Fluid Mechanics

Tommy Christianto

Oct - 2025

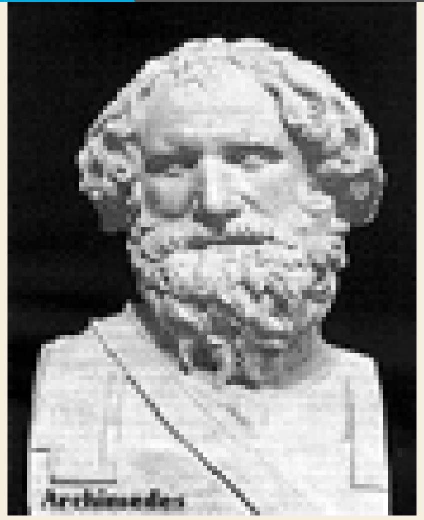
Read Me

1. **Let's Flow Together –** I've arranged this presentation from the **Munson, B.R., Okiishi, T.H., Huebsch, W.W., Rothmayer, A.P., (2013), Fundamentals of Fluid Mechanics, John Wiley & Sons, USA**. Please follow along.
2. **Prepare Your Questions –** If something pops into your mind, jot it down. We'll have **"pit stops"** for Q&A after each main section.
3. **Relate to Your Experience –** As we go, think about how these findings relate to your daily life.
4. **Find the Cause & Effect and Discover Solutions –** Watch how one change — it's like seeing the whole industrial condition as a living system
5. Enjoy! :)

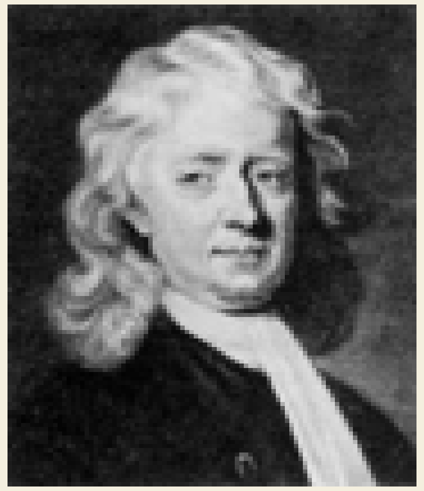
The Agenda

1. The Definition of Fluid Mechanics,
2. The Scope and Importance of Fluid Mechanics
3. The Physical Properties of Fluids
4. Static Fluid,
5. Dynamic Fluids

1. The Definition of Fluid Mechanics



Archimedes
(C. 287-212 BC)



Newton
(1642-1727)

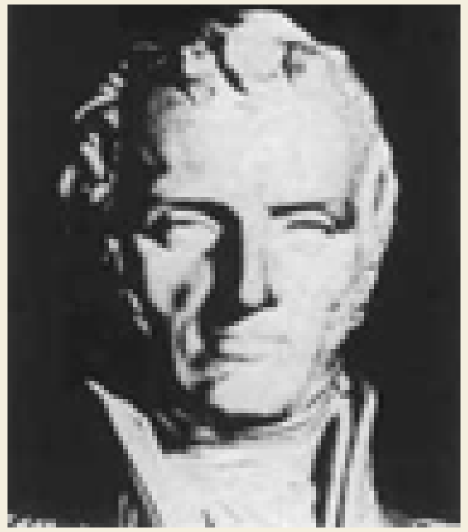
Leibniz
(1646-1716)

Bernoulli
(1667-1748)

Euler
(1707-1783)

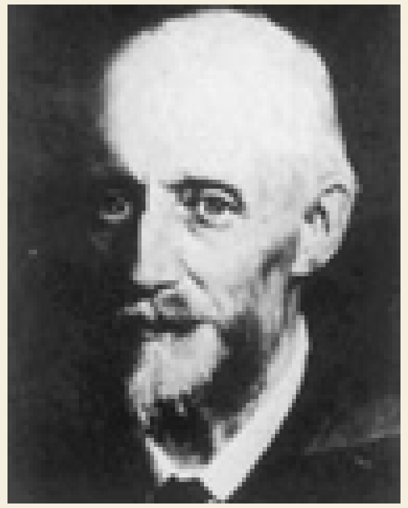
The Actors

Fluid Mechanics

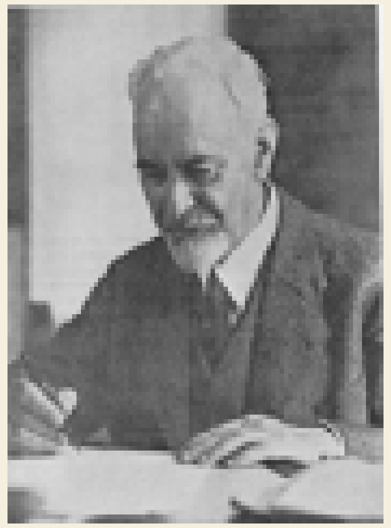


Navier
(1785-1836)

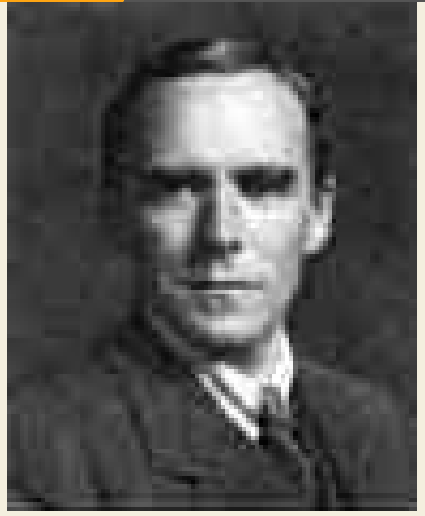
Stokes
(1819-1903)



Reynolds
(1842-1912)



Prandtl
(1875-1953)



Taylor
(1886-1975)

The Definition is

The science that deals with the behavior of fluids at rest (fluid statics) or in motion (fluid dynamics), and the interaction of fluids with solids or other fluids at the boundaries

Fluid Statics

The study of the laws and properties governing fluids at **REST.**

Fluid Dynamics

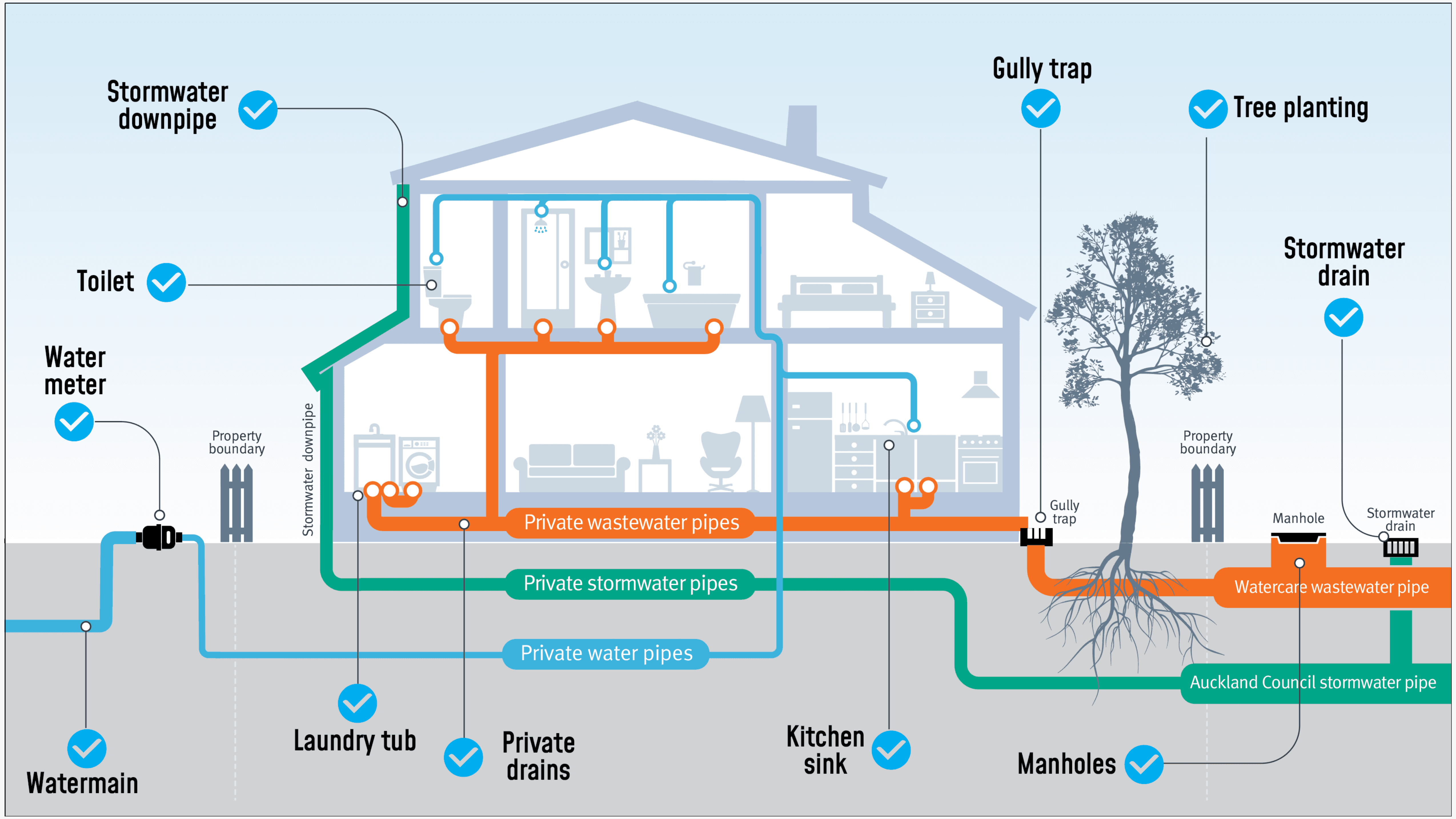
The study of motion fluids under the influence of **forces** and **energy interactions**.

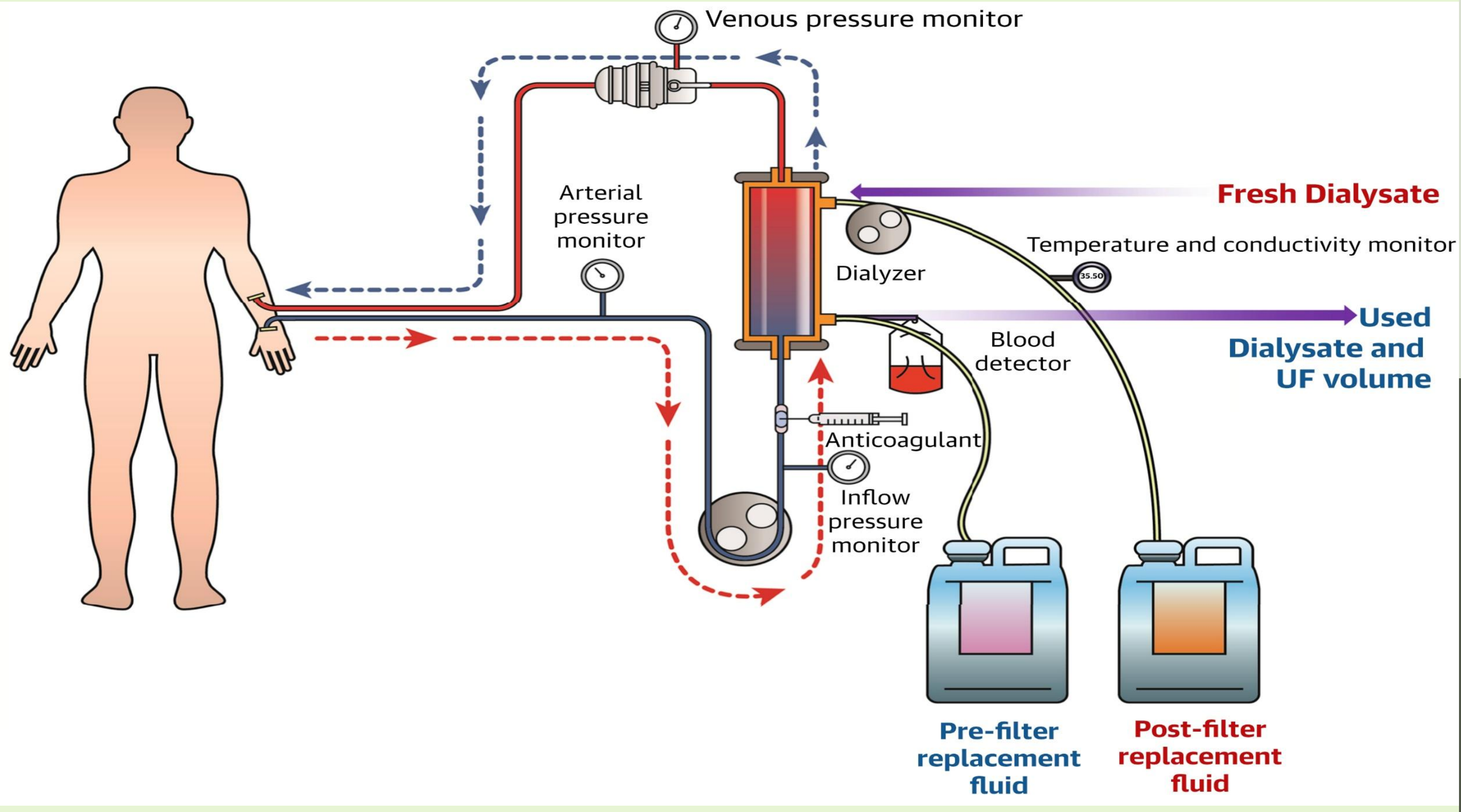
Fluid Kinematics

The study of the motion of fluids (liquids or gases) **without** considering the forces or energy that cause the motion.

2. The Scope and Importance of Fluid Mechanics

Application of Fluid Mechanics
(Household Applications)





Application of Fluid Mechanics

Human Body & Medicine

a life-saving medical device that uses principles of fluid dynamics to purify blood when the kidneys cannot

Application of Fluid Mechanics **(Transportation)**

Why are the sport cars able to reach such in high speed?

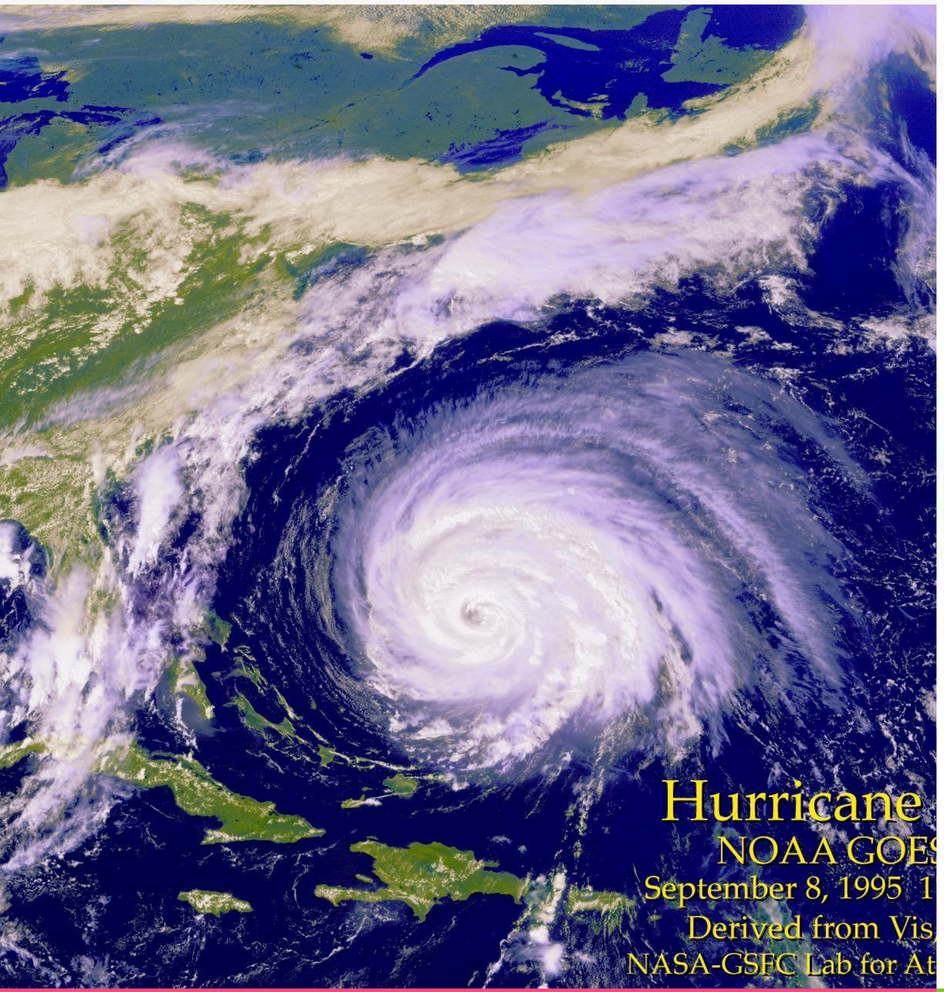
Formula 1

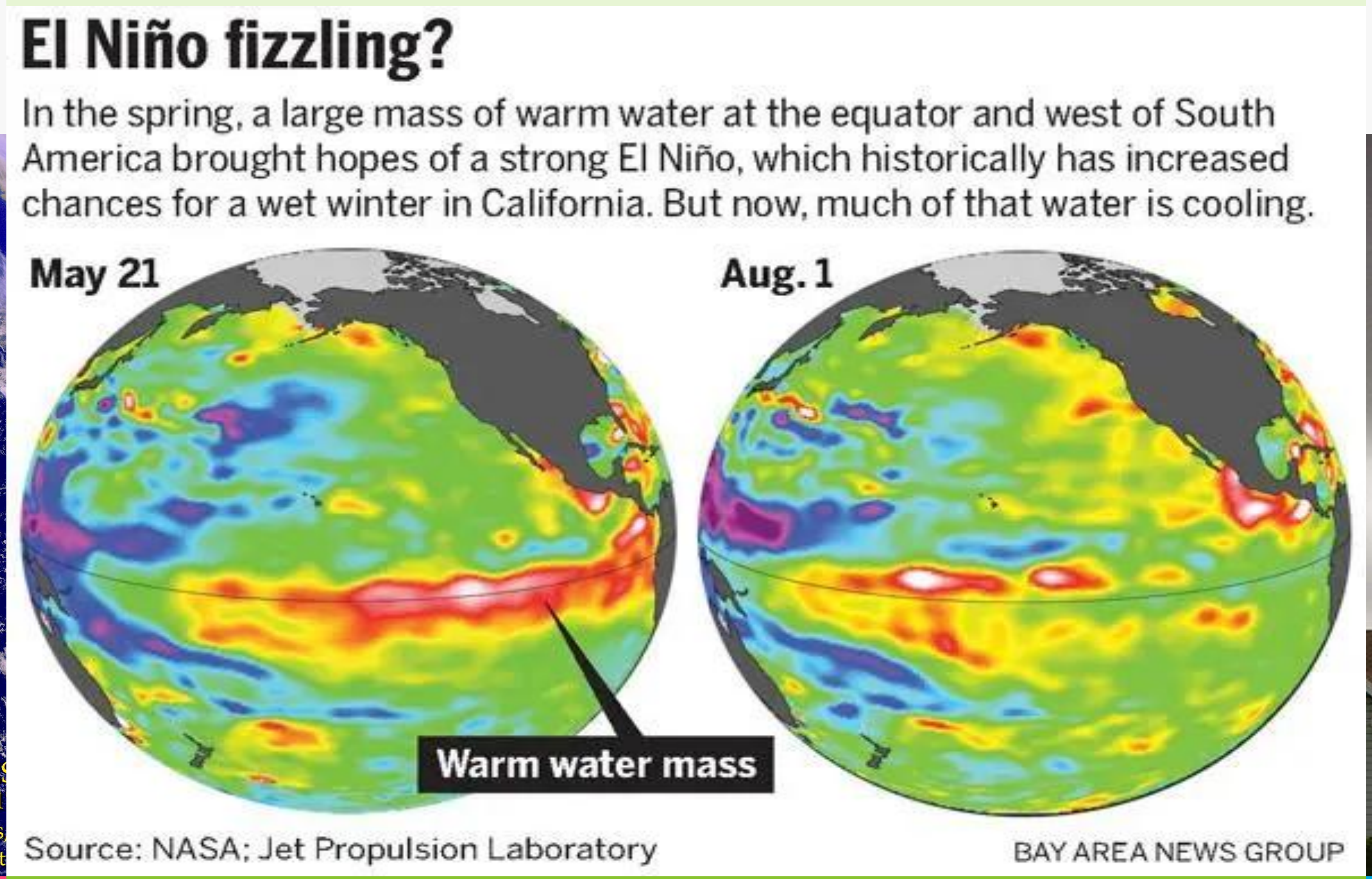
- Aerodynamics (Drag Reduction & Negative Lift),
- Ground Effect & Venturi Effect,
- Cooling Systems,
- Slipstream & Turbulence,
- Tire Interaction with Fluid Flow

CFD (Computational Fluid Dynamics)

The air flow simulation using CFD

Application of Fluid Mechanics

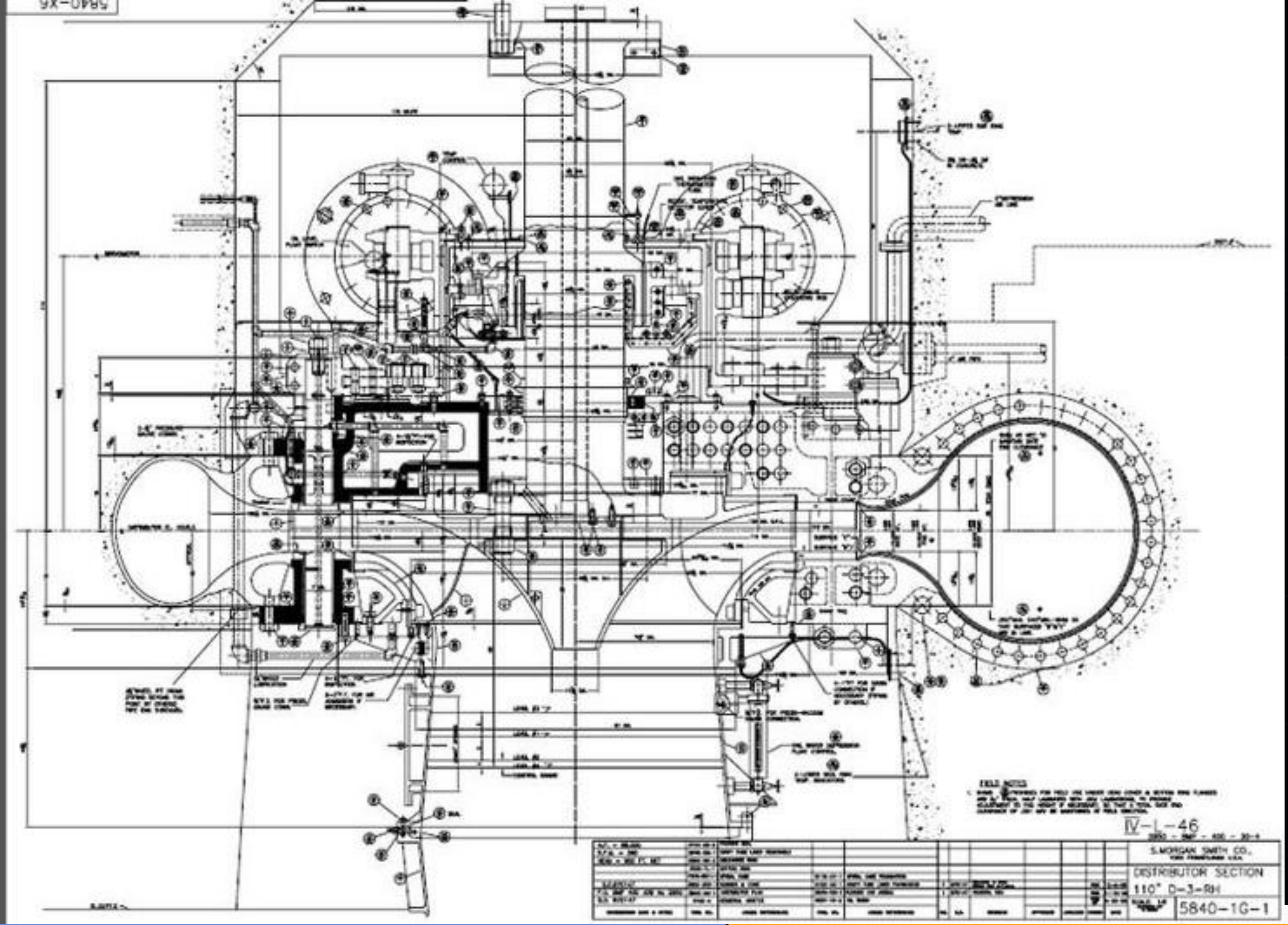


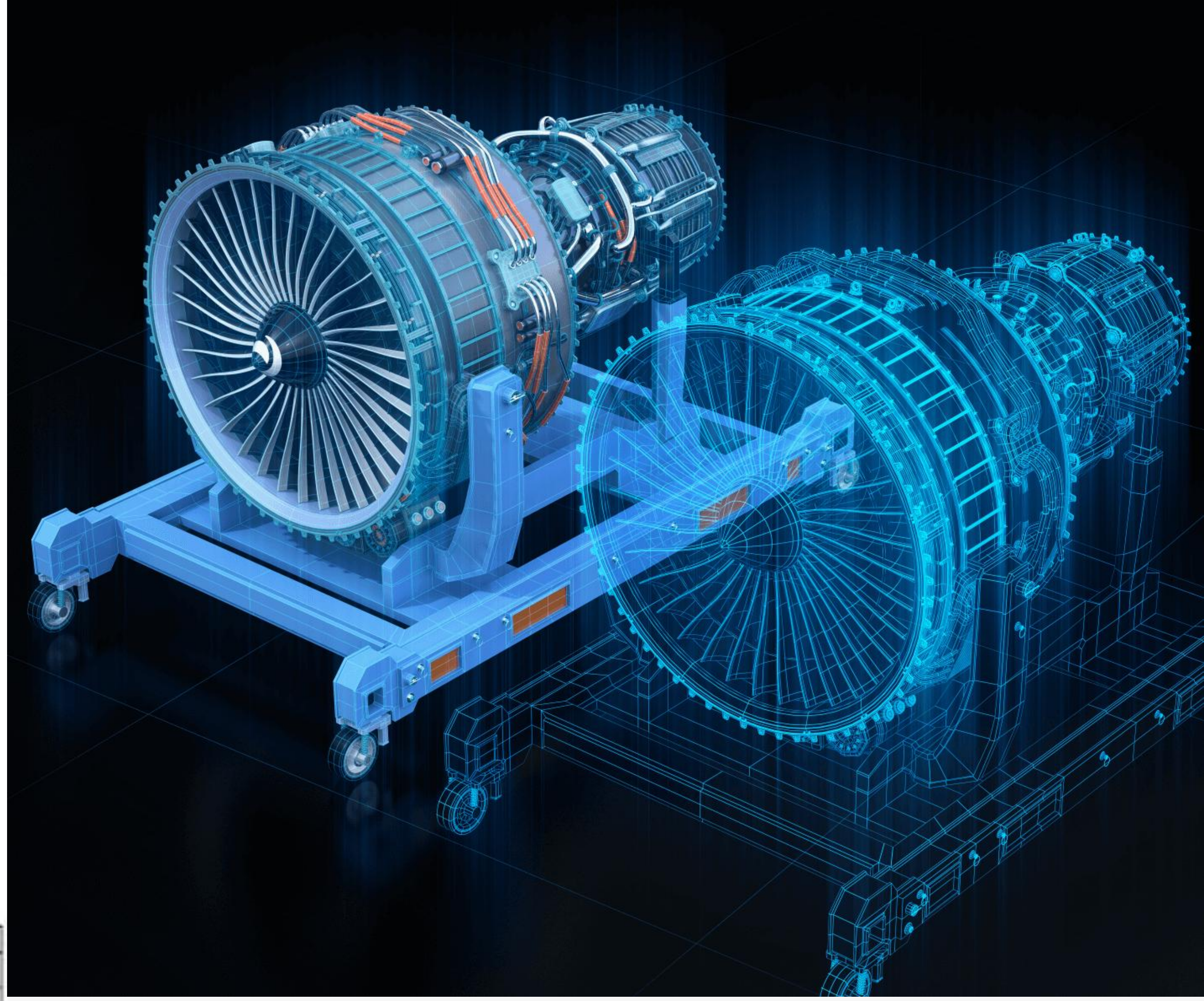


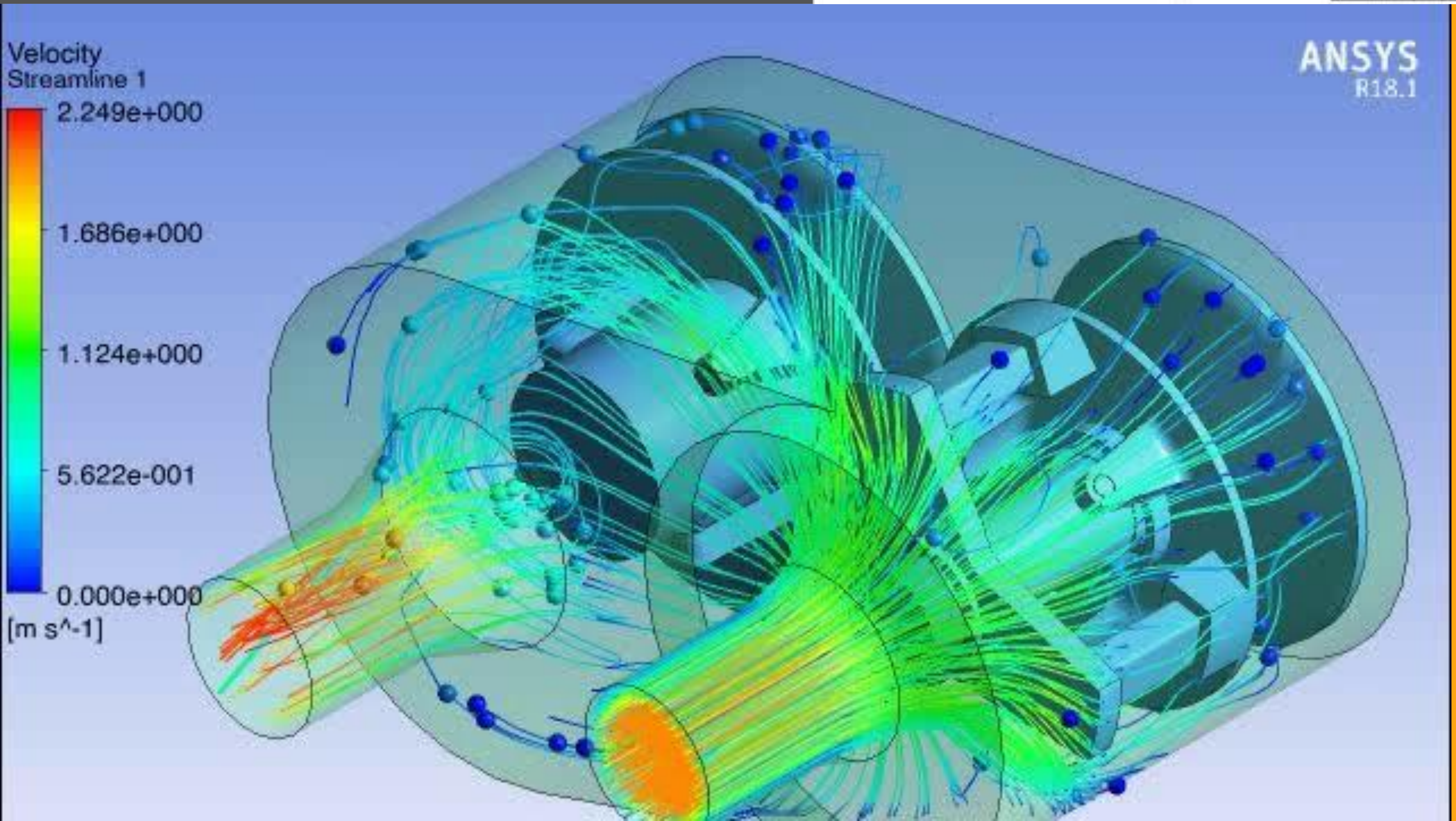
Environmental & Nature

Application of Fluid Mechanics

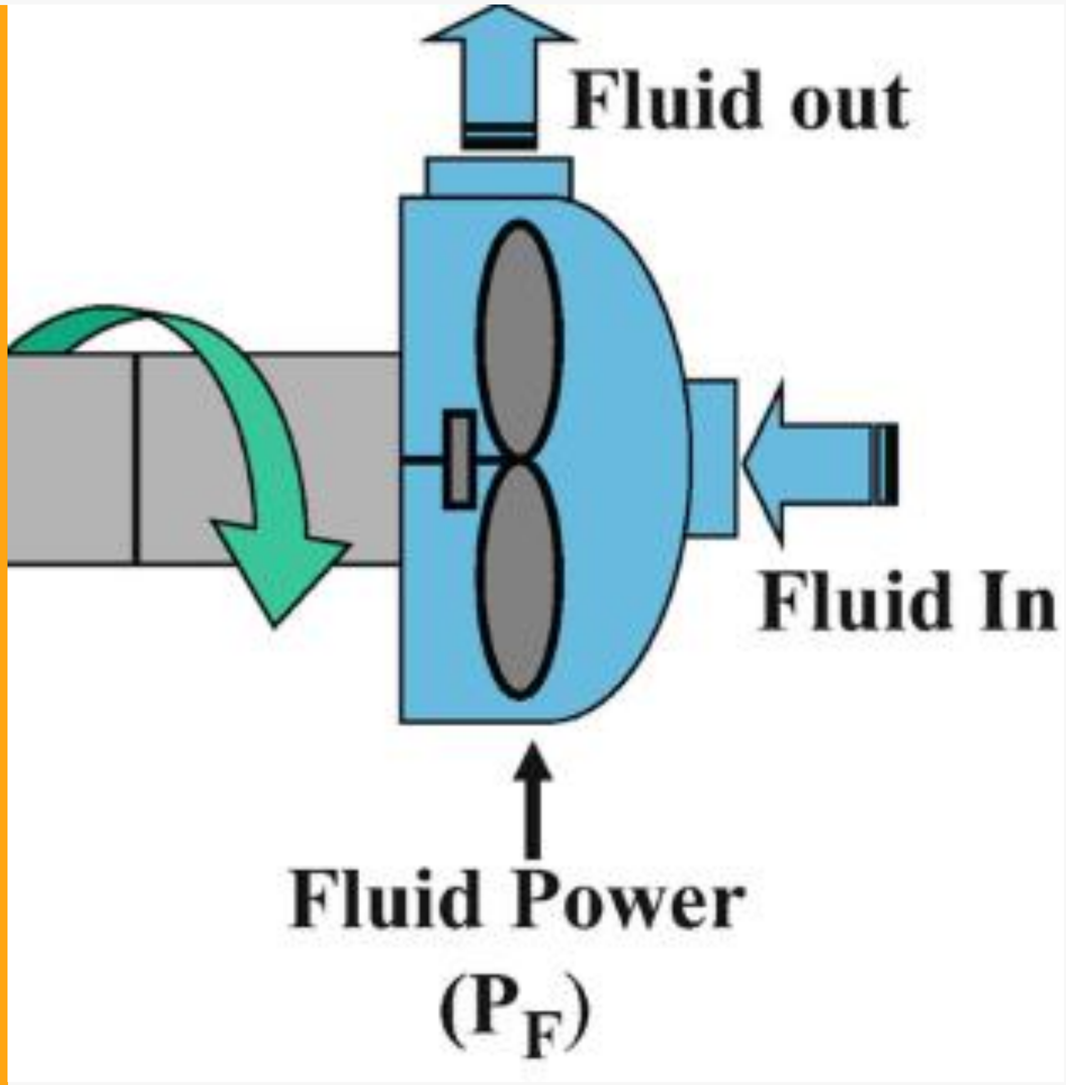
Industrial Applications





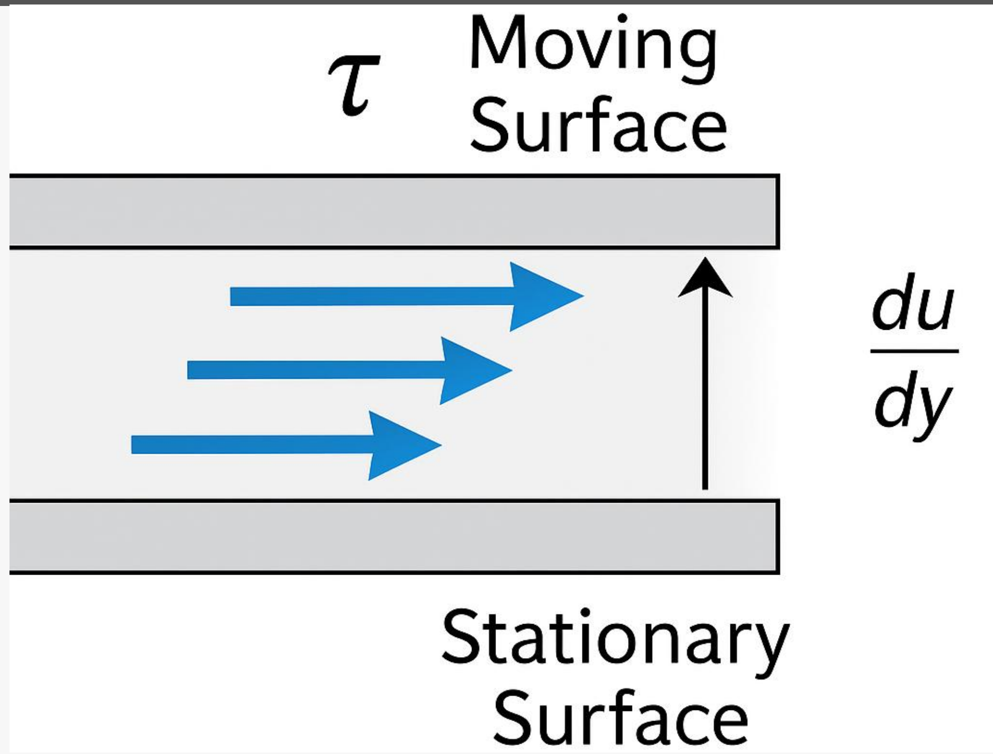


1. Technical Drawing,
2. Designing,
3. Simulation,
4. Technical Analysis,



3. The Physical Properties of Fluids

The Definition of Fluid



1^{st}

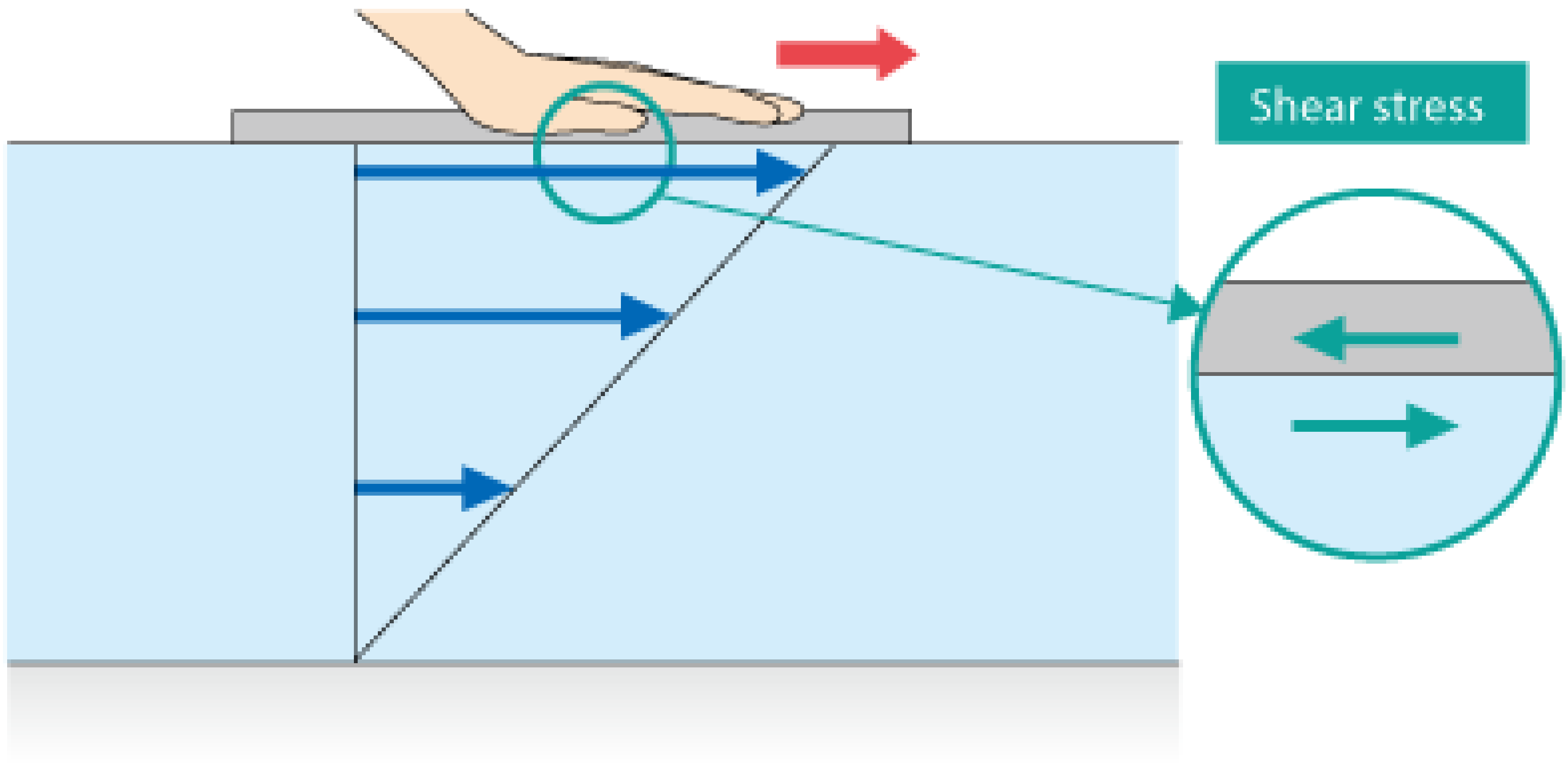
- a substance which deforms continuously ,or flows; under the action of shearing forces
- Fluid flow → Shear stress → Yes

2^{nd}

- if a shear stress is acting on a fluid it will flow and if a fluid is at rest there is no shear stress acting on it,
- Fluid rest → Shear Stress → No

Shear Stress in Moving Fluid

- Fluid is in motion --> shear stress are developed,
- The particles of the fluid move relative to each other,

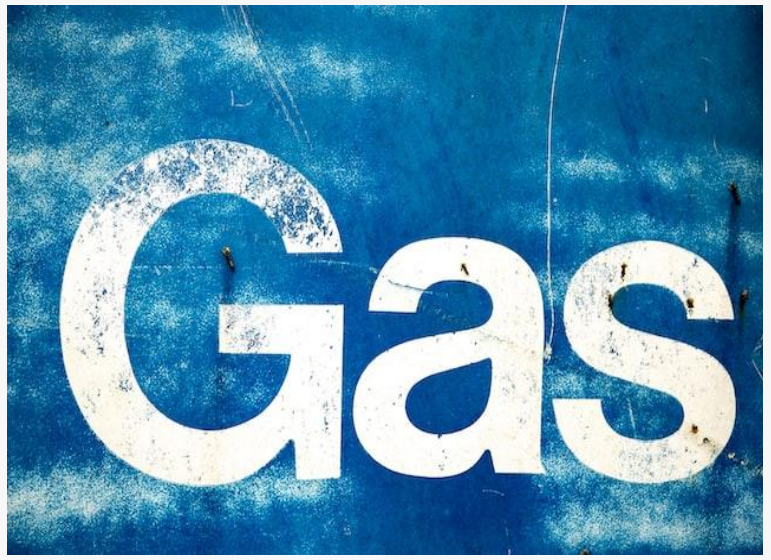


Adjacent particles have different velocities → the shape of the fluid to become distorted

Fluid Mechanics

Fluid + Mechanics

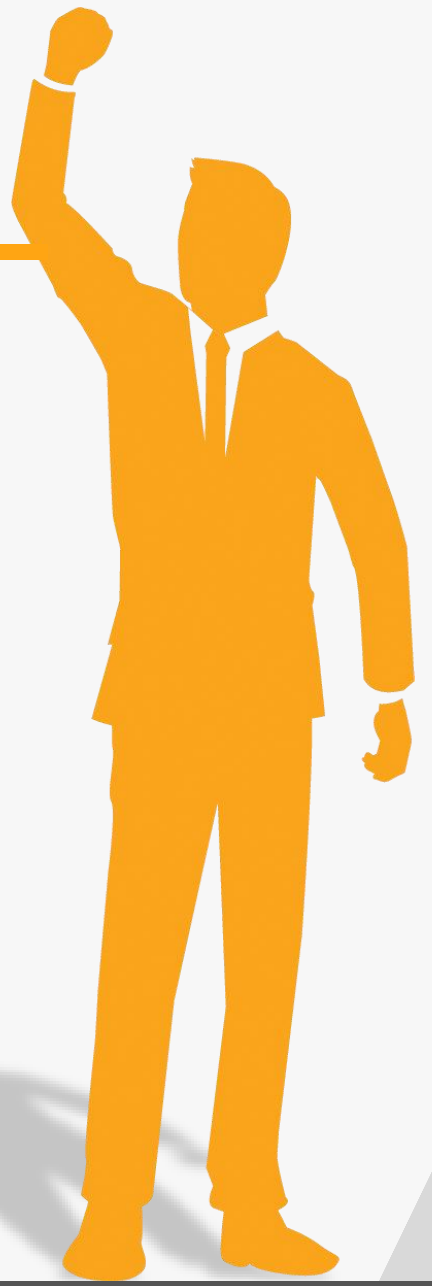
Fluid



Mechanics

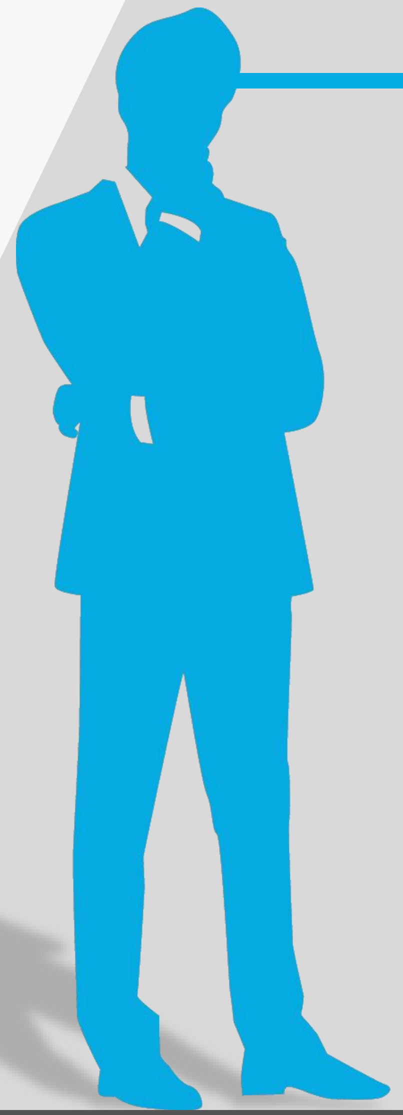
a. Static
b. Dynamic
c. Kinematic

Liquid



- Difficult to compress and often regarded as incompressible
- Occupies a fixed volume and will take the shape of the container
- A free surface is formed if the volume of container is greater than the liquid.

Gases



- Easily to compress – changes of volume is large, cannot normally be neglected and are related to temperature
- No fixed volume, it changes volume to expand to fill the containing vessels
- Completely fill the vessel so that no free surface is formed.

Liquid vs Gases

Liquid → definite volume, variable shape

Gas → variable volume, variable shape.

The Types of Fluid

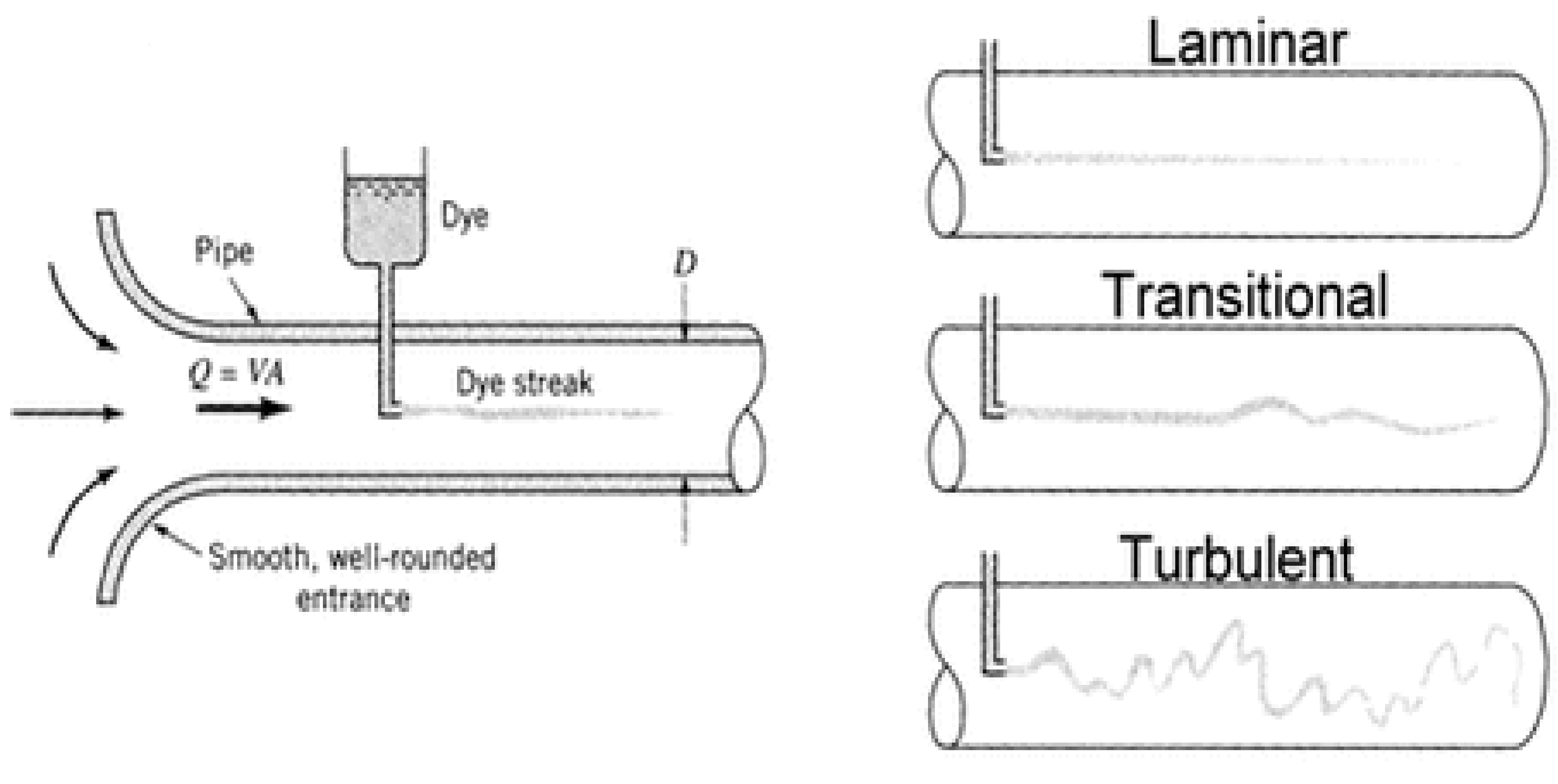
One Phase of Fluid

1. The form of a substance,
2. No substance changing

Multi Phase of Fluid

1. The form of 2 or more substances,
2. The substance changing be as simultaneous

The Types of Fluid Flow



1. **Laminar Flow,**

Fluid moves in smooth

2. **Transition Flow,**

An intermediate region between laminar and turbulent,

3. **Turbulent Flow**

Fluid moves in a chaotic, irregular, swirling motion

Dimensions and Base Units

A physical quantity independent of its numerical value or unit, commonly denoted using symbols

Unit-Free		SI Units	
Dimension	**Symbol**	**Unit**	**Symbol**
Mass	M	kilogram	kg
Length	L	metre	m
Time	T	second	s

- Dimensional equations help verify consistency of formulas,
- Connect units through the underlying quantity calculus that the SI formalizes

SI Unit

Quantity	Dimension	SI Unit	
		Derived	Base
Velocity	LT^{-1}	m/s	m s^{-1}
Acceleration	LT^{-2}	m/s^2	m s^{-2}
Force	MLT^{-2}	Newton, N	kg m s^{-2}
Pressure Stress	$ML^{-1}T^{2}$	Pascal, Pa N/m^2	kg m^{-1} s^{-2}
Density	ML^{-3}	kg/m^3	kg m^{-3}
Specific weight	$ML^{-2}T^{-2}$	N/m^3	kg m^{-2} s^{-2}
Relative density	Ratio	Ratio	Ratio
Viscosity	$ML^{-1}T^{-1}$	Ns/m^2	kg m^{-1} s^{-1}
Energy (work)	$ML^{2}T^{-2}$	Joule, J Nm	kg m^2 s^{-2}
Power	$ML^{2}T^{-3}$	Watt, W Nm/s	kg m^2 s^{-3}

Note: The acceleration due to gravity will always be taken as 9.81 m/s^2.

Properties of Fluids

Mass Density

Mass density:

$$\rho = \text{mass per unit volume}$$

$$\rho = \frac{\text{mass of fluid}}{\text{volume of fluid}}$$

(units: kg/m3)

Typical Value

- Water: $1000\ kg/m^3$;
- Mercury: $13546\ kg/m^3$;
- Air: $1.23\ kg/m^3$;
- Paraffin: $800\ kg/m^3$.

- Quantitative measure of matter contained in a substance is called as mass,
- Unit of SI System - kg

Properties of Fluids

Specific Gravity : Has no dimension

<u>Given:</u>

$m = 36\,g \quad v = 3\,mL \qquad \rho_{H_2O} = 1\,g/mL$

<u>Solution:</u>

$$density\ of\ the\ object = \frac{m}{v} = \frac{36\,g}{3\,mL} = \mathbf{12\,g/mL}$$

$$Specific\ Gravity = \frac{\rho_{object}}{\rho_{H_2O}} = \frac{\mathbf{12\,g/mL}}{\mathbf{1\,g/mL}} = \mathbf{12}$$

<u>Final Answer:</u>

The density of the object is 12 g/mL and the specific gravity is 12. The specific gravity is greater than 1, so the object will sink in water.

$$SG = \frac{\rho_{liquid}}{\rho_{water}} = \frac{\gamma_{liquid}}{\gamma_{water}}$$

Ratio of the specific weight of a liquid to the specific weight of standard fluid (water) at standard temperature and pressure (STP)

Ratio of mass density of a liquid to the mass density of standard fluid (water) at standard temperature and pressure (STP

Properties of Fluids

Specific Weight : ratio of weight of fluid to its volume

Density is the amount of mass per unit volume of a substance

$$\rho = \frac{m}{V}$$

kg/m^3

slugs/ft^3

Specific Weight is the amount of weight per unit volume of a substance

$$\gamma = \frac{w}{V}$$

N/m^3

lb/ft^3

Given:

Volume= 1 litre =0.001 m^3

Weight=7 N

Specific Weight[w]=$\frac{Weight}{Volume}$ =$\frac{7}{0.001}$ =7000 $\frac{N}{m^3}$

w.k.t Sp. Wt.[w]= ρ g

Density ρ =$\frac{w}{g}$ =$\frac{7000}{9.81}$ =713.56 kg/m^3

Specific gravity S =$\frac{Density\ of\ the\ liquid}{Density\ of\ water}$ =$\frac{713.56}{1000}$ = 0.714

Properties of Fluids

Specific Volume : Volume of fluid per unit mass of fluid

Density and Specific Volume

- Density (ρ) tells us the amount of mass we have per unit of volume

$$\rho = \frac{m}{V} \left[\frac{\text{kg}}{\text{m}^3}\right]$$

- Specific volume (v) tells us volume per unit mass

$$v = \frac{V}{m} = \frac{1}{\rho} \left[\frac{\text{m}^3}{\text{kg}}\right]$$

- Density and specific volume depend on pressure, temperature

EXAMPLE 3–5 Properties of Saturated Liquid–Vapor Mixture

An 80-L vessel contains 4 kg of refrigerant-134a at a pressure of 160 kPa. Determine (*a*) the temperature, (*b*) the quality, (*c*) the enthalpy of the refrigerant, and (*d*) the volume occupied by the vapor phase.

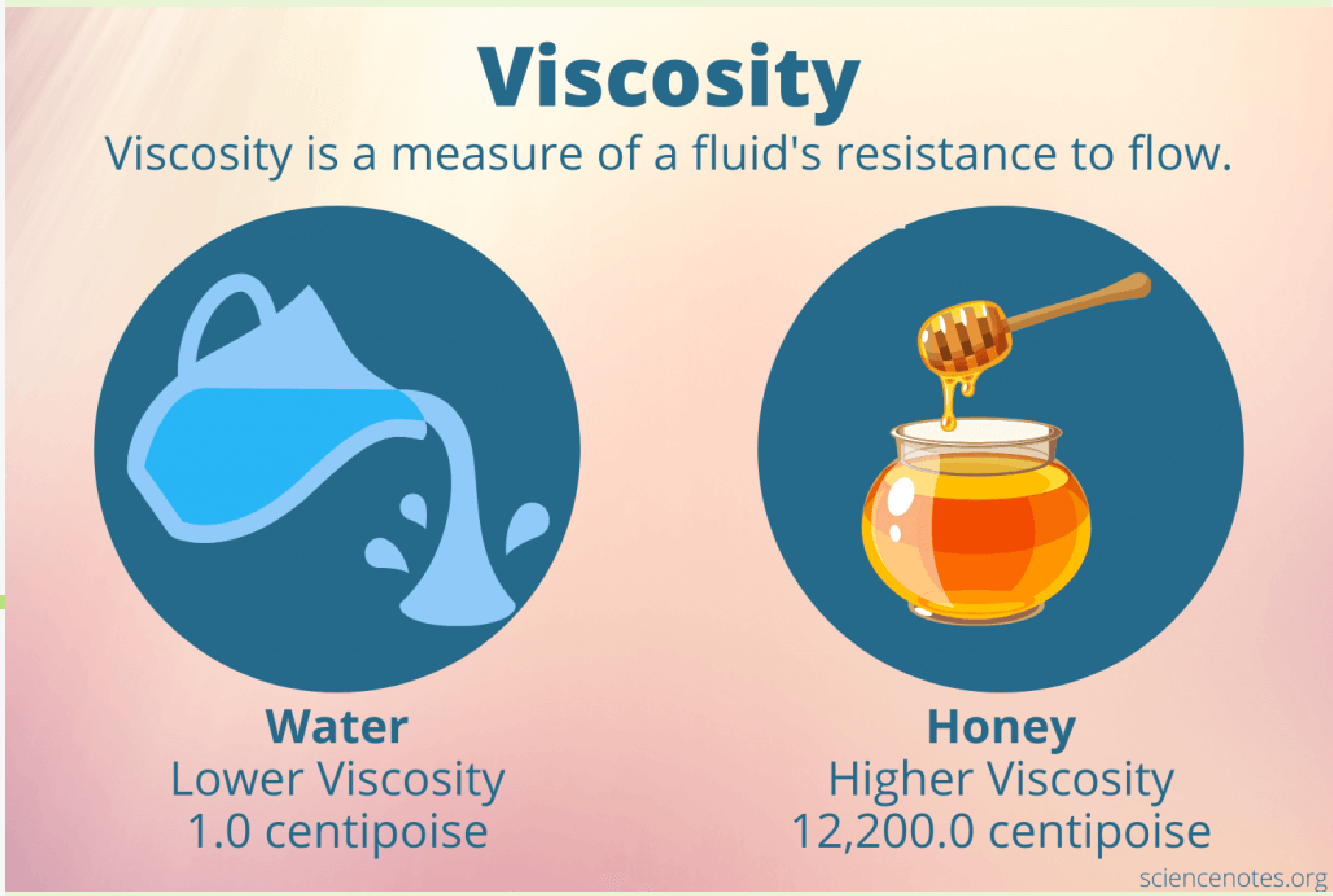
SOLUTION A vessel is filled with refrigerant-134a. Some properties of the refrigerant are to be determined.

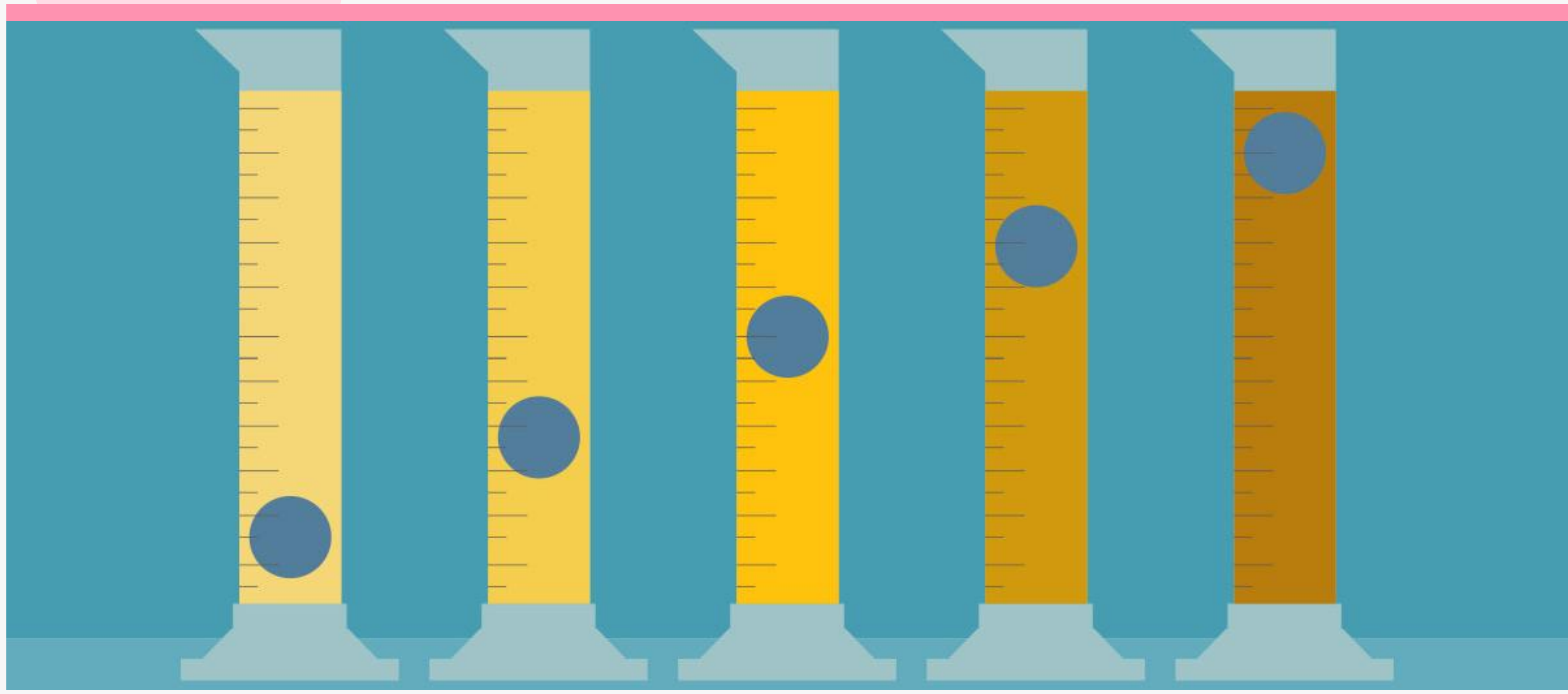
Analysis (*a*) The state of the saturated liquid–vapor mixture is shown in Fig. 3–36. At this point we do not know whether the refrigerant is in the compressed liquid, superheated vapor, or saturated mixture region. This can be determined by comparing a suitable property to the saturated liquid and saturated vapor values. From the information given, we can determine the specific volume:

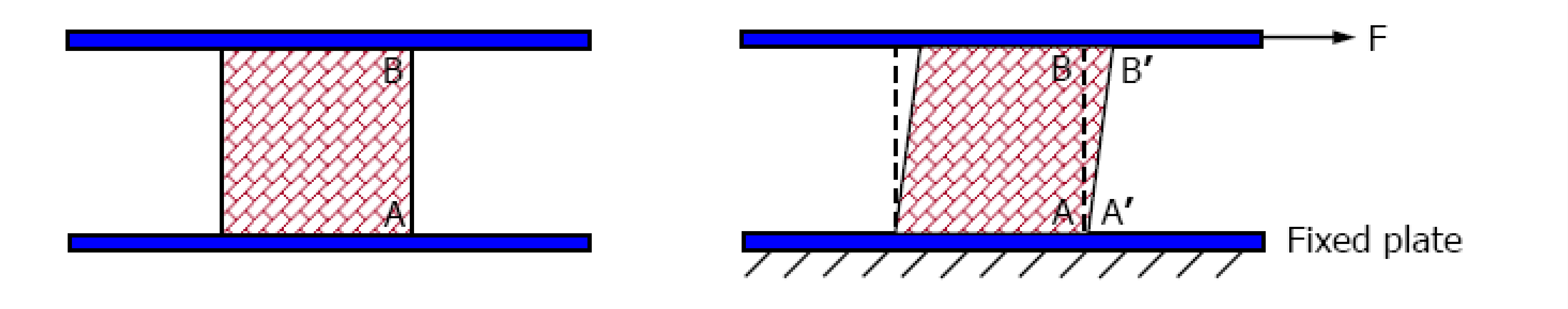
$$v = \frac{V}{m} = \frac{0.080 \text{ m}^3}{4 \text{ kg}} = 0.02 \text{ m}^3/\text{kg}$$

Properties of Fluids

Viscosity (μ): *Measure of a fluid resistance to shear and angular deformation*



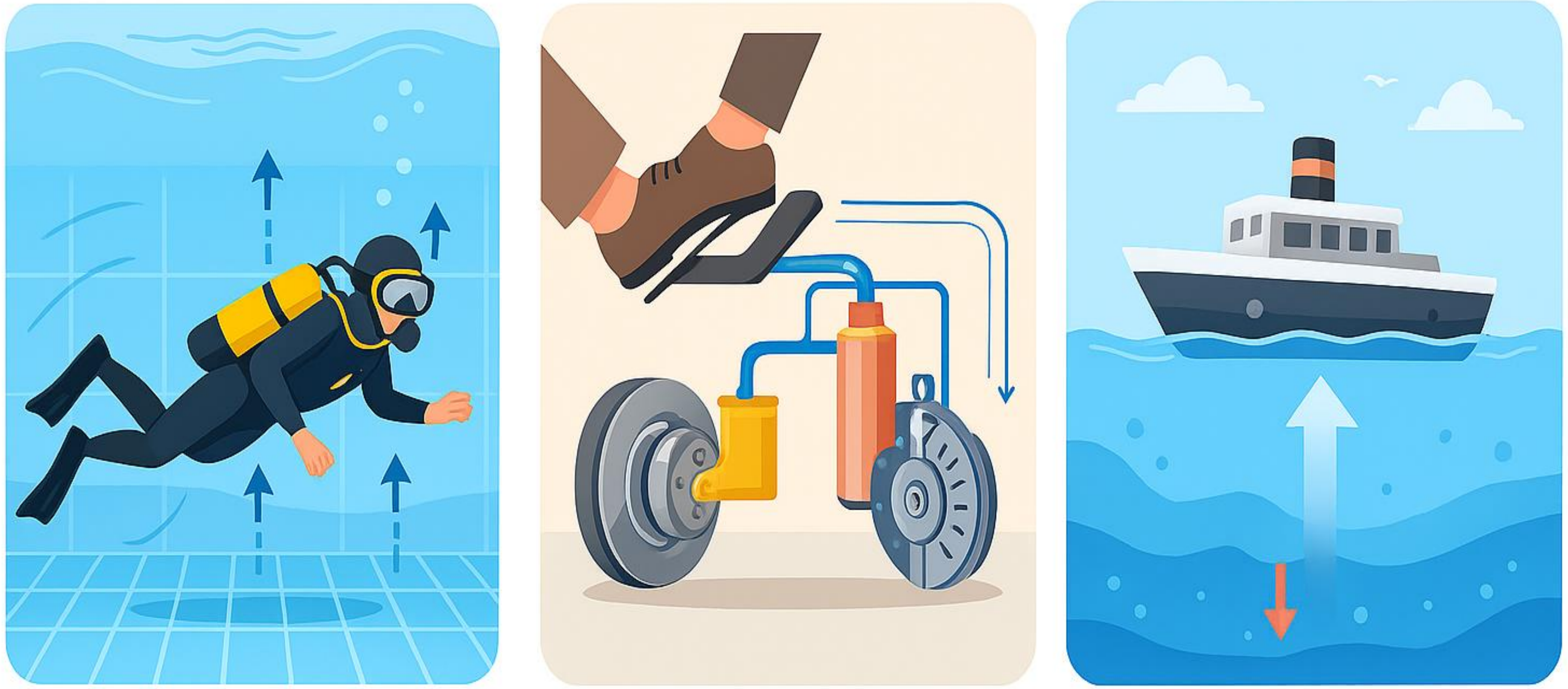




4. Static Fluids

Static Fluid

Static Fluid



1. Hydrostatic Pressure

Pressure increases with depth

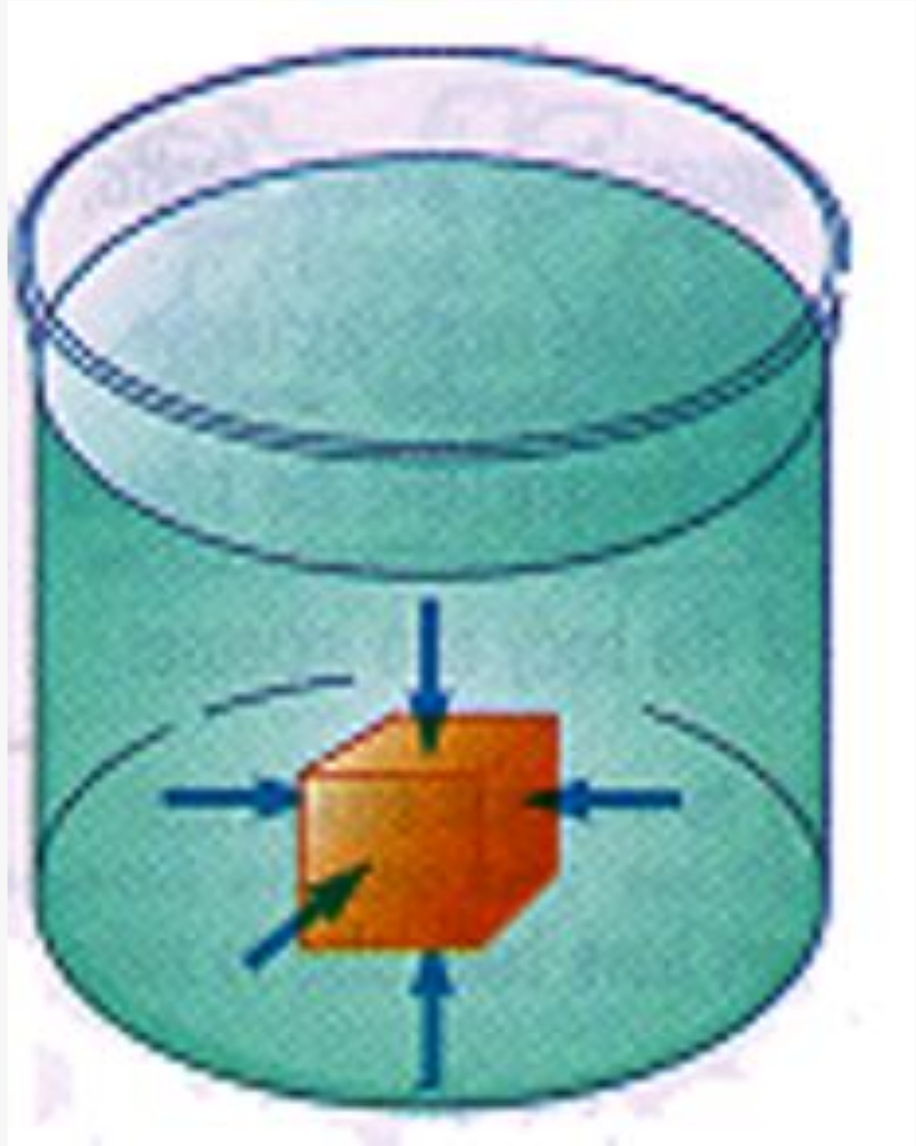
2. Pascal Law

Pressure spreads equally in a confined fluid

3. Archimedes Principle

Objects in fluid experience buoyancy

Hydrostatic Pressure

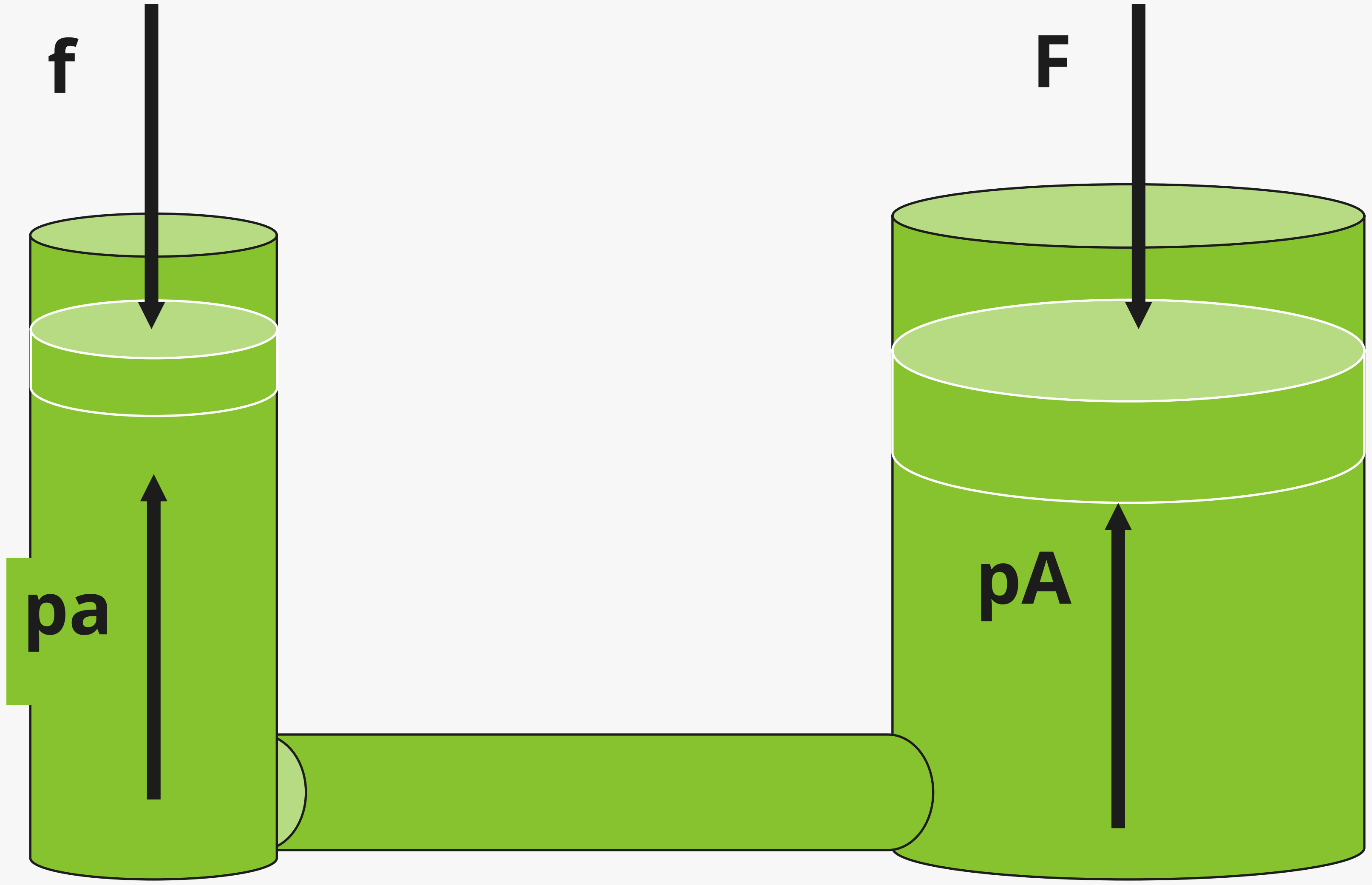


$$P = \frac{F}{A}$$

1. Tekanan fluida terjadi pada semua arah, tegak lurus dengan bidang
2. Distribusi tekanan dalam fluida cair umumnya tidak sama,
3. Sedangkan fluida gas dianggap sama
4. Satuan tekanan (dalam SI) : pascal (Pa)
→ 1 Pa = 1 N / m^2

Pascal Law

Tekanan yang diberikan pada fluida diteruskan kesetiap bagian fluida dengan sama besar (termasuk pada dinding tempat fluida)

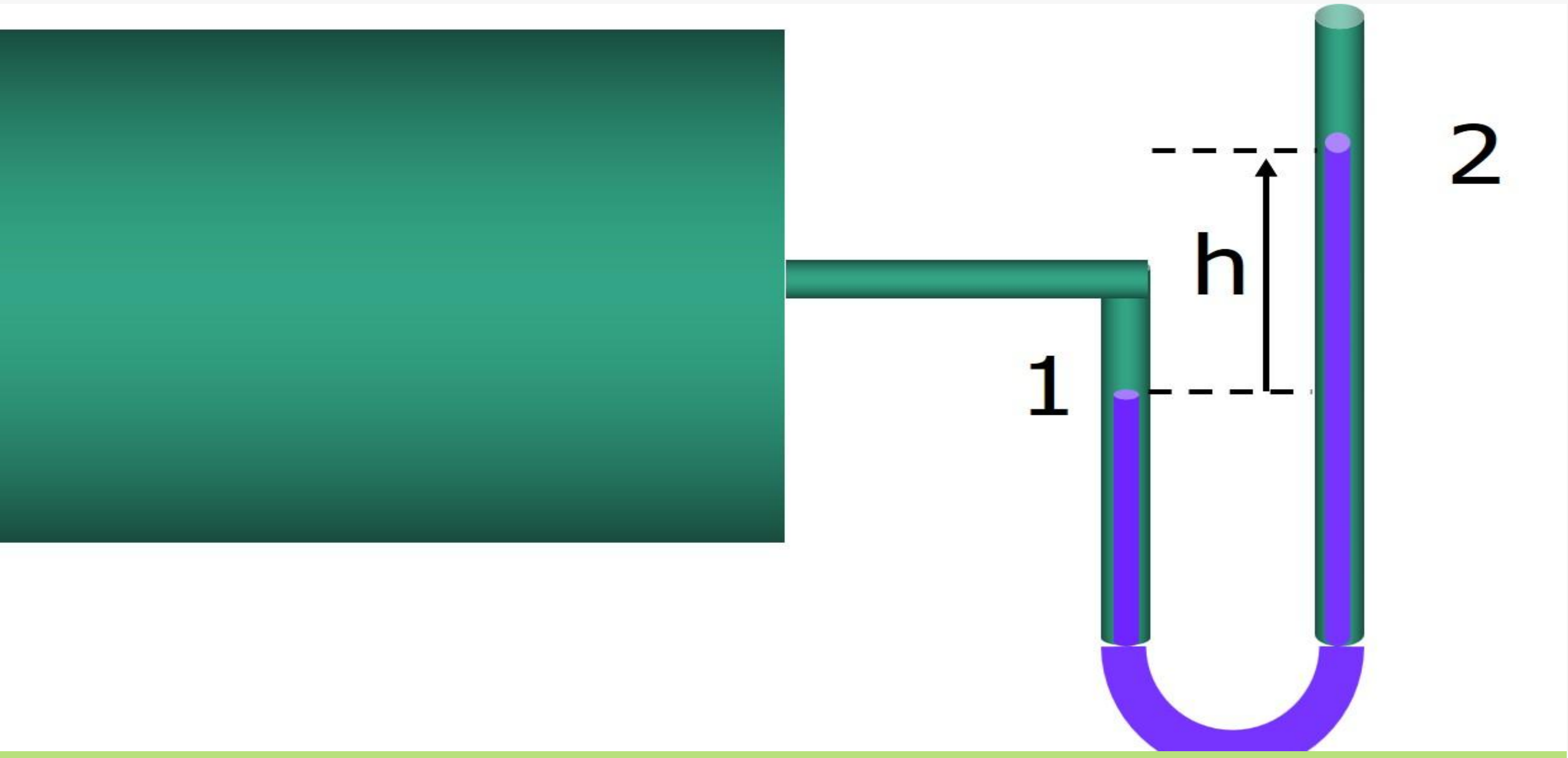


- Tekanan hidrolis, diteruskan kesetiap bagian fluida dengan sama besar,
- Tekanan di kaki kiri = tekanan di kaki kanan

$$p = \frac{f}{a} = \frac{F}{A} \qquad \text{atau} \qquad F = f\,\frac{A}{a}$$

Misal a= 0,1 m^2 , A = 1 m^2, f = 1 N, maka F =1 (1/0,1) = 10 N

Measurement Tools of **Pascal Law**



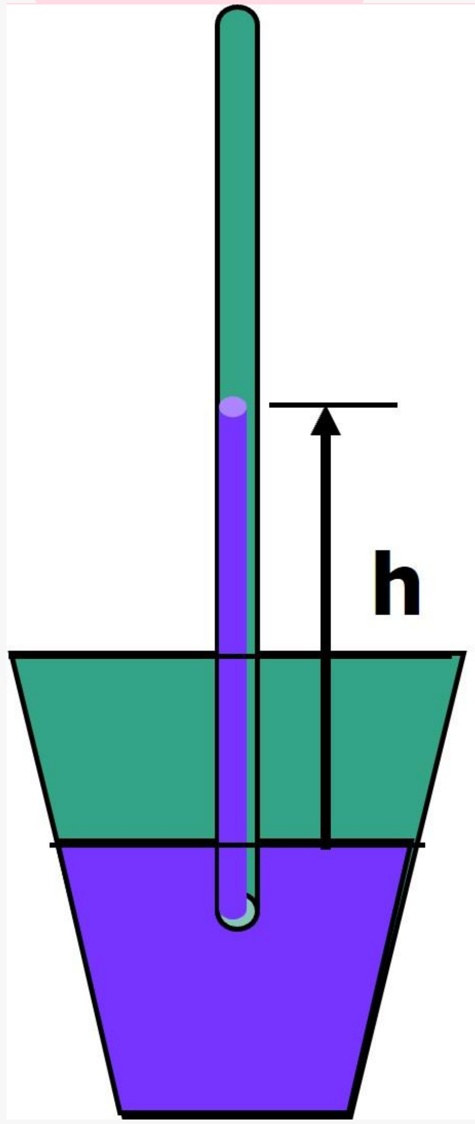
MANOMETER

Alat ukur tekanan di ruangan tertutup

$$P = P1 = \rho . g . h + P2$$
$$P1 - P2 = \rho . g . h$$

P1-P2 merupakan selisih tekanan didalam tabung dan diluar tabung, disebut **Delta Pressure**

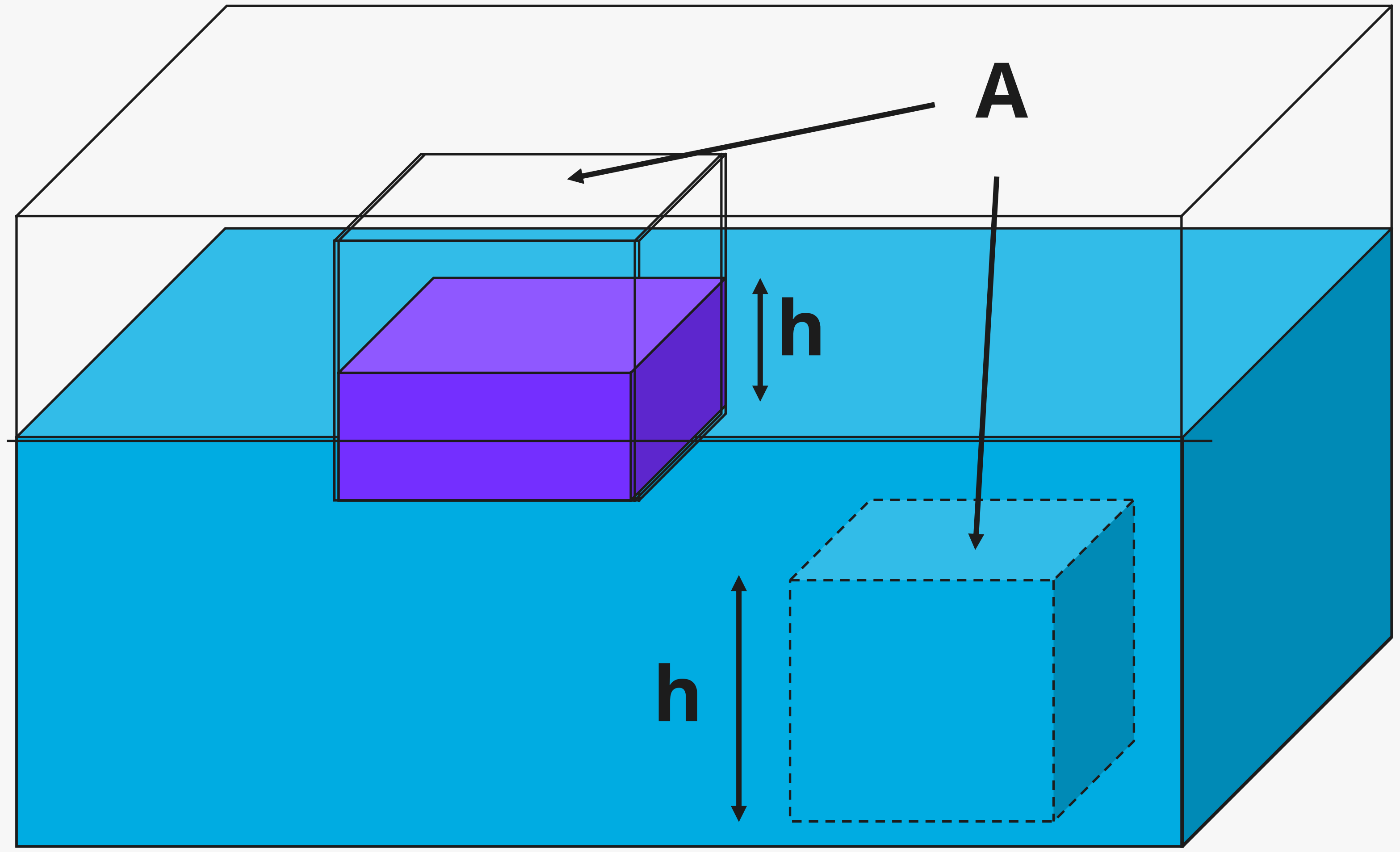
BAROMETER



Alat ukur ruangan terbuka,

$$P1 = \rho . g . h + P2$$
$$P2 = 0$$
$$P0 = \rho . g . h$$

Archimedes Principle



Gaya tekan ke atas yang dialami oleh benda yang tercelup di dalam fluida **sama dengan berat** fluida yang dipindahkan

Massa fluida yang dipindahkan
= rapat massa fluida x volume fluida yang dipindahkan

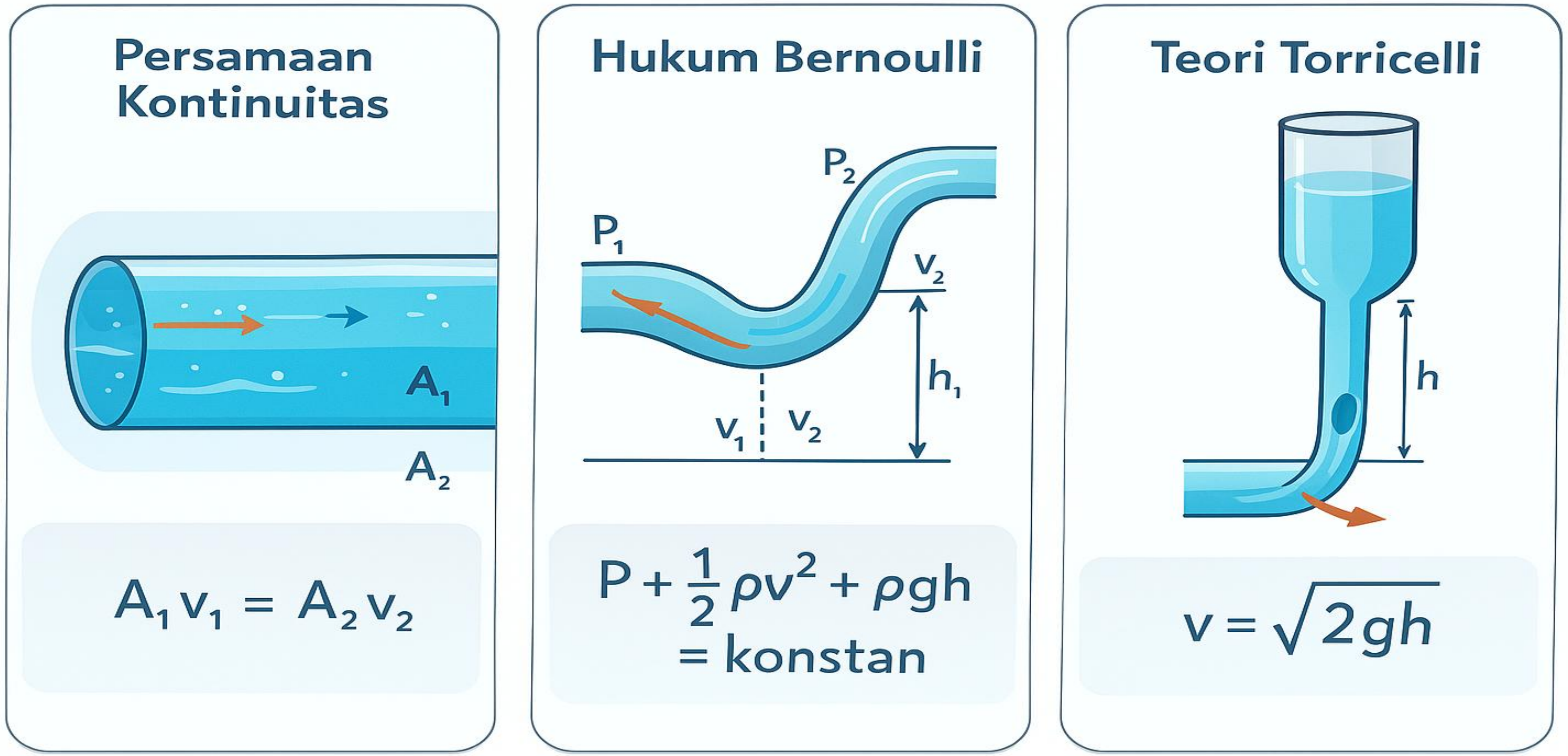
Volume fluida yang dipindahkan = volume benda yang tercelup

$$V = A \times h$$

5. Dynamic Fluids

Dynamic Fluid

Dynamic Fluid



1. **Persamaan Kontinuitas**

Massa fluida yang mengalir melalui suatu pipa tertutup per satuan waktu adalah konstan, selama tidak ada kebocoran

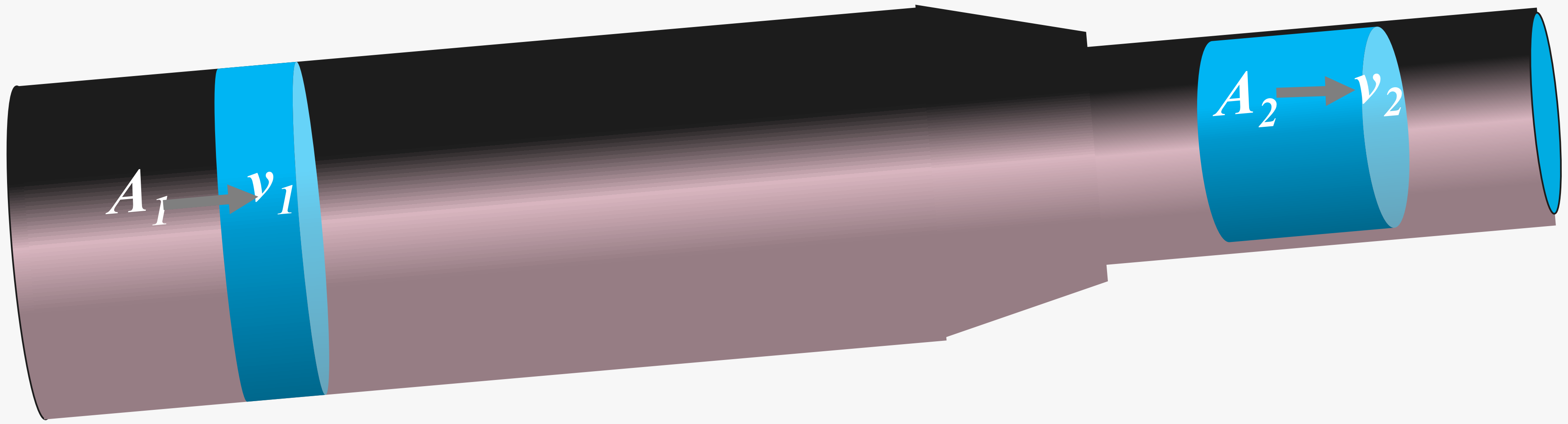
2. **Hukum Bernoulli**

Prinsip konservasi energi pada fluida bergerak. Energi total (tekanan, kinetik, dan potensial) dalam aliran fluida ideal adalah konstan.

3. **Teori Torricelli**

aplikasi hukum Bernoulli untuk fluida yang keluar dari lubang wadah.

Persamaan Kontinuitas



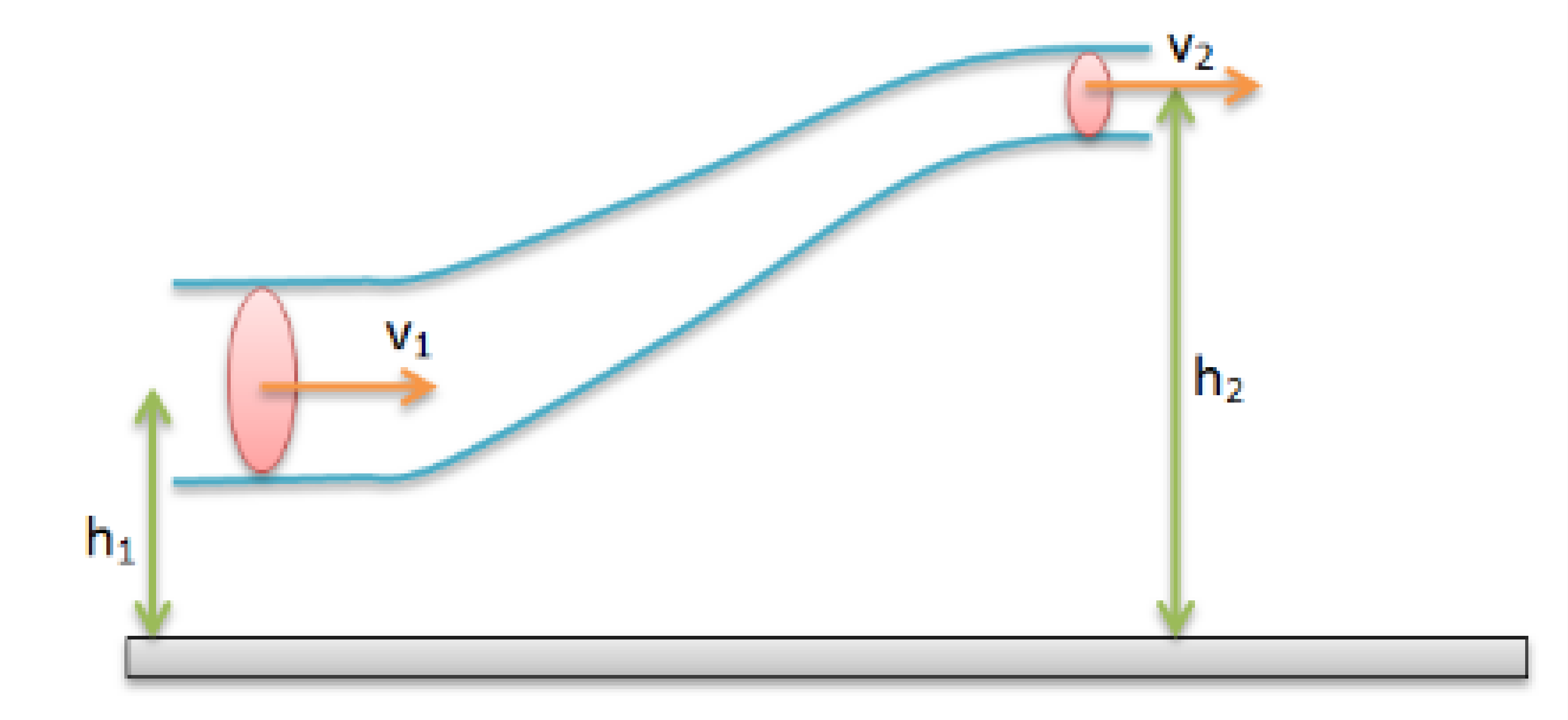
Jika fluida bersifat tak kompresibel, maka besarnya volume fluida yang lewat penampang A_1 dan A_2 persatuan waktu adalah sama besar

Air yang mengalir di dalam pipa air dianggap mempunyai debit yang sama di sembarang titik. Atau jika ditinjau 2 tempat, maka:

Debit aliran 1 = Debit aliran 2

$$A_1 v_1 = A_2 v_2$$

Hukum Bernoulli



Hukum Bernoulli menyatakan hubungan besaran fluida dalam pipa antara **tekanan**, **ketinggian**, dan **laju dinamika**.

Hukum ini menyatakan bahwa **jumlah tekanan (p), energi kinetik per satuan volume, dan energi potensial per satuan volume memiliki nilai yang sama pada setiap titik sepanjang suatu garis arus**

$$p_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = p_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$$

Keterangan :
P = tekanan (Pascal = Pa = N/m^2)
ρ = massa jenis cairan (kg/m^3)
g = percepatan gravitasi (m/s^2)
h = ketinggian (m)

Alat Ukur & Fungsi Portable Gas Analyzer

Portable Gas Analyzer : merupakan alat untuk kadar komposisi gas, seperti O2, CO2, SO2 dll

Alat Ukur & Kegunaan

–

Manometer & Pitot Tube

Manometer : merupakan alat yang berguna mengukur level tekanan fluida dan gas di ruangan tertutup.

Pitot tube : merupakan alat untuk melakukan pengukuran tekanan pada aliran fluida,

Manometer

Pitot Tube

Temp (oC)	Dynamic Pres. (mbar)	Dynamic Pres. (mmAq)	Static Pres. (mbar)	Static Pres. (mmAq)	Spec.Grav.Din (g/cm3)	Spec.Grav.Sta (g/cm3)	Coef of pitch tube	Gas Velocity (m/sec)	Area of Duct (m^2)	Gas Volume (m^3/h)	Massa (kg)
213	4.177	42.602	1.283	13.09	0.733	0.73	0.845	31.036	9.616	1,074,417	787,824
119	7.027	71.672	47.167	481.1	0.912	0.94	0.845	36.103	8.810	1,144,996	1,043,818
120.2	4.446	45.3458	81.000	826.2	0.907	0.97	0.845	28.797	9.616	996,914	903,757
133.5	2.570	26.214	2.053	20.944	0.875	0.87	0.845	22.283	9.616	771,401	675,189
270	9.047	92.276	15.243	155.482	0.659	0.66	0.845	48.166	1.227	212,682	140,248
168	1.287	13.124	1.590	16.218	0.806	0.80	0.845	16.432	1.227	72,559	58,467

Alat Ukur & Kegunaan

–

Thermometer & Thermocouple

Thermometer / Portable pyrometer : merupakan alat untuk mengukur temperatur fluida

Thermocouple / PT100 : merupakan sensor temperatur yang banyak digunakan untuk mengubah perbedaan temperatur fluida menjadi perubahan tegangan listrik

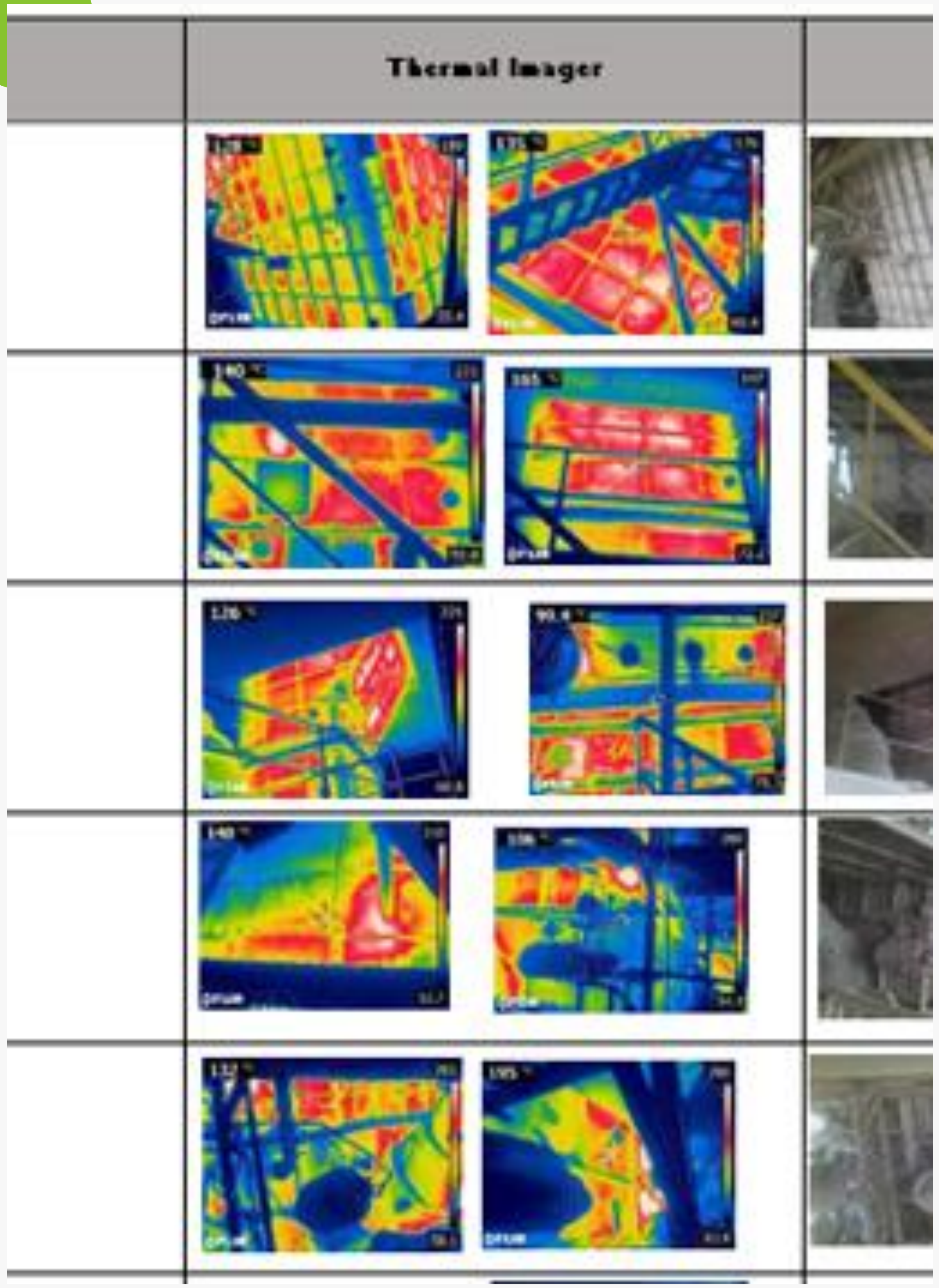
Temp (oC)	Dynamic Pres. (mbar)	Dynamic Pres. (mmAq)	Static Pres. (mbar)	Static Pres. (mmAq)	Spec.Grav.Din (g/cm3)	Spec.Grav.Stat (g/cm3)	Coef of pitch tube	Gas Velocity (m/sec)	Area of Duct (m^2)	Gas Volume (m^3/h)	Massa (kg)
213	4.177	42.602	1.283	13.09	0.733	0.731	0.845	31.036	9.616	1,074,417	787,824
119	7.027	71.672	47.167	481.1	0.912	0.947	0.845	36.103	8.810	1,144,996	1,043,818
120.2	4.446	45.3458	81.000	826.2	0.907	0.975	0.845	28.797	9.616	996,914	903,757
133.5	2.570	26.214	2.053	20.944	0.875	0.875	0.845	22.283	9.616	771,401	675,189
270	9.047	92.276	15.243	155.482	0.659	0.663	0.845	48.166	1.227	212,682	140,248
168	1.287	13.124	1.590	16.218	0.806	0.806	0.845	16.432	1.227	72,559	58,467

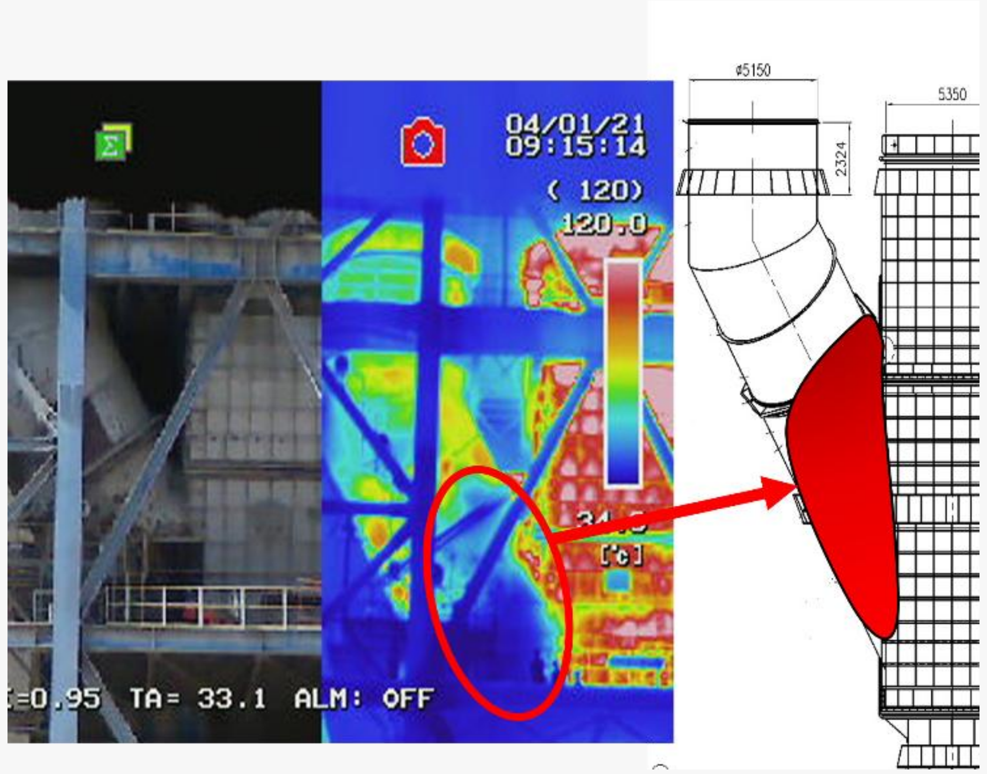
Anemometer : merupakan alat untuk mengukur kecepatan fluida gas,

Flow meter : merupakan alat untuk mengukur laju aliran atau jumlah fluida yeng bergerak mengalir dalam sebuah pipa tertutup

Alat Ukur & Kegunaan – Flow & Anemo Meter

Temp (oC)	Dynamic Pres. (mbar)	Dynamic Pres. (mmAq)	Static Pres. (mbar)	Static Pres. (mmAq)	Spec.Grav.Din (g/cm3)	Spec.Grav.Stat (g/cm3)	Coef of pitch tube	Gas Velocity (m/sec)	Area of Duct (m^2)	Gas Volume (m^3/h)	Massa (kg)
213	4.177	42.602	1.283	13.09	0.733	0.731	0.845	31.036	9.616	1,074,417	787,824
119	7.027	71.672	47.167	481.1	0.912	0.947	0.845	36.103	8.810	1,144,996	1,043,818
120.2	4.446	45.3458	81.000	826.2	0.907	0.975	0.845	28.797	9.616	996,914	903,757
133.5	2.570	26.214	2.053	20.944	0.875	0.875	0.845	22.283	9.616	771,401	675,189
270	9.047	92.276	15.243	155.482	0.659	0.663	0.845	48.166	1.227	212,682	140,248
168	1.287	13.124	1.590	16.218	0.806	0.806	0.845	16.432	1.227	72,559	58,467





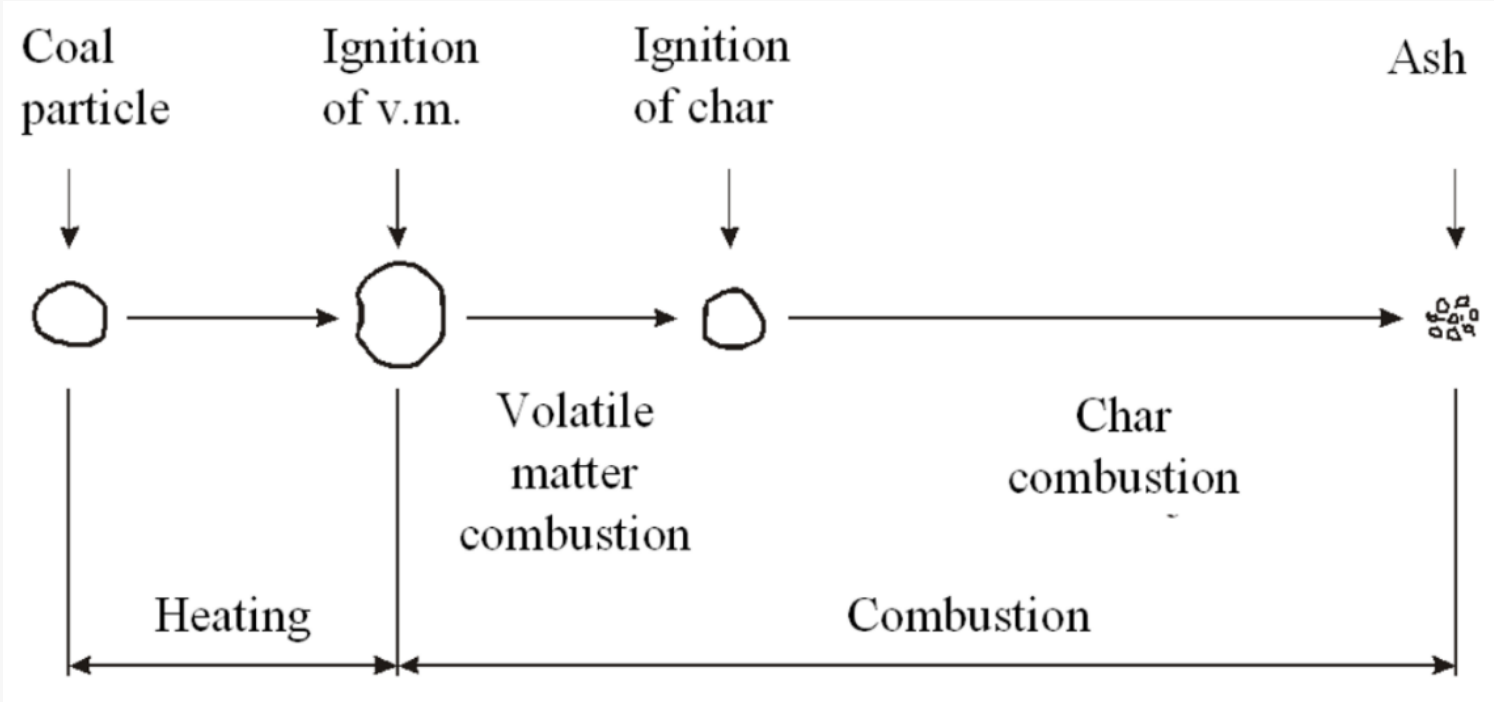
Alat Ukur & Kegunaan –

Thermal Imager

Thermal Imager merupakan alat yang untuk :

- Memberikan pencitraan temperatur suatu peralatan,
- Posisi coating,
- Posisi kebocoran udara

Technical considerations on fuel usage

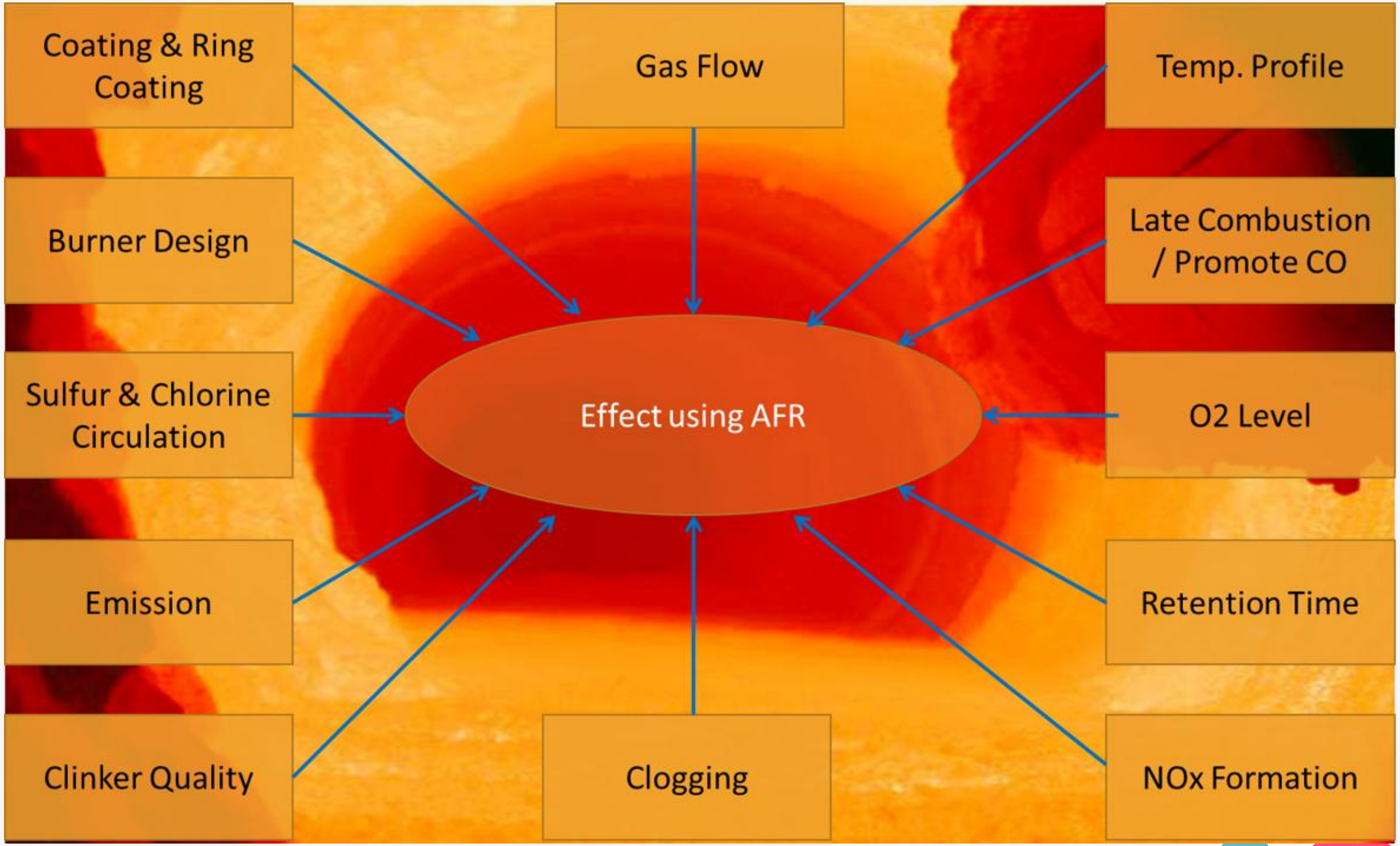


4. Ash

Ash dianggap sebagai kandungan inert dan mempengaruhi pembakaran,

High ash content → Low caloric value

Effect



Coating & Ring Coating
Gas Flow
Temp. Profile
Burner Design
Late Combustion / Promote CO
Sulfur & Chlorine Circulation
Effect using AFR
O2 Level
Emission
Retention Time
Clinker Quality
Clogging
NOx Formation

Thank You for your Interest!

Any Questions?

• • •