SHROFF S. R. ROTARY INSTITUTE OF CHEMICAL TECHNOLOGY
ANKLESHWAR

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REYNOLDS NUMBER

Dynamic Viscosity

$$\mu = \frac{\tau\left(\frac{N}{m^2}\right)}{\frac{du}{dy}\left(\frac{\frac{m}{s}}{m}\right)} = \frac{N.s}{m^2} = \frac{kg}{m.s}$$

In CGS units: poise or Dyne-sec/cm^2

1 poise = Dyne-sec/cm^2 =0.1 Pa. Sec (1 Pa = N/m^2)

1 cP = 10^{-2} poise = 10^{-3} N.s/m^2 = 10^{-3} Pa.s

μ = 1 cP (20°C) for water

μ = 0.0181 cP (20°C) for air

Types of Fluid Flow

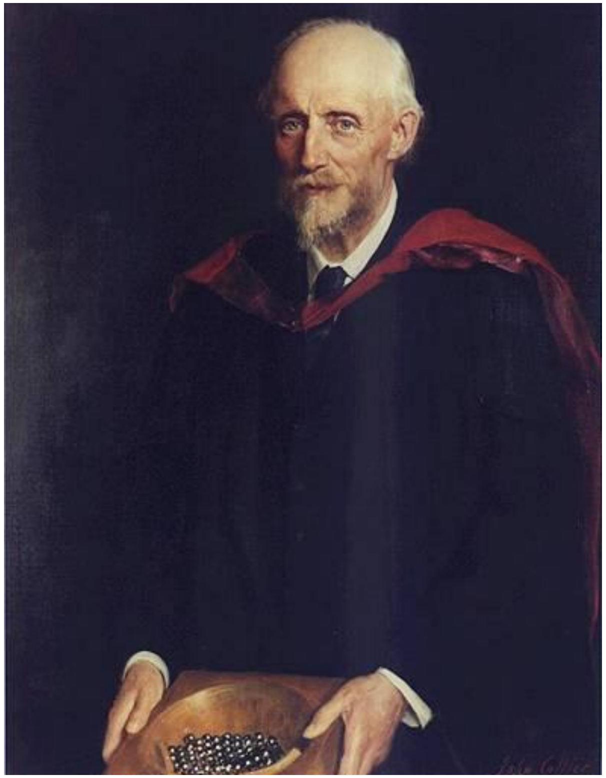
1. Steady and Unsteady flow
2. Uniform and non uniform flow
3. ***Laminar and Turbulent flow***
4. Compressible and Incompressible flow
5. Rotational and Irrotational flow
6. One, Two and Three dimensional flows

About Sir Osborne Reynolds

- The flow of real fluids can basically occur under two very different flow.

1. Laminar flow
2. Turbulent flow

- In 1883, Sir Osborne Reynolds addressed the problem of how laminar flow changes to turbulent flow.



Reynolds number

One problem Reynolds investigated experimentally is the transition of flow from the orderly kind that we call "laminar flow" to the more chaotic type of flow termed "turbulent flow."

Through careful experimentation, Reynolds established that the change in the nature of the flow occurs when a certain combination of the parameters in the flow crosses a threshold

Later, this combination was named the "Reynolds number."

For flow in a circular tube of diameter D, at an average velocity V, the Reynolds number ,Re is defined as follows:

$$\mathrm{Re} = \frac{D V \rho}{\mu} = \frac{D V}{\nu}$$

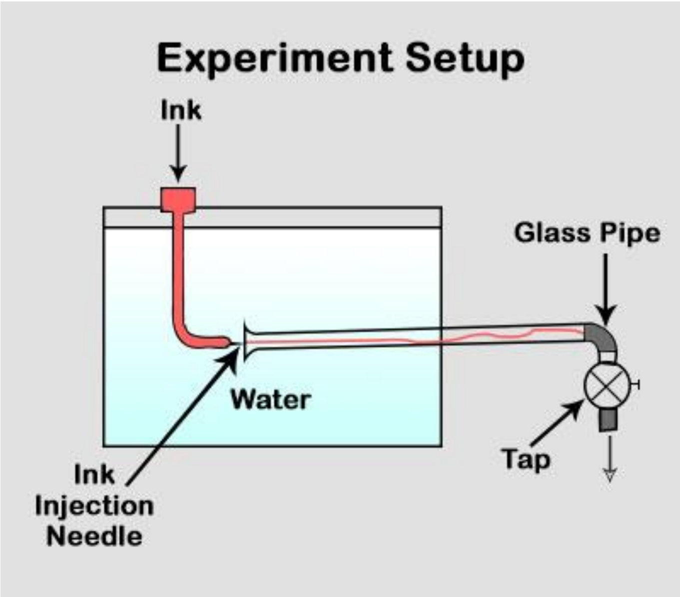
Here,

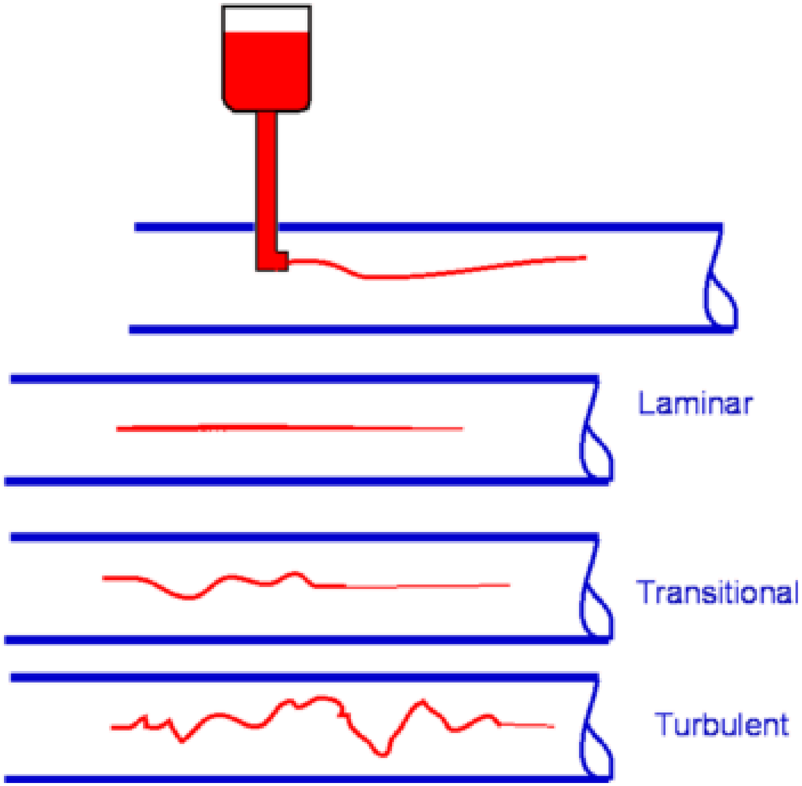
v is the dynamic viscosity of the fluid, and

ρ is the density of the fluid.

Reynolds Experiment

$N_{Re} < 2100$	• Laminar Flow
$2100 < N_{Re} < 4000$	• Transition flow
$N_{Re} > 4000$	•Turbulent flow





Physical Significance of Reynolds's number

In this form, we see that the denominator represents a characteristic shear stress in the flow, because it is the product of the viscosity of the fluid and a characteristic velocity gradient obtained by dividing the average velocity by the diameter of the tube.

The numerator, in contrast, describes an inertial stress; recall that the larger the density, the more massive a material is, and mass is a measure of inertia

$$\mathrm{Re} = \frac{\rho V^2}{\mu (V / D)}$$

$$\mathrm{Re} = \frac{\text{Inertia Force}}{\text{Viscous fore}}$$

The acid with sp. gravity of 1.06 is pumped at a rate of 0.02 m^3/s through a 75 mm i.d. Pipe. The viscosity of the acid is 0.0025 $N.s/m^2$. Calculate NRe and determine the type of flow?

Density of acid = 1060 kg/m^3

Diameter of pipe, D = 75 mm = 0.075 m

Viscosity = 0.0025 $N.s/m^2$ = 0.0025 kg/m.s

A = cross section area of pipe = (Л/4) d^2

u= average velocity = Q/A

u = 0.02 / 4.418 x 10^{-3} m/s

$$Re = \frac{DV\rho}{\mu}$$

N_{Re} = 144054; hence the flow is turbulent

A sugar syrup having sp. gravity of 1.04 is flowing through a 55 mm i.d. Pipe at a flow rate of 66.67 cm^3/sec. The viscosity of the syrup is 0.15 N.s/m^2. Calculate NRe and determine the type of flow?

Density of acid = 1040 kg/m^3

Diameter of pipe, D = 55 mm = 0.055 m

Viscosity = 0.15 N.s/m^2 = 0.15 kg/m.s

A = cross section area of pipe = (π/4) d^2

Q = volumetric flow= 66.67 cm^3/sec

Q = 6.667 x 10^{-5} m^3/sec

u = average velocity = Q/A

u = 0.028 m/s

$$Re = \frac{DV\rho}{\mu}$$

N_{Re} = 10.67; hence the flow is laminar

Waste water with sp. gravity of 0.996 is flowing through a 25 mm i.d. Pipe at a flow rate of 0.8 lit/sec. The viscosity of the syrup is 0.8mPa.s. Calculate N_{Re} and determine the type of flow?

Density of acid = 996 kg/m^3

Diameter of pipe, D = 25 mm = 0.025 m

Viscosity = 0.8 mPa.s = 0.8 x 10^{-3} kg/m.s

A = cross section area of pipe = $(\pi/4)\ d^2$

Q = volumetric flow= 0.8 lit/sec

Q = 0.8 x 10^{-3} m^3/sec

u = average velocity = Q/A

u = 1.63 m/s

$$Re = \frac{DV\rho}{\mu}$$

N_{Re} = 50734; hence the flow is ________

Example : Water having Viscosity of 1.310 cP flowing at an average velocity of 2m/s in a 100mm pipe. Find the Flow.

Ans. : Given data :

μ=1.310 cP =0.00131 kg/ms = 0.00131 Ns/m^2

V=2 m/s

D=100 mm = 0.1 m

$$R_e = \frac{\rho V D}{\mu} = \frac{1000 * 2 * 0.1}{0.00131}$$

$$= \mathbf{152671.7}$$

The Flow is **TURBULENT FLOW.**

Example : Polymer melt with a Density of 900 kg/m^3 and Viscosity of 1 Pa-s flowing at 0.2 m/s in a 20 mm tube. What should be the flow for polymer ?

Ans. : Given data :

μ=1 Pa-s = 1 kg/ms = 1 Ns/m^2

ρ=900 kg/m^3

V=0.2 m/s

D=20 mm = 0.02 m

$$R_e = \frac{\rho V D}{\mu}$$

$$= \frac{900 * 0.2 * 0.02}{1}$$

$$= \mathbf{3.6}$$

The Flow is **LAMINAR FLOW.**

Volumetric flow rate or Discharge

Volumetric flow rate or Discharge is the volume of fluid which passes per unit time; usually represented by the symbol *Q*

Volumetric flow rate can also be defined by: Q = v . A

Where; v= flow velocity and A = cross section area

$$discharge = Q = \frac{volume\ of\ fluid}{time}$$

$$= \frac{mass\ of\ fluid}{density\ x\ time} \quad \left(density = \frac{mass}{volume} \right)$$

$$= \frac{mass\ fluid\ rate}{density} = \frac{m}{\rho}$$

Mass flow rate

mass flow rate is the mass of a substance which passes per unit of time. Its unit is kilogram per second in SI units, and slug per second or pound per second in US customary units. The common symbol is $\dot{m}$

Mass flow rate can also be calculated by:

$$\dot{m} = \rho \cdot \dot{V} = \rho \cdot \mathbf{v} \cdot \mathbf{A}$$

where:

- $\dot{V}$ or **Q** = Volume flow rate,
- ρ = mass density of the fluid,
- **v** = Flow velocity of the mass elements,
- **A** = cross-sectional vector area/surface,

Water at 20C is flowing in a pipe of 25 mm ID at the rate of 1000 kg/min. Calculate the Reynolds number and find the type of flow?

Given;

Viscosity = 1 X 10-3 kg/m.s

Diameter = 25 mm = 0.025 m

Mass flow rate = 1000 kg/min

Mass flow rate can also be calculated by:

$$\dot{m} = \rho \cdot \dot{V} = \rho \cdot \mathbf{v} \cdot \mathbf{A}$$

m = A v g

Where;

A = c/s area of pipe = (Л/4) d^2

v = Velocity of fluid

m = 1000/60 = 16.66kg/sec

v = _____ m/s

1. Reynolds's number does not depend upon:
   a. Viscosity b. diameter of pipe c. temperature d. density

2. 1 kg/ms = ________ Ns/m^2

3. Physical significance of Reynolds's number is **Viscous force/Inertial force.**
TRUE of FALSE