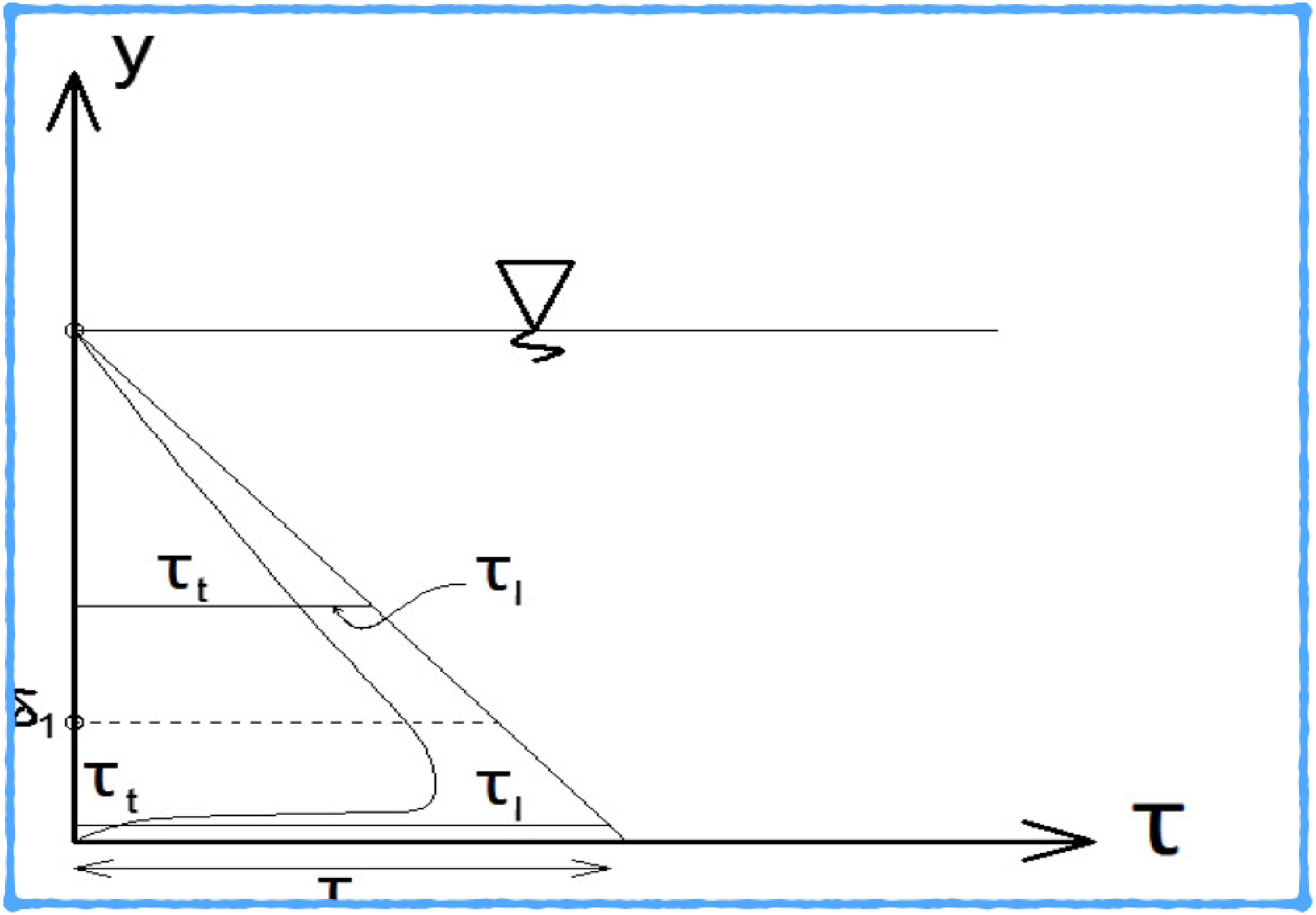
$$\tau_{Tot} = (-\rho.\overline{v}'\overline{u}') + \mu.\frac{du}{dy}$$

$$\bar{\tau}_{Tot} = \mu_T \frac{du}{dy} + \mu.\frac{du}{dy}$$

μ_T shows the nature of low and μ shows the nature of fluid

*On this condition, **Prandtl length** of path is a magnitude of path perpendicular to the wall that a fluid particle obtained from the start of flow until it loses its **identity***

Distribution of shear stress



Let δ_l is the thickness of the laminar film layer in the viscous sub-later.

For $y < \delta_l$, $\tau_l >>>> \tau_T$

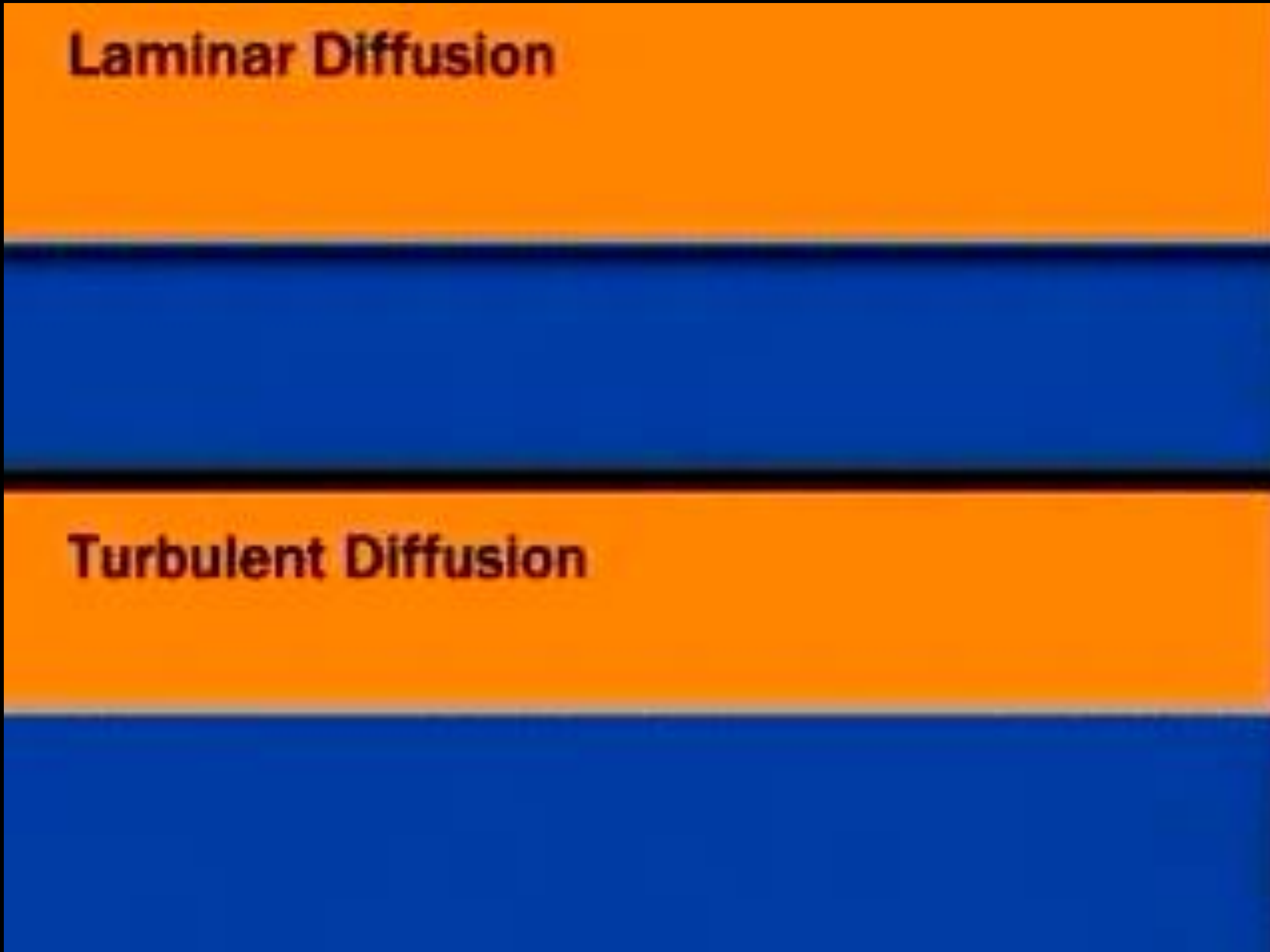
$$\Rightarrow \tau_{Tot} \cong \tau_l = \mu \frac{du}{dy} \text{ as } \tau_T \cong 0$$

For $y > \delta_l$, $\tau_T >>>> \tau_l$

$$\Rightarrow \tau_{Tot} \cong \tau_T = -\rho.\overline{u}'.\overline{v}' = \rho.l^2.\left(\frac{du}{dy}\right)^2 = C \text{ (constant)}$$

$$\tau_l \cong 0$$

Laminar Turbulent Difusion Speeds



Al-Kitāb al-mukhtaṣar fī hīsāb al-ğabr wa'l-muqābala

-al-Kwarizmi

The duty of the man who investigates the writings of scientists, if learning the truth is his goal, is to make himself an enemy of all that he reads, and ... attack it from every side. He should also suspect himself as he performs his critical examination of it, so that he may avoid falling into either prejudice or leniency.

-Hasan Ibn al-Haytham (Alhazen)

Thanks to

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http://www.cfdsupport.com

https://tr.wikipedia.org/wiki/Osborne_Reynolds

http://udel.edu/~inamdar/EGTE215/Laminar_turbulent.pdf

Fluid Mechanics: Fundamentals and Applicationsby Çengel & Cimbala

Munson, Young and Okiishi's Fundamentals of Fluid Mechanics, 8th Edition