Program: B. Sc. in Electrical & Electronic Engineering
Semester: 3rd

Date: 9 December, 2023
Time: 1:30 pm – 4:30 pm

ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)
ORGANISATION OF ISLAMIC COOPERATION (OIC)
DEPARTMENT OF MECHANICAL AND PRODUCTION ENGINEERING

Semester Final Examination
Course Number: MCE 4391
Course Title: Basic Mechanical Engineering (EEE)

Winter Semester: 2022 - 2023
Full Marks: 150
Time: 3 Hours

There are **six** questions. Answer **all the** questions. The symbols have their usual meanings. Marks of each question are mentioned with the questions and corresponding CO and PO and the total marks are written on the right side. Assume reasonable value of missing data.

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1. a) A refrigerator uses refrigerant-134a as the working fluid and operates on an ideal vapor-compression refrigeration cycle between 0.2 MPa and 0.5 MPa. The mass flow rate of the refrigerant is 0.08 kg/s. **25 (CO2) (PO2)**

(i) **Illustrate** the system diagram along with P-h diagram. **(3 marks)**
(ii) **Briefly explain** the function of the components of the system. **(5 marks)**
Determine the followings:
(iii) **Enthalpy** at all points. **(4 marks)**
(iv) The **rate of heat removal** from the refrigerated space. **(2 marks)**
(v) The **power input** to the compressor. **(2 marks)**
(vi) The **rate of heat rejection** to the environment. **(2 marks)**
(vii) The **COP** of the refrigerator. **(2 marks)**

b) **Derive** mathematical relation between COP of refrigeration and heat pump system **(5 marks)**

2. a) (i) **Describe** how steam is formed and illustrate the effect of increasing and decreasing pressure on the process using P-v diagram. Identify different lines and points from the P-v diagram. **(5 marks)** **25 (CO4) (PO1)**

(ii) **Find the properties** of steam mentioned below, under the following conditions using the steam table:
a. Saturation temperature at 160 kPa. **(2 mark)**
b. Saturation pressure at 150^0C. **(1 mark)**
c. At saturated condition, T=120^0C and h = 2500 kJ/Kg find the dryness fraction. **(2 marks)**
d. At superheated condition, P=16 MPa and T=600^0C find the enthalpy. **(2 mark)**

b) (i) **Discuss the working principle** of boiler through the **illustration** of simple diagram. **(5 marks)**

(ii) Write a **short note** on boiler mountings and accessories. **(4 marks)**

(iii) Explain **any two** of the following terms briefly: **(4 marks)**

a. Superheater.
b. Water level indicator.
c. Manhole.
d. Economizer

3. a) (i) **Define vapor pressure** and **cavitation**. **(4 marks)** **25**

(ii) **Classify** different types of **fluid flow**. **(5 marks)** **(CO5)**

(iii) **Differentiate** between **Newtonian fluid** and **non-Newtonian fluid**. **(3 marks)** **(PO1)**

(iv) **Explain** the reason why viscosity of liquids decreases, and the viscosity of gases increases with temperature. **(3 marks)** **(PO2)**

b) A piezometer and a Pitot tube are tapped into a 40-mm diameter horizontal water pipe, and the height of the water columns are measured to be 0.26 m in the piezometer and 350 mm in the Pitot tube (both measured from the top surface of the pipe).

(i) **Draw** the setup described above. **(2 marks)**

(ii) **Determine** the velocity at the center of the pipe. **(3 marks)**

c) The pressure difference between an oil pipe and waterpipe is measured by a double-fluid manometer, as shown in **Fig.1**. For the given fluid heights and specific gravities, calculate the pressure difference $\Delta P = P_B - P_A$. **(5 marks)**

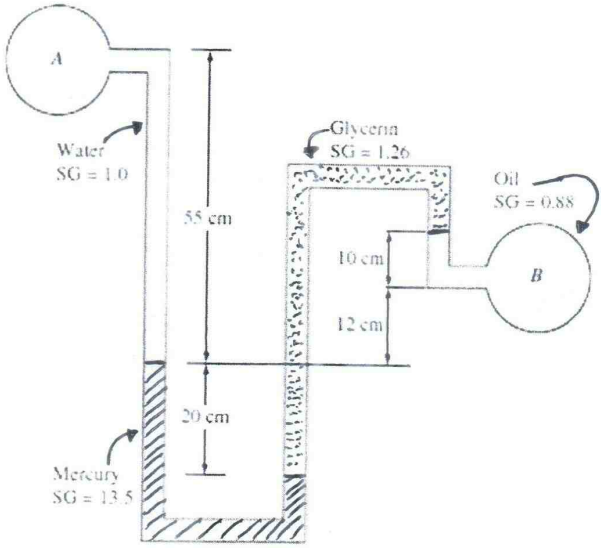

Fig.1

4 a) **Illustrate** the construction details of an IC engine. **(4 marks)** **25 (CO3) (PO1)**

b) **Illustrate** the engine terminologies in a single diagram and explain them briefly. **(8 marks)**

c) (i) **Illustrate and explain** the working principle of a two-stroke engine. **(7 marks)**

(ii) **Illustrate and explain** briefly, **any three** from the following terms: **(6 marks)**

a. Cylinder block and Cylinder liner
b. Piston and Crankcase
c. Connecting Rod and Crankshaft
d. Intake and exhaust valve, Cylinder Head

5 a) (i) **Define priming** and its necessity in centrifugal pump. **(3 marks)** **25 (CO5) (PO1)**

(ii) **Differentiate** between **pump, fan, blower,** and **compressor** in a tabular format. **(4 marks)**

b) **Illustrate** the components of a **hydroelectric powerplant** and explain briefly. **(6 marks)**

c) (i) **State** a side-by-side comparison between **impulse** and **reaction turbine**. **(4 marks)**

(ii) **Illustrate** a **Pelton wheel**, **Francis** and **Kaplan** turbine with proper labelling and explain them briefly. **(8 marks)**

6 a) In a piston cylinder arrangement, a gas of with volume 0.192 m^3 is compressed with compression ratio of 13.5 using the law $pv^{1.37}=C$. At the beginning of the compression, the state of working fluid is 1 bar and 316 K. **25 (CO2) (PO2)**

[R=289 J/kg.K, Cp = 0.996 kJ/kg.K]

a. **Identify and illustrate** the process through P-v diagram. **(1 marks)**
b. **Determine** the mass of the working fluid. **(1 marks)**
c. **Determine** temperature, pressure, and volume at the end of the compression. **(3 marks)**

b) **State and elaborate** the Clausius and Kelvin-Planck statements and discuss the perpetual motion machine of second kind based on those statements. **(5 marks)**

c) An ideal otto cycle has a compression ratio of 8 using 1 kg of air. At the beginning of the compression process, air is at 100 kPa and 17^0C. 800 kJ/kg heat is transferred to air during the constant-volume heat addition process. (Take R=0.287 kJ/kg.K, C_p = 1.001 kJ/kg.K and C_v = 0.707 kJ/kg.K)

(i) **Illustrate** the P-v and T-s diagram of the above-mentioned cycle and identify the processes. **(4 marks)**

(ii) **Find** T, P and V at each state. **(8 marks)**

(iii) **Calculate** the W_{in}. **(2 marks)**

(iv) **Calculate** the thermal efficiency of the system. **(1 marks)**

Saturated Water-Pressure Table

TABLE A–5

Saturated water—Pressure table

		Specific volume, m³/kg		Internal energy, kJ/kg			Enthalpy, kJ/kg			Entropy, kJ/kg·K		
Press., P kPa	Sat. temp., T_{sat} °C	Sat. liquid, v_f	Sat. vapor, v_g	Sat. liquid, u_f	Evap., u_{fg}	Sat. vapor, u_g	Sat. liquid, h_f	Evap., h_{fg}	Sat. vapor, h_g	Sat. liquid, s_f	Evap., s_{fg}	Sat. vapor, s_g
20	60.06	0.001017	7.6481	251.40	2204.6	2456.0	251.42	2357.5	2608.9	0.8320	7.0752	7.9073
25	64.96	0.001020	6.2034	271.93	2190.4	2462.4	271.96	2345.5	2617.5	0.8932	6.9370	7.8302
30	69.09	0.001022	5.2287	289.24	2178.5	2467.7	289.27	2335.3	2624.6	0.9441	6.8234	7.7675
40	75.86	0.001026	3.9933	317.58	2158.8	2476.3	317.62	2318.4	2636.1	1.0261	6.6430	7.6691
50	81.32	0.001030	3.2403	340.49	2142.7	2483.2	340.54	2304.7	2645.2	1.0912	6.5019	7.5931
75	91.76	0.001037	2.2172	384.36	2111.8	2496.1	384.44	2278.0	2662.4	1.2132	6.2426	7.4558
100	99.61	0.001043	1.6941	417.40	2088.2	2505.6	417.51	2257.5	2675.0	1.3028	6.0562	7.3589
101.325	99.97	0.001043	1.6734	418.95	2087.0	2506.0	419.06	2256.5	2675.6	1.3069	6.0476	7.3545
125	105.97	0.001048	1.3750	444.23	2068.8	2513.0	444.36	2240.6	2684.9	1.3741	5.9100	7.2841
150	111.35	0.001053	1.1594	466.97	2052.3	2519.2	467.13	2226.0	2693.1	1.4337	5.7894	7.2231
175	116.04	0.001057	1.0037	486.82	2037.7	2524.5	487.01	2213.1	2700.2	1.4850	5.6865	7.1716
200	120.21	0.001061	0.88578	504.50	2024.6	2529.1	504.71	2201.6	2706.3	1.5302	5.5968	7.1270
225	123.97	0.001064	0.79329	520.47	2012.7	2533.2	520.71	2191.0	2711.7	1.5706	5.5171	7.0877
250	127.41	0.001067	0.71873	535.08	2001.8	2536.8	535.35	2181.2	2716.5	1.6072	5.4453	7.0525
275	130.58	0.001070	0.65732	548.57	1991.6	2540.1	548.86	2172.0	2720.9	1.6408	5.3800	7.0207

Saturated Water-Temperature Table

TABLE A–4

Saturated water—Temperature table

		Specific volume, m³/kg		Internal energy, kJ/kg			Enthalpy, kJ/kg			Entropy, kJ/kg·K		
Temp., T °C	Sat. press., P_{sat} kPa	Sat. liquid, v_f	Sat. vapor, v_g	Sat. liquid, u_f	Evap., u_{fg}	Sat. vapor, u_g	Sat. liquid, h_f	Evap., h_{fg}	Sat. vapor, h_g	Sat. liquid, s_f	Evap., s_{fg}	Sat. vapor, s_g
100	101.42	0.001043	1.6720	419.06	2087.0	2506.0	419.17	2256.4	2675.6	1.3072	6.0470	7.3542
105	120.90	0.001047	1.4186	440.15	2071.8	2511.9	440.28	2243.1	2683.4	1.3634	5.9319	7.2952
110	143.38	0.001052	1.2094	461.27	2056.4	2517.7	461.42	2229.7	2691.1	1.4188	5.8193	7.2382
115	169.18	0.001056	1.0360	482.42	2040.9	2523.3	482.59	2216.0	2698.6	1.4737	5.7092	7.1829
120	198.67	0.001060	0.89133	503.60	2025.3	2528.9	503.81	2202.1	2706.0	1.5279	5.6013	7.1292
125	232.23	0.001065	0.77012	524.83	2009.5	2534.3	525.07	2188.1	2713.1	1.5816	5.4956	7.0771
130	270.28	0.001070	0.66808	546.10	1993.4	2539.5	546.38	2173.7	2720.1	1.6346	5.3919	7.0265
135	313.22	0.001075	0.58179	567.41	1977.3	2544.7	567.75	2159.1	2726.9	1.6872	5.2901	6.9773
140	361.53	0.001080	0.50850	588.77	1960.9	2549.6	589.16	2144.3	2733.5	1.7392	5.1901	6.9294
145	415.68	0.001085	0.44600	610.19	1944.2	2554.4	610.64	2129.2	2739.8	1.7908	5.0919	6.8827
150	476.16	0.001091	0.39248	631.66	1927.4	2559.1	632.18	2113.8	2745.9	1.8418	4.9953	6.8371
155	543.49	0.001096	0.34648	653.19	1910.3	2563.5	653.79	2098.0	2751.8	1.8924	4.9002	6.7927
160	618.23	0.001102	0.30680	674.79	1893.0	2567.8	675.47	2082.0	2757.5	1.9426	4.8066	6.7492
165	700.93	0.001108	0.27244	696.46	1875.4	2571.9	697.24	2065.6	2762.8	1.9923	4.7143	6.7067
170	792.18	0.001114	0.24260	718.20	1857.5	2575.7	719.08	2048.8	2767.9	2.0417	4.6233	6.6650

Superheated Water

TABLE A–6

Superheated water (*Concluded*)

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg·K	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg·K	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg·K
	P = 15.0 MPa (342.16°C)				P = 17.5 MPa (354.67°C)				P = 20.0 MPa (365.75°C)			
Sat.	0.010341	2455.7	2610.8	5.3108	0.007932	2390.7	2529.5	5.1435	0.005862	2294.8	2412.1	4.9310
350	0.011481	2520.9	2693.1	5.4438								
400	0.015671	2740.6	2975.7	5.8819	0.012463	2684.3	2902.4	5.7211	0.009950	2617.9	2816.9	5.5526
450	0.018477	2880.8	3157.9	6.1434	0.015204	2845.4	3111.4	6.0212	0.012721	2807.3	3061.7	5.9043
500	0.020828	2998.4	3310.8	6.3480	0.017385	2972.4	3276.7	6.2424	0.014793	2945.3	3241.2	6.1446
550	0.022945	3106.2	3450.4	6.5230	0.019305	3085.8	3423.6	6.4266	0.016571	3064.7	3396.2	6.3390
600	0.024921	3209.3	3583.1	6.6796	0.021073	3192.5	3561.3	6.5890	0.018185	3175.3	3539.0	6.5075
650	0.026804	3310.1	3712.1	6.8233	0.022742	3295.8	3693.8	6.7366	0.019695	3281.4	3675.3	6.6593
700	0.028621	3409.8	3839.1	6.9573	0.024342	3397.5	3823.5	6.8735	0.021134	3385.1	3807.8	6.7991
800	0.032121	3609.3	4091.1	7.2037	0.027405	3599.7	4079.3	7.1237	0.023870	3590.1	4067.5	7.0531
900	0.035503	3811.2	4343.7	7.4288	0.030348	3803.5	4334.6	7.3511	0.026484	3795.7	4325.4	7.2829
1000	0.038808	4017.1	4599.2	7.6378	0.033215	4010.7	4592.0	7.5616	0.029020	4004.3	4584.7	7.4950
1100	0.042062	4227.7	4858.6	7.8339	0.036029	4222.3	4852.8	7.7588	0.031504	4216.9	4847.0	7.6933
1200	0.045279	4443.1	5122.3	8.0192	0.038806	4438.5	5117.6	7.9449	0.033952	4433.8	5112.9	7.8802
1300	0.048469	4663.3	5390.3	8.1952	0.041556	4659.2	5386.5	8.1215	0.036371	4655.2	5382.7	8.0574
	P = 25.0 MPa				P = 30.0 MPa				P = 35.0 MPa			
375	0.001978	1799.9	1849.4	4.0345	0.001792	1738.1	1791.9	3.9313	0.001701	1702.8	1762.4	3.8724
400	0.006005	2428.5	2578.7	5.1400	0.002798	2068.9	2152.8	4.4758	0.002105	1914.9	1988.6	4.2144
425	0.007886	2607.8	2805.0	5.4708	0.005299	2452.9	2611.8	5.1473	0.003434	2253.3	2373.5	4.7751
450	0.009176	2721.2	2950.6	5.6759	0.006737	2618.9	2821.0	5.4422	0.004957	2497.5	2671.0	5.1946
500	0.011143	2887.3	3165.9	5.9643	0.008691	2824.0	3084.8	5.7956	0.006933	2755.3	2997.9	5.6331
550	0.012736	3020.8	3339.2	6.1816	0.010175	2974.5	3279.7	6.0403	0.008348	2925.8	3218.0	5.9093
600	0.014140	3140.0	3493.5	6.3637	0.011445	3103.4	3446.8	6.2373	0.009523	3065.6	3399.0	6.1229
650	0.015430	3251.9	3637.7	6.5243	0.012590	3221.7	3599.4	6.4074	0.010565	3190.9	3560.7	6.3030
700	0.016643	3359.9	3776.0	6.6702	0.013654	3334.3	3743.9	6.5599	0.011523	3308.3	3711.6	6.4623
800	0.018922	3570.7	4043.8	6.9322	0.015628	3551.2	4020.0	6.8301	0.013278	3531.6	3996.3	6.7409
900	0.021075	3780.2	4307.1	7.1668	0.017473	3764.6	4288.8	7.0695	0.014904	3749.0	4270.6	6.9853

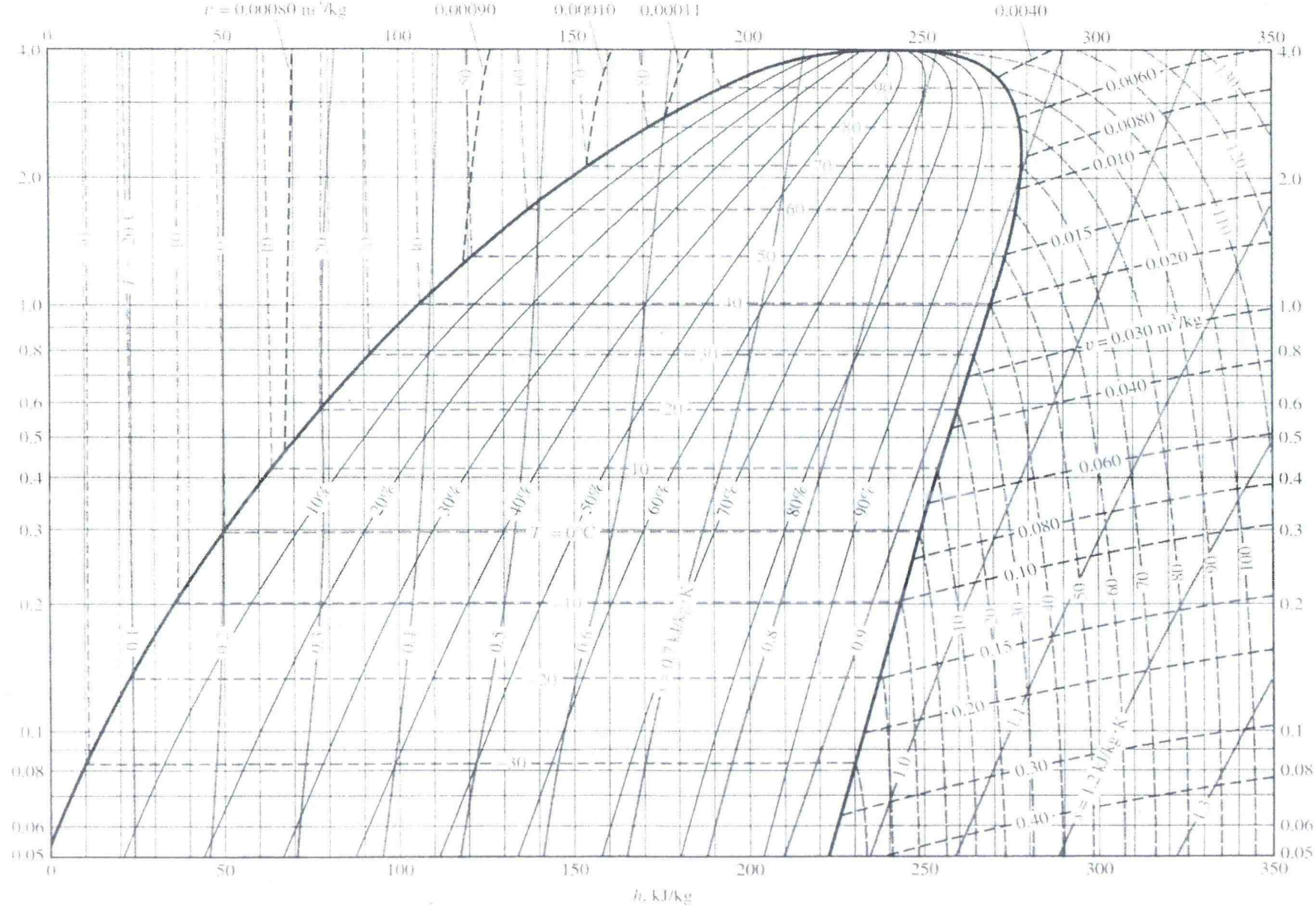

Chart A-11 R134a *ph* diagram. (*Source:* Based on *Thermodynamic Properties of HFC-134a (1,1,1, 2-tetrafluoroethane)*, DuPont Company, Wilmington, Delaware, 1993, with permission.)