VIT
Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

**SLOT: E1+TE1**

**SCHOOL OF MECHANICAL ENGINEERING**

**CONTINUOUS ASSESSMENT TEST – II**

**WINTER SEMESTER 2023-2024**

**Programme Name & Branch: BMA, BME, BMM**

**Course Code: BMEE204L**

**Course Name: Fluid Mechanics and Machines**

**Faculty Name(s):** Dr. Thundil Karuppa Raj R; Dr. Rajesh Kanna P; Dr. Edison gundabattini; Dr. Mohamed Ibrahim M; Dr. Aruna Kumar Behura; Dr. Sreeja Sadasivam, Dr. Sreethul Das; Dr. Abinash Mohanta; Dr. Deepakkumar R

**Emp.ID(s):**

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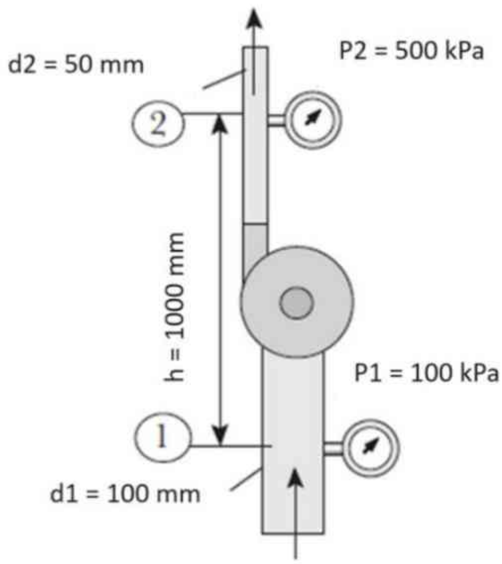
**Class Number(s):**

**Exam Duration: 90 minutes** **Maximum Marks: 50**

**General instruction(s):**

| **Q.No** | **Question** | Marks | Course Outcome (CO) | Bloom's Taxonomy (BL) |
|---|---|---|---|---|
| 1. | A pump in a supply line increases the pressure of water from 100 kPa to 500 kPa, as shown in Fig.1. The discharge through the pump is 1000 L/min. Calculate the power delivered to water by the pump. Neglect the losses due to friction. | 10 | CO3 | BL3 |




**Sol:**

Applying energy balance between sections 1 and 2,

$$\frac{p_1}{\rho}+\frac{V_1^2}{2}+gz_1+w=\frac{p_2}{\rho}+\frac{V_2^2}{2}+gz_2$$

From continuity equation,

$$Q=A_1V_1=A_2V_2$$

The velocities at sections 1 and 2,

$$V_1=\frac{Q}{A_1}=\frac{4Q}{\pi d_1^2}$$

Q = 1000 lit/min = 1000 * $10^{-3}$/60 $m^3/s$ = 0.0166 $m^3/s$

$V_1$ = (0.0166 * 4)/ (3.14*0.1*0.1)

$V_1$ = 2.114 m/s

$$V_2=\frac{Q}{A_2}=\frac{4Q}{\pi d_2^2}$$

$V_2$ = (0.0166 * 4) / (3.14 * 0.05 * 0.05) m/s

$V_2$ = 8.458 m/s

Rewriting Eq. (1) to find out the pump work

$$w=\frac{p_2-p_1}{\rho}+\frac{V_2^2-V_1^2}{2}+gh$$

W = ((500-100)/1000) +(($8.458^2$-$2.114^2$)/2) + (9.81*1) J/kg

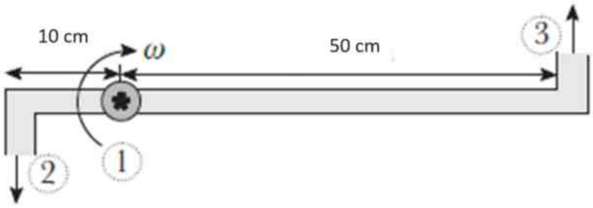
W = 443.34 J/kg

The power delivered to the water

$$P=\rho Q w$$

P=1000*0.0166*443.34

P= 7.359 kW

| | | | | |
|---|---|---|---|---|
| 2. | A lawn sprinkler with unequal arms, shown in Fig. 2, discharges water at 2 L/s through its each opening of area 2 $cm^2$. Determine (a) the rotational speed of the sprinkler in absence of restraining torque (b) the restraining torque required to keep it stationary.<br><br><br>**Fig. 2.**<br>Sol:<br>Water jet velocity at both nozzle 2 and 3<br>$v = Q/A = 2*10^{-3}/2*10^{-4} = 10 m/s$<br>$T = \rho Q v_2 r_2 + \rho Q v_3 r_3$<br>*Here,*<br>$v_2 = v - \omega r_2$<br>$v_3 = v - \omega r_3$<br>(a) In absence of restraining torque setting T = 0 in this equation, the rotational speed of the sprinkler is given as<br>$T = \rho Q[(v - \omega r_2) r_2 + (v - \omega r_3) r_3]$<br>$\omega = v (r_2 + r_3) / (r_2^2 + r_3^2)$<br>$\omega = 10*(0.1+0.5) / ((0.1*0.1) +(0.5*0.5))$<br>$\omega = 23.07$ rad/s or N = 220.3 rpm<br><br>(b) The restraining torque required to keep the sprinkler stationary, that is, $\omega = 0$<br>$T = \rho Q v(r_2+r_3)$<br>$T = 1000*2*10^{-3}*10*(0.1+0.5)$<br>T = 12Nm | 10 | CO3 | BL3 |
| 3. | A pump takes in water from a level 5 m below its centre line and delivers it at a height of 30 m above the centre line, the rate of flow being 3 $m^3$/hr. The diameter of the pipe line all through is 50 mm (ID). The fittings introduce losses equal to 10 m length of pipe in addition to the actual length of 45 m of pipe used. Determine the head to be developed by the pump.<br>Sol:<br>The head to be developed will equal the static head, friction head and the dynamic head.<br>Static head = 30 + 5 = 35 m,<br>Friction head = $f L u_m^2/2g D$,<br>Here, L = 45 + 10 = 55 m, D = 0.05 m,<br>$u_m = (3/3600) *4 / (\pi \times 0.05^2) = 0.4244$ m/s. | 10 | CO4 | BL3 |

| | | | | |
|---|---|---|---|---|
| | Assuming the temperature as 20 °C,<br>$\nu = 1.006 \times 10^{-6}$ m$^2$ / s.<br>Re = $u_m$ D/ $\nu$ = 0.05 × 0.4244/1.006 × $10^{-6}$<br>Re = 21093<br>The flow is turbulent<br>Assuming smooth pipe<br>f = 0.316/Re$^{0.25}$<br>= 0.02622<br>Frictional loss of head<br>= 0.02622 × 55 × 0.4244$^2$/(2 × 9.81 × 0.05)<br>= 0.265 m<br><br>Dynamic head<br>= $u_m^2/2g$<br>= 0 4244$^2$/ (9.81*2)<br>= 0.0092 m<br>Total head = 35 + 0.265 + 0.0092 = 35.2562 m.<br>Head to be developed by the pump = 35.2562 m head of water. | | | |
| 4. | Water flows in an experimental 50 mm square pipe at a temperature of 10°C. The flow velocity is 0.012 m/s. Determine the head drop over a length of 10 m. Compare the same with circular section of the same area, $v = 1.4 \times 10^{-6}$ m$^2$/s.<br><br>Sol:<br>As the **section is square**, the hydraulic diameter is to be used.<br>$D_h$ = 4 area/perimeter = 4a$^2$/4a = a = 0.05 m<br>Re = $D_h u/v$ = 0.05 × 0.012/1.4 × $10^{-6}$ = 428.6<br>The flow is laminar<br>$f$ = 64/Re = 64/428.6<br>$h_f = fLu^2/2g D_h$ = (64/428.6) × 10 × 0.012$^2$/(2 × 9.81 × 0.05)<br>**= 2.19 × $10^{-4}$ m head of water.**<br>**Circular section:** $\pi D^2/4 = \pi 0.05^2/4$<br>$D$ = 0.05642 m<br>Re = 0.05642 × 0.012/1.4 × $10^{-6}$ = 483.6, laminar<br>$f$ = 64/483.6 = 0.1323<br>**$h_f$** = 0.1323 × 10 × 0.012$^2$/2 × 9.81 × 0.05642<br>= **1.722 × $10^{-4}$ m**<br><br>Lower by: 21.4% | 10 | CO4 | BL3 |
| 5. | The drag force on a smooth sphere is found to be affected by the velocity of flow, u, the dimaeter D of the sphere and the fluid properties density ρ and viscosity μ. Using dimensional analysis obtain the dimensionless groups to correlate the parameters.<br><br>Sol: | 10 | CO5 | BL3 |

The dimensions of the influencing variables are listed below, using M, L, T set.

| S.No. | Variables | Unit | Dimensions |
|---|---|---|---|
| 1 | Drag force, $F$ | $N$, (kgm/s$^2$) | $ML/T^2$ |
| 2 | Diameter, $D$ | m | $L$ |
| 3 | Velocity, $u$ | m/s | $L/T$ |
| 4 | Density, $\rho$ | kg/m$^3$ | $M/L^3$ |
| 5 | Viscosity, $\mu$ | kg/ms | $M/LT$ |

**There are five variables and three dimensions. So two $\pi$ terms can be obtained.** Choosing $D$, $u$ and $\rho$ as repeating variables,

Let $\pi_1 = F D^a u^b \rho^c$, or $M^0L^0T^0 = \frac{ML}{T^2} L^a \frac{L^b}{T^b} \frac{M^c}{L^{3c}}$

Comparing the values of indices for $M$, $L$ and $T$

$$1 + c = 1, \quad \therefore \quad c = -1, 1 + a + b - 3c = 0, -2 - b = 0$$

$\therefore$ $b = -2, a = -2$

Substituting the values of $a$, $b$, $c$

$\therefore$ $\boldsymbol{\pi_1 = F/\rho u^2 D^2}$

Let $\pi_2 = \mu D^a u^b \rho^c$ or $M^0L^0T^0 = \frac{M}{LT} L^a \frac{L^b}{T^b} \frac{M^c}{L^{3c}}$

Comparing the values of indices of $M$, $L$ and $T$

$\therefore$ $1 + c = 0, -1 + a + b - 3c = 0, -1 - b = 0 \quad \therefore \quad c = -1, b = -1, a = -1$

Susbtituting the values of $a$, $b$, $c$.

$\therefore$ $\boldsymbol{\pi_2 = \mu/\rho u D}$ **or** $\boldsymbol{\rho u D/\mu}$

$\therefore$ $\frac{F}{\rho u^2 D^2} = f\left[\frac{\rho u D}{\mu}\right]$; Check for dimensions of $\pi_1$ and $\pi_2$.

$$\pi_1 = \frac{ML}{T^2} \frac{L^3}{M} \frac{T^2}{L^2} \frac{1}{L^2} = M^0L^0T^0 \quad \text{or} \quad \pi_2 = \frac{M}{L^3} \frac{L}{T} L \frac{LT}{M} = M^0L^0T^0$$

**Note:** the significance of the $\pi$ term. $F/\rho u^2D^2 \rightarrow F/\rho u\, Du \rightarrow F/mu \rightarrow$ Drag force/inertia force.