UNIVERSITY OF JOHANNESBURG

PROGRAM	: BENGTECH ENGINEERING: MECHANICAL
SUBJECT	: FLUID MECHANICS II
CODE	: FLMMIA2
DATE	: JUNE MAIN EXAMINATION 25 May 2019
DURATION	: (SESSION 1) 08:30 – 11:30 AM
WEIGHT	: 60% OF FINAL MARK
TOTAL MARKS	: 100 MARKS

Examiner	: MR VT. HASHE
Moderator	: MR S. SIMELANE

INSTRUCTIONS:

1. PLEASE ANSWER ALL QUESTIONS NEATLY
2. SHOW ALL CALCULATIONS
3. ANSWERS WITHOUT UNITS WILL BE PENALIZED
4. NUMBER YOUR ANSWERS STRICTLY ACCORDING TO THE QUESTIONS
5. **DRAW DIADRAMS**

NUMBER OF PAGES : 9 including cover page and 3 pages annexure

QUESTION 1

1.1 A thin 30 x 30 cm flat plate is pulled at 3 m/s horizontally through a 3.6 mm SAE 30 engine oil layer sandwiched between two plates, one stationary and the other moving at a constant velocity of 0.3 m/s. The dynamic viscosity of the oil is 0.027 Pa.s. Assuming the velocity in each oil layer to vary linearly (and indicating any two further assumptions used in arriving to the solution).

(*a*) Plot a detailed velocity profile and locate where the oil velocity is zero and (8)

(*b*) Investigate if a force of 7.29 N will be sufficient to maintain the motion. (10)

1.2 The magnitude of the capillary rise in a circular tube can be determined from a force balance on the cylindrical liquid column of height *h* in the tube. With the use of a figure, prove that the capillary rise and depression are given by:

$$h = \frac{2\sigma}{\rho g R}\, Cos\ \phi$$

Use two separate schematic diagrams for both the rise and depression phenomena.

(15)

1.3 A pump is used to transport water at 20°C to a higher reservoir. If cavitation is to be avoided, what is the minimum pressure that must exist in the pump to avoid cavitation? (2)

[35]

QUESTION 2

Figure 2 shows a differential manometer of U-tube type. Evaluate (showing all steps of your calculations) if the differential pressure is given by the expression:

$$P_A - P_B = gh(\rho_G - \rho_1) + \rho_2 gy - \rho_1 gx$$

Where ρ_G , ρ_1 and ρ_2 are the density of heavy liquid, density of liquid at A and density of liquid at B respectively. (7)

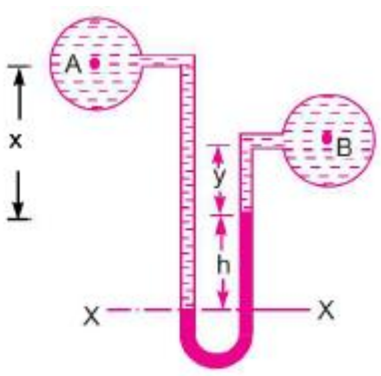

Figure 2

[7]

QUESTION 3

A vertical sluice gate is used to cover an opening and closing of the Vaal dam. The opening is 2 m wide and 1.2 m high as shown in Figure 3. On the upstream of the gate, the liquid of specific gravity 1.45 lies up to a height of 1.5 m above the top of the gate, whereas on the downstream side the water is available up to a height touching the top of the gate.

a) Find the magnitude (Newtons) and the position (metres) of the resultant force (28)

b) Prove (using calculations) that a horizontal force of 9.597 kN acting at the top of the gate is capable of opening the gate. (4)

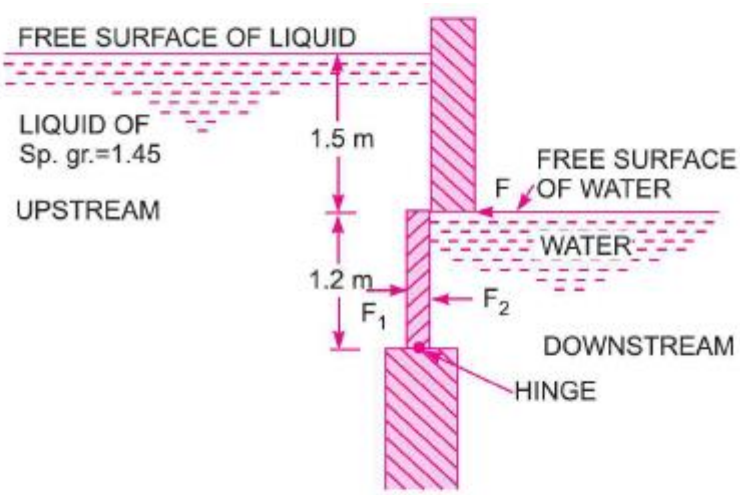

Figure 3

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QUESTION 4

Develop an expression necessary to calculate the coefficient of discharge of a venturimeter shown in figure 4.

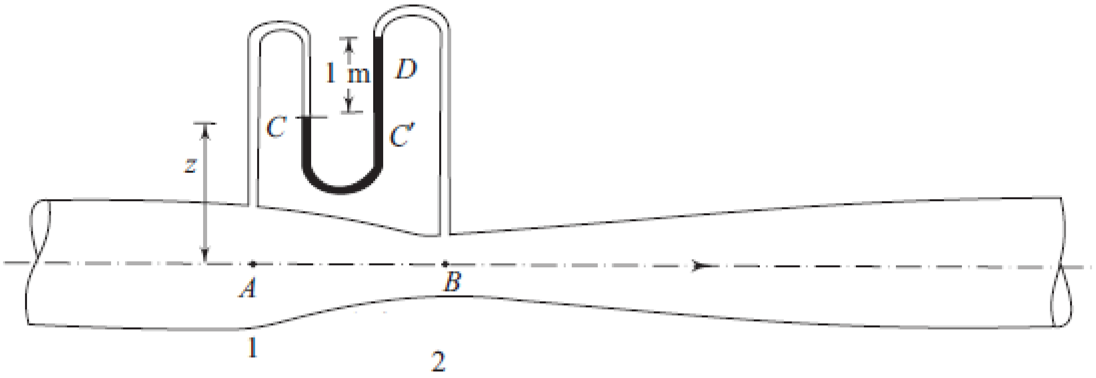
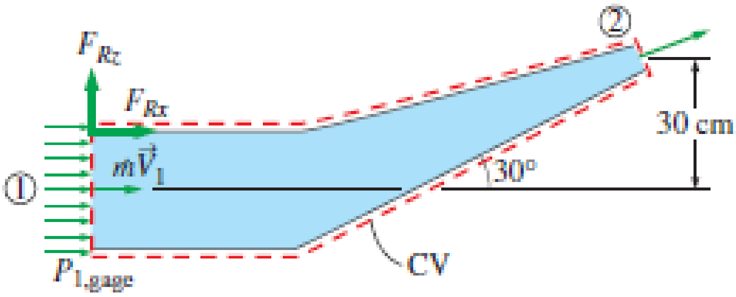


Figure 1

[10]

QUESTION 5

A reducing elbow in Figure 5 is used to deflect water flow from a fire engine truck to a burning building. Water is allowed to flow through the elbow at a rate of 14 kg/s in a horizontal pipe upward 30° while accelerating. The elbow discharges water into the atmosphere. The cross sectional area of the elbow is 113 cm^2 at the inlet and 7 cm^2 at the outlet. The elevation difference between the centres of the outlet and the inlet is 30 cm. Verify if an anchoring force of 144 N will be sufficient to hold the elbow in place.



[16]

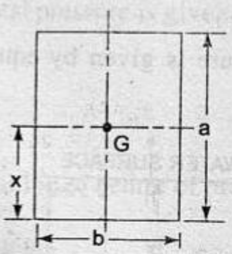
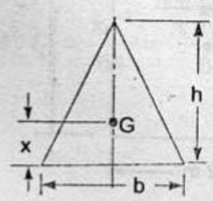
Properties of saturated water

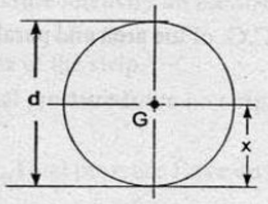
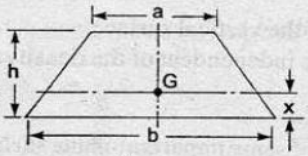
Temp. T, °C	Saturation Pressure P_{sat}, kPa	Density ρ, kg/m³ Liquid	Density ρ, kg/m³ Vapor	Enthalpy of Vaporization h_{fg}, kJ/kg	Specific Heat c_p, J/kg·K Liquid	Specific Heat c_p, J/kg·K Vapor	Thermal Conductivity k, W/m·K Liquid	Thermal Conductivity k, W/m·K Vapor	Dynamic Viscosity μ, kg/m·s Liquid	Dynamic Viscosity μ, kg/m·s Vapor	Prandtl Number Pr Liquid	Prandtl Number Pr Vapor	Volume Expansion Coefficient β, 1/K Liquid	Surface Tension, N/m Liquid
0.01	0.6113	999.8	0.0048	2501	4217	1854	0.561	0.0171	1.792×10^{-3}	0.922×10^{-5}	13.5	1.00	-0.068×10^{-3}	0.0756
5	0.8721	999.9	0.0068	2490	4205	1857	0.571	0.0173	1.519×10^{-3}	0.934×10^{-5}	11.2	1.00	0.015×10^{-3}	0.0749
10	1.2276	999.7	0.0094	2478	4194	1862	0.580	0.0176	1.307×10^{-3}	0.946×10^{-5}	9.45	1.00	0.733×10^{-3}	0.0742
15	1.7051	999.1	0.0128	2466	4186	1863	0.589	0.0179	1.138×10^{-3}	0.959×10^{-5}	8.09	1.00	0.138×10^{-3}	0.0735
20	2.339	998.0	0.0173	2454	4182	1867	0.598	0.0182	1.002×10^{-3}	0.973×10^{-5}	7.01	1.00	0.195×10^{-3}	0.0727
25	3.169	997.0	0.0231	2442	4180	1870	0.607	0.0186	0.891×10^{-3}	0.987×10^{-5}	6.14	1.00	0.247×10^{-3}	0.0720
30	4.246	996.0	0.0304	2431	4178	1875	0.615	0.0189	0.798×10^{-3}	1.001×10^{-5}	5.42	1.00	0.294×10^{-3}	0.0712
35	5.628	994.0	0.0397	2419	4178	1880	0.623	0.0192	0.720×10^{-3}	1.016×10^{-5}	4.83	1.00	0.337×10^{-3}	0.0704
40	7.384	992.1	0.0512	2407	4179	1885	0.631	0.0196	0.653×10^{-3}	1.031×10^{-5}	4.32	1.00	0.377×10^{-3}	0.0696
45	9.593	990.1	0.0655	2395	4180	1892	0.637	0.0200	0.596×10^{-3}	1.046×10^{-5}	3.91	1.00	0.415×10^{-3}	0.0688
50	12.35	988.1	0.0831	2383	4181	1900	0.644	0.0204	0.547×10^{-3}	1.062×10^{-5}	3.55	1.00	0.451×10^{-3}	0.0679
55	15.76	985.2	0.1045	2371	4183	1908	0.649	0.0208	0.504×10^{-3}	1.077×10^{-5}	3.25	1.00	0.484×10^{-3}	0.0671
60	19.94	983.3	0.1304	2359	4185	1916	0.654	0.0212	0.467×10^{-3}	1.093×10^{-5}	2.99	1.00	0.517×10^{-3}	0.0662
65	25.03	980.4	0.1614	2346	4187	1926	0.659	0.0216	0.433×10^{-3}	1.110×10^{-5}	2.75	1.00	0.548×10^{-3}	0.0654
70	31.19	977.5	0.1983	2334	4190	1936	0.663	0.0221	0.404×10^{-3}	1.126×10^{-5}	2.55	1.00	0.578×10^{-3}	0.0645
75	38.58	974.7	0.2421	2321	4193	1948	0.667	0.0225	0.378×10^{-3}	1.142×10^{-5}	2.38	1.00	0.607×10^{-3}	0.0636
80	47.39	971.8	0.2935	2309	4197	1962	0.670	0.0230	0.355×10^{-3}	1.159×10^{-5}	2.22	1.00	0.653×10^{-3}	0.0627
85	57.83	968.1	0.3536	2296	4201	1977	0.673	0.0235	0.333×10^{-3}	1.176×10^{-5}	2.08	1.00	0.670×10^{-3}	0.0617
90	70.14	965.3	0.4235	2283	4206	1993	0.675	0.0240	0.315×10^{-3}	1.193×10^{-5}	1.96	1.00	0.702×10^{-3}	0.0608
95	84.55	961.5	0.5045	2270	4212	2010	0.677	0.0246	0.297×10^{-3}	1.210×10^{-5}	1.85	1.00	0.716×10^{-3}	0.0599
100	101.33	957.9	0.5978	2257	4217	2029	0.679	0.0251	0.282×10^{-3}	1.227×10^{-5}	1.75	1.00	0.750×10^{-3}	0.0589
110	143.27	950.6	0.8263	2230	4229	2071	0.682	0.0262	0.255×10^{-3}	1.261×10^{-5}	1.58	1.00	0.798×10^{-3}	0.0570
120	198.53	943.4	1.121	2203	4244	2120	0.683	0.0275	0.232×10^{-3}	1.296×10^{-5}	1.44	1.00	0.858×10^{-3}	0.0550
130	270.1	934.6	1.496	2174	4263	2177	0.684	0.0288	0.213×10^{-3}	1.330×10^{-5}	1.33	1.01	0.913×10^{-3}	0.0529
140	361.3	921.7	1.965	2145	4286	2244	0.683	0.0301	0.197×10^{-3}	1.365×10^{-5}	1.24	1.02	0.970×10^{-3}	0.0509
150	475.8	916.6	2.546	2114	4311	2314	0.682	0.0316	0.183×10^{-3}	1.399×10^{-5}	1.16	1.02	1.025×10^{-3}	0.0487
160	617.8	907.4	3.256	2083	4340	2420	0.680	0.0331	0.170×10^{-3}	1.434×10^{-5}	1.09	1.05	1.145×10^{-3}	0.0466
170	791.7	897.7	4.119	2050	4370	2490	0.677	0.0347	0.160×10^{-3}	1.468×10^{-5}	1.03	1.05	1.178×10^{-3}	0.0444
180	1,002.1	887.3	5.153	2015	4410	2590	0.673	0.0364	0.150×10^{-3}	1.502×10^{-5}	0.983	1.07	1.210×10^{-3}	0.0422
190	1,254.4	876.4	6.388	1979	4460	2710	0.669	0.0382	0.142×10^{-3}	1.537×10^{-5}	0.947	1.09	1.280×10^{-3}	0.0399
200	1,553.8	864.3	7.852	1941	4500	2840	0.663	0.0401	0.134×10^{-3}	1.571×10^{-5}	0.910	1.11	1.350×10^{-3}	0.0377
220	2,318	840.3	11.60	1859	4610	3110	0.650	0.0442	0.122×10^{-3}	1.641×10^{-5}	0.865	1.15	1.520×10^{-3}	0.0331
240	3,344	813.7	16.73	1767	4760	3520	0.632	0.0487	0.111×10^{-3}	1.712×10^{-5}	0.836	1.24	1.720×10^{-3}	0.0284
260	4,688	783.7	23.69	1663	4970	4070	0.609	0.0540	0.102×10^{-3}	1.788×10^{-5}	0.832	1.35	2.000×10^{-3}	0.0237
280	6,412	750.8	33.15	1544	5280	4835	0.581	0.0605	0.094×10^{-3}	1.870×10^{-5}	0.854	1.49	2.380×10^{-3}	0.0190
300	8,581	713.8	46.15	1405	5750	5980	0.548	0.0695	0.086×10^{-3}	1.965×10^{-5}	0.902	1.69	2.950×10^{-3}	0.0144
320	11,274	667.1	64.57	1239	6540	7900	0.509	0.0836	0.078×10^{-3}	2.084×10^{-5}	1.00	1.97		0.0099
340	14,586	610.5	92.62	1028	8240	11,870	0.469	0.110	0.070×10^{-3}	2.255×10^{-5}	1.23	2.43		0.0056
360	18,651	528.3	144.0	720	14,690	25,800	0.427	0.178	0.060×10^{-3}	2.571×10^{-5}	2.06	3.73		0.0019
374.14	22,090	317.0	317.0	0	—	—	—	—	0.043×10^{-3}	4.313×10^{-5}				0

PHYSICAL PROPERTIES OF COMMON LIQUIDS AT 20°C AND 1 ATMOSPHERE

Liquid	Density ρ [$kg.m^{-3}$]	Dynamic viscosity μ [$kg.m^{-1}s^{-1}$]	Surface tension σ [$N.m^{-1}$]	Bulk modulus K [$GN.m^{-2}$]
Alcohol, ethyl	789	1.197×10^{-3}	0.0223	1.32
Benzene	879	0.647×10^{-3}	0.0289	1.1
Carbon tetrachloride	1632	0.972×10^{-3}	0.0268	1.12
Glycerol	1262	620×10^{-3}	0.063	4.03
Mercury	13546	1.552×10^{-3}	0.472	26.2
Paraffin oil	800	1.900×10^{-3}	0.026	1.62
Water, sea	1025	1.120×10^{-3}	Assume same as for tap water	

Table 3.1 The moments of inertia and other geometric properties of some important plane surfaces

Plane surface	*C.G. from the base*	*Area*	*Moment of inertia about an axis passing through C.G. and parallel to base* (I_G)	*Moment of inertia about base* (I_0)
1. Rectangle 	$x = \frac{d}{2}$	bd	$\frac{bd^3}{12}$	$\frac{bd^3}{3}$
2. Triangle 	$x = \frac{h}{3}$	$\frac{bh}{2}$	$\frac{bh^3}{36}$	$\frac{bh^3}{12}$

Plane surface	*C.G. from the base*	*Area*	*Moment of inertia about an axis passing through C.G. and parallel to base (I_G)*	*Moment of inertia about base (I_0)*
3. Circle 	$x = \frac{d}{2}$	$\frac{\pi d^2}{4}$	$\frac{\pi d^4}{64}$	—
4. Trapezium 	$x = \left(\frac{2a+b}{a+b}\right)\frac{h}{3}$	$\frac{(a+b)}{2} \times h$	$\left(\frac{a^2+4ab+b^2}{36(a+b)}\right) \times h^3$	—

FORMULAS

$P = F/A$

$\tau = \mu\, du/dy$

$h = 4\delta \cos\phi / \rho g d$

$h = 4\delta / \rho g d$

$p = \rho g h$

$F = \rho g A \bar{h}$

$\hat{h} = (I_G \sin^2\phi / A\bar{h}) + \bar{h}$

$\hat{h} = (I_G / A\bar{h}) + \bar{h}$

$P/\rho + v^2/2g + z = c$

$\dot{m} = \rho A v$