UNACADEMY
CIVIL ENGINEERING
HYDRAULIC MACHINE
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HYDRAULIC MACHINE

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(Ex IES)

• Dynamic action of fluid

→ A stream of fluid entering in machine (turbine, pump, motor) has fixed or definite direction.

→ A force would be required to be acted on fluid to a change its velocity (either in direction or in magnitude).

→ The fluid also exert the same amount of force on the machine as is being acting on it (according to Newton's third law of motion).

→ Also, this force is exerted by the fluid on the machine or its component is by virtue of motion and is termed as "DYNAMIC FORCE" (and must not be confused with the hydrostatic force).

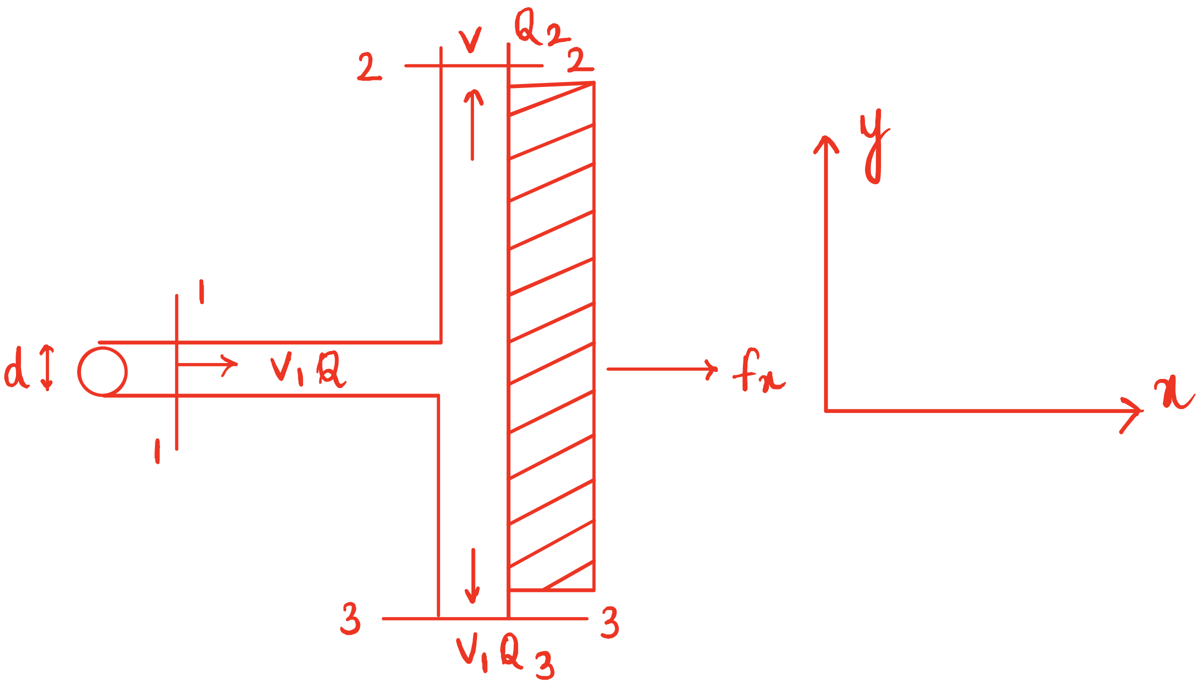
→ Thus, dynamic force on jet of fluid can be computed using momentum equation.

Dynamic force on jet of fluid (In given direction) = rate of change of linear momentum of jet in same direction.

Also force on machine or component = force on jet of fluid.

I. Force Exerted by fluid jet on stationary plate (flat).

a) Plate held normal to the jet.



→ If plate is frictionless, using energy equation between 1-1, 2-2, 3-3.

$$\frac{P_1}{\gamma} + Z_1 + \frac{V_1^2}{2g} = \frac{P_2}{\gamma} + Z_2 + \frac{V_2^2}{2g} + h_2$$

$$= \frac{P_3}{\gamma} + Z_3 + \frac{V_3^2}{2g} + h_3.$$

$V_1 = V_2 = V_3 = V$

Now force exerted by jet on the plate = − force exerted on jet by plate.

$f_x = -(\rho Q(0) - \rho Q V) = \rho Q V.$

$= \rho (AV) V = \rho A V^2.$

$$\boxed{f_x = \rho A V^2}$$

$f_y = -[\{\rho Q_2 V + \rho Q_3(-V)\} - \rho Q(0)]$ —— (i)

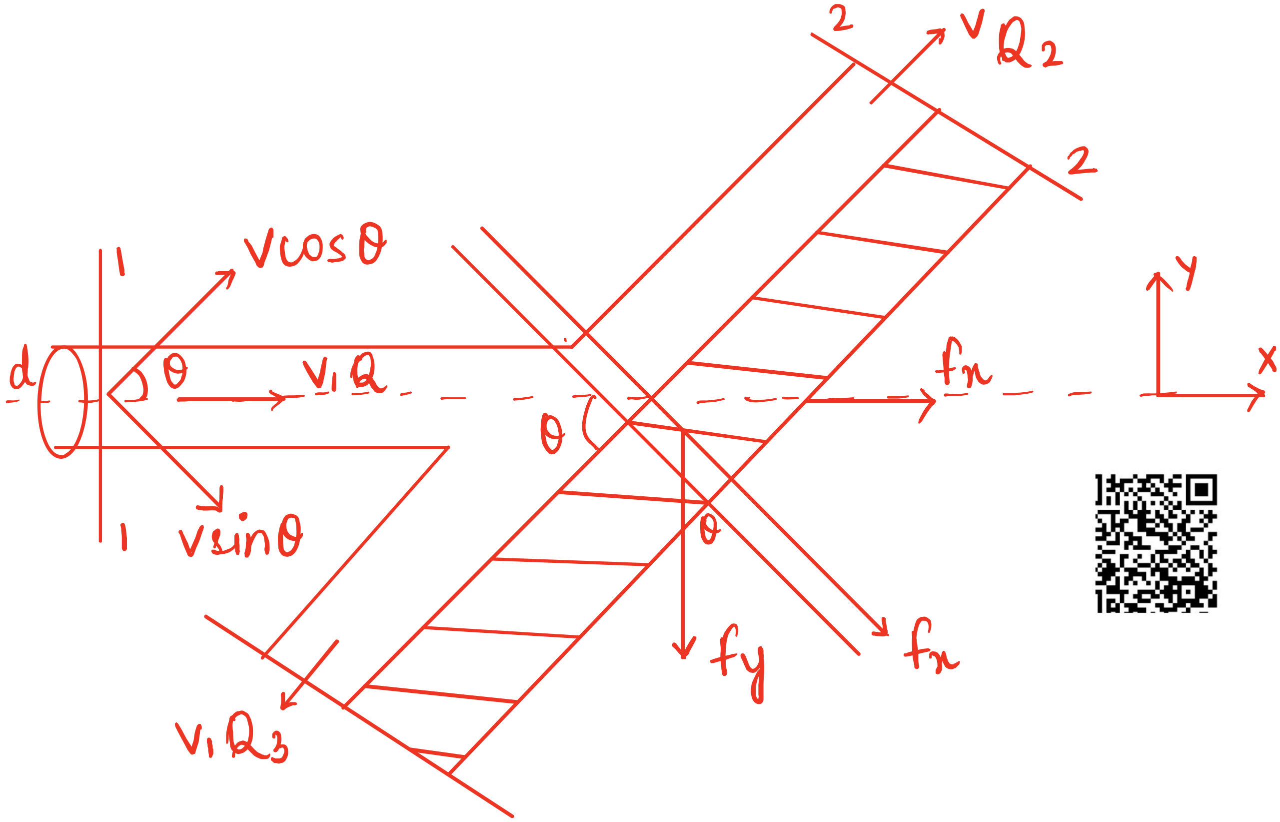
$Q_2 = Q_3$ —— (ii)

from (i) and (ii), $f_y = 0$.

Also, $Q = Q_2 + Q_3$

$\Rightarrow Q_2 = Q_3 = \dfrac{Q}{2}.$

b). Plate held at an inclination to the jet.



$$f_n = -[\rho Q(0) - \rho Q V \sin\theta) = \rho Q V \sin\theta = \rho A V^2 \sin\theta.$$

Also,

$$f_x = f_n \sin\theta = \rho A V^2 \sin^2\theta.$$

$$f_y = f_n \cos\theta = \rho A V^2 \sin\theta \cos\theta.$$

Now, $f_s = 0$.

$$f_s = -[\{\rho Q_2 V + \rho Q_3(-V)\} - \rho Q V \cos\theta = 0.$$

$$Q_2 - Q_3 = Q\cos\theta \quad \text{—— (I)}$$

$$Q_2 + Q_3 = Q \quad \text{—— (II)}$$

from (I) and (II)

$Q_2 = \frac{Q}{2}(1+\cos\theta)$	$Q_3 = \frac{Q}{2}(1-\cos\theta)$.

<u>Question</u>: A flat plate, hinged atouts its top edge is suspended vertically and weighing 10 kN. A jet of water 50 mm in dia and 50 m/sec velocity strikes normal to it at its mid point. Compute

a) The horizontal force that must be applied to its bottom edge to keep at vertical.

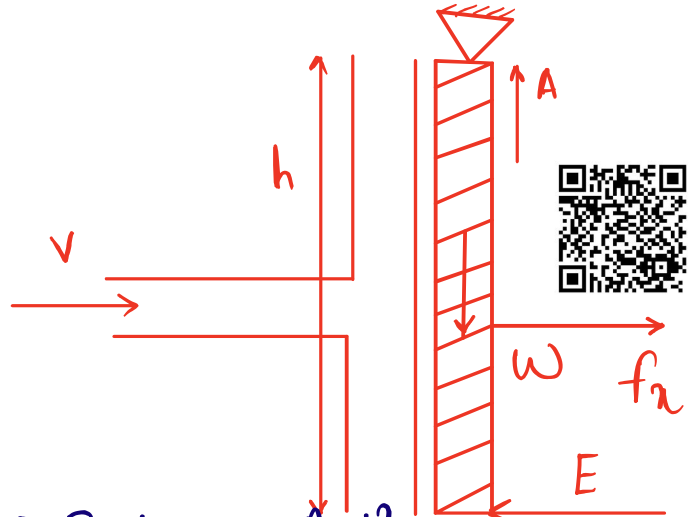
b). The angle of deflection, where its stage in equilibrium.

<u>Answer</u>: a) for plate to remain vertical.

$$\Sigma M_A = 0$$

$$f \cdot h = f_x \cdot \frac{h}{2}$$

$$f = \frac{f_x}{2}$$



$$f_x = -\rho Q(0 - V) = \rho Q V = \rho A V^2$$

$$f = \frac{\rho A V^2}{2}$$

$$= 10^3 \times \frac{\pi}{4} \times (50)^2 \times 50^2 \times \frac{1}{2} \times 10^{-6} \times 10^{-3}$$

$$= 2.454 \text{ kN.}$$

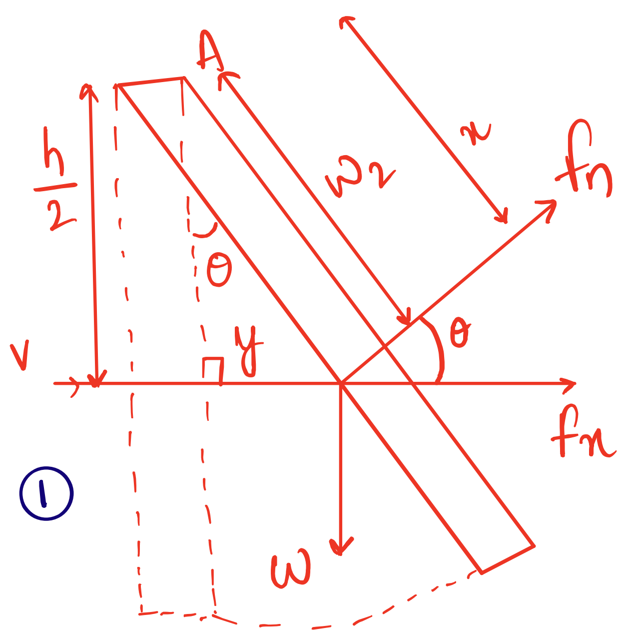
b) At equilibruim $\Sigma M_A = 0$.

$$w y - f_n \cdot x = 0.$$

$$w \cdot \frac{h}{2} \sin\theta$$

$$= f_n \cdot \frac{h}{2\cos\theta}$$

$$\sin\theta = \frac{f_n}{w} \cdot \sec\theta \quad \text{—— (1)}$$



$$f_n = -[\rho Q(0) - V\cos\theta)] = \rho Q V \cos\theta$$

$$= \rho A V^2 \cos\theta \text{ —— (ii)}$$

from (i) and (ii)

$$\sin\theta = \frac{\rho A V^2 \cos\theta \cdot \sec\theta}{\omega}$$

$$\theta = \sin^{-1}\left[10^3 \times \frac{\pi}{4}(50\times 10^{-3})^2 \times 50^2 \times \frac{1}{10\times 10^3}\right]$$

$$\theta = 29.398^\circ.$$