MIDDLE EAST TECHNICAL UNIVERSITY
DEPARTMENT OF MECHANICAL ENGINEERING
ME 402 FLUID MACHINERY

HOMEWORK 6

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 m/s, 30.93°, 0.009377 m, 96 m)

2. An inward flow radial turbine (see the below figure) involves a nozzle angle, $\alpha_1$, of 60 degrees and an inlet rotor tip speed, $U_1$, of 9 m/s. The ratio of rotor inlet to outlet diameters is 2.0. The radial component of velocity remains constant at 6 m/s through the rotor, and the flow leaving the rotor at section (2) is without angular momentum. (a) If the flowing fluid is water and the stagnation pressure drop across the rotor is 110 kPa, determine the loss of available energy across the rotor and the efficiency involved. (b) If the flowing fluid is air and the static pressure drop across the rotor is 0.07 kPa, determine the loss of available energy across the rotor and the rotor efficiency. (16.6 J/kg, 0.849, 17.4 J/kg, 0.843)

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 m$^3$/s, 28°, 38.6°)
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 $\beta_{1v} = 90^\circ$. Water leaves the inlet guide vanes with an angle of $\alpha_1 = 15^\circ$ with the tangential direction.

a) Find meridional (axial) velocity
b) Find the rotational speed of the impeller
c) Find the outlet blade angle

$(6.06 \text{ m/s}, 1233 \text{ rpm, } 57^\circ)$

5. The device shown in the below figure is used to investigate the power produced by a Pelton wheel turbine. Water supplied at a constant flowrate issues from a nozzle and strikes the turbine buckets as indicated. The angular velocity, $\omega$, of the turbine wheel is varied by adjusting the tension on the Prony brake spring, thereby varying the torque, $T_{shaft}$, applied to the output shaft. This torque can be determined from the measured force, $R$, needed to keep the brake arm stationary as $T_{shaft} = Fl$, where $l$ is the moment arm of the brake force.

Experimentally determined values of $\omega$ and $R$ are shown in the following table. Use these results to plot a graph of torque as a function of the angular velocity. On another graph plot the power output as a function of the angular velocity. On each of these graphs plot the theoretical curves for this turbine, assuming 100 percent efficiency. Compare the experimental and theoretical results and discuss some possible reasons for any differences between them.

![Diagram of Pelton wheel turbine]

<table>
<thead>
<tr>
<th>$\omega$ (rpm)</th>
<th>$R$ (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td>360</td>
<td>8.5</td>
</tr>
<tr>
<td>450</td>
<td>8.2</td>
</tr>
<tr>
<td>600</td>
<td>7.5</td>
</tr>
<tr>
<td>700</td>
<td>7</td>
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<tr>
<td>940</td>
<td>5.2</td>
</tr>
<tr>
<td>1120</td>
<td>3.96</td>
</tr>
<tr>
<td>1480</td>
<td>0.71</td>
</tr>
</tbody>
</table>

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 $28^\circ$ measured from axial direction and relative velocity angle from axial direction is $56^\circ$. At the hub position, the absolute velocity outlet angle is $56^\circ$ and relative velocity outlet angle is $28^\circ$, both from axial direction. The rotor rotates at 5000 rpm and the density of air is 1.2 kg/m$^3$. 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 ($V_0*r=\text{constant}$)
e) Degree of reaction at the tip

Assume constant axial velocity in radial direction.

(a) $110.5 \text{ m/s}$ b) $18.7 \text{ kg/s}$ c) $437.2 \text{ kW}$ d) $25.4 \& 52.9$ e) $0.6$)