AHMEDABAD UNIVERSITY
School of Engineering and Applied Science
2025-2026 Monsoon

MEC 303 Thermal Energy Systems
End-Term Examination
Friday 05 December 2025. 17:00 - 20:00

Name:	Roll no.	A U 2	Marks /50

Attach this sheet to the answer book and then submit it. Answer all questions. Open book. Open notes. Access to the net is not allowed. Only calculators are allowed. Use of any other electronic devices, mobile calculator, and accessing the net is not permitted. Use property data and make appropriate assumptions wherever required, and clearly state them. The gas constant of air is R = 0.287 kJ/kg·K, and k=1.4. Irrelevant writing will be penalized

Q.1. The Airbus A-340 passenger plane has a maximum takeoff weight of about 260,000 kg, a length of 64 m, a wingspan of 60 m, a maximum cruising speed of 945 km/h, a seating capacity of 271 passengers, a maximum cruising altitude of 14,000 m, and a maximum range of 12,000 km. The air temperature at the cruising altitude is about –60°C. Determine the Mach number of this plane for the stated limiting conditions. (2 marks)

Q.2. In which medium does a sound wave travel faster: in cool air or in warm air? Give a brief explanation supporting your answer (1 Mark)

Q.3. A converging nozzle has an exit area of 0.001 m^2. Air enters the nozzle with negligible velocity at a pressure of 1.0 MPa and a temperature of 360 K. For isentropic flow of an ideal gas with k = 1.4, determine the mass flow rate, in kg/s, and the exit Mach number for back pressures of (a) 500 kPa and (b) 784 kPa. (7 mark)

Q.4. Determine the enthalpy of combustion of methane (CH_4) at 25°C and 1 atm, using the enthalpy of formation data from the property table. Assume that the water in the products is in liquid form. (4 Mark)

Q.5. What are the higher and the lower heating values of a fuel? How is the heating value of a fuel related to the enthalpy of combustion of that fuel? (1 Mark)

Q.6. Air enters a window air conditioner at 1 atm, 30°C, and 80 percent relative humidity at a rate of 10 m^3/min, and it leaves as saturated air at 14°C. Part of the moisture in the air that condenses during the process is also removed at 14°C. Determine the rates of heat and moisture removal from the air. (4 Mark)

Q.7 Is it possible to obtain saturated air from unsaturated air without adding any moisture? Explain. briefly (1 Mark)

Q.8. (a) A gas mixture initially composed of 1 kmol H_2O and 2 kmol of oxygen (O_2) is subjected to high-temperature conditions in a combustion chamber, where it is heated to 4000 K at 1 atm. Under these extreme thermal conditions, dissociation reactions become significant. Determine the equilibrium composition of this mixture, assuming that only H_2O, OH, O_2, and H_2 are present (5 Mark)

(b) Determine the equilibrium constant K_P for the reaction $CH_4 + 2O_2 \leftrightarrow CO_2 + 2H_2O$ at 25°C. Universal gas constant 8.314 kJ/kmol (3 Mark)

(c) Explain when a reaction achieves a chemical equilibrium using the concept of Gibbs free energy. Why can a reaction not proceed in the direction of increasing Gibbs function? (2 Mark)

Q.9. (a) For a hydrogen fuel cell, Gibbs free energy is provided by the manufacturer. Explain how I can estimate the electrical work of the given hydrogen fuel cell. (3 Marks)

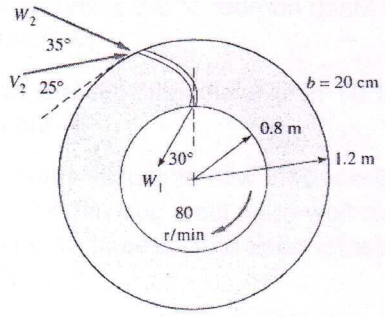
(b) A company is installing a portable weather monitoring station. Given the availability of methanol in nearby areas, engineers opted to utilize a direct methanol fuel cell, which operates on methanol as its fuel. For this fuel cell, considering 6 moles of electrons transferred and F is Faraday's constant 96500 C/mol. Calculate the following (3 Mark)

(a) Δh°_{rxn}, Δs°_{rxn}, Δg°_{rxn} (b) Standard reversible voltage

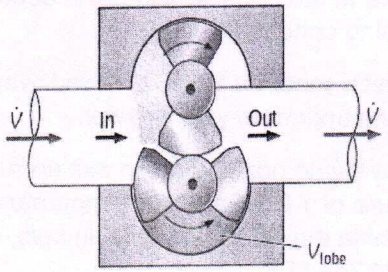
$CH_3OH + 3/2\ O_2 \rightarrow CO_2 + 2H_2O_{(liq)}$

Chemical Species	Δh°_f (kJ/mol)	s°(J/mol.K)
CH3OH	-200.95	239.83
O2	0	205.14
CO2	-393.51	213.8
$H_2O_{(liq)}$	-285.83	69.95

(c) An idealized radial turbine is shown in the following figure (Fig 1a). The absolute flow enters at 25° with the blade angles as shown. The flow rate is 8 m^3/s of water at 20°C. The blade thickness is constant at 20 cm. Compute the theoretical power developed. (density 998 kg/m^3) (4 Mark)



(Fig1a)

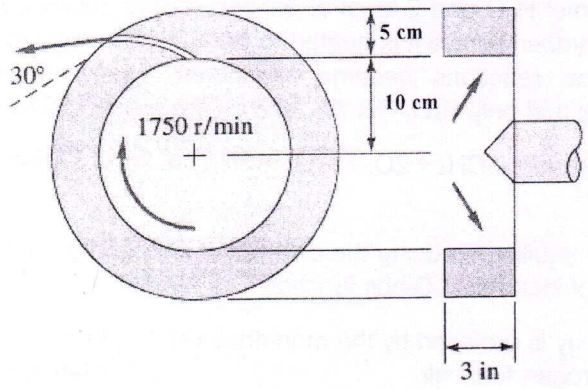


(Fig 1b)

Q.10. (a) What is the more common term for an energy producing turbomachine? How about an energy-absorbing turbomachine? Explain this terminology. In particular, from which frame of reference are these terms defined, that of the fluid or that of the surroundings? (2 Mark)

(b) Explain the classification of the pump briefly. A two-lobe rotary positive-displacement pump (Fig. b), moves 0.45 cm^3 of SAE 30 motor oil in each lobe volume, Calculate the volume flow rate of oil for the case where n= 900 rpm. (3 Mark)

(c) The centrifugal pump in following figure (Fig. 2) develops a flow rate of 16 m^3/min with gasoline at 20°C and near-radial absolute inflow. Estimate the theoretical (a) power; (b) head rise; and (c) appropriate blade angle at the inner radius. (Take density of gasoline =680 kg/m^3) (5 Mark)



(Fig. 2)

Natural logarithms of the equilibrium constant K_p

The equilibrium constant K_p for the reaction $\nu_A A + \nu_B B \rightleftharpoons \nu_C C + \nu_D D$ is defined as $K_p \equiv \frac{P_C^{\nu_C} P_D^{\nu_D}}{P_A^{\nu_A} P_B^{\nu_B}}$

Temp., K	$H_2 \rightleftharpoons 2H$	$O_2 \rightleftharpoons 2O$	$N_2 \rightleftharpoons 2N$	$H_2O \rightleftharpoons H_2 + \frac{1}{2}O_2$	$H_2O \rightleftharpoons \frac{1}{2}H_2 + OH$	$CO_2 \rightleftharpoons CO + \frac{1}{2}O_2$	$\frac{1}{2}N_2 + \frac{1}{2}O_2 \rightleftharpoons NO$
298	−164.005	−186.975	−367.480	−92.208	−106.208	−103.762	−35.052
500	−92.827	−105.630	−213.372	−52.691	−60.281	−57.616	−20.295
1000	−39.803	−45.150	−99.127	−23.163	−26.034	−23.529	−9.388
1200	−30.874	−35.005	−80.011	−18.182	−20.283	−17.871	−7.569
1400	−24.463	−27.742	−66.329	−14.609	−16.099	−13.842	−6.270
1600	−19.637	−22.285	−56.055	−11.921	−13.066	−10.830	−5.294
1800	−15.866	−18.030	−48.051	−9.826	−10.657	−8.497	−4.536
2000	−12.840	−14.622	−41.645	−8.145	−8.728	−6.635	−3.931
2200	−10.353	−11.827	−36.391	−6.768	−7.148	−5.120	−3.433
2400	−8.276	−9.497	−32.011	−5.619	−5.832	−3.860	−3.019
2600	−6.517	−7.521	−28.304	−4.648	−4.719	−2.801	−2.671
2800	−5.002	−5.826	−25.117	−3.812	−3.763	−1.894	−2.372
3000	−3.685	−4.357	−22.359	−3.086	−2.937	−1.111	−2.114
3200	−2.534	−3.072	−19.937	−2.451	−2.212	−0.429	−1.888
3400	−1.516	−1.935	−17.800	−1.891	−1.576	0.169	−1.690
3600	−0.609	−0.926	−15.898	−1.392	−1.088	0.701	−1.513
3800	0.202	−0.019	−14.199	−0.945	−0.501	1.176	−1.356
4000	0.934	0.796	−12.660	−0.542	−0.044	1.599	−1.216
4500	2.486	2.513	−9.414	0.312	0.920	2.490	−0.921
5000	3.725	3.895	−6.807	0.996	1.689	3.197	−0.686
5500	4.743	5.023	−4.666	1.560	2.318	3.771	−0.497
6000	5.590	5.963	−2.865	2.032	2.843	4.245	−0.341

Source: Gordon J. Van Wylen and Richard E. Sonntag, *Fundamentals of Classical Thermodynamics*, English/SI Version, 3rd ed. (New York: John Wiley & Sons, 1986), p. 723, table A.14. Based on thermodynamic data given in JANAF, *Thermochemical Tables* (Midland, MI: Thermal Research Laboratory, The Dow Chemical Company, 1971).

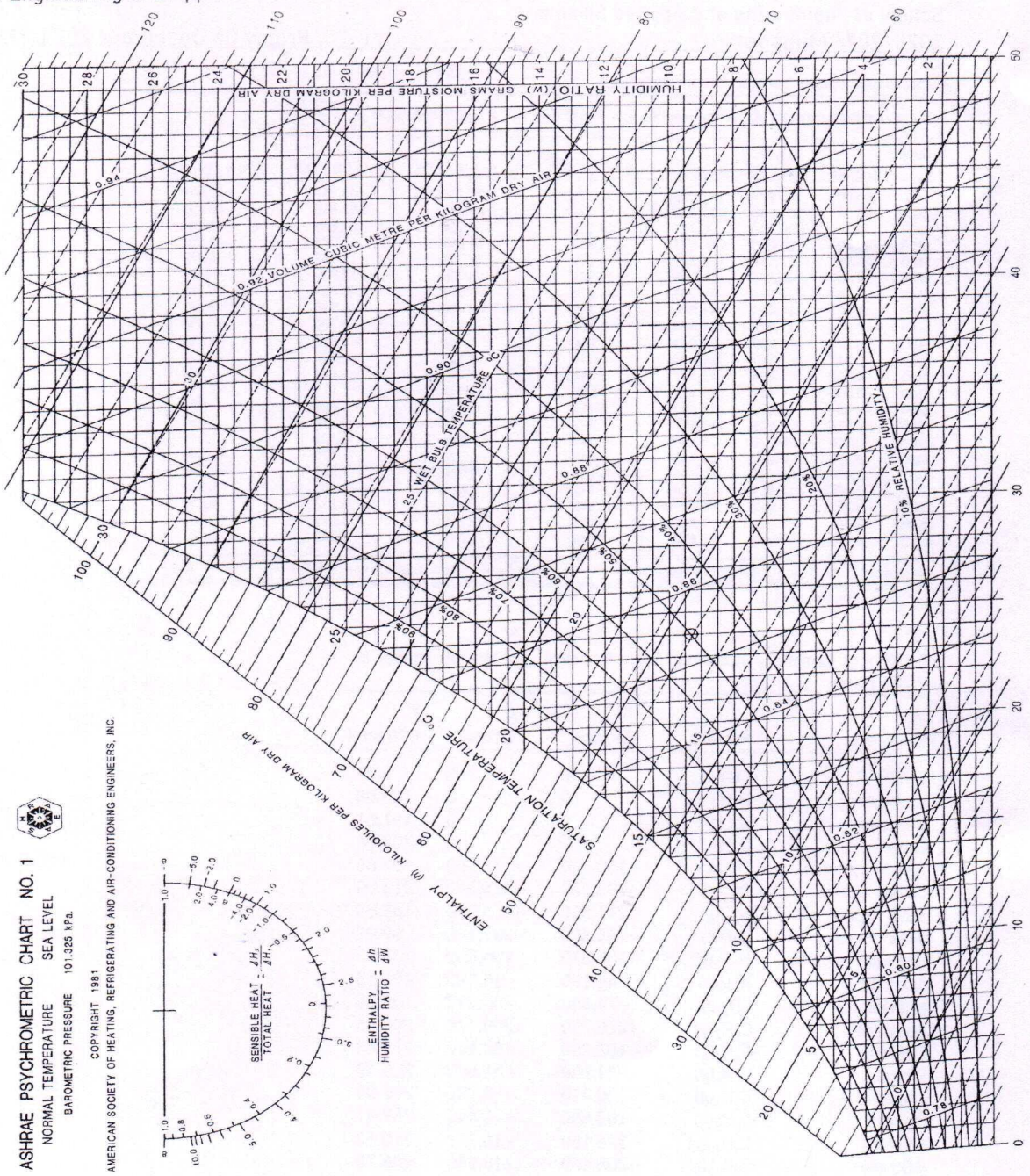
Enthalpy of formation, Gibbs function of formation, and absolute entropy at 25°C, 1 atm

Substance	Formula	$\bar{h}_f^\circ$ kJ/kmol	$\bar{g}_f^\circ$ kJ/kmol	$\bar{s}^\circ$ kJ/kmol·K
Carbon	$C(s)$	0	0	5.74
Hydrogen	$H_2(g)$	0	0	130.68
Nitrogen	$N_2(g)$	0	0	191.61
Oxygen	$O_2(g)$	0	0	205.04
Carbon monoxide	$CO(g)$	−110,530	−137,150	197.65
Carbon dioxide	$CO_2(g)$	−393,520	−394,360	213.80
Water vapor	$H_2O(g)$	−241,820	−228,590	188.83
Water	$H_2O(\ell)$	−285,830	−237,180	69.92
Hydrogen peroxide	$H_2O_2(g)$	−136,310	−105,600	232.63
Ammonia	$NH_3(g)$	−46,190	−16,590	192.33
Methane	$CH_4(g)$	−74,850	−50,790	186.16
Acetylene	$C_2H_2(g)$	+226,730	+209,170	200.85
Ethylene	$C_2H_4(g)$	+52,280	+68,120	219.83
Ethane	$C_2H_6(g)$	−84,680	−32,890	229.49
Propylene	$C_3H_6(g)$	+20,410	+62,720	266.94
Propane	$C_3H_8(g)$	−103,850	−23,490	269.91
n-Butane	$C_4H_{10}(g)$	−126,150	−15,710	310.12
n-Octane	$C_8H_{18}(g)$	−208,450	+16,530	466.73
n-Octane	$C_8H_{18}(\ell)$	−249,950	+6,610	360.79
n-Dodecane	$C_{12}H_{26}(g)$	−291,010	+50,150	622.83
Benzene	$C_6H_6(g)$	+82,930	+129,660	269.20
Methyl alcohol	$CH_3OH(g)$	−200,670	−162,000	239.70
Methyl alcohol	$CH_3OH(\ell)$	−238,660	−166,360	126.80
Ethyl alcohol	$C_2H_5OH(g)$	−235,310	−168,570	282.59
Ethyl alcohol	$C_2H_5OH(\ell)$	−277,690	−174,890	160.70
Oxygen	$O(g)$	+249,190	+231,770	161.06
Hydrogen	$H(g)$	+218,000	+203,290	114.72
Nitrogen	$N(g)$	+472,650	+455,510	153.30
Hydroxyl	$OH(g)$	+39,460	+34,280	183.70

Source: From JANAF, *Thermochemical Tables* (Midland, MI: Dow Chemical Co., 1971); *Selected Values of Chemical Thermodynamic Properties*, NBS Technical Note 270-3, 1968; and *API Research Project 44* (Carnegie Press, 1953).

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ASHRAE PSYCHROMETRIC CHART NO. 1
NORMAL TEMPERATURE SEA LEVEL
BAROMETRIC PRESSURE 101.325 kPa.

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