

# National Exams May 2008

98 Mec B6 Fluid Machinery

3 hours duration

## NOTES

- 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 This is an OPEN BOOK EXAM  
Any Casio or Sharp approved model calculators allowed
- 3 FIVE (5) questions constitute a complete exam paper  
The first five questions as they appear in the answer book will be marked
- 4 Each question is of equal value

**QUESTION #1**

A tank with a wall height of 11 m and a diameter of 9 m 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 ( $\sum K$ ) are respectively 28 m, 0.3 m, 0.032 and 3.1 in the case of the suction pipe and 80 m, 0.2 m, 0.032 and 2.1 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 a vertical distance  $Z$  above the surface of the water in the reservoir. The head discharge characteristics of the pump are given below.

- (a) Given that  $Z = 33$  m, determine (i) the time  $T$  taken to fill the tank and (ii) the power that must be supplied by the pump.  
 (b) If  $Z$  is greater than 33 m, would  $T$  be greater or smaller than the value found in part (a)? Why?

$H_P$ (m)	53.09	52.74	51.23	47.51	42.86
$Q$ ( $m^3/s$ )	0.08	0.10	0.12	0.14	0.16

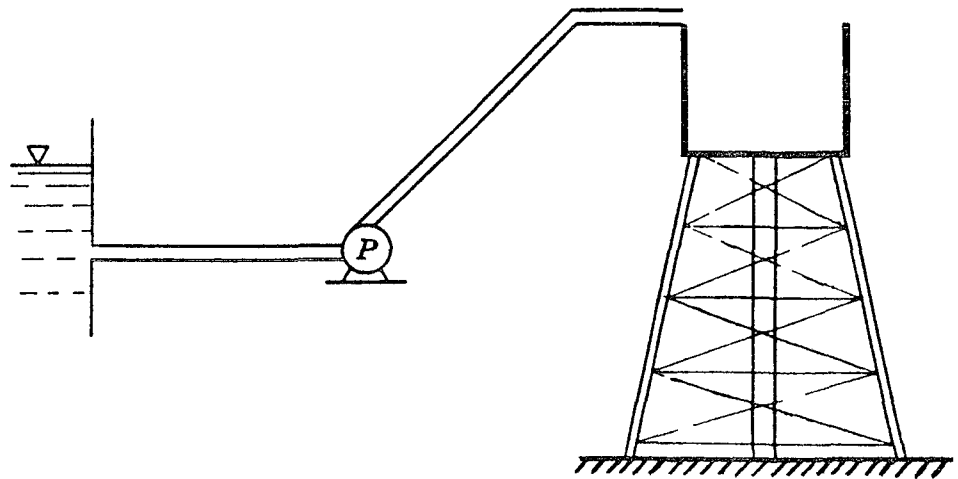


Figure 1

**QUESTION #2**

Water is transported at a rate of  $0.25 \text{ m}^3/\text{s}$  by means of a  $0.4 \text{ m}$  diameter centrifugal pump operating at  $750 \text{ rpm}$ . The diameters of the suction and discharge pipes of the pump are  $0.16 \text{ m}$  and  $0.14 \text{ m}$  respectively. The pump impeller blades are backward facing at  $60^\circ$  to the tangent and the outer width of the pump impeller is  $0.06 \text{ m}$ . The reading of a mercury water differential U tube manometer connected between the flanges of the suction and discharge pipes is  $1.23 \text{ m}$  of mercury ( $S = 13.6$ ). Given that there is no pre rotation of the water entering the pump impeller and that the volumetric and mechanical efficiencies of the pump are  $98\%$  and  $94\%$  respectively determine (i) the pump head (ii) the hydraulic efficiency of the pump and (iii) the power that must be supplied to the pump.

**QUESTION #3**

A Pelton wheel impulse turbine with a wheel diameter ( $D_w$ ) of  $0.75 \text{ m}$ , a nozzle diameter ( $D_N$ ) of  $77 \text{ mm}$ , a speed factor ( $\phi$ ) of  $0.465$  and a bucket angle ( $\beta_2$ ) of  $172^\circ$  operates at a speed of  $400 \text{ rpm}$ . The overall efficiency of the turbine is  $85\%$ . The diameter of the penstock ( $D_P$ ) supplying water to the nozzle is  $0.2 \text{ m}$  and the pressure in the penstock at the base of the nozzle is  $559 \text{ kPa}$ . Determine (i) the flow rate in the penstock (ii) the brake power produced by the turbine and (iii) the power associated with the water leaving the wheel buckets based on the assumption that bucket (friction) losses are negligible.

**QUESTION #4**

A pump operating at a speed of  $2800 \text{ rpm}$  is used to transport water from a reservoir at a flow rate of  $55 \text{ litres per second}$ . The corresponding dimensionless suction specific speed in radians is  $4.1$ . The height of the pump above the surface of the water in the reservoir is  $0.62 \text{ m}$ . The suction pipe of the pump has a diameter of  $0.18 \text{ m}$  and an absolute roughness of  $0.036 \text{ mm}$ . The minor head loss between the reservoir and the pump is due to a filter at the pipe inlet and the associated minor head loss coefficient is  $1.3$ . The temperature of the water in the reservoir is  $15^\circ \text{C}$  and the barometric pressure is  $100 \text{ kPa}$ . Determine (i) the required net positive suction head (NPSH) of the pump under operating conditions and (ii) the maximum permissible length of the suction pipe for cavitationless pump performance.

**QUESTION #5**

Under best efficiency point (BEP) operating conditions the speed of a Francis reaction turbine is  $1200 \text{ rpm}$  and the net turbine head is  $26 \text{ m}$  of water. At the inlet of the turbine runner the runner width is  $30\%$  of the runner diameter. The inlet guide vane angle is  $25^\circ$  and the inlet runner vane angle is  $110^\circ$ . The hydraulic and overall efficiencies of the turbine are respectively  $90\%$  and  $85\%$ . Neglecting the thickness of the runner vanes determine (i) the diameter of the turbine runner and (ii) the brake power produced by the turbine.

**QUESTION #6**

Water ( $\nu = 10^{-6} \text{ m}^2/\text{s}$ ) is to be pumped through a pipeline from one reservoir with a water surface elevation of 3.5 m to another reservoir with a water surface elevation of 28.3 m by means of a number of identical pumps. The length, diameter, and absolute roughness of the pipeline are respectively 300 m, 0.3 m, and 0.24 mm, and the sum of the minor head loss coefficients is 5.2. The head discharge characteristics of each pump are given by

$$H_p = 14.7 + 35.2Q - 281.6Q^2$$

where  $H_p$  is pump head in metres and  $Q$  is pump discharge in cubic metres per second. Determine (i) the minimum number of pumps that must be used and (ii) the total brake power that must be supplied to these pumps given that the overall efficiency of each pump under operating conditions is 0.78.

**QUESTION #7**

Air is compressed at a rate of 1.950 kilograms per hour by means of an adiabatic centrifugal compressor operating at 7000 rpm under BEP conditions. The overall and mechanical efficiencies of the compressor are respectively 78% and 93%. The absolute pressure and temperature of the air at the inlet of the compressor casing are respectively 101 kPa and 15°C. The inlet and outlet areas of the casing are respectively 17600 mm<sup>2</sup> and 9300 mm<sup>2</sup>. At the outlet of the compressor impeller, the diameter and width are respectively 310 mm and 195 mm. The absolute pressure of the air at the outlet of the casing is 112.4 kPa. Determine (i) the brake power supplied to the compressor and (ii) the outlet impeller vane angle.

Note: For air,  $R = 287 \text{ J/kg}\cdot\text{K}$ ,  $k = 1.4$ ,  $c_p = 1.004 \text{ J/kg}\cdot\text{K}$ .

