FDE 205 FLUID MECHANICS

OVERALL MOMENTUM BALANCE

- A momentum balance is similar to the overall mass balance.
- Momentum is a vector quantity.
- The total linear momentum vector (P) of the total mass (M) of a moving fluid having a velocity of v is

$$P = Mv$$

The unit of momentum is kg.m/s

OVERALL MOMENTUM BALANCE

- Newton's second law:

The time rate of change of momentum of a system is equal to the summation of all forces acting on the system and takes place in the direction of the net force.

$$\underbrace{\sum F}_{\text{Force (N)}} = \frac{dP}{dt}$$

- The equation for the conservation of the momentum with respect to a control volume can be written as follows:

Sum of forces acting on control volume=
Rate of momentum out of control volume−
Rate of momentum into control volume+
Rate of accumulation of momentum in control volume

We should note that ΣF in general may have a component in any direction (x, y, z), and that F is the force the surroundings exert on the control volume fluid.

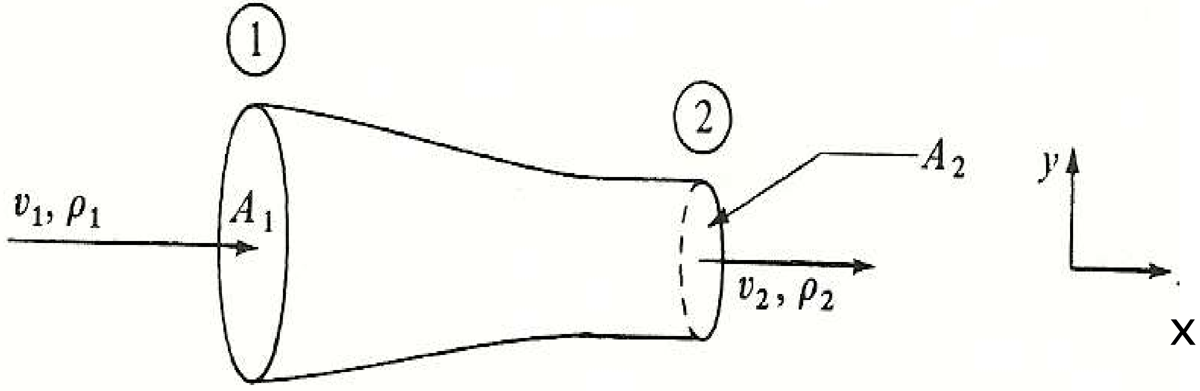
Overall Momentum Balance in Flow Systems in One Direction:

- ΣF_x=sum of forces only in x direction
- 1.Body force: The body force (F_{xg}) is the x-directed force caused by gravity acting on the total mass M in the control volume. It is zero if the x direction is horizontal.
- 2. Pressure force: The force (F_{xp}) is the x-directed force caused by the pressure forces acting on the surface of the fluid system.

Overall Momentum Balance in Flow Systems in One Direction:

- 3.Friction force: When the fluid is flowing, and x-directed friction force (F_{xs}) is present. In many cases, this frictional force may be negligible compared to the other forces.
- 4. Solid Surface force: (R_x) This is the force exerted by the solid surface on the fluid. Typically occurs when the control volume includes a section of pipe and the fluid it contains.

Overall Momentum Balance in Flow Systems in One Direction:



$$\sum F_x = \frac{\dot{m}\upsilon_2}{\beta} - \frac{\dot{m}\upsilon_1}{\beta}$$

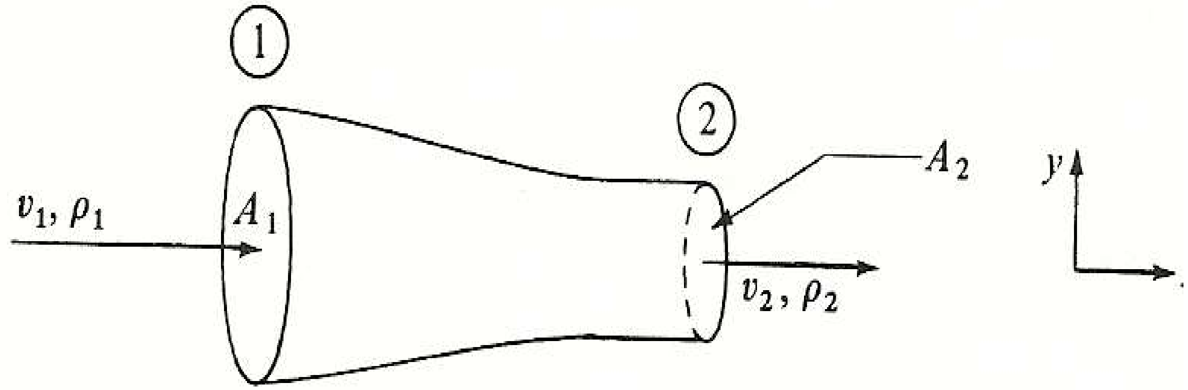
Overall Momentum Balance in Flow Systems in One Direction:

$$F_{xg} + F_{xp} + F_{xs} + R_x = \frac{\dot{m}\upsilon_2}{\beta} - \frac{\dot{m}\upsilon_1}{\beta}$$

- If the flow is turbulent
- Frictional losses are negligible

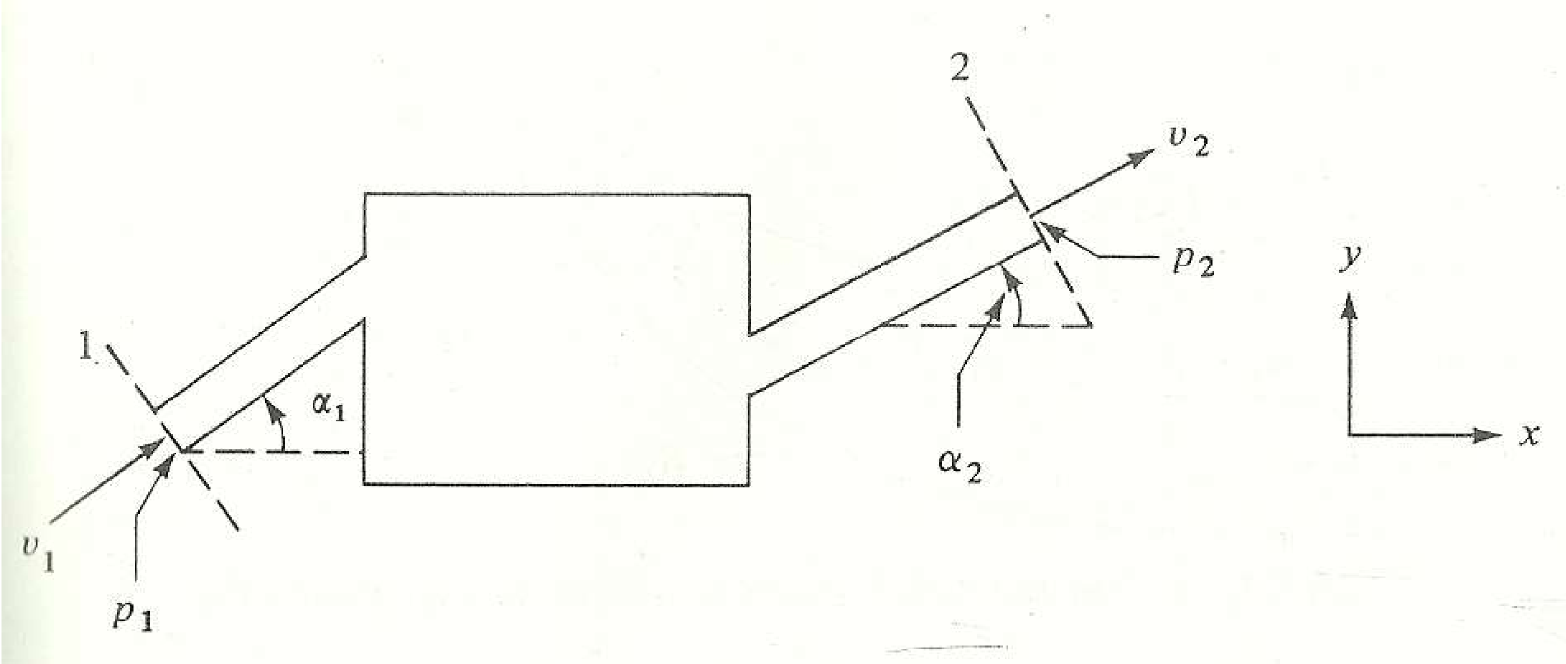
$$R_x = \dot{m}\upsilon_2 - \dot{m}\upsilon_1 + P_2 A_2 - P_1 A_1$$

Example 2.8-2



- Water is flowing at a rate of 0.03154m3/s through a horizontal nozzle shown in the figure above and discharges to the athmosphere at point 2. The nozzle is attached at the upstream end at point 1 and frictional forces are considered negligible. The upstream ID is 0.0635m and the downstream 0.0286 m. Calculate the resultant force on the nozzle. The density of the water is 1000 kg/m3.

Overall Momentum Balance in Two Direction:

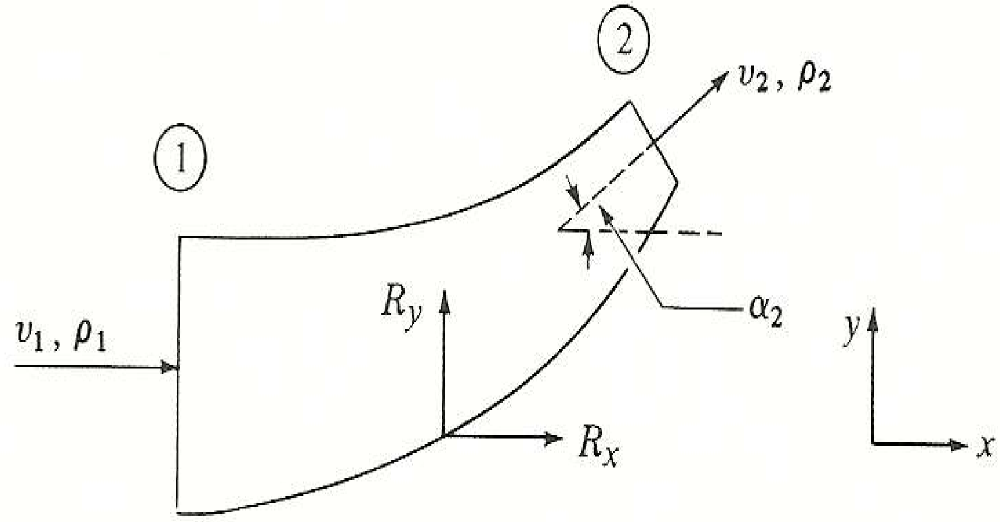


$$R_x = \dot{m}\upsilon_2 \cos\alpha_2 - \dot{m}\upsilon_1 \cos\alpha_1 + P_2 A_2 \cos\alpha_2 - P_1 A_1 \cos\alpha_1$$

$$R_y = \dot{m}\upsilon_2 \sin\alpha_2 - \dot{m}\upsilon_1 \sin\alpha_1 + P_2 A_2 \sin\alpha_2 - P_1 A_1 \sin\alpha_1 + M_t g$$

$$|R| = \sqrt{(R_x^2 + R_y^2)}$$

Example 2.8.3



- Fluid is flowing at steady state through a reducing pipe bend. Turbulent flow will be assumed with frictional forces negligible. The volumetric flow rate of the liquid and the pressure p2 at point 2 are known, as are the pipe diameters at both ends. Derive the equations to calculate the forces on the bend. Assume that The density(ρ) is constant.