SWM’S PHYSICS LESSON (5 OCT 2025)

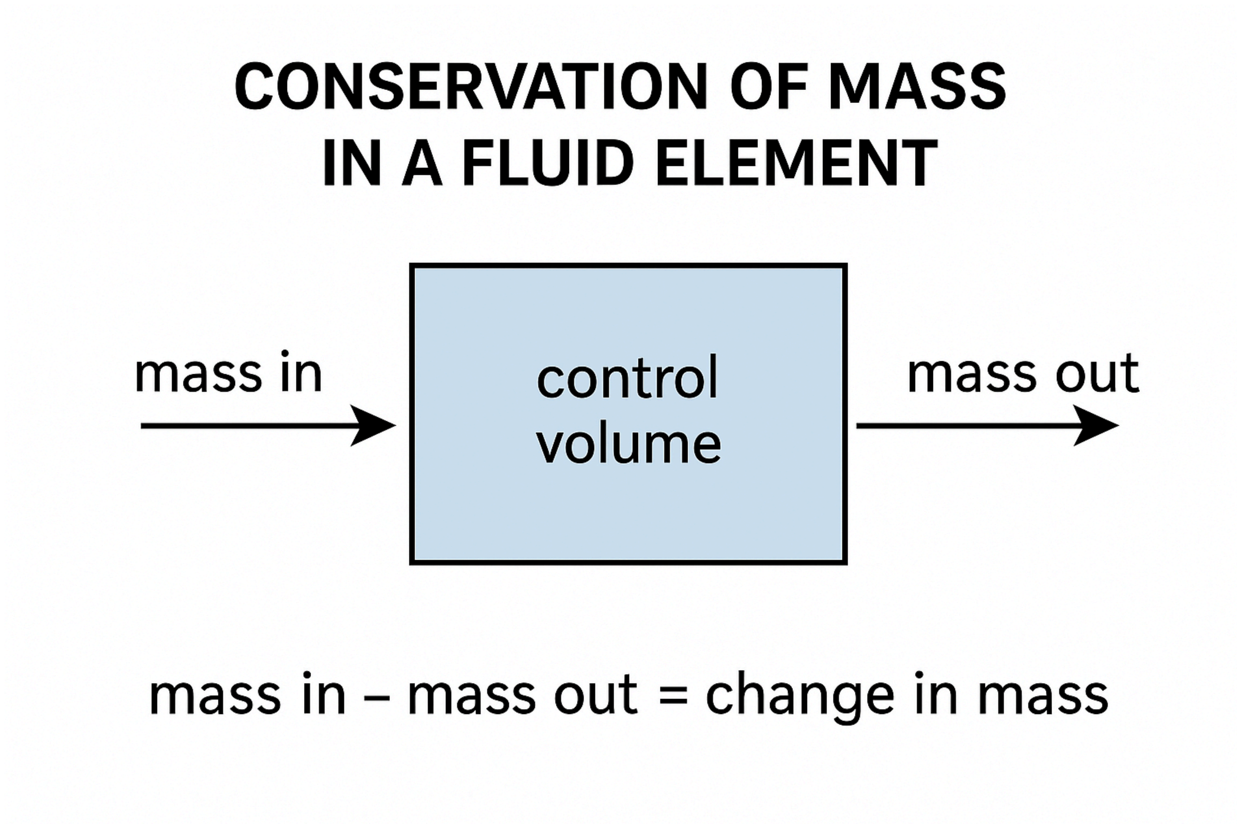
For Stump the Teacher: Find a text about “transport phenomena” that does not use the term.

"Now imagine the ‘stuff’ for which the conservation of mass has been derived are actually lots of tiny carriers capable of carrying such quantities like energy, momentum or money. If we assume the flow of these quantities is only possible through the tiny carriers, then we can write a conservation equation that has such general forms:

Total accumulation = massin * amt carried per carrier – massout * amt carried per carrier

This is a general conservation equation for moving body/fluid without any diffusive component or body force. In the case of energy, the amount carried per carrier is given by the enthalpy per mass and multiplying this with massin/massout gives the flux of enthalpy into/out of the differential volume due to the migration of these tiny carriers. The same is true for momentum. Since momentum is the product of mass and velocity, the flux of momentum into/out of the differential element is given by the product of massin/massout and velocity, u. Note that momentum flux has the same dimension as force. Hence, the balance of momentum flux is also a force balance. It is important to remember both definitions when you are writing the differential equation for a fluid system. A typical force balance for a fluid element takes into account the following contributions:

- Rate of momentum in/out across surfaces on the side by momentum diffusion
- Rate of momentum in/out across cross-sectional surface by convective transport
- Pressure force acting on the cross-sectional surface
- Body force such as gravity"



What if the fluid elements carry money?

- Total accumulation of money = (mass-in) x (money/mass) - (mass-out) x (money/mass)

What if the fluid elements carry momentum?

- If forces act on the control volume, then the total momentum will change.
- If no forces act on the control volume, then the total momentum will not change.

Momentum – Definition:

In physics, **momentum** is the quantity of motion an object has. It depends on both the **mass** and **velocity** of the object. The formula for linear momentum is:

$$p = m \times v$$

where

- p = momentum (kg·m/s)
- m = mass (kg)
- v = velocity (m/s)

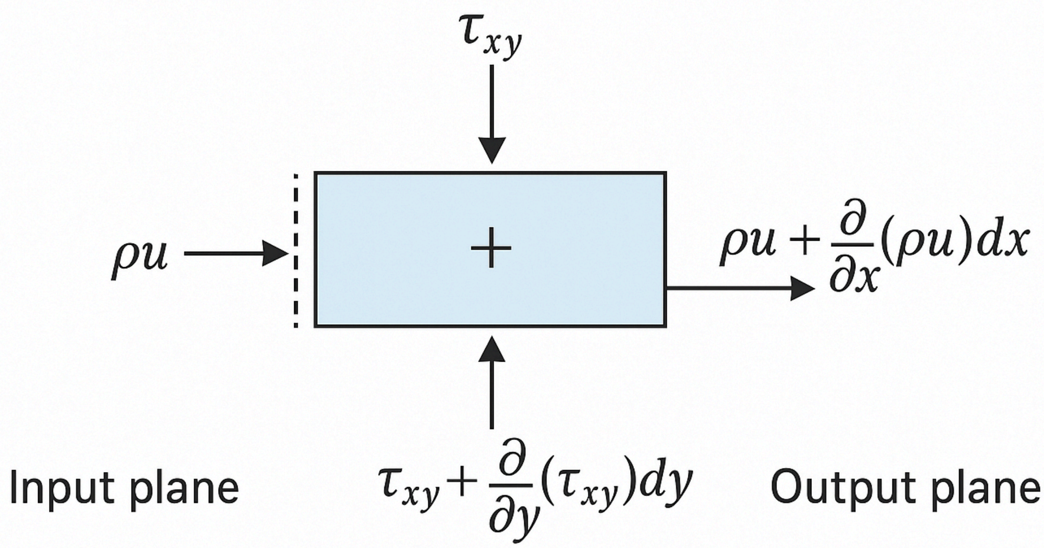
Role of Momentum in Physics:

1. **Describes Motion:**
   Momentum measures how hard it is to stop or change the motion of an object. The greater the momentum, the more force or time is needed to bring it to rest.
2. **Conservation Law:**
   In a closed system (no external forces), **total momentum is conserved**. This is known as the **law of conservation of momentum**, which is fundamental in understanding collisions and explosions.
3. **Explains Interactions:**
   Momentum helps analyze how objects interact — for example, in collisions between cars, particles, or even celestial bodies.
4. **Foundation in Mechanics:**
   Momentum connects **force** and **motion** through **Newton's Second Law**, which can be written as

   $$F = \frac{dp}{dt}$$

   (force equals the rate of change of momentum).

CONSERVATION OF MOMENTUM IN FLUID ELEMENT



🧭 1. What it means

The **conservation of momentum** in a fluid element says:

> The **rate of change of momentum** of a fluid element equals the **sum of all forces** acting on it.

This is basically **Newton's Second Law** ($F = ma$) written for a **fluid** instead of a solid object.

⚙️ 2. Mathematical form (vector form)

For a small fluid element, the momentum equation is:

$$\rho \frac{D\mathbf{V}}{Dt} = \sum \text{forces per unit volume}$$

where

- ρ = density of the fluid
- $\mathbf{V}$ = velocity vector
- $\frac{D}{Dt}$ = **material derivative**, meaning "rate of change as you move with the fluid"
- The right side includes all **body forces** (like gravity) and **surface forces** (like pressure and viscosity).

💧 3. Expanded form (Navier–Stokes base)

Breaking it down gives:

$$\rho \frac{D\mathbf{V}}{Dt} = -\nabla p + \mu \nabla^2 \mathbf{V} + \rho \mathbf{g}$$

This is the **momentum conservation equation** for a **Newtonian fluid**, known as the **Navier–Stokes equation**.

- $-\nabla p$: pressure force
- $\mu \nabla^2 \mathbf{V}$: viscous (friction) force
- $\rho \mathbf{g}$: gravitational body force
- Left side ($\rho \frac{D\mathbf{V}}{Dt}$): rate of change of momentum

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🧠 4. In simple words

In a fluid:

- The **momentum can change** because of pressure pushing on it, viscous drag, or external forces (like gravity).
- But if you take a whole system (like all the fluid . . pipe section), the **total momentum is conserved** — it only changes when forces act on the boundaries.