L-3/T-1/ME **Date : 29/10/2019**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2018-2019

Sub : **ME 305** (Heat Transfer)

Full Marks : 210 Time : 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this section. Answer any **THREE**.

Symbols used to have their usual meaning.

1. (a) What are the Prandtl's boundary layer approximations? Using these approximations, obtain Prandtl boundary layer equations for forced convection heat transfer. **(10)**

(b) How are the hydrodynamic and the thermal entry lengths defined for flow in a heated tube? What will be those energy lengths for both laminar and turbulent flow through a tube? **(10)**

(c) Air at 10°C and 1 atm pressure is flowing over a flat plate at a velocity of 3 m/s. If the plate is 30 cm wide and 50 cm long, and at a temperature of 10°C, calculate the ratio of hydrodynamic boundary layer thickness at a distance of 30 cm from the leading edge of the plate to the critical length of the plate. **(15)**

2. (a) Consider a rectangular fin that is used to cool a motorcycle engine. The fin is 0.15 m long and at a temperature of 250°C, while the motorcycle is moving at 80 km/h in air at 27°C. The air is in parallel flow over both surfaces of the fin, and turbulent flow conditions may be assumed to exist throughout. What is the rate of heat removal per unit width of the fin? **(15)**

(b) Air at 300 K and 1 atm enters a smooth tube having a diameter of 2 cm and length of 10 cm. The air velocity is 40 m/s. What constant heat flux must be applied at the tube surface to result in an air temperature rise of 5°C? Determine convection heat transfer coefficient for this case. **(20)**

3. (a) Explain the cases of stable and unstable fluid circulation during the presence of (positive/negative) temperature gradient across a fluid layer between hot and cold surfaces. **(13)**

(b) Show the effect of Prandtl number on hydrodynamic and thermal boundary layer thickness during natural convection over a vertical isothermal flat plate. **(7)**

(c) Consider a 15-cm × 20-cm printed circuit/ board (PCB) that has electronic components on one side. The board is placed in a moon at 20°C. The heat loss from the back surface of the board is negligible. If the circuit board is dissipating 8 W of power in steady operations, determine the average temperature of the hot surface of the board, assuming the board is horizontal with hot surface facing up. Take the emissivity of the surface of the board to be 0.8 and assume the surrounding surfaces to be at the same temperature as the air in the room. **(15)**

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4. (a) Ethyl-alcohol (S_c = 10^3) spilled out from a flask on a smooth surface of a laboratory table. A fan is used to evaporate that chemical from the table surface. If the fan creates a uniform air flow at a speed of u_∞ over the surface, and the concentration of ethyl-alcohol at the table is C_s and in the air is C_∞ draw and table the boundary layers developed over the table surface for C_sC_∞ and show the corresponding boundary layer thickness for each boundary layer. **(10)**

(b) Define Nusselt and Sherwood numbers. Derive the relationship between convection heat and mass transfer coefficient during simultaneous heat and mass transfer using Chilton-Colburn analogy. **(10)**

(c) During a certain experiment involving the flow of dry air at 27°C and 1 atm over a body covered with a layer of naphthalene, it is observed that 12g of naphthalene has sublimated in 15 min. The surface area of the body is 0.3 m^2. Both the body and the air were kept at 27°C during the study. The vapor pressure of naphthalene at 27°C is 11 Pa. Determine the mass transfer coefficient under the same flow conditions over the same geometry. Given that molecular weights of dry air and naphthalene are 28.96 and 128.2 g/mol, respectively. **(15)**

SECTION – B

There are **FOUR** questions in this section. Answer any **THREE**.

5. (a) Considering a medium of constant thermo-physical properties, derive the general heat conduction equation for cylindrical co-operate system applying the principle of energy balance in a differential control volume. Hence obtain "Laplace Equation" with necessary assumptions. **(18)**

(b) Consider a homogeneous sphere of radioactive material of radius r_0 = 0.04 m, generating heat at a constant rate $\dot{e}_{gen} = 5\times10^7$ W/m^3 as shown in Fig. for Q.5(b). The heat generated is dissipated to the environment steadily. The outer surface of the sphere is maintained at a uniform temperature of 110°C and thermal conductivity of the sphere is k = 15 W/m.K. **(17)**

Assuming steady one-dimensional heat transfer, obtain a relation for the variation of temperature in the sphere and determine the temperature at the center of the sphere.

6. (a) A thin silicon chip and an 8-mm-thick aluminum substrate by a 0.02 mm thick epoxy joint. The chip and substrate are each 10 mm on a side, and their exposed surfaces are cooled by air, which is at a temperature of 25°C and provides a convection coefficient of 100 W/m^2K. If the chip dissipates 104 W/m^2 under normal conditions, will it operate below a maximum allowable temperature of 85°C? Consider the schematic of the system as delineated in the Fig. for Q. 6(a) and the attached table for the appropriate thermal resistance solid/solid interfaces. **(17)**

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(b) A thermocouple junction, which may be approximated as a sphere, is to be used for temperature measurement in a gas stream. The convection coefficient between the junction surface and the gas is h = 400 W/m^2.K, and the junction thermo-physical properties are k = 20 W/m.K, c_p = 400 J/kg.K and ρ = 8500 kg/m^3. Determine the junction diameter needed for the thermocouple to have a tie constant of 1 s. If the junction is at 25°C and is placed in a gas stream that is at 400°C, how long will it take for the junction to reach 390°C? **(18)**

7. (a) How can you differentiate among Black Body, Real Surface and Gray Surface? Show their characteristics in terms of variation of spectral emissivity and spectral emissive power with wavelength. **(15)**

(b) Define View factor used in radiation study. Determine the view factor F_{12} and F_{23} between rectangular surfaces a shown in Fig. for 7(b). **(10)**

(c) A thin aluminum sheet with an emissivity of 0.1 on both sides a placed between two very large parallel plates that are maintained at uniform temperature T_1 = 800 K and T_2 = 500 K and have emissivities ε_1 = 0.2 and ε_2 = 0.7, respectively, as shown in Fig. for Q. 7 (c). Determine the net rate of radiation heat transfer between the two plates per unit surface area of the plates and compare the result to that without the shield. **(10)**

8. (a) Differentiate pool boiling and flow boiling. **(5)**

(b)With neat sketch briefly describe the characteristic of flow boiling regimes in case of internal flow boiling inside a vertical tube. Also show the variation of heat transfer coefficient and quality along the tube length. **(10)**

(c) In case of condensation over a vertical plate, which mode of condensation (i.e. dropwise/filmwise) is more preferable and why? **(5)**

(d) The condenser of a steam power plant operates at a pressure of 7.38 kPa (Saturation Temp. 40°C). Steam at this pressure condenses on the outer surfaces of horizontal tubes through which cooling water circulates. The outer diameter of the pipes is 3 cm, and the outer surfaces of the tubes are maintained at 30°C. Assuming laminar film condensation case, determine:

(a) Rate of heat transfer to the cooling water circulating in the tubes and

(b) Rate of condensation of steam per unit length of a horizontal tube.

For laminar film condensation over horizontal tube, heat transfer coefficient "h" can be calculated as: **(15)**

$$h_{horiz} = 0.729\left[\frac{g\rho_l(\rho_l-\rho_v)h^*_{fg}k_l^3}{\mu_l(T_{sat}-T_s)D}\right]^{1/4} \qquad (\mathrm{W/m^2.K})$$

Symbols have their usual meaning. Use the enclosed tables for properties of water and water vapor.

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Table A-5 | Properties of air at atmospheric pressure.†

The values of μ, k, c_p, and Pr are not strongly pressure-dependent and may be used over a fairly wide range of pressures

T, K	ρ kg/m³	c_p kJ/kg · °C	$\mu \times 10^5$ kg/m · s	$\nu \times 10^6$ m²/s	k W/m · °C	$\alpha \times 10^4$ m²/s	Pr
100	3.6010	1.0266	0.6924	1.923	0.009246	0.02501	0.770
150	2.3675	1.0099	1.0283	4.343	0.013735	0.05745	0.753
200	1.7684	1.0061	1.3289	7.490	0.01809	0.10165	0.739
250	1.4128	1.0053	1.5990	11.31	0.02227	0.15675	0.722
300	1.1774	1.0057	1.8462	15.69	0.02624	0.22160	0.708
350	0.9980	1.0090	2.075	20.76	0.03003	0.2983	0.697
400	0.8826	1.0140	2.286	25.90	0.03365	0.3760	0.689
450	0.7833	1.0207	2.484	31.71	0.03707	0.4222	0.683
500	0.7048	1.0295	2.671	37.90	0.04038	0.5564	0.680
550	0.6423	1.0392	2.848	44.34	0.04360	0.6532	0.680
600	0.5879	1.0551	3.018	51.34	0.04659	0.7512	0.680
650	0.5430	1.0635	3.177	58.51	0.04953	0.8578	0.682
700	0.5030	1.0752	3.332	66.25	0.05230	0.9672	0.684
750	0.4709	1.0856	3.481	73.91	0.05509	1.0774	0.686
800	0.4405	1.0978	3.625	82.29	0.05779	1.1951	0.689
850	0.4149	1.1095	3.765	90.75	0.06028	1.3097	0.692
900	0.3925	1.1212	3.899	99.3	0.06279	1.4271	0.696
950	0.3716	1.1321	4.023	108.2	0.06525	1.5510	0.699
1000	0.3524	1.1417	4.152	117.8	0.06752	1.6779	0.702
1100	0.3204	1.160	4.44	138.6	0.0732	1.969	0.704
1200	0.2947	1.179	4.69	159.1	0.0782	2.251	0.707
1300	0.2707	1.197	4.93	182.1	0.0837	2.583	0.705
1400	0.2515	1.214	5.17	205.5	0.0891	2.920	0.705
1500	0.2355	1.230	5.40	229.1	0.0946	3.262	0.705
1600	0.2211	1.248	5.63	254.5	0.100	3.609	0.705
1700	0.2082	1.267	5.85	280.5	0.105	3.977	0.705
1800	0.1970	1.287	6.07	308.1	0.111	4.379	0.704
1900	0.1858	1.309	6.29	338.5	0.117	4.811	0.704
2000	0.1762	1.338	6.50	369.0	0.124	5.260	0.702
2100	0.1682	1.372	6.72	399.6	0.131	5.715	0.700
2200	0.1602	1.419	6.93	432.6	0.139	6.120	0.707
2300	0.1538	1.482	7.14	464.0	0.149	6.540	0.710
2400	0.1458	1.574	7.35	504.0	0.161	7.020	0.718
2500	0.1394	1.688	7.57	543.5	0.175	7.441	0.730

Summary of Correlation for Forced Convection Flow over Flat Plates
Properties evaluated at Film temperature

Type	Restrictions	Fluid Flow	Heat Transfer: Isothermal (T_w = constant)	Heat Transfer: Isoflux (q_w = constant)
Local	Laminar: $Re_x < 5 \times 10^5$; $0.6 < Pr < 50$	$C_{f,x} = 0.664 Re_x^{-1/2}$	$Nu_x = 0.332 Re_x^{1/2} Pr^{1/3}$	$Nu_x = 0.453 Re_x^{1/2} Pr^{1/3}$
Average	Laminar: $Re_L < 5 \times 10^5$; $0.6 < Pr < 50$	$C_f = 1.328 Re_L^{-1/2}$	$Nu_L = 0.664 Re_L^{1/2} Pr^{1/3}$	$Nu_L = 0.680 Re_L^{1/2} Pr^{1/3}$
Local	Turbulent: $5 \times 10^5 \le Re_x \le 10^7$; $0.6 \le Pr \le 60$	$C_{f,x} = 0.059 Re_x^{-1/5}$	$Nu_x = 0.0296 Re_x^{4/5} Pr^{1/3}$	$Nu_x = 0.0308 Re_x^{4/5} Pr^{1/3}$
Average	Turbulent: $5 \times 10^5 \le Re_L \le 10^7$; $0.6 \le Pr \le 60$	$C_f = 0.074 Re_L^{-1/5}$	$Nu_L = 0.037 Re_L^{4/5} Pr^{1/3}$	$Nu_L = 0.037 Re_L^{4/5} Pr^{1/3}$
Average	Partly Laminar, Partly Turbulent: $5 \times 10^5 \le Re_L \le 10^7$; $0.6 \le Pr \le 60$ $Re_{cr} = 5 \times 10^5$	$C_f = 0.074 Re_L^{-1/5} - 1742 Re_L$	$Nu_L = \left(0.037 Re_L^{4/5} - 871\right) Pr^{1/3}$	$Nu_L = \dfrac{0.037 Re_L^{4/5} Pr^{1/3}}{1 + 12.33 \times 10^6 Re_L^{-6/5}}$

Correlations for Fully Developed Turbulent Forced Convection Flow inside Circular Pipe
Properties evaluated at Mean Bulk Fluid temperature, $T_b = (T_i + T_e)/2$ otherwise mentioned

Equation	Restrictions
Colburn Equation	**Restrictions**
$Nu = 0.023\, Re_D^{0.8}\, Pr^{1/3}$	$0.7 < Pr < 160$; $Re_D > 10000$; $L/D > 60$; small to moderate temperature differences
Dittus-Boelter Equation	**Restrictions**
$Nu = 0.023\, Re_D^{0.8}\, Pr^n$	$n = 0.4$ ($T_w > T_b$); $n = 0.3$ ($T_w < T_b$); $0.6 < Pr < 160$; $6000 < Re_D < 10^7$; $L/D > 60$; For duct flow, D is replaced by D_h
Sieder and Tate Equation	**Restrictions**
$Nu = 0.027\, Re_D^{0.8}\, Pr^{1/3} \left(\dfrac{\mu_b}{\mu_w}\right)^{0.14}$	$0.7 < Pr < 10000$; $6000 < Re_D < 10^7$; $L/D > 60$; μ_w is evaluated at wall (surface) temperature; For duct flow, D is replaced by D_h

Figure 6-6 | Turbulent thermal entry Nusselt numbers for circular tubes with q_w = constant.

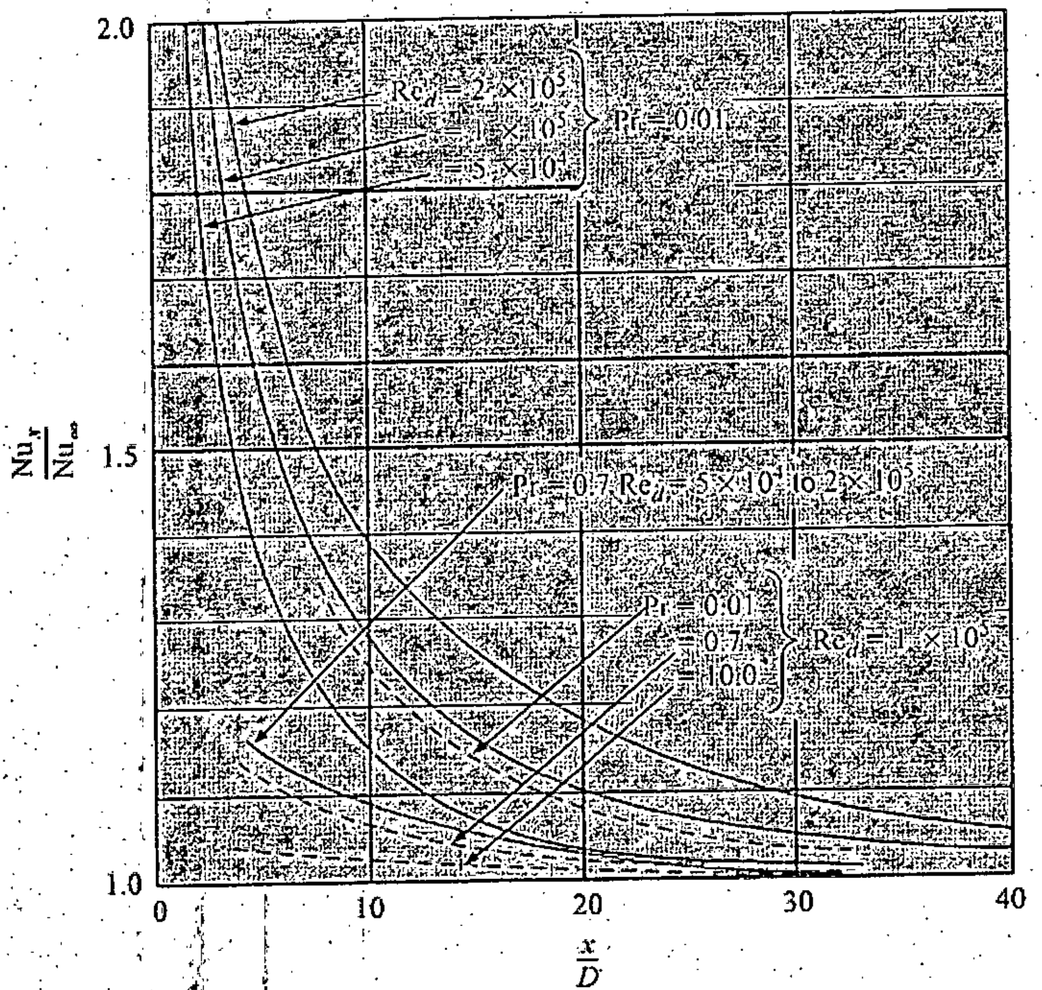

Table 1: Summary of Correlations for External Natural Convection on Horizontal Plate

Correlation(s)	Restrictions	Evaluation of Fluid Properties	Thermal condition
McAdams: $Nu_{L_c} = 0.54 Ra_{L_c}^{1/4}, L_c = \frac{A_s}{p}$	Upper surface hot or lower surface cool $10^5 \le Ra_{Lc} \le 10^7$	$T_f = (T_s + T_\infty)/2$, except for gases β at T_∞	Isothermal
McAdams: $Nu_{L_c} = 0.15 Ra_{L_c}^{1/3}, L_c = \frac{A_s}{p}$	Upper surface hot or lower surface cool $10^7 < Ra_{Lc} \le 10^{10}$		
McAdams: $Nu_{L_c} = 0.27 Ra_{L_c}^{1/4}, L_c = \frac{A_s}{p}$	Lower surface hot or Upper surface cool $10^5 \le Ra_{Lc} \le 10^{10}$		
$Nu_L = 0.13 Ra_L^{1/3}$	Upper surface hot $Ra_L < 2 \times 10^{10}$	$T_m = \overline{T}_s - 0.25(\overline{T}_s - T_\infty)$, β at $T_f = (\overline{T}_s + T_\infty)/2$	Isoflux
$Nu_L = 0.16 Ra_L^{1/3}$	Upper surface hot $2 \times 10^8 < Ra_L < 10^{11}$		
$Nu_L = 0.58 Ra_L^{1/5}$	Lower surface hot $10^6 < Ra_L < 10^{11}$		

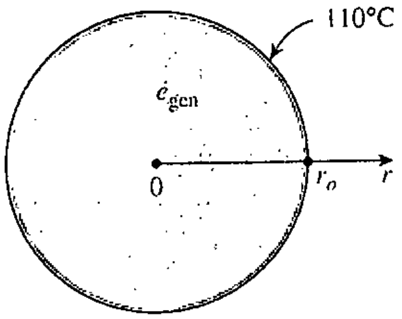

Figure for Q. 5 (b)

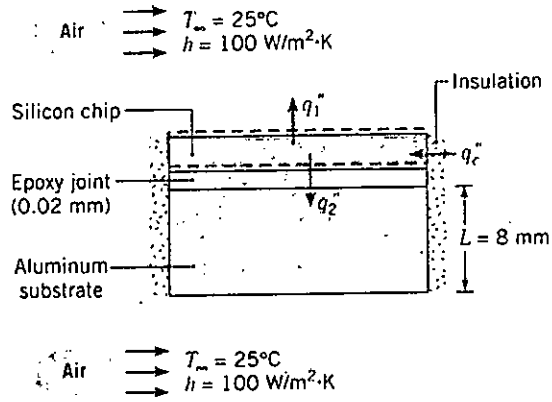

Figure for Q. 6 (a)

TABLE: Thermal resistance of representative solid/solid interfaces

Interface	$R''_{t,c} \times 10^4$ ($m^2 \cdot K/W$)
Silicon chip/lapped aluminum in air (27–500 kN/m²)	0.3–0.6
Aluminum/aluminum with indium foil filler (~100 kN/m²)	~0.07
Stainless/stainless with indium foil filler (~3500 kN/m²)	~0.04
Aluminum/aluminum with metallic (Pb) coating	0.01–0.1
Aluminum/aluminum with Dow Corning 340 grease (~100 kN/m²)	~0.07
Stainless/stainless with Dow Corning 340 grease (~3500 kN/m²)	~0.04
Silicon chip/aluminum with 0.02-mm epoxy	0.2–0.9
Brass/brass with 15-μm tin solder	0.025–0.14

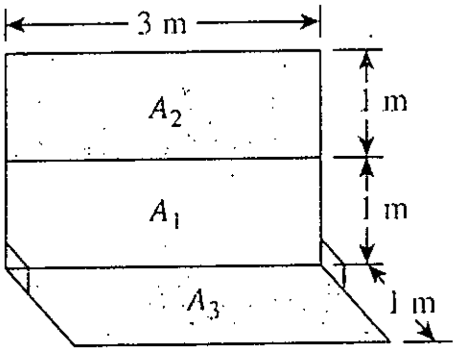

Figure for Q. 7 (b)

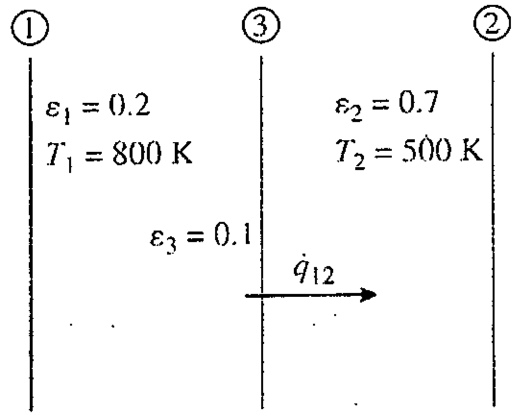

Figure for Q. 7 (c)

~~Table: Properties of Saturated Water~~

Table: Properties of Saturated Water

Temp. T, °C	Saturation Pressure P_{sat}, kPa	Density ρ, kg/m³ Liquid	Density Vapor	Enthalpy of Vaporization h_{fg}, kJ/kg	Specific Heat c_p, J/kg·K Liquid	Specific Heat Vapor	Thermal Conductivity k, W/m·K Liquid	Thermal Conductivity Vapor	Dynamic Viscosity μ, kg/m·s Liquid	Dynamic Viscosity Vapor
0.01	0.6113	999.8	0.0048	2501	4217	1854	0.561	0.0171	1.792×10^{-3}	0.922×10^{-5}
5	0.8721	999.9	0.0068	2490	4205	1857	0.571	0.0173	1.519×10^{-3}	0.934×10^{-5}
10	1.2276	999.7	0.0094	2478	4194	1862	0.580	0.0176	1.307×10^{-3}	0.946×10^{-5}
15	1.7051	999.1	0.0128	2466	4185	1863	0.589	0.0179	1.138×10^{-3}	0.959×10^{-5}
20	2.339	998.0	0.0173	2454	4182	1867	0.598	0.0182	1.002×10^{-3}	0.973×10^{-5}
25	3.169	997.0	0.0231	2442	4180	1870	0.607	0.0186	0.891×10^{-3}	0.987×10^{-5}
30	4.246	996.0	0.0304	2431	4178	1875	0.615	0.0189	0.798×10^{-3}	1.001×10^{-5}
35	5.628	994.0	0.0397	2419	4178	1880	0.623	0.0192	0.720×10^{-3}	1.016×10^{-5}
40	7.384	992.1	0.0512	2407	4179	1885	0.631	0.0196	0.653×10^{-3}	1.031×10^{-5}
45	9.593	990.1	0.0655	2395	4180	1892	0.637	0.0200	0.596×10^{-3}	1.046×10^{-5}
50	12.35	988.1	0.0831	2383	4181	1900	0.644	0.0204	0.547×10^{-3}	1.062×10^{-5}
55	15.76	985.2	0.1045	2371	4183	1908	0.649	0.0208	0.504×10^{-3}	1.077×10^{-5}
60	19.94	983.3	0.1304	2359	4185	1916	0.654	0.0212	0.467×10^{-3}	1.093×10^{-5}
65	25.03	980.4	0.1614	2346	4187	1926	0.659	0.0216	0.433×10^{-3}	1.110×10^{-5}
70	31.19	977.5	0.1983	2334	4190	1936	0.663	0.0221	0.404×10^{-3}	1.126×10^{-5}
75	38.58	974.7	0.2421	2321	4193	1948	0.667	0.0225	0.378×10^{-3}	1.142×10^{-5}
80	47.39	971.8	0.2935	2309	4197	1962	0.670	0.0230	0.355×10^{-3}	1.159×10^{-5}
85	57.83	968.1	0.3536	2296	4201	1977	0.673	0.0235	0.333×10^{-3}	1.176×10^{-5}
90	70.14	965.3	0.4235	2283	4206	1993	0.675	0.0240	0.315×10^{-3}	1.193×10^{-5}
95	84.55	961.5	0.5045	2270	4212	2010	0.677	0.0246	0.297×10^{-3}	1.210×10^{-5}
100	101.33	957.9	0.5978	2257	4217	2029	0.679	0.0251	0.282×10^{-3}	1.227×10^{-5}
110	143.27	950.6	0.8263	2230	4229	2071	0.682	0.0262	0.255×10^{-3}	1.261×10^{-5}
120	198.53	943.4	1.121	2203	4244	2120	0.683	0.0275	0.232×10^{-3}	1.296×10^{-5}
130	270.1	934.6	1.496	2174	4263	2177	0.684	0.0288	0.213×10^{-3}	1.330×10^{-5}
140	361.3	921.7	1.965	2145	4286	2244	0.683	0.0301	0.197×10^{-3}	1.365×10^{-5}
150	475.8	916.6	2.546	2114	4311	2314	0.682	0.0316	0.183×10^{-3}	1.399×10^{-5}
160	617.8	907.4	3.256	2083	4340	2420	0.680	0.0331	0.170×10^{-3}	1.434×10^{-5}
170	791.7	897.7	4.119	2050	4370	2490	0.677	0.0347	0.160×10^{-3}	1.468×10^{-5}
180	1,002.1	887.3	5.153	2015	4410	2590	0.673	0.0364	0.150×10^{-3}	1.502×10^{-5}
190	1,254.4	876.4	6.388	1979	4460	2710	0.669	0.0382	0.142×10^{-3}	1.537×10^{-5}
200	1,553.8	864.3	7.852	1941	4500	2840	0.663	0.0401	0.134×10^{-3}	1.571×10^{-5}
220	2,318	840.3	11.60	1859	4610	3110	0.650	0.0442	0.122×10^{-3}	1.641×10^{-5}
240	3,344	813.7	16.73	1767	4760	3520	0.632	0.0487	0.111×10^{-3}	1.712×10^{-5}
260	4,688	783.7	23.69	1663	4970	4070	0.609	0.0540	0.102×10^{-3}	1.788×10^{-5}
280	6,412	750.8	33.15	1544	5280	4835	0.581	0.0605	0.094×10^{-3}	1.870×10^{-5}
300	8,581	713.8	46.15	1405	5750	5980	0.548	0.0695	0.086×10^{-3}	1.965×10^{-5}
320	11,274	667.1	64.57	1239	6540	7900	0.509	0.0836	0.078×10^{-3}	2.084×10^{-5}
340	14,586	610.5	92.62	1028	8240	11,870	0.469	0.110	0.070×10^{-3}	2.255×10^{-5}
360	18,651	528.3	144.0	720	14,690	25,800	0.427	0.178	0.060×10^{-3}	2.571×10^{-5}
374.14	22,090	317.0	317.0	0	—	—	—	—	0.043×10^{-3}	4.313×10^{-5}

L-3/T-1/ME **Date : 02/11/2019**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2018-2019

Sub : **ME 321** (Fluid Mechanics-I)

Full Marks : 210 Time : 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this section. Answer any **THREE**.

1. (a) How can you visualize the flow behavior in analytical fluid dynamics? Consider few simple fluid dynamic problems and sketch the corresponding flow pattern. Formulate a mathematical expression to obtain such flow pattern. **(10)**

(b) What do you mean by fluid kinematics? Consider a velocity field given by

$u(x, t) = u_0 \sin(kx - Ft)$

where u_0, k and F are positive constants,

(i) Determine the total acceleration experienced by a fluid particle in this flow field. **(10)**

(ii) Show that the ratio of convective acceleration to local acceleration of the fluid particle can be expressed by $-\frac{k}{F}u(x,t)$.

(c) Define stream function. A two-dimensional incompressible flow field for x > 0 is described by

$$\bar{V}(x,y) = \left(y \ln x, -\frac{y^2}{2x} \right)$$ **(10)**

Find the stream function and determine the rate of flow through the passage between the points (1, 1) and (2, 2).

(d) Show that for a 2-D inviseid irrotational flow, the continuity equation may be expressed as a Laplace equation in velocity potential function ϕ. **(5)**

2. (a) Consider a source and a sink of equal strength initially located at (-b, 0) and (b, 0). respectively, along x-axis. Determine the stream function of the resultant flow field in the limiting case when $b \to 0$. **(10)**

Show that the streamlines of such resultant flow are circles passing through the origin (0, 0) and tangent to x-axis.

(b) How can you theoretically model a steady potential flow over a stationary circular cylinder of radius. R? Show that the pressure coefficient on the cylinder surface can be predicted by $C_p = 1 - 4son^2\theta$ **(15)**

where the symbols have their usual meaning.

(c) Wind at V_∞ and p_∞ flows past a Quonset hut which is a half-cylinder of radius R and length L as shown in Fig. for Q. 2(a). The internal pressure is p_i. Using potential theory, derive an expression for the upward force acting on the hut. **(10)**

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3. (a) A rotating circular cylinder of radius R is subjected to a uniform flow with velocity V_∞ as shown in Fig. for Q. 3(a). **(10)**

Consider incompressible potential flow:

(i) Draw the typical streamlines.

(ii) Is there any stagnation point in the flow field? If yes, locate them.

(iii) Is there any resultant fluid mechanical force in the flow field? If yes, identify the force (s) with direction.

(b) The mechanical power output from a wind turbine can be theoretically predicted using momentum principle. Two streamlines and the associated control volume are shown in Fig. for Q. No. 3(b) to implement this principle. Accordingly, show that he mechanical efficiency of such turbine is limited by 59.3%. **(15)**

(c) Air at 20°C and 1 atm flows in a 25-cm diameter duct at 15 m/s as shown in Fig. for Q. 3(c). The exit is choked by a 90° cone as shown. Estimate the force of the airflow on the cone. **(10)**

4. (a) A vane on wheels moves with constant velocity V_a when a stream of water having a nozzle exit velocity of V_1 is turned by the vane as indicated in Fig. for Q. 4(a). The speed of the water jet leaving the nozzle is 30 m/s, and the vane is moving to the right with a constant speed of 6 m/s.

Determine the magnitude and direction of the force exerted by the stream of water on the vane surface. Consider ideal fluid flow and neglect the body force. **(15)**

(b) How can you differentiate the integral analysis and differential analysis of fluid dynamics? Derive the differential form of continuity equation and hence show that for steady incompressible flow, it can be expressed by **(15)**

$$\text{div}\ \vec{V} = 0$$

(c) Write down the Navier-Stokes equations for a 2-D viscous, incompressible flow is Cartesian coordinate system (x,y,z). **(5)**

SECTION – B

There are **FOUR** questions in this section. Answer any **THREE**.

5. (a) What happens when the local pressure is a liquid flow drops below the vapor pressure What are the favorable locations for such conditions to occur? **(6)**

(b) A 25-cm-diameter horizontal disk rotates at a gap of 100 micron above a flat surface. The gap is filled with a viscous liquid. Calculate the viscosity of the liquid in the gap if 10 W power is required to rotate the disk at 400 rpm. **(16)**

(c) Show that the pressure difference between two points in a fluid body may be expressed as **(13)**

$$\mathbf{d_p = -\rho a_x\, dx - \rho a_y\, dy - \rho\, (a_z + g) dz}$$

Contd P/3

6. (a) What is vena contracta? Show its location with a neat sketch. (3)

   (b) The pipe flow in Fig. Q6b fills a cylindrical surge tank as shown. At time t = 0, the water depth in the tank is 30 cm. Estimate the time required to fill the remainder of the tank. (16)

   (c) In Fig. Q6c, the flowing fluid is oil with specific gravity 0.85, if p_1 = 170 kPa and the manometer fluid is water, estimate (a) p_2 and (b) the oil flow rate in liter/hr. Neglect viscous losses. (16)

7. (a) What do you mean by the term 'head' in a fluid flow? Explain how and why a fluid flow is affected when the velocity head vanishes. (6)

   (b) The horizontal pump in Fig. Q7b discharges water is 57 m^3/h. Neglecting losses, what power in kW is delivered to the water by the pump? (14)

   (c) Gate AB in Fig. Q7c is a homogeneous mass of 180 kg, 1.2 m wide into the paper, resting on smooth bottom B. For what water depth 'h' will the force at point B be zero? Take, specific gravity of glycerin = 1.26. (15)

8. (a) What is metacentre? Explain with a sketch. (5)

   (b) Consider a homogeneous right circular cylinder of length L, radius R, and specific gravity SG = 0.5, floating in water (SG = 1). Show that the body will be stable (16)

   (i) with its axis horizontal if $L/R > 2$.

   (ii) with its axis vertical if $L^2/R^2 < 2$.

   (c) The tank of water in Fig. Q8c is full open to the atmosphere at point A, as shown. For what acceleration a_x, will the pressure at point B in the figure be (i) atmospheric; and (ii) zero absolute (neglecting cavitation)? (14)

   (iii) Determine the pressure at C when pressure at B is atmospheric.

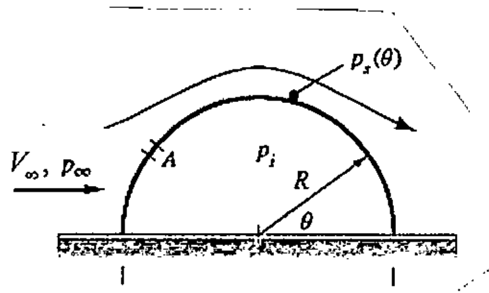

Fig. for Q. 2(a)

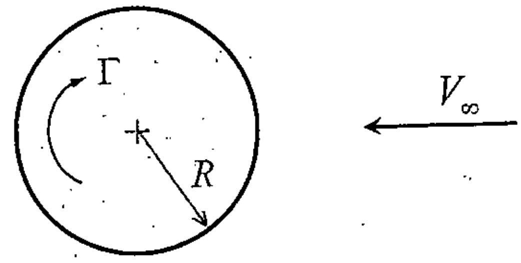

Fig. for Q. No. 3(a)

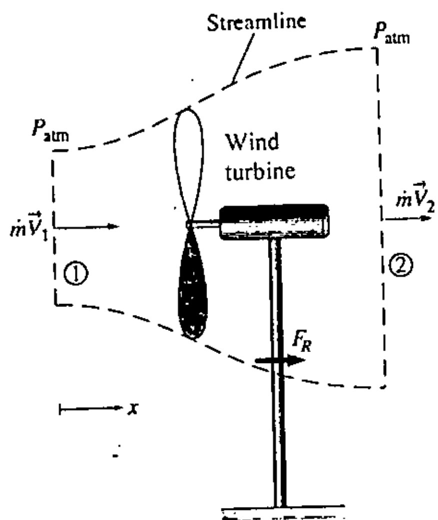

Fig. for Q. No. 3(b)

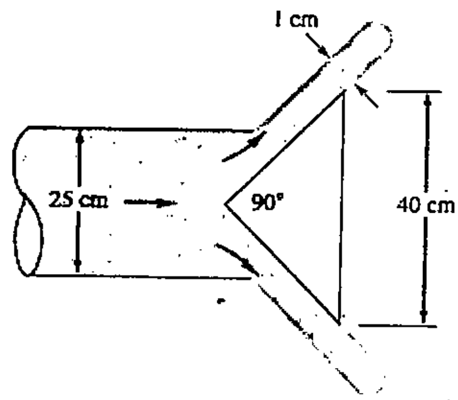

Fig. for Q. No. 3(c)

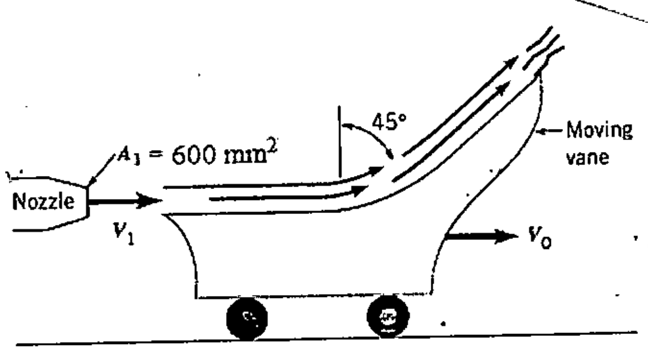

Fig. for Q. 4(a)

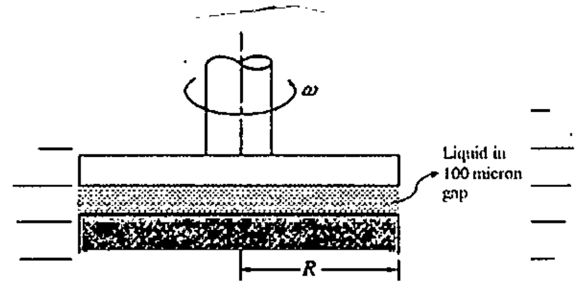

Figure for Q5b

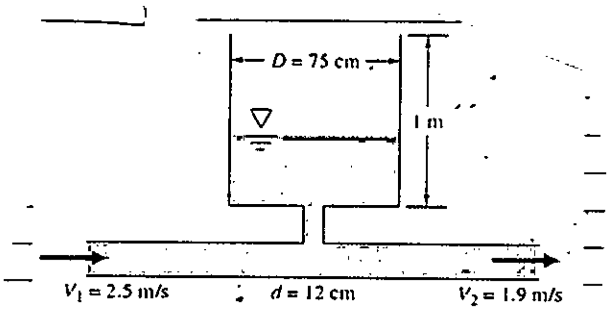

Figure for Q6b

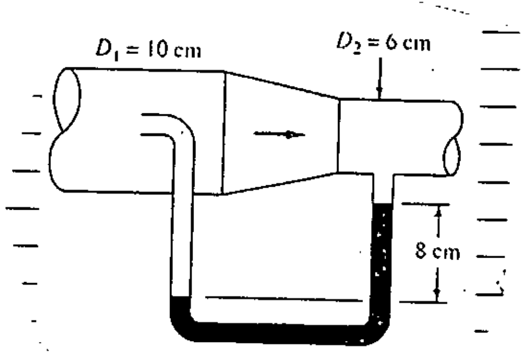

Figure for Q6c

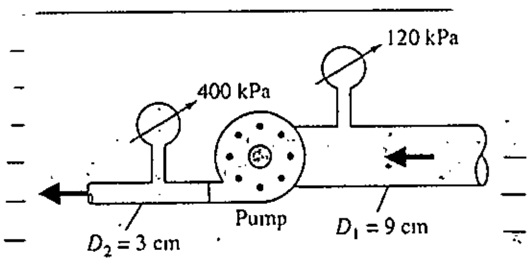

Figure for Q7b

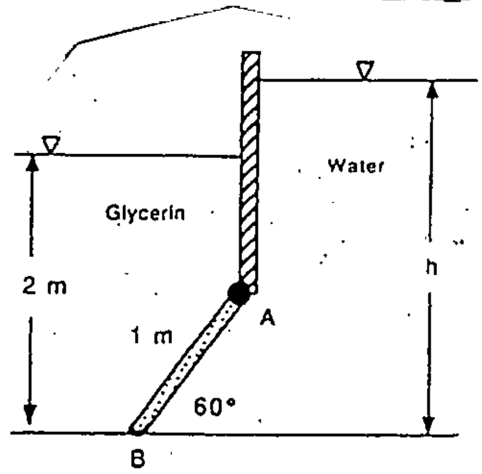

Figure for Q7c

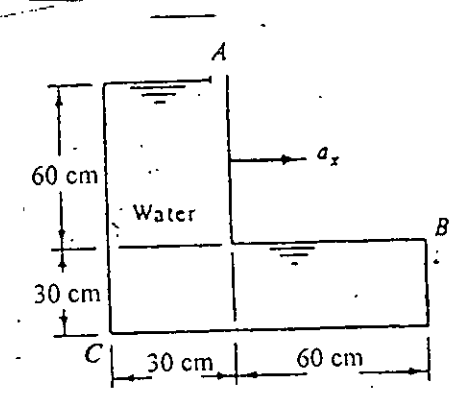

Figure for Q8c

L-3/T-1/ME Date : 06/11/2019

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2018-2019

Sub : **ME 361** (Instrumentation and Measurement)

Full Marks : 210 Time : 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this section. Answer any **THREE**.

Assume any data if necessary. Symbols used have their usual meaning.

1. (a) In a block diagram show the different stages of a measurement system along with examples of devices used in those stages. How is a calibration system different from a typical measurement of system? **(12)**

(b) Briefly describe the basic sensor properties which need to be calibrated to compensate for duration when used in a measurement system. **(12)**

(c) A certain binary-weighted-input DAC as shown in figure below has binary input of 1101. If a High input is +3.0V and a low input is 0V, what is the output voltage, V_{out}? **(11)**

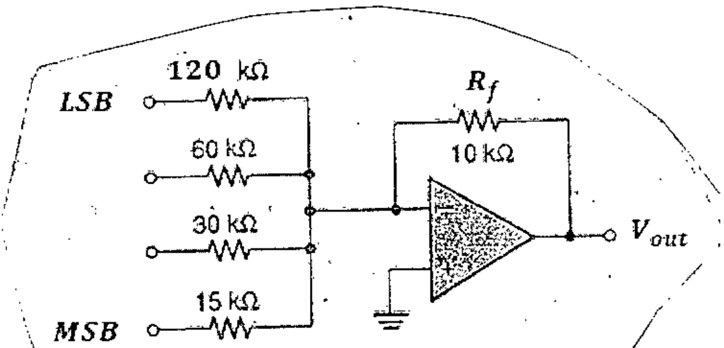

Fig. for Q. No. 1(c)

2. (a) What do you understand by 'open-loop' and 'closed-loop' gain of an ideal op-amp? State two 'golden' rules of an ideal op-amp and calculate the 'closed-loop' gain of the following op-amp circuit using golden rules of an ideal op-amp. **(12)**

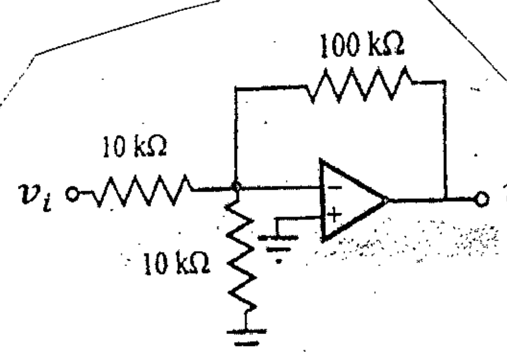

Fig. for Q. No. 2(a)

(b) Draw the circuit diagram of robust multi-stage instrumentation amplifier system and develop an expression for its gain. **(12)**

(c) Draw an active band-pass filter circuit that provides a constant output from a certain minimum frequency up to a maximum cutoff frequency and passes no signal above or below that frequency range. Also show the expression for the determination of the minimum and the maximum frequency. **(11)**

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3. (a) Using SOP or POS method, show that the Boolean expression for driving the motor with three sensor inputs according to the following truth table is given by M = AB + $\overline{C}$. Also draw the logic circuit. **(12)**

Input Sensors			Output Motor
A	B	C	M
OFF	OFF	OFF	ON
OFF	OFF	ON	OFF
OFF	ON	OFF	ON
OFF	ON	ON	OFF
ON	OFF	OFF	ON
ON	OFF	ON	OFF
ON	ON	OFF	ON
ON	ON	ON	ON

(b) Simplify the logic circuit shown in Fig. for Q.No. 3(b) and draw the simplified circuit. **(12)**

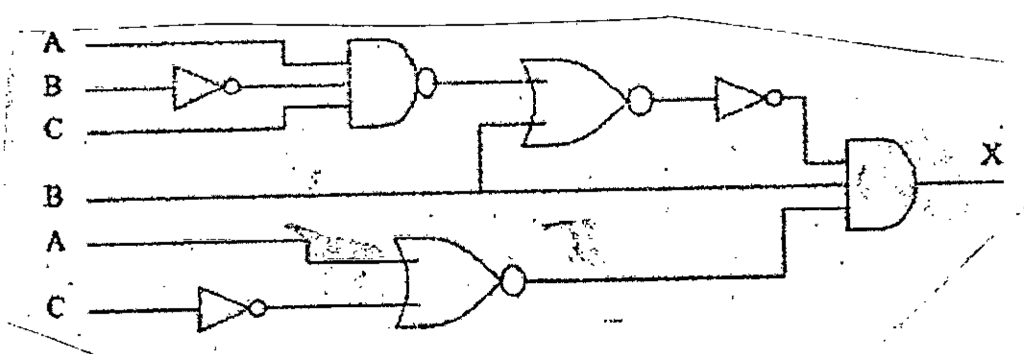

Fig. for Q. No. 3(b)

(c) With a block diagram explain the working principle of a "Successive Approximation ADC". **(11)**

4. (a) Illustrate the working principles of a vortex flow meter and an ultra-sonic flow meter. List the merits and demerits of an ultra-sonic flowmeter. **(16)**

(b) What is a hynamometer? List its types and illustrate the working principle of any one of them. **(12)**

(c) In telephony, the bandwidth allocated for human voice-frequency transmission is usually 4 kH. During telephonic conversation, the sound pressure level normally varies between 0 to 60 dB. Determine the sampling rate of an ADC to faithfully record the telephonic conversation and the required bit-size for detecting a change of 0.5 dB in conversation. **(7)**

SECTION – B

There are **FOUR** questions in this section. Answer any **THREE**.

5. (a) Identify the key stages in a 'temperature charet recorder' as a measuring instrument. **(10)**

(b) Define 'accuracy' and 'precision' of measurements Elaborate "bias and 'systematic' errors in typical measurements. **(10)**

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Contd..... Q. No. 5

(c) Estimate the nominal value and uncertainty of density using the following data:

R = 287 J/kg-k

P = 125 kPa + 1%

T = 30 ± 0.5°C. **(10)**

(d) Ten measurements are mode for the thickness of a metal plate:

3.58, 3.51, 3.52, 3.54, 3.48, 3.45, 3.49, 3.60, 3.50, 3.55 mm. Estimate the near value and tolerance limit for 95% confidence using student's t-distribution. **(5)**

6. (a) Explain different types or responses of measuring systems. Mention some of the key response characteristics of 0'th order systems. **(10)**

   (b) Derive an expression of transfer-function of a second-order system. What are the scope and limitations of transfer function approach of analysis? **(10)**

   (c) A first-order sensor to be installed into a nuclear -reactor vessel to monitor ad control temperature. If a sudden rise in temperature greater than 100°C should occur, shut down of the reactor will need to begin with in 2.0 seconds. Determine the minimum allowable time contact of the sensor. **(10)**

   (d) Write a short note on mechanical and analogous electrical systems. **(5)**

7. (a) Briefly present the thermoelectric Laws utilized in thermocouple based temperature measurement systems. **(10)**

   (b) Write a short note on resistance thermometry. **(10)**

   (c) Make a brief comparison between thermocouple thermistor, RTD and IC based temperature measurement systems. **(15)**

8. (a) Briefly present a pressure measured system using LVDT. **(10)**

   (b) Briefly explain the working principle of pirari pressure guage. **(10)**

   (c) Define static and total pressure. Elaborate how Pitot tube can be used to measure the flow velocity of a fluid stream. **(15)**

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=4=

Values of Student's t-distribution

ν	t_{50}	t_{90}	t_{95}	t_{99}
1	1.000	6.314	12.706	63.657
2	0.816	2.920	4.303	9.925
3	0.765	2.353	3.182	5.841
4	0.741	2.132	2.770	4.604
5	0.727	2.015	2.571	4.032
6	0.718	1.943	2.447	3.707
7	0.711	1.895	2.365	3.499
8	0.706	1.860	2.306	3.355
9	0.703	1.833	2.262	3.250
10	0.700	1.812	2.228	3.169
11	0.697	1.796	2.201	3.106
12	0.695	1.782	2.179	3.055
13	0.694	1.771	2.160	3.012
14	0.692	1.761	2.145	2.977
15	0.691	1.753	2.131	2.947
16	0.690	1.746	2.120	2.921
17	0.689	1.740	2.110	2.898
18	0.688	1.734	2.101	2.878
19	0.688	1.729	2.093	2.861
20	0.687	1.725	2.086	2.845
21	0.686	1.721	2.080	2.831
30	0.683	1.697	2.042	2.750
40	0.681	1.684	2.021	2.704
50	0.680	1.679	2.010	2.679
60	0.679	1.671	2.000	2.660
∞	0.674	1.645	1.960	2.576

L-3/T-1/ME Date : 19/10/2019

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2018-2019

Sub : **ME 349** (Mechanics of Machinery)

Full Marks : 210 Time : 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this section. Answer any **THREE**.

1. (a) The details of an externally applied brake are given in Figure 1(a). The brake is pivoted about the fixed pin at C and is operated by the force F which acts at right angles to OD. The brake lining is of uniform width, it subtends an angle of 75° at the drum shaft O and it obeys Hooke's Law in compression. The coefficient of friction is 0.36. The drum has a diameter of 200 mm. When the drum is rotating clockwise the brake is applied with the force F = 135 N. Determine (i) the force on the pin at C and (ii) the braking torque. **(17)**

   (b) A motor vehicle of all-up mass 900 kg has a track of 1.5m and the center of gravity is 0.38m above ground level. The four road wheels have a total moment of inertia of 5 kg.m^2 and a rolling radius of 0.3m. The vehicle is travelling at a speed of 45m/s in a circular path of radius 180m. Determine the angle of banking necessary for there to be no tendency for the vehicle to sideslip. **(18)**

2. (a) In the gear as shown in Figure 2(a) the input shaft X is directly connected to the sun-wheel A of the epicyclic gear and the shaft X rotates the annular wheel B through the geared side shaft, turning about a fixed axis, and the pinion D and external wheel B_0 on the casing of B. The teeth are all of the same pitch and the numbers are as follows:

   $$E = E_1 = 75,\ D = 30,\ B_0 = 120,\ A = 40,\ C = 30,\ B = 100.$$

   If the speed of the input shaft is 112 rev/min, find the speed of the output shaft Z. **(17)**

   (b) A mass m_1 is suspended from a fixed point by means of a spring of stiffnes s_1. Attached to m_1 by means of a second spring of stiffness s_2 is another mass m_2. When the system is set in free vibration, if the inertia of the springs be neglected, show that

   $$m_1 m_2 w^4 - \{m_1 s_2 + m_2(s_1 + s_2)\}w^2 + s_1 s_2 = 0$$

   where w is the phase velocity.

   If m_1 and m_2 are each 225 kg, and s_1 and s_2 are 240 and 120 kN/m respectively, find the frequencies of oscillation. **(18)**

3. (a) A uniform beam, of mass 31 kg/m run, is simply supported on a span of 3.6 m. Taking EI for the beam as 7 MN-m^2, calculate the frequency of transverse vibrations. **(17)** This frequency is to be reduced by 40% by fixing three equal masses to the beam, at the mid-point and the quarter points. Calculate how much these masses should be.

   (b) Two rotors I_1 and I_2 are mounted on a shaft, 45mm diameter, with a free length of 530 mm between them. At a distance of 330 mm from I_1 it is desired to take off a drive which shall be free from oscillating movement and to effect this the remaining 200mm of shaft adjacent to I_2 is reduced in diameter. For I_1, the mass is 40 kg and the radius of gyration is 140 mm, and for I_2 the mass is 18 kg and the radius of gyration is 160 mm. Find the frequency of torsional vibration for the system and diameter of the reduced portion of the shaft. Assume G = 80 GPa. **(18)**

4. (a) A light uniform bar of man M and length l is hinged at one end while the other end is carried by a spring of stiffness S so that in its rest position the bar is horizontal. Half way along the bar a dash-pot is attached which produces a damping force of C per unit velocity.
Write down the equation of motion obtained by taking moments about the hinge, and give an expression for the time period. **(17)**

(b) Write down the equation of simple harmonic motion for a body subject to damping proportional to the velocity and acted upon by a periodic simple harmonic force. Find the solution. **(18)**
If the maximum value of the impressed force would produce a deflection of 48 mm, find the value of the damping coefficient if the deflection is not to exceed 6 mm when the impressed periodicity is the same as the natural frequency, 5 Hz. Mass of body is 4 kg.

SECTION – B

There are **FOUR** questions in this section. Answer any **THREE**.

5. A can is to be designed for a knife edge follower with the following data: **(35)**
(i) Follower lift is 20 mm during 60° of cam rotation.
(ii) Dwell the next 90°.
(iii) During the next 60° of cam rotation, the follower returns.
(iv) Rise and return will take place with constant acceleration and retardation. The magnitude of acceleration is double the magnitude of retardation.
(v) Dwell during the remaining rotation.
(vi) The direction of motion of the follower is 10 mm offsetted.
(vii) The radius of the base circle is 40 mm. Draw the cam profile.

6. (a) A four crank engine has two outer cranks set of 120° to each other, and their reciprocating masses are each 400 kg. The distance between the planes of rotation of adjacent cranks are 450 mm, 750 mm and 600 mm. If the engine is to be in compete primary balance, find the reciprocating mass and the relative angular position for each of the inner cranks.
If the length of each crank is 300 mm, the length of each connecting rod is 1.2 m and the speed of rotation is 240 rpm, find the maximum secondary unbalanced force and its direction. **(18)**

(b) A three cylinder radial engine driven by a common crank has the cylinders spaced at 120°. The stroke is 125 mm, length of the connecting rod 225 mm and the mass of the reciprocating parts per cylinder 2 kg. Calculated the primary and secondary forces at crank. Shaft speed of 1200 rpm. **(17)**

7. (a) The equation of the turning moment diagram for the three crank engine is given by:

$$T(N-m) = 25000 - 7500 \sin 3\theta$$

where θ radians is the crank angle from inner dead centre. The moment of inertia of the flywheel is 400 kg-m^2 and the mean engine speed is 300 rpm. Calculate the power of the engine and the percentage fluctuation of speed of flywheel, if the resisting torque is **(18)**

$$25000 + 3600 \sin \theta \; (N-m).$$

(b) A machine has to carry out punching operation at the rate of 12 holes per minute. It does 6 *kN–m* of work per mm^2 of the sheared area in cutting 25 mm diameter holes in 20 mm thick plates. A flywheel is fitted to the machine shaft which is driven by a constant torque. The fluctuation of speed is between 180 and 200 rpm. The actual punching takes 1.5 seconds. The frictional losses are equivalent to 1/6 of the work done during punching. Find (i) Power required to drive the punching machine. (ii) Mass of the flywheel if the radius of gyration of the wheel is 0.5 m. **(17)**

8. (a) A differential band brake acting on the 3/4th of the circumference of a drum of 450 mm diameter, is to provide a braking torque of 225 *N–m*. One and of the band is attached to a pin 100 mm from the fulcrum of the lever and the other end to another pin 25 mm from the fulcrum on the other side of it where the operating force is acting. If the operating force is applied at 500 mm from the fulcrum and the coefficient of friction is 0.25, find the two values of the operating force corresponding to two directions of rotation of the drum. **(18)**

(b) Power is transmitted between two shafts by a *V*-belt whose mass is 0.9 kg/m length. The maximum permissible tension in the belt is limited to 2.5 *kN*. The angle of lap is 175° and the groove angle 45°. If the coefficient of friction between the belt and pulleys is 0.17, find (i) velocity of the belt for maximum power. (ii) Power transmitted at this velocity. **(17)**

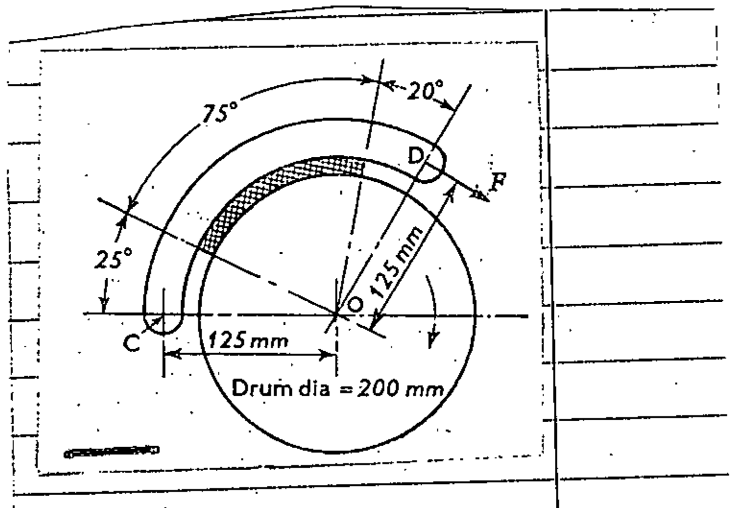


Figure 1 (a)

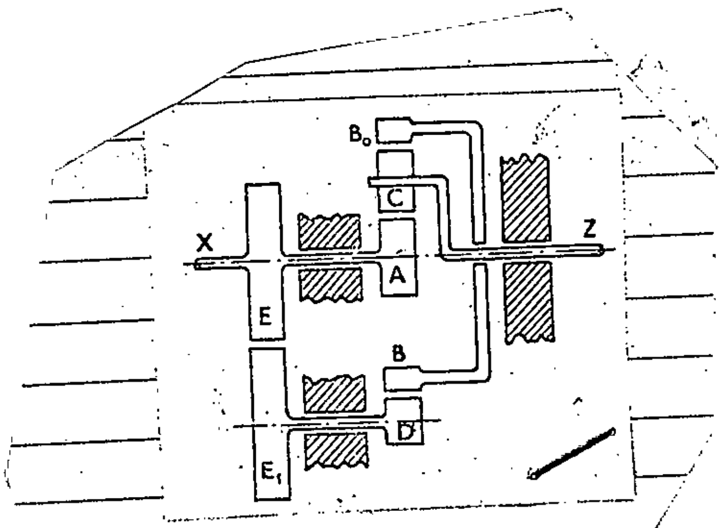


Figure 2 (a)

L-3/T-2/ME **Date: 24/10/2019**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-2 B. Sc. Engineering Examinations 2018-2019

Sub: **IPE 331** (Production Processes)

Full Marks: 280 Time: 3 Hours

USE SEPARATE SCRIPTS FOR EACH SECTION

The figures in the margin indicate full marks

SECTION – A

There are **FOUR** questions in this section. Answer any **THREE**.

1. (a) Briefly describe the different types of pattern allowances. With the help of diagrams, describe (i) Split pattern, (ii) Gated pattern and (iii) Sweep pattern. **(16)**

   (b) What is the difference between gating system and mold design? With the help of diagrams discuss (i) Gravity die casting and (ii) Centrifugal Casting. **(16)**

   (c) Describe the different defects encountered in casting processes using suitable diagrams. How might defective castings be repaired to permit successful use in their intended application? **($14\frac{2}{3}$)**

2. (a) Draw a single point turning tools and visualize its different rake angles, clearance angles and cutting edge angles. Derive the expression for chip reduction coefficient in orthogonal cutting in terms of rake angle and coefficient of friction. **(16)**

   (b) With the help of Earnest and Merchant model, show that $P_z = 2\tau_s S_o t \cot \beta$ where the notations indicate their usual meaning. **(16)**

   (c) SAFE 133 cold rolled steel rod of 150 mm diameter is turned at a speed of 450 rpm, feed of 0.24 mm/rev. and 2 mm depth of cut by a tool having rake angle 6° and principal cutting edge angle 60°. It was noted that the magnitudes of the tangential component and the axial component of the cutting force 1050 N and 450 N respectively and the value of chip reduction coefficient is 1.8. Using MCD, determine the values of μ, P_s and P_n. **($14\frac{2}{3}$)**

3. (a) Sketch the various weld joints and welds used in making a joint. With the help of neat sketch, describe briefly the principles of operation of submersed arc welding. **(16)**

   (b) With the help of suitable diagrams, describe (i) Resistance projection welding and (ii) Percussion welding. **(16)**

   (c) Describe the features of a weld nugget. Explain the similarities and differences between electron beam and laser beam welding. Give typical application for each. **($14\frac{2}{3}$)**

4. (a) Explain why the strength-to-weight ratio of die-cast parts increases with decreasing wall thickness. Explain the differences in the importance of drafts between green sand casting and die mold casting. **(16)**

Contd P/2

IPE 331

Contd... Q. No. 4

(b) State the difference among abrasion wear, adhesion wear and diffusion wear in respect of cutting tool wear. What properties should a cutting tool materials essentially possess and why? **(16)**

(c) Discuss the factors that influence weld quality. Why are residual stresses important in welded components? Describe the methods used for relieving or reducing residual stresses in welds. **($14\frac{2}{3}$)**

SECTION – B

There are FOUR questions in this section. Answer any THREE.

5. (a) Describe different roll mill configurations with necessary sketches. **(20)**

(b) With necessary diagrams, illustrate the typical steps involved with hole making processes. **(20)**

(c) Derive the expression for MRR for the drilling operation of a blind-hole. **($6\frac{2}{3}$)**

6. (a) Describe the dividing head setup for differential indexing with suitable diagram and derive the expression for the change gear quadrant ratio. **(20)**

(b) Distinguish between open-die forging and closed-die forging. Mention the relative advantages and disadvantages of open-die forging compared to closed-die forging. **(10+6)**

(c) How do shaping and planning differ? Draw some common geometry produced by shaping and planning operations. **($10\frac{2}{3}$)**

7. (a) With neat sketches describe the following finishing processes:

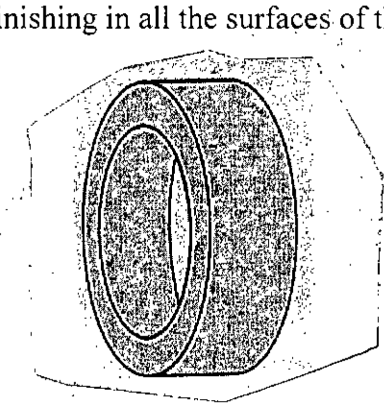
(i) Honing

(ii) Super finishing **(16)**

(b) How can you distinguish hot extrusion form cold extrusion? Describe the working principles of direct extrusion, indirect extrusion and impact extrusion with necessary figures. **(15)**

(c) Derive the expressions for approach distance for slab milling and face milling operations. **($15\frac{2}{3}$)**

8. (a) Consider the following hollow cylindrical part. Describe the grinding processe(s) required to achieve fine finishing in all the surfaces of the part. **(20)**



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(b) In a turning operation, the engineer has dictated that a single pass must be completed on the cylindrical job in 5.0 min. The piece is 400 mm long and150 mm in diameter. Using feed = 0.30 mm/rev an depth of cut = 4.0 mm, what cutting speed must be used to meet this machining time requirement? Also, Calculate the MRR. Over-travel allowance is 33.33% of the job's length. **(16)**

(c) With neat sketches describe the following processes: **($10\frac{2}{3}$)**

i. Upsetting and Heading

ii. Roll forging
