National Exams December 2002

98-Mec-B6, Fluid Machinery

<u>3 hours duration</u>

<u>NOTES:</u>

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper a clear statement of any assumptions made.

2. Candidates may use one of two calculators, the Casio or Sharp approved models. This is an Open Book exam.

3. Any five questions constitute a complete paper. Only the first five questions as they appear in your answer book will be marked.

4. All questions are of equal value.

QUESTION #1

A 12-m-high, 10-m-diameter tank, which is initially empty, is filled with water from a reservoir by means of a pump-pipe system, as depicted in Figure 1 below. The pipe length (L), the pipe diameter (D), the pipe friction factor (f) and the total minor head-loss coefficients (ΣK) are, respectively, 25 m, 0.22 m, 0.025 and 2.4 in the case of the suction pipe, and 75 m, 0.17 m, 0.025 and 1.8 in the case of the discharge pipe. The downstream end of the discharge pipe, which is attached to the top of the tank as indicated in Figure 1, is open to the atmosphere and is located 55 m above the surface of the water in the reservoir. The head-discharge characteristics of the pump are given below. Determine (i) the time taken to fill the tank, and (ii) the power that must be supplied by the pump.

H_P (m)	81.35	79.30	76.79	73.83	70.41
Q (m^3/s)	0.08	0.10	0.12	0.14	0.16

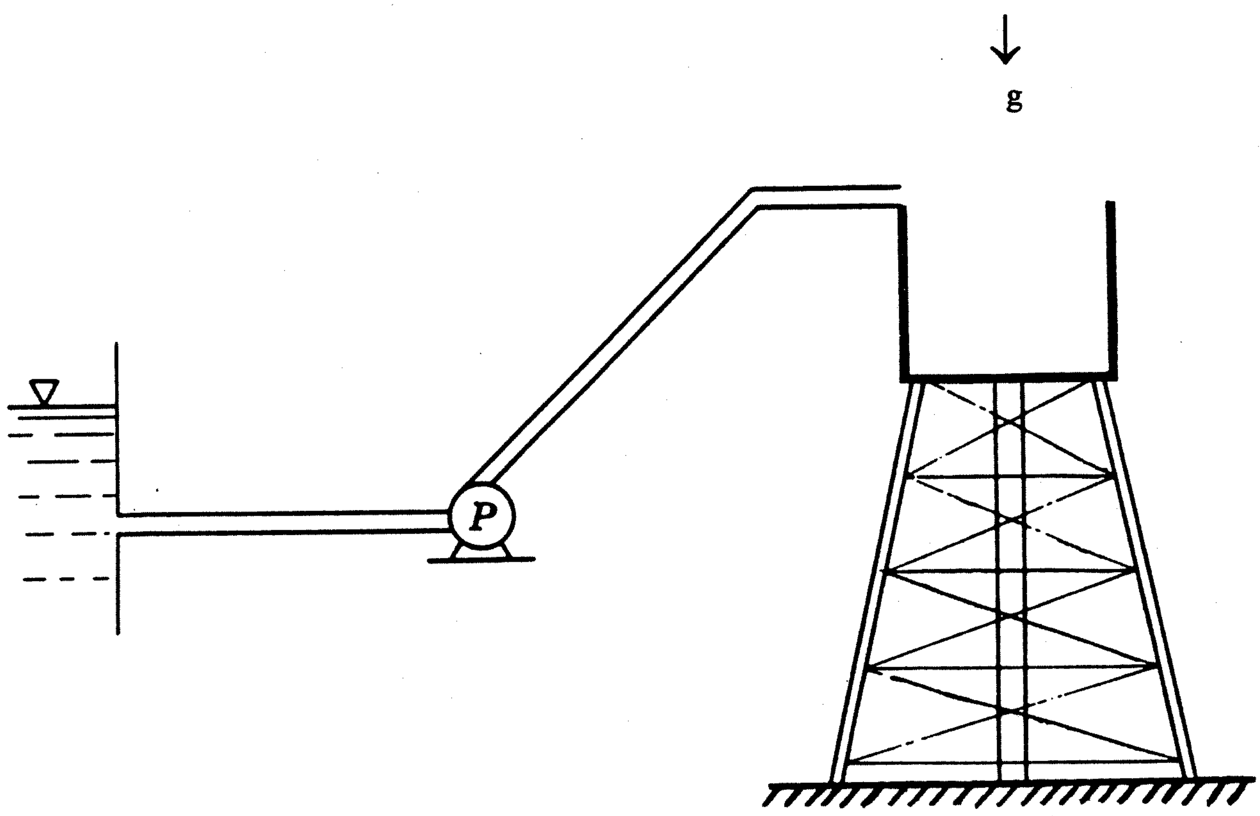

Figure 1

QUESTION #2

A prototype pump-pipe system that is used to transport oil with a specific gravity of 0.91 and a dynamic viscosity of 0.045 Pa.s is simulated by means of a 1:10 geometrically-similar model system, which is depicted in Figure 2. The prototype pump is required to develop a head of 28 m and to have a flow rate of 6.6 m^3/s under steady state operating conditions. The model system is tested with water at 20°C, and the power input to the model pump is 0.54 kW under the conditions indicated in Figure 2. Reynolds number similarity exists between the model and prototype systems, and the overall efficiency of the prototype pump is the same as that of the model pump. Determine (i) the flow rate through the model pump, (ii) the head developed by the model pump, (iii) the overall efficiency of the pumps, and (iv) the power that must be supplied to the prototype pump.

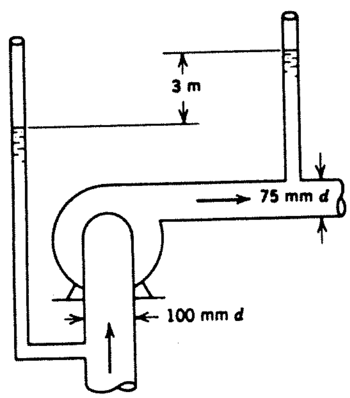

Figure 2

QUESTION #3

The speed of a radial-flow reaction water turbine operating under best-efficiency-point (BEP) conditions is 1,000 rpm and the overall turbine head is 16 m. The inner diameter of the turbine runner is 0.26 m, and the inlet angle and width of the runner vanes are, respectively, 125° and 72 mm. The hydraulic and overall efficiencies of the turbine are, respectively, 88% and 85%. Determine (i) the inlet guide vane angle, and (ii) the power developed by the turbine.

QUESTION #4

A centrifugal pump operating under BEP conditions is used to transport water at a flow rate of 0.07 m^3/s from one reservoir with a free-surface elevation of 2 m to another reservoir with a free-surface elevation of 45 m. The pump's suction and delivery pipes have a diameter of 0.18 m, a combined length of 60 m, a friction factor of 0.021, and minor loss coefficients totalling 2.9. The dimensionless specific speed of the pump (based on speed in radians per second) is 0.4. The pump impeller has forward-curved vanes with an outlet angle of 135° and an outlet width of 65 mm. The vanes occupy 5% of the circumference of the impeller. The (outer) diameter of the impeller is 0.3 m. Determine (i) the pump head, (ii) the pump speed (in rpm), and (iii) the hydraulic efficiency of the pump.

QUESTION #5

An impulse turbine has a 2.4-m-diameter Pelton wheel with a bucket angle of 168°. This wheel is acted upon by a 0.16-m-diameter water jet discharged under a head of 280 m from a nozzle with a velocity coefficient of 0.97; also, the hydraulic efficiency of the turbine is 82%, and its peripheral-velocity (or speed) factor is 0.46. Determine (i) the flow rate through the turbine, (ii) the power transferred to the wheel, (iii) the power lost as a result of hydraulic friction in the buckets of the wheel, and (iv) the power lost in the water discharged from the buckets. (Assume that the angle between the jet velocity and the bucket velocity is zero.)

QUESTION #6

An axial-flow pump with fixed guide vanes located upstream of the pump impeller is used to convey crude oil with a specific gravity of 0.86. The impeller has inner and outer diameters of 175 mm and 325 mm respectively. The outlet impeller blade angle is 65°, and the guide vanes impart an angle of 80° to the oil as it enters the impeller region. The pump speed is 600 rpm, and the power supplied to the pump is 8.75 kW. The overall and hydraulic efficiencies of the pump are 0.77 and 0.82 respectively. Determine the pump discharge.

QUESTION #7

A single-stage axial-flow gas turbine, consisting of a set of stator blades and a set of rotor blades, has a mass flow rate of 14 kg/s. The specific heat ratio of the gas is 1.3, and the gas constant is 190 J/kg·K. At the inlet to the stator blades, the absolute stagnation pressure and temperature are 320 kPa and 930 K respectively. At the rotor exit, the absolute stagnation pressure is 225 kPa. The gas leaves the stator blades with an absolute velocity that makes an angle of 15° with the direction of the tangential velocity of the rotor blades. The axial velocity of the gas is 110 m/s, and the tangential velocity of the rotor blades is 160 m/s. Determine (i) the theoretical power developed by the turbine, (ii) the inlet and outlet rotor blade angles.

Note: The gas can be considered to be an ideal gas with constant specific heats.

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