Solution to Problem 225B:

The low pressure liquid oxygen pump in the Space Shuttle Main Engine is designed to deliver $887lbs/s$ ($Q = 16.1ft^3/s$) of liquid oxygen (assuming a liquid oxygen density of $55lbs/ft^3$ and a pressure rise of $310psi$ ($H = 812ft$) at a rotating speed of $5000rpm$ ($\Omega = 524rad/s$.

The specific speed of this pump is

$$N = \frac{\Omega Q^{\frac{1}{2}}}{(gH)^{\frac{3}{4}}} = 1.02 \qquad (1)$$

This would suggest an axial or mixed flow pump.

With an inlet tip diameter of $11in$ ($r_{T1} = 0.458ft$) it follows that the tip speed at $5000rpm$ would be $240ft/s$ and the flow coefficient, ϕ, would be

$$\phi = \frac{Q}{\pi \Omega r_{T1}^3} = 0.1 \qquad (2)$$

and this would suggest an inlet blade tip angle of

$$\arctan \phi = 5.71^\circ \qquad (3)$$

Using the simple one-dimensional performance analysis (neglecting frictional losses), the head coefficient is given by

$$\psi = \frac{g\Delta H}{\Omega^2 r_{T1}^2} = 0.453 = 1 - \phi \cot(\beta_2) \qquad (4)$$

where β_2 is the flow and blade angle at discharge and assuming $\alpha_1 = 0$. From this it follows that the blade angle at discharge

$$\beta_2 = \arctan\left(\frac{\phi}{(1-\psi)}\right) = 10.5^\circ \qquad (5)$$