EX/PROD/PC/B/T/212/2025

B.E. PRODUCTION ENGINEERING SECOND YEAR FIRST SEMESTER EXAMINATION 2025

SUBJECT: THERMODYNAMICS AND HEAT TRANSFER

Time: Three hours **Full marks: 100**

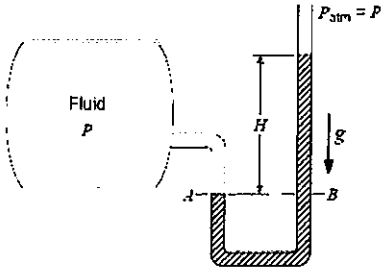
Answer **five** questions taking **at least two from each group**

Group-A

1. (a) Compare path functions and point functions. (3M)
   (b) State Carnot's theorem and Prove $COP_{HP}=COP_R+1$. (6M)
   (C) Discuss about psychrometric charts. What is the difference between dry bulb temperature and wet bulb temperature? (4M)
   (d) Steam enters a turbine at 30bar (u=2750KJ/Kg; h=2993KJ/Kg) and exits the turbine as saturated liquid at 15kPa. Heat loss to the surroundings is 50 KJ/Kg (u=225KJ/Kg; h=226KJ/Kg) of the steam flowing to the turbine. Neglecting the kinetic energy and potential energy, calculate the work output of the turbine in KJ/Kg of the steam. (3M)
   (e) What is the advantage of T-S diagram over P-V diagram? Also mention the shape of constant pressure lines in wet region and super heated region. (4M)

2. (a) State first law of thermodynamics and state how that internal energy is a property of the system. (5M)
   (b) (i) Derive the steady flow energy equation for a nozzle stating the assumptions
   (ii)The working fluid in a steady flow process flows at a rate of 220Kg/min. The fluid rejects 100KJ/s passing through the system. The condition of fluid at inlet and outlet are given as V_1 = 320m/s; p_1=6.0 bar, u_1 = 200KJ/Kg, $\vartheta_1 = 0.36\ m^3/Kg$ and V_2= 140m/s, p_2= 1.2 bar, u_2 = 1400KJ/Kg, $\vartheta_2 = 1.3\ m^3/Kg$. The suffix 1 indicates the conditions at the inlet and the suffix 2 indicates the conditions at the outlet of the system. Determine the power capacity of the system in MW. The change in potential energy may be neglected. (8M+5M)
   (c) A stationary mass of gas was compressed without friction at constant pressure. Its initial state of 0.4 m^3 and 0.105Mpa was found to change to final state of 0.20m^3. There was a transfer of 42.5KJ of heat from the gas during the process. Calculate the change in internal energy of the gas. (2M)

3. (a) Show that if any given quantity of air receives a fixed amount of heat at constant volume, the rise in pressure produced is directly proportional to the initial absolute pressure and inversely proportional to the initial absolute temperature. (4M)
   (b) An air vessel has capacity of 10 m^3 and has air at 10 atm and 27°C. Some leakage in the vessel causes air pressure to drop sharply to 5 atm till leak is repaired. Assuming process to be of reversible adiabatic type determine the mass of air leaked. (5M)
   (c) The temperature at which water vapour starts condensing is called_. (1M+4M)
   A mercury manometer is used to measure the pressure in a vessel shown in figure. The mercury has a density of 13590Kg/m^3 and height difference between the two columns is measured to be 24cm. Determine the pressure inside the vessel.



(d) Find the enthalpy and internal energy of 1Kg of steam at a pressure of 10 Kgf/cm^2 when the (i) steam is dry and satureated ; (ii) when steam is superheated to 230^{0}C and (iii) when the dryness fraction is 0.75. (6M)

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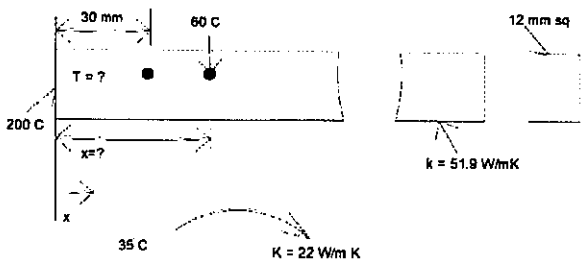
4. (a) What do you understand by Vapour compression cycle? Explain the simple vapor compression cycle process on p-h and T-S diagrams. (3M)
(b) Discuss briefly the working of actual vapour compression cycle with the help of flow diagram and p-h diagram. (10M)
(b) A simple vapour compression plant produces 6 tonnes of refrigeration. The enthalpy values at inlet to the compressor and at exit from the condenser are 180.5, 205 and 75KJ/Kg respectively. Estimate:
(i) the refrigerant flow rate.
(ii) COP.
(iii) the power required to drive the compressor.
(iv) the rate of heat rejection to the condenser. (7M)

5. (a) Show that entropy is a property of the system. (3M+3M+4M)
(b) What is the principle of increase of entropy?
(c) Derive an expression for change in entropy of a gas for an isothermal process.
(d) A gas undergoes a thermodynamic cycle consisting of following processes. Process 1-2 is constant pressure process p=1.4 bar, $V_1 = 0.028m^3$ and $W_{1\text{-}2}$=10.5kJ.
Process 2-3 is compression pV= constant, $U_3=U_2$
Process 3-1 is constant volume U_1-U_3= -26.4KJ.
There is no significant change in the kinetic and potential energy. Sketch the cycle on PV diagram . calculate the net work for the cycle in KJ and calculate the net heat for the process 1-2. Show that $\sum_{cycle} Q = \sum_{cycle} W$. (10M)

Group B

6. (a) Distinguish between parallel flow and counter flow heat exchangers with respect to (i) direction of flow (ii) temperature variation. (6M)
(b) State Krichoff's law of radiation. (2M)
(c)What are velocity and thermal boundary layers and under what conditions do they develop? (3M)
(d) What is thermal resistance and state electrical analogy for heat transfer process. (4M)
(e) A long rod 12 mm square section made of low carbon steel protrudes into air at 35°C from a furnace wall at 200°C. The convective heat transfer coefficient is estimated at $22W/m^2K$. The conductivity of the material is 51.9 W/mK. Determine the location from the wall at which the temperature will be 60°C. Also calculate the temperature at 80 mm from base. (5M)



7. (a) A pipe carrying steam at 230°C has an internal diameter of 12 cm and the pipe thickness is 7.5 mm. The conductivity of the pipe material is 49 W/mK the convective heat transfer coefficient on the inside is 85 W/m^2K. The pipe is insulated by two layers of insulation one of 5 cm thickness of conductivity 0.15 W/mK and over it another 5 cm thickness of

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conductivity 0.48 W/mK. The outside is exposed to air at 35°C with a convection coefficient of 18 W/m^{2}K. Determine the heat loss for 5 m length. Also determine the interface temperatures and the overall heat transfer coefficient based on inside and outside areas. Draw the equivalent thermal circuit for this system. (10M)

(b) What is heat transfer coefficient? (3M)

(c) Explain about critical radius of insulation. What is the advantage of critical thickness of insulation. Explain why an insulated small diameter wire has higher current carrying capacity than an uninsulated one. (7M)

8. (a) What is effectiveness of heat exchanger? (2M)

(b) Hot oil with a capacity of 2500 W/K flows through a double pipe heat exchanger. It enters at 360^0 C and leaves at 300^0 C. Cold fluid enters at 20^{0}C and leaves at 200^{0}C. If overall heat transfer coefficient is 822W/m^{2}K, Find the area of the heat exchanger required for

(i) parallel flow (ii) counter flow.

Also find the LMTD, NTU and Effectivenss of the heat exchangers in parallel flow and counter flow configurations. (14 M)

(c)How does the number of tube passes affect the performance of shell and tube type heat exchange? (4M)

9. (a) Explain Reynolds number, Nusselt Number, Prandtl number and Grashoff's number (8M)

(b)Air flow through a long rectangular air conditioning duct maintains the outer duct surface temperature at 15^{0}C. If the duct is uninsulated and exposed to air at 25^{0}C, calculate the heat gained by the duct per meter length assuming it to be horizontal. Properties of air at 20^0 C :

$\rho = 1.205 kg/m^3$; $\vartheta = 15.06\ X\ 10^{-6}\ m^2/sK = 25.93\ W/mK$

$\Pr = 0.705\ \beta = 3.41X10^{-3}$ (10M)

(c) Define fin effectiveness. (2M)

10. (a) What is absorptivity, reflectivity and transmissivity. (3M)

(b) Determine the shape factor from the base of the cylinder to the curved surface. Also, determine the shape factor from curved surface to the base and curved surface itself. (7M)

(c) Define Wein's law of displacement. (3M)

(d) Derive expression for thermal radiation heat transfer between two black body surfaces (7M)

Saturated Water and Steam (Temperature) Tables

(t)	(p)	(v_f)	(v_g)	(h_f)	(h_{fg})	(h_g)	(s_f)	(s_{fg})	(s_g)	(t)
120	1.985 4	0.001 061	0.891 52	503.7	2 202.3	2 706.0	1.528	5.601	7.129	120
122	2.114 5	0.001 063	0.840 45	512.2	2 196.6	2 708.8	1.549	5.559	7.108	122
124	2.250 4	0.001 064	0.792 83	520.7	2 190.9	2 711.6	1.570	5.517	7.087	124
126	2.393 3	0.001 066	0.748 40	529.2	2 185.2	2 714.4	1.592	5.475	7.067	126
128	2.543 5	0.001 068	0.706 91	537.8	2 179.4	2 717.2	1.613	5.433	7.046	128
130	2.701 3	0.001 070	0.668 14	546.3	2 173.6	2 719.9	1.634	5.392	7.026	130
132	2.867 0	0.001 072	0.631 88	554.8	2 167.8	2 722.6	1.655	5.351	7.006	132
134	3.040 7	0.001 074	0.597 95	563.4	2 161.9	2 725.3	1.676	5.310	6.986	134
136	3.222 9	0.001 076	0.566 18	572.0	2 155.9	2 727.9	1.697	5.270	6.967	136
138	3.413 8	0.001 078	0.536 41	580.5	2 150.0	2 730.5	1.718	5.229	6.947	138
140	3.613 9	0.001 080	0.508 49	589.1	2 144.0	2 733.1	1.739	5.189	6.928	140
142	3.823 1	0.001 082	0.482 30	597.7	2 137.9	2 735.6	1.760	5.150	6.910	142
144	4.042 0	0.001 084	0.457 71	606.3	2 131.8	2 738.1	1.780	5.111	6.891	144
146	4.270 9	0.001 086	0.434 60	614.9	2 125.7	2 740.6	1.801	5.071	6.872	146
148	4.510 1	0.001 089	0.412 88	623.5	2 119.5	2 743.0	1.821	5.033	6.854	148
150	4.760 0	0.001 091	0.392 45	632.2	2 113.2	2 745.4	1.842	4.994	6.836	150
155	5.433 3	0.001 096	0.346 44	653.8	2 097.4	2 751.2	1.892	4.899	6.791	155
160	6.180 6	0.001 102	0.306 76	675.5	2 081.2	2 756.7	1.943	4.805	6 748	160
165	7.007 7	0.001 108	0.272 40	697.2	2 064.8	2 762.0	1.992	4.713	6.705	165
170	7.920 2	0.001 114	0.242 55	719.1	2 048.0	2 767.1	2.042	4.621	6.663	170
175	8.924 4	0.001 121	0.216 54	741.1	2 030.7	2 771.8	2.091	4.531	6.622	175
180	10.027	0.001 128	0.193 80	763.1	2 013.2	2 776.3	2.139	4.443	6.582	180
185	11.233	0.001 135	0.173 86	785.3	1 995.1	2 780.4	2.187	4.355	6.542	185
190	12.551	0.001 142	0.156 32	807.5	1 976.8	2 784.3	2.236	4.268	6.504	190
195	13.987	0.001 149	0.140 84	829.9	1 957.9	2 787.8	2.283	4.182	6.465	195
200	15.549	0.001 156	0.127 16	852.4	1 938.5	2 790.9	2.331	4.097	6.428	200
205	17.243	0.001 164	0.115 03	875.0	1 918.8	2 793.8	2.378	4.013	6.391	205
210	19.077	0.001 172	0.104 24	897.7	1 898.5	2 796.2	2.425	3.929	6.354	210
215	21.060	0.001 181	0.094 625	920.6	1 877.7	2 798.3	2.471	3.846	6.317	215
220	23.198	0.001 190	0.086 038	943.7	1 856.2	2 799.9	2.518	3.764	6.282	220

Specific Enthalpy of Superheated Steam 19

p/t°C	0(S.)	100	150	200	250	300	350	400	500	600	700	800
2.5	127.4		2 764.5	2 868.0	2 969.6	3 070.9	3 172.8	3 275.9	3 486.5	3 703.6	3 927.3	4 157.6
3.0	133.5		2 760.4	2 865.5	2 967.9	3 069.7	3 171.9	3 275.2	3 486.0	3 703.2	3 927.0	4 157.3
3.5	138.9	..	2 756.3	2 863.0	2 966.2	3 068.4	3 170.9	3 274.4	3 485.4	3 702.7	3 926.7	4 157.1
4.0	143.6	.	2 752.0	2 860.4	2 964.5	3 067.2	3 170.0	3 273.6	3 484.9	3 702.3	3 926.4	4 156.9
4.5	147.9	.	2 746.7	2 857.8	2 962.8	3 066.0	3 169.1	3 272.9	3 484 3	3 701.9	3 926.1	4 156.7
5.0	151.8	..	..	2 855.1	2 961.1	3 064.8	3 168.1	3 272.1	3 483.8	3 701.5	3 925.8	4 156.4
6.0	158.8	..	..	2 849.7	2 957.6	3 062.3	3 166.2	3 270.6	3 482.7	3 700.7	3 925.1	4 155.9
7.0	165.0	..	..	2 844.2	2 954.0	3 059.8	3 164.3	3 269.0	3 481.6	3 699.9	3 924.5	4 155.5
8.0	170.4	..	..	2 838.6	2 950.4	3 057.3	3 162.4	3 267.5	3 480.5	3 699.1	3 923.9	4 155.0
9.0	175.4	..	..	2 832.7	2 946.8	3 054.7	3 160.5	3 266.0	3 479.4	3 698.2	3 923.3	4 154.5
10.0	179.9	..	..	2 826.8	2 943.0	3 052.1	3 158.5	3 264.4	3 478.3	3 697.4	3 922.7	4 154.1
11.0	184.1	..	..	2 820.7	2 939.3	3 049.6	3 156.6	3 262.9	3 477.2	3 696.6	3 922.0	4 153.6
12.0	188.0	..	..	2 814.4	2 935.4	3.046.9	3 154.6	3 261.3	3 476.1	3 695.8	3 921.4	4 153.1
13.0	191.6	..	..	2 808.0	2 931.5	3.044.3	3 152.7	3 259.7	3 475.0	3 695.0	3 920.8	4 152.7
14.0	195.0	..	..	2 801.4	2 927.6	3 041.6	3 150.7	3 258.2	3 473.9	3 694.1	3 920.2	4 152.2
15.0	198.3	..	..	2 794.7	2 923.5	3 038.9	3 148.7	3 256.6	3 472.8	3 693.3	3 919.6	4 151.7
16.0	201.4	..	..	..	2 919.4	3 036.2	3 146.7	3 255.0	3 471.7	3 692.5	3 918.9	4 151.3
17.0	204.3	..	..	..	2 915.3	3 033.5	3 144.7	3 253.5	3 470.6	3 691.7	3 918.3	4 150.8
18.0	207.1	..	..	..	2 911.0	3 030.7	3 142.7	3 251.9	3 469.5	3 690.9	3 917.7	4 150.3
19.0	209.8	..	..	..	2 906.7	3 027.9	3 140.7	3 250.3	3 468.4	3 690.0	3 917.1	4 149.8
20.0	212.4	..	..	..	2 902.4	3 025.0	3 138.6	3 248.7	3 467.3	3 689.2	3 916.5	4 149.4
22.0	217.2	..	..	..	2 893.4	3 019.3	3 134.5	3 245.5	3 465.1	3 687.6	3 915.2	4 148.4
24.0	221.8	..	..	..	2 884.2	3 013.4	3 130.4	3 242.3	3 462.9	3 685.9	3 914.0	4 147.5
26.0	226.0	..	..	..	2 874.7	3 007.4	3 126.1	3 239.0	3 460.6	3 684.3	3 912.7	4 146.6
28.0	230.0	..	..		2 864.9	3 001.3	3 121.9	3 235.8	3 458.4	3 682.6	3 911.5	4 145.6
30.0	233.8	..	..	..	2 854.8	2 995.1	3 117.5	3 232.5	3 456.2	3 681.0	3 910.3	4 144.7
32.0	237.4	..	..	..	2 844.4	2 988.7	3 113.2	3 229.2	3 454.0	3 679.3	3 909.0	4 143.8
34.0	240.9	..	..	..	2 833.6	2 982.2	3 108.7	3 225.9	3 451.7	3 677.7	3 907.8	4 142.8
36.0	244.2	..	..	..	2 822.5	2 975.6	3 104.2	3 222.5	3 449.5	3 676.1	3 906.5	4 141.9
38.0	247.3				2 811.0	2 968.9	3 099.7	3 219.1	3 447.2	3 674.4	3 905.3	4 141.0

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Specific Enthalpy of Superheated Steam

(kg/cm²)	(°C)	1000	1150	2000	2500	3000	3500	4000	5000	6000	7000	8000
2.5	127.4	..	7.169	7.400	7.604	7.789	7.960	8.119	8.410	8.674	8.917	9.142
3.0	133.5	..	7.077	7.312	7.518	7.703	7.874	8.034	8.326	8.590	8.833	9.058
3.5	138.5	..	6.998	7.237	7.444	7.631	7.802	7.962	8.254	8.518	8.761	8.986
4.0	143.6	..	6.929	7.171	7.380	7.568	7.740	7.899	8.192	8.456	8.699	8.925
4.5	147.9	..	6.866	7.112	7.323	7.512	7.684	7.844	8.137	8.402	8.645	8.870
5.0	151.8	..	..	7.059	7.272	7.461	7.634	7.795	8.088	8.353	8.596	8.821
6.0	158.8	..	..	6.966	7.183	7.374	7.548	7.709	8.003	8.268	8.511	8.737
7.0	165.0	..	..	6.886	7.107	7.300	7.475	7.636	7.931	8.196	8.440	8.665
8.0	170.4	..	..	6.815	7.040	7.235	7.411	7.573	7.868	8.134	8.377	8.603
9.0	175.4	..	..	6.751	6.980	7.177	7.354	7.517	7.812	8.079	8.323	8.549
10.0	179.9	..	..	6.692	6.926	7.125	7.303	7.467	7.763	8.029	8.273	8.500
11.0	184.1	..	..	6.638	6.876	7.078	7.257	7.421	7.718	7.985	8.229	8.455
12.0	188.0	..	..	6.587	6.831	7.034	7.214	7.379	7.677	7.944	8.188	8.415
13.0	191.6	..	..	6.539	6.788	6.994	7.175	7.340	7.639	7.906	8.151	8.378
14.0	195.0	..	..	6.494	6.748	6.956	7.139	7.305	7.603	7.871	8.116	8.343
15.0	198.3	..	..	6.451	6.710	6.921	7.104	7.271	7.570	7.839	8.084	8.311
16.0	201.4	..	..	..	6.674	6.887	7.072	7.239	7.540	7.808	8.054	8.281
17.0	204.3	..	..	..	6.640	6.856	7.042	7.210	7.511	7.779	8.025	8.252
18.0	207.1	..	..	..	6.607	6.826	7.013	7.182	7.483	7.752	7.998	8.226
19.0	209.8	..	..	..	6.576	6.797	7.986	7.155	7.457	7.727	7.973	8.200
20.0	212.4	..	..	..	6.545	6.770	6.960	7.130	7.432	7.702	7.949	8.176
22.0	217.2	..	..	..	6.488	6.718	6.911	7.082	7.386	7.657	7.904	8.132
24.0	221.8	..	..	..	6.434	6.670	6.866	7.038	7.344	7.615	7.862	8.091
26.0	226.0	..	..	..	6.382	6.625	6.824	6.998	7.305	7.577	7.825	8.053
28.0	230.0	..	..		6.333	6.582	6.784	6.960	7.269	7.541	7.789	8.018
30.0	233.8	..	..	..	6.286	6.542	6.747	6.925	7.235	7.508	7.756	7.986
32.0	237.4	..	..	..	6.240	6.504	6.712	6.891	7.203	7.477	7.726	7.955
34.0	240.9	..	..	..	6.195	6.467	6.679	6.860	7.172	7.447	7.697	7.927
36.0	244.2	..	..	..	6.151	6.432	6.647	6.829	7.144	7.420	7.669	7.900
38.0	247.3	..	..	..	6.109	6.397	6.616	6.801	7.117	7.393	7.643	7.874