UNIVERSITY OF JOHANNESBURG

PROGRAM	:	**NATIONAL DIPLOMA** *ENGINEERING: MECHANICAL*
SUBJECT	:	**HYDRAULIC MACHINES III**
CODE	:	**MHM 301**
DATE	:	**SSA EXAMINATION** 3rd DECEMBER 2014
DURATION	:	(SESSION 1) 08:00 - 11:00
WEIGHT	:	40 : 60
TOTAL MARKS	:	100

EXAMINER	:	MR. L NGO
MODERATOR	:	MR A MWESIGYE
NUMBER OF PAGES	:	5 PAGES (Including cover page)
REQUIREMENTS	:	1 SHEET OF GRAPH PAPER

INSTRUCTIONS:

- PLEASE ANSWER ALL QUESTIONS.
- NUMBER ALL YOUR QUESTIONS CLEARLY AND UNDERLINE YOUR FINAL ANSWER.
- SHOW ALL THE CALCULATIONS.
- ANSWERS WITHOUT UNITS WILL BE PENALIZED.
- ASSUME ALL CONSTANTS AND PARAMETERS YOU NEED FOR YOUR CALCULATIONS.
- NO MARKS WILL BE GIVEN TO ILLEGIBLE WORK.

QUESTION 1

A laboratory test on a centrifugal pump yielded the following law:

$$H = 43.5 + 260Q - 3800Q^2$$

where H is the effective head in m and Q is the flow rate in m^3/s. The pump is then used to deliver water through a pipeline 785 m long and with 300 mm internal diameter. The static lift is 24.5 m. The losses in the bends and fittings amount to an equivalent pipe length of 15 m and the Moody friction factor $f = 0.032$.

1.1 Estimate the power required to drive the pump, assuming an overall efficiency of 70% at the operating point. (16)

1.2 Sketch the performance curves indicating operating point and the efficiency of the pump (4)

[20]

QUESTION 2

A Pelton wheel has a head of 90 m and head lost due to friction in the penstock is 30 m. The main bucket speed is 12 m/s and the nozzle discharge is 1.0 m^3/s. If the water is leaving the bucket at an angle of 165° and $C_v = 0.98$, determine the power of Pelton wheel and the hydraulic efficiency.

[17]

QUESTION 3

A centrifugal fan rotates at a speed of 1460 rpm and must deliver 1.3 m^3/s of air of density 1.22 kg/m^3 at a total pressure of 370 Pa. Assume the manometric efficiency of the fan is 55% and that the whirl component velocity at the exit of the impeller is double that of the peripheral velocity. Ignore mechanical losses and calculate:

3.1 the peripheral velocities at inlet and outlet of the impeller (16)

3.2 the diameter of the impeller and (4)

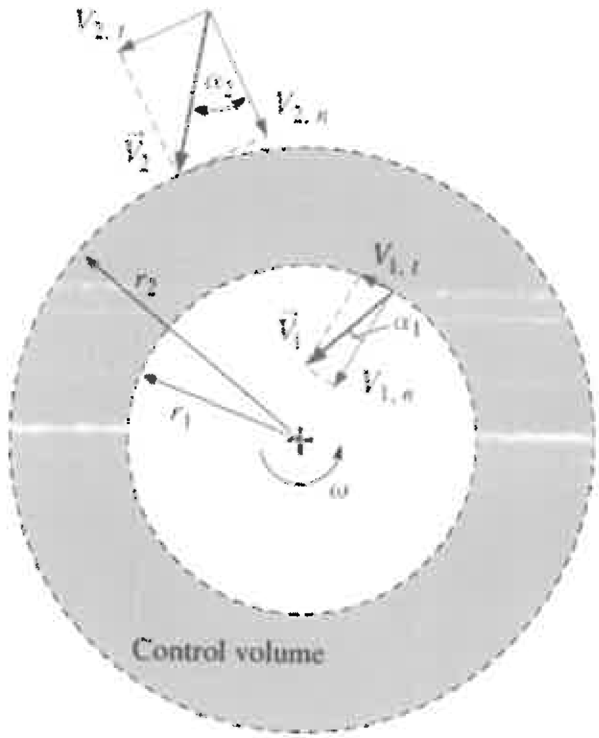
3.3 the power required to drive the fan (3)

[23]

QUESTION 4

A Francis radial-flow hydroturbine has the following dimensions, where location 2 is at the inlet to the runner and location 1 at the outlet of the runner:

$r_2 = 2.0$ m, $r_1 = 1.3$ m, $b_2 = 0.85$ m, and $b_1 = 2.10$ m. The runner blade angles are $\beta_2 = 66°$ and $\beta_1 = 18.5°$ at the turbine inlet and outlet, respectively. The runner rotates at $N = 100$ rpm. The volume flow rate at design conditions is 80.0 m^3/s. Irreversible losses are neglected in this preliminary analysis. Calculate the swirl angle α_1, where α_1 is measured from the radial direction at the runner outlet (see figure below). Does this turbine have forward or reverse swirl? Predict the power output (MW) and required net head (m).



[17]

QUESTION 5

Two geometrically similar pumps are running at the same speed of 800 rpm. One pump has the impeller diameter of 0.2 m and lifts water at the rate of 15 l/s against a head of 12 m. Determine the head and impeller diameter of a similar pump required to deliver 12 l/s of discharge.

[8]

QUESTION 6

Water at 25 °C flows in a 6 m wide rectangular channel at a depth of 0.55 m and a flow rate of 12 m^3/s. Determine

6.1 the critical depth (3)

6.2 thether the flow is subcritical or supercritical and (6)

6.3 the alternate depth (6)

[15]

FULL MARKS: 100

TOTAL MARKS: 100

USEFUL HYDRAULIC MACHINES FORMULAE

$$H = \frac{1}{g}\left(\omega r_2 V_{2,t} - \omega r_1 V_{1,t}\right)$$

$$Q = 2\pi r_1 b_1 V_{1,n} = 2\pi r_2 b_2 V_{2,n}$$

$$bhp = \omega T_{shaft} = \rho\omega Q\left(r_2 V_{2,t} - r_1 V_{1,t}\right)$$

$$H_L = \frac{8 f L Q^2}{\pi^2 g D^5}$$ Moody equation

$$W_{ideal} = \rho\omega r Q(V_j - \omega r)(1 - \cos\beta)$$

$$V_{jet} = C_v\sqrt{2gH}$$

$$\left(\frac{Q}{ND^3}\right)_P = \left(\frac{Q}{ND^3}\right)_m ; \left(\frac{H}{N^2 D^2}\right)_P = \left(\frac{H}{N^2 D^2}\right)_m ; \left(\frac{P}{D^5 N^3}\right)_P = \left(\frac{P}{D^5 N^3}\right)_m$$

$$\mathrm{Re} = \frac{\rho V R_h}{\mu} ; \mathrm{Fr} = \frac{V}{\sqrt{g y_u}}$$