1. A centrifugal pump produces a head of 25 m at a volumetric flow rate of 0.15 m$^3$/s when it is rotating at 1470 rpm. The inlet and exit diameters of the impeller are 0.15 m and 0.4 m, respectively. The blade width at the inlet is 0.025 m, while the blade angle at the inlet is 60°. The meridional velocity across the impeller remains the same. The blade and fluid angles are the same. Assuming axisymmetric flow and neglecting losses, determine
   a) the tangential component of the absolute velocity at the inlet,
   b) the blade angle at the outlet,
   c) the blade width at the outlet and
   d) shut-off head.

2. A centrifugal pump having an impeller outside diameter of 0.2 m delivers 0.02 m$^3$/s of water when it is rotating at 1450 rpm. Blades are extending up to the inlet eye where the hub and tip radii are 3 cm and 6 cm, respectively. There are no inlet guide vanes and the blade angle at the exit is 20°. The meridional velocity is constant throughout the impeller. Assuming that the fluid and blade angles are equal and neglecting friction, determine the head of the pump.

3. A centrifugal pump impeller has an outlet diameter two times the inlet, and has an angular velocity of $U_2$. The relative fluid angles at the inlet and outlet are $\beta_1$ and $\beta_2$ respectively both being 45°; backward curved. The radial velocity at the inlet and outlet are same ($V_{m1}=V_{m2}$). Inlet and outlet flow areas are given as $A$. Show that the degree of reaction in terms of $U_1$, $Q$ and $A$ is

   \[ R = \frac{1}{2\left(1 - \frac{Q}{3AU_1}\right)} \]

4. An axial flow fan has tip diameter of 2 m, a hub diameter of 0.8 m, and rotates at 1450 rpm. For the condition of zero inlet whirl estimate the velocity diagrams at the tip section, if the inlet absolute velocity is 55 m/s the air has a density of 1.2 kg/m$^3$ and losses are ignored. Estimate also the fluid power, if $\Delta p$ is 5 kN/m$^2$.

5. By applying Bernoulli equation to the relative flow in an axial impeller. Show that the static pressure rise across an axial flow rotor

   \[ p_2 - p_1 = \frac{1}{2} \rho \left[ V_{\theta 1}^2 - V_{\theta 2}^2 + 2 \mu (V_{\theta 2} - V_{\theta 1}) \right] \]