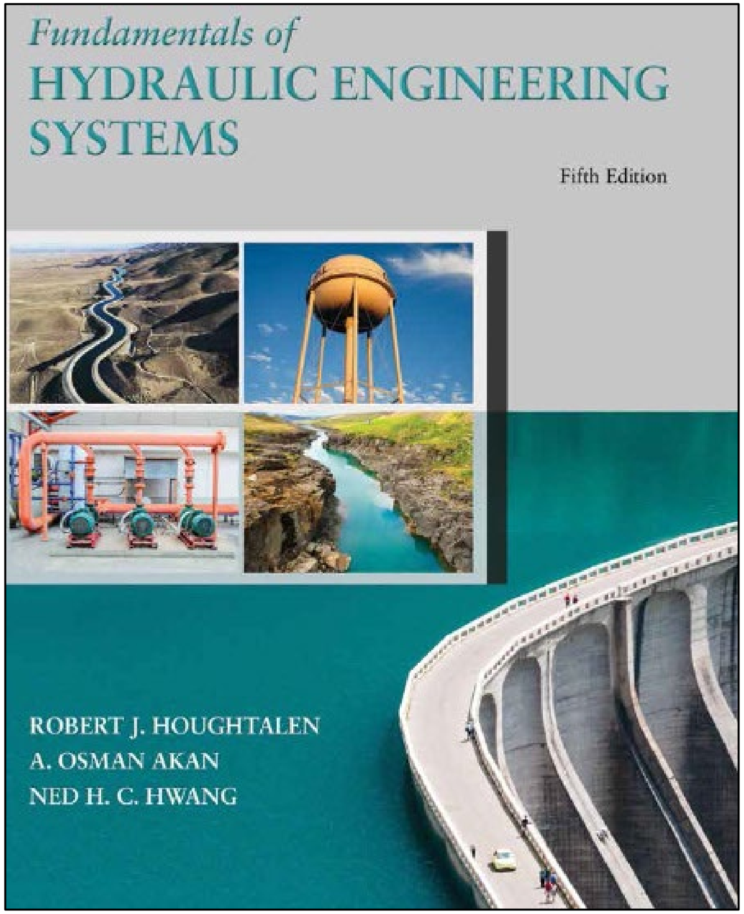
Fundamentals of Hydraulic Engineering Systems

Fifth Edition



Chapter 5a

Water Pumps

Learning Objectives

5.1 Describe the operational difference between **centrifugal pumps** and other types of pumps.

5.2 Define and use **pump characteristic curves.**

5.3 Describe the operation of **pumps** in **pipelines, branching systems,** and **pipe networks**.

5.4 Explain **series** and **parallel pump** configurations.

5.5 Understand the concepts of **cavitation, specific speed,** and **pump similarity.**

5.6 Recognize how **pump selection** is accomplished.

5.7 Calculate solutions to various pump analysis and design problems involving these concepts.

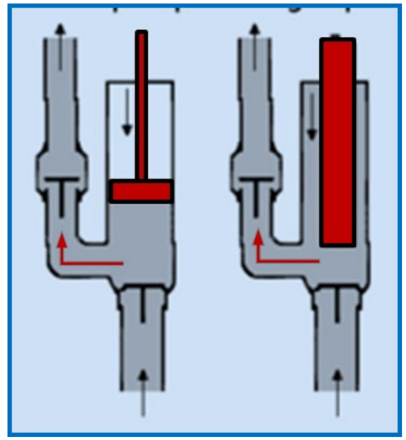
Description of Pumps and Pump Types

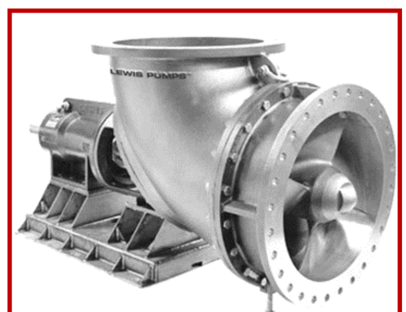
Definitions and Visualization

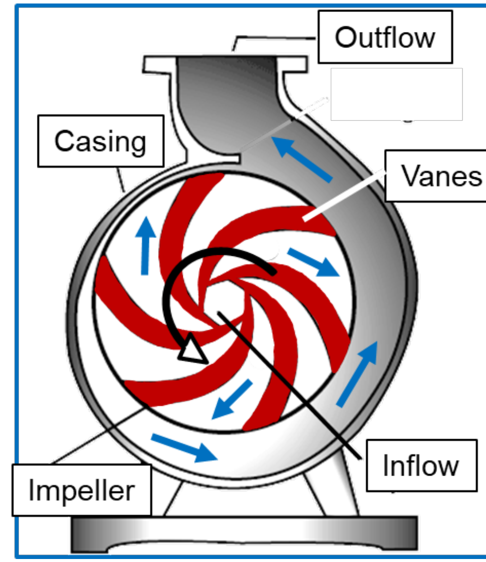
Pump: a device that converts mechanical to hydraulic energy

Turbo-hydraulic: fluid moved by rotating vanes or another moving fluid (e.g., centrifugal, jet, and propeller pumps)

Positive displacement: fluid moved by precise machine displacements (e.g., screw and reciprocal pumps)







Q: Guess these pump types.

Centrifugal (Radial Flow) Pumps

Visualization and Flow Principles

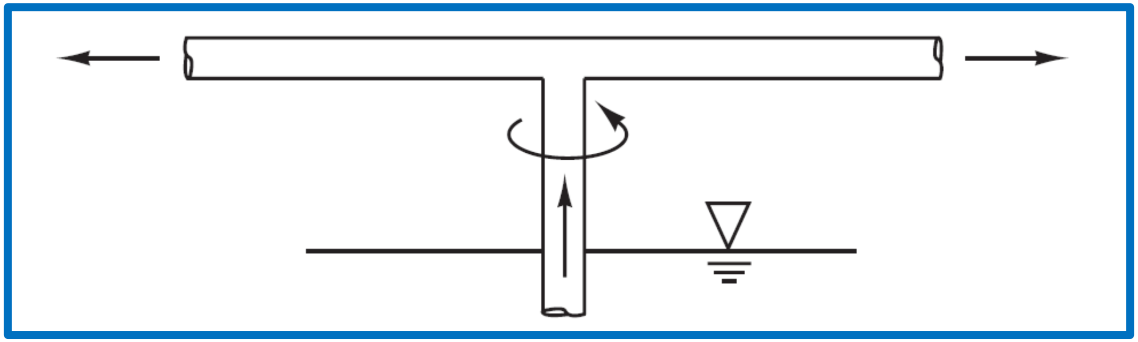
Q: Will water be ejected from the pipe T if we spin it?

A: Only if it is filled with water (primed) first.

Q: What principle of physics is being utilized to move water?

A: Centrifugal Force and Momentum Conservation

Figure 5.1 Demour's centrifugal pump



Centrifugal (Radial Flow) Pumps (2 of 7)

Visualization and Derivation of Power Input

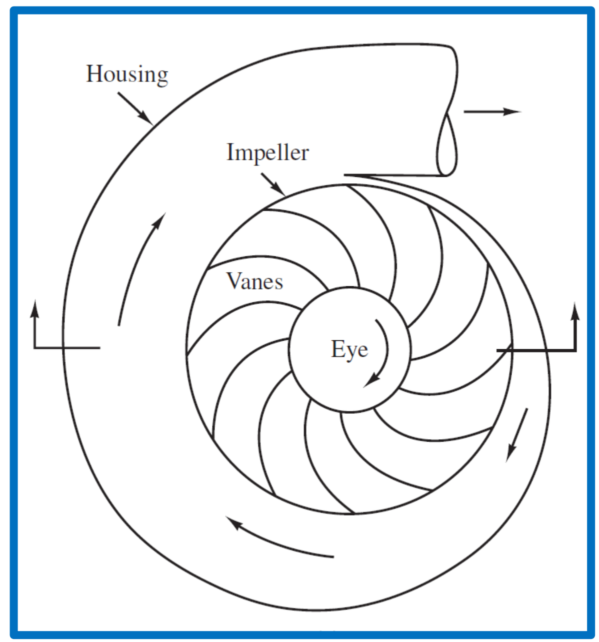
From Newton's 2nd Law, derive the impulse momentum equation:

$$F = ma = m\left(\frac{dV}{dt}\right) = \left(\frac{m}{dt}\right)(dv) = \rho Q\left(V_o - V_i\right) \rightarrow \textbf{from Chap 3}$$

Q: What is the relationship between force and torque (T)?

$$\textbf{A}: T = \text{force} \times \text{perpendicular distance} = F \cdot d$$

applied to impulse-momentum:



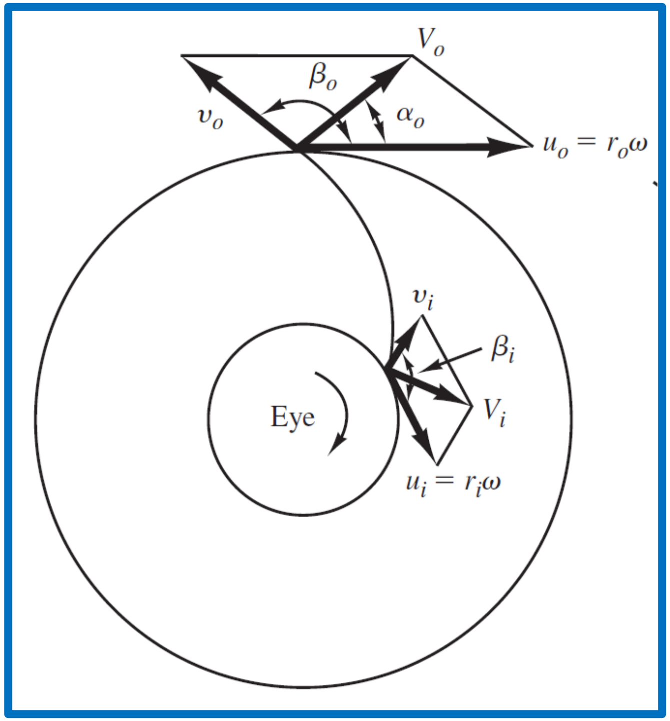
Centrifugal (Radial Flow) Pumps (3 of 7)

$$T = \rho Q\left(r_o V_o \cos\alpha_o - r_i V_i \cos\alpha_i\right)$$

Also, Power $\left(P\right) = \omega T;$

So the **Pump Power Input** is:

$$P_i = \rho Q\omega\left(r_o V_o \cos\alpha_o - r_i V_i \cos\alpha_i\right)$$



Centrifugal (Radial Flow) Pumps (6 of 7)

Equations for Power Output & Efficiency

Q: Does energy increase on the output side of the pump? If so, in what form? Does the flow rate increase?

A: The energy increase is in the form of pressure head (see figure below). Flow does not increase (i.e., continuity).

Pump Power Output:

$$P_o = \gamma Q H_p$$

Pump Efficiency:

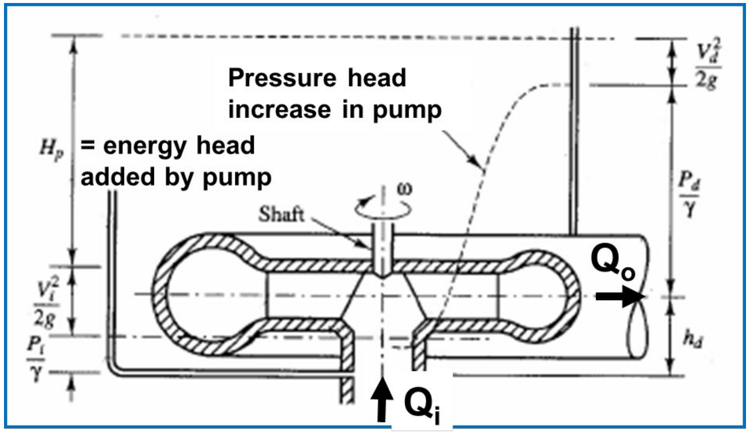
$$e_p = \frac{P_o}{P_i}$$

Motor Efficiency:

$$e_m = \frac{P_i}{P_m}$$

Overall Efficiency:

$$e = e_p e_m = \frac{P_o}{P_m}$$



Centrifugal (Radial Flow) Pumps (7 of 7)

Pump and Motor Selection Example Problem

A centrifugal pump is required to lower the stormwater depth in a 12 ft by 10 ft rectangular sump at the rate of 1 foot every minute. The pump must overcome a lift of 20 feet. If the overall efficiency rating of the pump is 75%, select the appropriate pump (flow rate in gpm) and motor (power in kW). Assume pipeline losses are negligible.

$$\textbf{Ans. Q} = \left[\frac{(12')(10')(1')}{60\text{ sec}}\right]\left(\frac{449\text{ gpm}}{1\text{ cfs}}\right) \approx \textbf{900 gpm}$$

$$P_o = \gamma Q H_P = \left(62.3\text{ lb}/\text{ft}^3\right)\left(2\text{ ft}^3/\text{s}\right)\left(20\text{ ft}\right) = 2{,}490\text{ ft}-\text{lb/sec}$$

$$P_o = \left(2{,}490\text{ ft}-\text{lb}/\text{sec}\right)\left(\frac{1\text{ hp}}{550\text{ ft}\cdot\text{lb/sec}}\right) = 4.53\text{ hp}$$

$$\mathbf{P_m = \frac{P_o}{e}} = \left[\frac{4.53\text{ hp}}{(0.75)}\right]\left(\frac{1\text{ kW}}{1.341\text{ hp}}\right) = \textbf{4.50 kW}$$

First Drop of Water from a Hand Pump

Everyone is smiling in Jambo, South Sudan.

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