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MODULE TITLE : FLUID MECHANICS

TOPIC TITLE : DIMENSIONAL ANALYSIS AND HYDRAULIC MACHINES

TUTOR MARKED ASSIGNMENT 3

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FM - 3 - TMA (v1)

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IMPORTANT

Before you start please read the following instructions carefully.

1. This assignment forms part of the formal assessment for this module. If you fail to reach the required standard for the assignment then you will be allowed to resubmit but a resubmission will only be eligible for a Pass grade, not a Merit or Distinction.

   You should therefore not submit the assignment until you are reasonably sure that you have completed it successfully. Seek your tutor's advice if unsure.

2. Ensure that you indicate the number of the question you are answering.

3. **Make a copy** of your answers before submitting the assignment.

4. **Complete all details on the front page of this TMA** and return it with the completed assignment including supporting calculations where appropriate. The preferred submission is via your TUOL(E) Blackboard account:

   https://eat.tees.ac.uk

5. Your tutor’s comments on the assignment will be posted on Blackboard.

1. It is found experimentally that the terminal velocity u_t of a spherical particle in a fluid depends upon the diameter d of particle, the dynamic viscosity μ of fluid and the buoyancy weight W of the particle [given by the difference in density between the particle and the fluid ($\Delta\rho$) $\times$ gravitational acceleration (g)]. Determine the nature of the relationship between these variables.

2. (a) Water (density 1000 kg m^{-3}) is maintained at a gauge pressure of 4 MPa in a horizontal pipe of diameter 100 mm. It is passed through a nozzle of diameter 15 mm which discharges a horizontal jet into the atmosphere. If the frictional losses reduce the theoretical discharge velocity by 6% in this process, calculate the actual velocity of the jet and its flow rate in kg s^{-1}.

   (b) This jet strikes an upward curved vane moving at 15 m s^{-1} in a horizontal direction away from the jet, which deflects the water through an angle of 120°. The impact is shockless. Calculate:

   (i) the magnitude and direction of the velocity of the fluid leaving the vane

   (ii) the thrust on the vane in a horizontal direction

   (iii) the thrust on the vane in a vertical direction

   (iv) the power generated by the impact in the horizontal direction.

3. (a) Distinguish, with the aid of simple sketches where appropriate, between the construction, operation and applications of the Pelton wheel, Francis turbine and Kaplan turbine.

(b) In a Francis turbine, the supply head (H) is 20 m of water (density 1000 kg m^{-3}). The discharge rate to atmosphere is 600 kg s^{-1}. The external radius of the runner (R_1) is 0.43 m and the internal radius (R_2) is 0.20 m. The runner blades are radial at inlet and they rotate at 300 revs min^{-1}. The blades occupy 5% of the circumferential area and are shaped to ensure that the radial velocity (u_{1R}) is kept constant and equal to $0.2\sqrt{2gH}$.

If the shaft power is 80% of the water power, determine the:

(i) guide vane angle
(ii) blade exit angle
(iii) water power
(iv) diagram power
(v) shaft power
(vi) height of runner blade at inlet and outlet.

4. A centrifugal pump has the following pressure – capacity characteristics:

Pressure (kPa)	*500*	*495*	*490*	*480*	*465*	*455*	*420*	*395*	*360*	*325*	*285*
Capacity ($m^3\ h^{-1}$)	*0*	*25*	*50*	*75*	*100*	*125*	*150*	*175*	*200*	*225*	*250*

It is planned to use this for a process having the following system characteristic:

Pressure (kPa)	*350*	*370*	*400*	*435*	*465*	*505*	*545*	*595*	*660*	*725*	*800*
Capacity ($m^3\ h^{-1}$)	*0*	*25*	*50*	*75*	*100*	*125*	*150*	*175*	*200*	*225*	*250*

(a) Determine the operating point for this pump with this system.

(b) The actual flowrate required by the process is 50 $m^3\ h^{-1}$. If the overall efficiency of the pump at this flowrate is 70%, determine the power consumed when the liquid being pumped has a density of 1200 kg m^{-3}.

(c) A second pump is available which has the following characteristics:

Pressure (kPa)	*400*	*395*	*390*	*380*	*370*	*360*	*345*	*320*	*305*	*280*	*255*
Capacity ($m^3\ h^{-1}$)	*0*	*25*	*50*	*75*	*100*	*125*	*150*	*175*	*200*	*225*	*250*

For the same flowrate (50 $m^3\ h^{-1}$), this pump has an overall efficiency of 80%.

(i) Determine the power used by this pump at a flowrate of 50 $m^3\ h^{-1}$.

(ii) Would it be a better choice? Give reasons for your answer.

(iii) What other factors should be considered before a final choice is made?

5. A process requires the precise control of the flow of a fluid to a reactor operating at 100 bar pressure (1 bar = 100 kPa). The flowrate may need to change to match the required reactor output. The flow should be relatively non-pulsating.

(i) Suggest a suitable pump for this duty. Give reasons for your choice.

(ii) Describe, with the aid of a suitable diagram, the construction and operation of your chosen pump.

6. It is proposed to pump 1500 m^3 of a liquid (density 1100 kg m^{-3}) each day through a total head of 10 m (including all losses) by using either a centrifugal pump or a reciprocating pump.

The centrifugal pump discharges 2.0 m^3 min^{-1} when driven by an electric motor supplying a power of 5 kW.

The reciprocating pump has a discharge rate of 1.75 m^3 min^{-1} when driven by an electric motor supplying 3.5 kW.

(a) Calculate the efficiency of each pump.

(b) If electricity costs 8p per kWh, select the most economical pump and determine the cost saving over 300 days of operation.

(c) State **two** other factors which should be considered before a final choice of pump is made.