UWE Bristol

Thermodynamics & Fluids

UFMEQU-20-1

FLUIDS

Lecture 5: Fluid Momentum

University of the West of England

BRISTOL

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Today's Lecture

- A move away from Fluid in Pipes
- Fluid Momentum
  – To determine the forces produced by flow
  – e.g. A jet of water impinging on a turbine blade, the thrust of a rocket etc.

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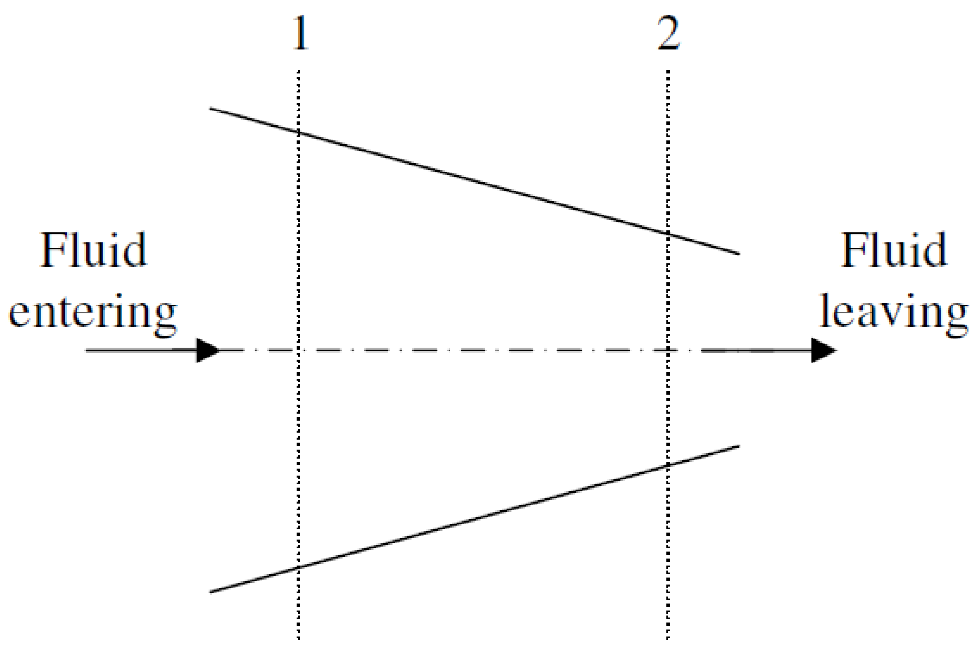
Fluid Momentum

- Consider steady flow along a horizontal tapering pipe:



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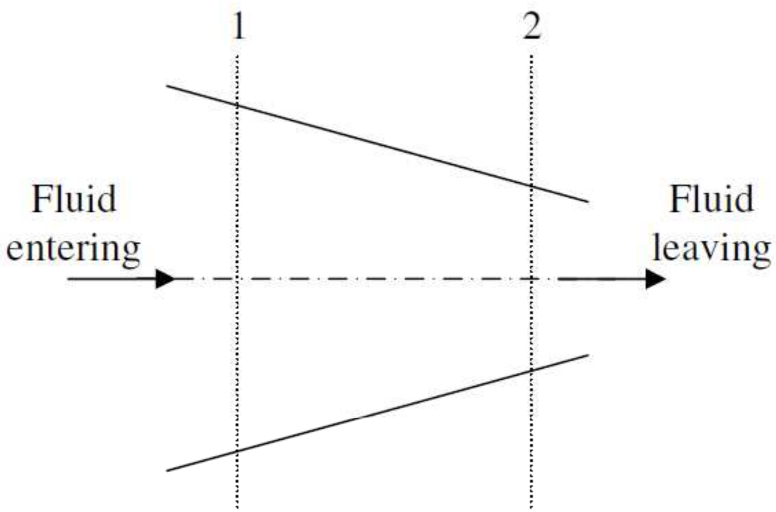
Fluid Momentum



- Let:
  - C_1 = entry flow velocity
  - C_2 = exit flow velocity
  - $\dot{m}$ = mass flow rate

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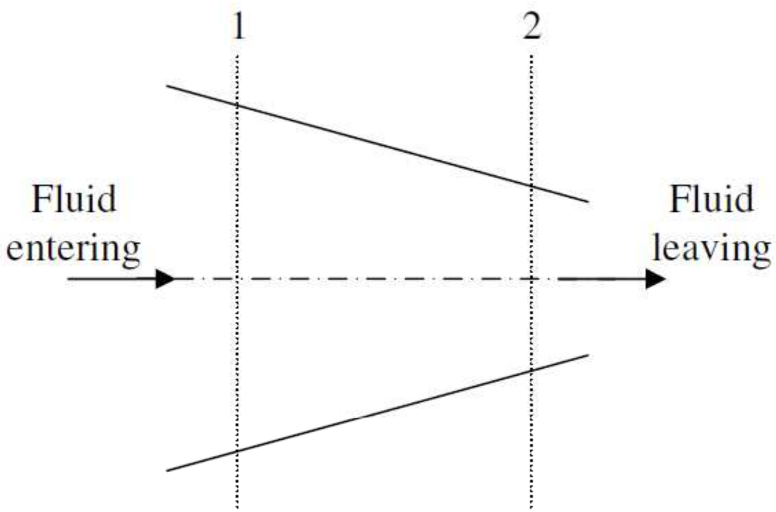
Fluid Momentum



- In 1 second, $\dot{m}$ kg of fluid undergoes a change in velocity from C_1 to C_2.
- An acceleration must have occurred:

$$a = \frac{C_2 - C_1}{t} = C_2 - C_1 \text{ m/s}^2$$

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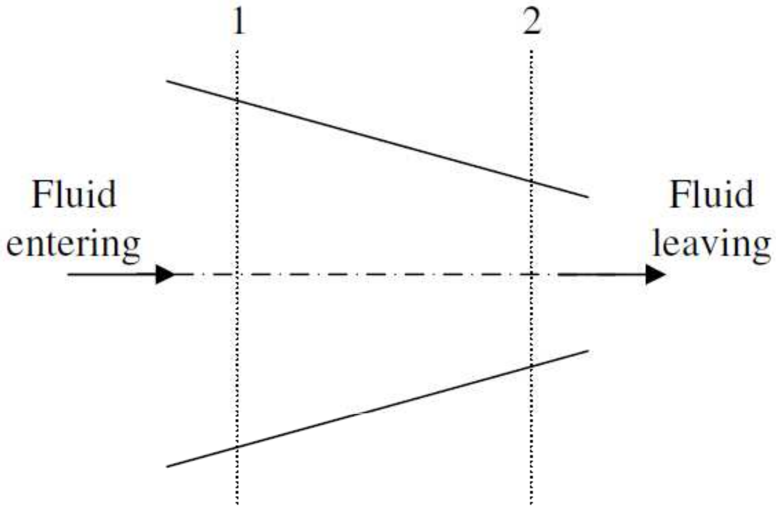
Fluid Momentum



- To undergo an acceleration, the fluid must experience a force.
- Newton’s second law:

$$F = ma = \dot{m}\left(C_2 - C_1\right)$$

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Fluid Momentum

- So:
  - Force acting ***on*** the fluid is
    - Mass flow rate multiplied by
    - Change in velocity

$$F = \dot{m}\left(C_2 - C_1\right)$$

  - So force ***on object*** by the fluid is:

$$-F = -\dot{m}\left(C_2 - C_1\right)$$

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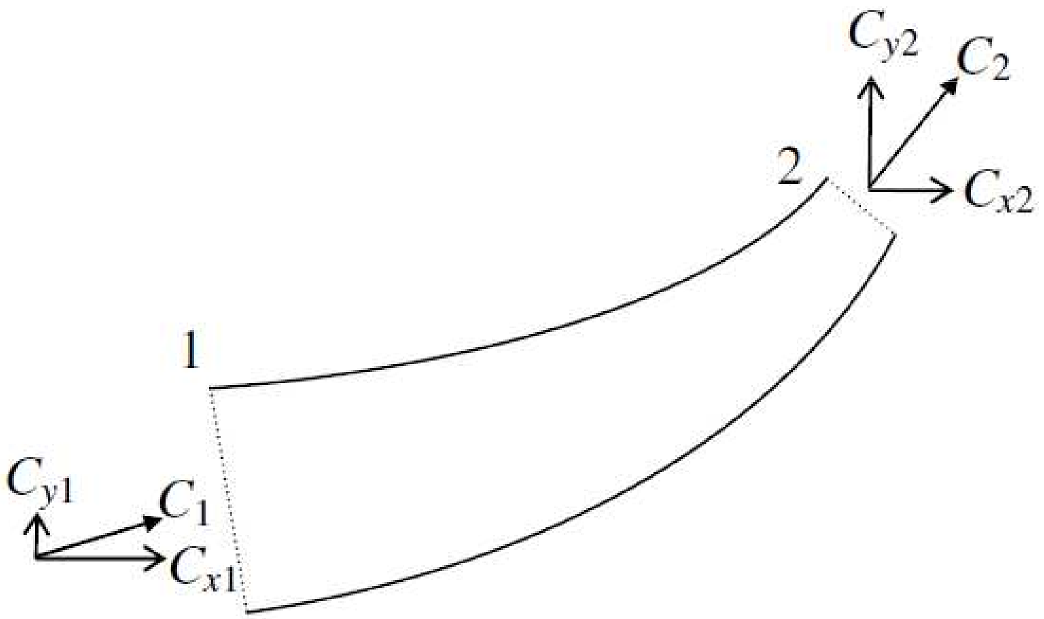
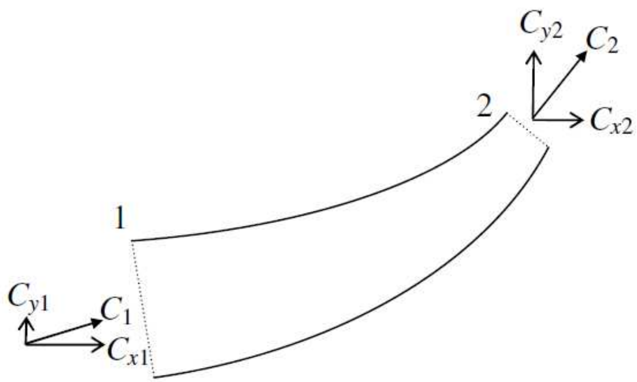
Fluid Momentum

- What about if direction changes during change in velocities?



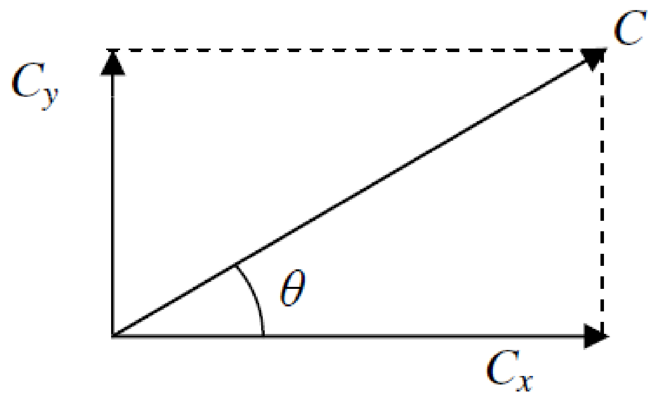
Fluid Momentum



- Use components:
  - C_{x1} and C_{x2} → $F_x = \dot{m}\left(C_{x2} - C_{x1}\right)$
  - C_{y1} and C_{y2} → $F_y = \dot{m}\left(C_{y2} - C_{y1}\right)$

Fluid Momentum

- Remember:
  - Calculate components from trigonometry:



$$C_x = C\cos\theta \qquad C_y = C\sin\theta$$

Fluid Momentum

- Remember:
  - ***Mass*** flow rate:
    - **Density** x **Area** x **Velocity**

$$\dot{m} = \rho A C$$

    - Does not matter which velocity to take
    - Mass flow rate is constant

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Fluid Momentum

- Remember:
  - Generally (unless otherwise stated) the **magnitude** of C_2 = **magnitude** of C_1:

$$|C_1| = |C_2|$$

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Examples

- On Visualiser

Summary

- Fluid Momentum: allows us to calculate forces **on** fluid *and* **on object** by fluid

$$F = \dot{m}\left(C_2 - C_1\right)$$

- Use components if there is a direction change:

$$F_x = \dot{m}\left(C_{x2} - C_{x1}\right)$$

$$F_y = \dot{m}\left(C_{y2} - C_{y1}\right)$$

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