1. A centrifugal pump produces a head of 25 m at a volumetric flow rate of 0.15 m³/s when it is rotating at 1470 rpm. The inlet and exit diameter of the impeller 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 the frictional effects 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 m³/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. By applying Bernoulli equation to the relative flow in an axial impeller. Show that the static pressure rise across an axial flow rotor
   \[ p_2 - p_1 = \frac{1}{2} \rho \left( V_{\theta 2}^2 - V_{\theta 1}^2 + 2u(V_{\theta 2} - V_{\theta 1}) \right) \]

4. A centrifugal pump produces a head of 17 m at a volumetric flow rate of 0.04 m³/s when it is rotating at 1470 rpm. The loss due to leakage is 0.001 m³/s and the mechanical loss due to the friction is 0.5 kW. The inlet and outlet diameters of the impeller are 10 cm and 25 cm, respectively, while the width of the impeller at the inlet and exit are 2 cm and 1 cm, respectively. The relative fluid angle at the outlet is 30°. There are no inlet guide vanes. Determine
a) the relative fluid angle at the inlet,
b) the absolute fluid angle at the outlet,
c) the absolute velocity at the outlet,
d) the hydraulic efficiency and
e) the overall efficiency

5. An impeller rotating at 3500 rpm has an outside diameter of 25 cm. The outlet blade angle $\beta_2$ is $22^\circ$ and the radial velocity at the outlet $V_m^2= 3.64$ m/sec. Assuming radial inlet flow to the impeller (No inlet whirl), draw the ideal velocity diagrams calculating various velocities and angles. What is the ideal (theoretical) head.

6. 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 $45^\circ$; backward curved. The radial velocity at the inlet and outlet are same ($V_m^1=V_m^2$). Inlet and outlet flow areas are given as A. Show that the degree of reaction in terms of $U_1$,Q and A is

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

7. The reaction ratio R is defined as the ratio of the static pressure rise across the rotor row to the total pressure rise across the rotor. Show that in the absence of friction R can be expressed as

$$ R = \frac{1}{2} \left[ 1 - \frac{V_m}{u} (\cot(\alpha_1) - \cot(\beta_2)) \right] $$ for axial flow machines.