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.
\[(4.196 \text{ m/s}, 30.93°, 0.009377 \text{ m}, 96 \text{ m})\]

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. \[(13.46 \text{ m})\]

3. In a particular centrifugal pump with 5.5m head, the rotational speed is 286 rpm and the meridional velocity along the blades is 2.4 m/s and is constant along the blades. The outlet diameter of the impeller is 0.6m and the blade widths at the outlet and inlet of the rotor are 0.03m and 0.06m, respectively. Assume that there is no inlet swirl and the blade angles are equal to fluid angles.
   a) Calculate the flowrate through the pump
   b) Draw velocity profiles at the inlet and outlet of the impeller
   c) Calculate blade angles at the inlet and outlet of the impeller
\[(0.136 \text{ m}^3/\text{s})\]

4. The net head of an axial flow turbine is 10m and its hydraulic efficiency is 90%. The quantity of water passing through the turbine is 1m$^3$/s. The best description of flow through the impeller may be made if the velocity diagrams at the middle of the blades are considered. The impeller has a hub diameter of 20 cm and a tip diameter of 50 cm. Entry to the runner is shockless ($\beta_1v = \beta_1$). The inlet blade angle is $\beta_1v=90°$. Water leaves the inlet guide vanes with an angle of $\alpha_1=15°$ with the tangential direction.
   a) Find meridional (axial) velocity
   b) Find the rotational speed of the impeller
   c) Find the outlet blade angle
\[(6.06 \text{ m/s}, 1233 \text{ rpm}, 57°)\]

5. By applying Bernoulli equation to the relative flow in an axial impeller. Show that the static pressure rise across an axial flow rotor
\[p_2 - p_1 = \frac{1}{2} \rho \left[ V_{\theta 1}^2 - V_{\theta 2}^2 + 2\mu (V_{\theta 2} - V_{\theta 1}) \right]\]
6. An axial flow compressor has a tip diameter of 0.95 m and a hub diameter of 0.85 m. At the hub, the absolute velocity of air makes an angle of 28° measured from axial direction and relative velocity angle from axial direction is 56°. At the hub position, the absolute velocity outlet angle is 56° and relative velocity outlet angle is 28°, both from axial direction. The rotor rotates at 5000 rpm and the density of air is 1.2 kg/m³. Draw velocity triangles at hub and determine:

a) The axial velocity
b) The mass flow rate
c) Power required for compression
d) Absolute fluid angles at the tip for a free vortex design condition (V₀*ᵣ=constant)
e) Degree of reaction at the tip

Assume constant axial velocity in radial direction.

(a) 110.5 m/s b) 18.7 kg/s c) 437.2 kW d) 25.4 & 52.9 e) 0.6)