



UNIVERSITY OF GHANA
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B.Sc ENGINEERING FIRST SEMESTER EXAMINATION: 2018/2019

SCHOOL OF ENGINEERING SCIENCES

FAEN 205: THERMODYNAMICS I (3 credits)

INSTRUCTIONS

TIME ALLOWED: 2HRS

Please read the following INSTRUCTIONS carefully

- [1] Answer TWO questions in SECTION A
- [2] Answers to SECTION A must be written in an Answer Booklet
- [3] Answer ALL questions in SECTION B
- [4] Answers to SECTION B must be written on the question paper
- [5] Write your STUDENT ID NUMBER on all the applicable question sheets and tie them inside the Answer Booklet

SECTION A**Answer TWO questions in this Section**

1. Saturated-vapour steam at 125 kPa is compressed adiabatically in a centrifugal compressor to 750 kPa at the rate of 2.5 kg/s. The compressor efficiency is 70%. What is
 - a) the actual power requirement of the compressor
 - b) the final temperature of the steam?
 - c) the enthalpy of the steam in its final state?

Steam tables have been provided.

2. A pump operates adiabatically with liquid water entering at T_1 and P_1 with a mass flowrate \dot{m} . The discharge pressure is P_2 , and the pump efficiency is 0.75. For the following set of operating conditions, determine:
 - a) the power requirement of the pump and
 - b) the temperature of the water discharged from the pump:

Data:

$$T_1 = 50^\circ\text{C}$$

$$P_1 = 100 \text{ kPa}$$

$$\dot{m} = 20 \text{ kg/s}$$

$$P_2 = 2,500 \text{ kPa}$$

Properties of saturated liquid water at 50°C :

$$V = 1,010 \text{ cm}^3/\text{kg}; C_p = 4.178 \text{ kJ/kg}\cdot\text{K}; \beta = 257.2 \times 10^{-6} \text{ K}^{-1}$$

3. a) Find the work done when 1 mol of gas goes through a reversible, isothermal compression at 425°C and 1 bar in a piston/cylinder assembly, if the molar volume of the gas is given by

$$V = \frac{RT}{P} + b$$

and b and R are given by:

$$b = 0.1 \text{ V cm}^3 \text{ mol}^{-1}$$

$$R = 83.14 \text{ cm}^3 \text{ bar/mol K}$$

Take the final volume to be half the initial volume.

- b) Steam at 200 psia and 600°F (state 1) enters a turbine through a 4-in diameter pipe with a velocity of 9 ft/s. The exhaust from the turbine is carried through a 10-in diameter pipe and is at 5 psia and 250°F (state 2). What is the power output of the turbine Btu/s?

$$\text{Data: } H_1 = 1,300 \text{ Btu/lb}_m; H_2 = 1,150 \text{ Btu/lb}_m$$

$$V_1 = 3.06 \text{ ft}^3/\text{lb}_m; V_2 = 80.0 \text{ ft}^3/\text{lb}_m$$

$$g_c = 32.174 (\text{lb}_m)(\text{ft})/(\text{lb}_f)(\text{s}^2); \text{Btu} = 778.2 (\text{ft})(\text{lb}_f)$$

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SECTION B:

Answer ALL questions in this Section

1. Write down an equation for the first law of thermodynamics for a closed system

2. What state function is introduced by the first law of thermodynamics?

3. Write down the defining expression for compressibility factor, Z :

4. Write down the first law for flow systems:

5. Write down the defining equation for enthalpy in terms of internal energy U , pressure P and volume V :

6. If the heat capacity of gas is $20.78 \text{ J mol}^{-1} \text{ K}^{-1}$, what is the enthalpy change if 3 moles go from 70°C to 120°C ?

7. Write down the phase rule. Define the terms.

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8. Using the phase rule calculate the degrees of freedom of water as a saturated vapour?

8. If an ideal gas at 1 bar and 50°C is compressed to 4 bar at the same temperature, calculate the change in internal energy U , if the heat capacity at constant volume, C_v is given by 20.8 J/mol-K

9. State the mathematical definition of the Second law of Thermodynamics.

10. Write down the energy balance equation for steady-state flow processes for one entrance and one exit

11. What state function is introduced as a result of the second law of thermodynamics?

12. Write down the first three terms of the virial equation of state in terms of pressure.

13. On a PV diagram, the critical isotherm exhibits a horizontal inflection at the critical point, leading to two derivative expressions. Write them down.

14. Write down the celebrated van der Waals equation of state.

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15. The principle that correlates reduced temperature T_r and reduced pressure P_r of gases to their compressibility factor Z , is known as?

16. Write down the generalized expression for the compressibility factor in terms of Z^0 , Z^1 and acentric factor ω :

$$Z =$$

17. Write down the equation relating the heat capacities, C_v and C_p with the universal gas constant R for an ideal gas

18. If the hot and cold reservoir temperatures of a Carnot cycle are 500°C and 100°C respectively, what is the efficiency of the cycle?

19. If a Carnot cycle taken in 80,000 kW of energy and discards 15,000 kW to a cold reservoir, what is the thermal efficiency?

20. Write down the Maxwell relation resulting from the following fundamental property relation: $dG = VdP - SdT$

21. Name two intensive variables in thermodynamics?

a)

b)

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22. Write down the defining expression for the residual property of a generic thermodynamic function M . What is the residual enthalpy of an ideal gas, H^R ?

23. State two methods for calculating residual properties of a gas

a)

b)

24. Write down the names of two cubic equations of state:

a)

b)

25. If the enthalpy of the saturated-liquid and saturated-vapour of a system coexisting in equilibrium are 450 kJ/kg and 2,700 kJ/kg what is the enthalpy of vapour-liquid mixture with a quality of 0.4.

26. If a process takes place reversibly and adiabatically in a system of 2kg mass, and the temperature changes from 100°C to 300°C, what is the change in its entropy ΔS ?

27. Write down the defining equation for the efficiency of a turbine, in terms of enthalpies:

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28. Sketch the reversible and irreversible paths for a compressor on a Mollier (H-S) diagram.

29. On a T-S diagram, draw the four steps of a Carnot cycle.

30. On a T-S diagram, draw the stages of a Rankine cycle.

Table F.1: Saturated Steam, SI Units

V = SPECIFIC VOLUME $\text{cm}^3 \text{g}^{-1}$
 U = SPECIFIC INTERNAL ENERGY kJ kg^{-1}
 H = SPECIFIC ENTHALPY kJ kg^{-1}
 S = SPECIFIC ENTROPY $\text{kJ kg}^{-1} \text{K}^{-1}$

t $^{\circ}\text{C}$	T K	P kPa	SPECIFIC VOLUME V			INTERNAL ENERGY U			ENTHALPY H			ENTROPY S		
			sat. liq.	evap.	sat. vap.	sat. liq.	evap.	sat. vap.	sat. liq.	evap.	sat. vap.	sat. liq.	evap.	sat. vap.
0	273.15	0.611	1.000	206300.	206300.	-0.04	2375.7	2375.6	-0.04	2501.7	2501.6	0.0000	9.1578	9.1578
0.01	273.16	0.611	1.000	206200.	206200.	0.00	2375.6	2375.6	0.00	2501.6	2501.6	0.0000	9.1575	9.1575
1	274.15	0.657	1.000	192600.	192600.	4.17	2372.7	2376.9	4.17	2499.2	2503.4	0.0153	9.1158	9.1311
2	275.15	0.705	1.000	179900.	179900.	8.39	2369.9	2378.3	8.39	2496.8	2505.2	0.0306	9.0741	9.1047
3	276.15	0.757	1.000	168200.	168200.	12.60	2367.1	2379.7	12.60	2494.5	2507.1	0.0459	9.0326	9.0785
4	277.15	0.813	1.000	157300.	157300.	16.80	2364.3	2381.1	16.80	2492.1	2508.9	0.0611	8.9915	9.0526
5	278.15	0.872	1.000	147200.	147200.	21.01	2361.4	2382.4	21.01	2489.7	2510.7	0.0762	8.9507	9.0269
6	279.15	0.935	1.000	137800.	137800.	25.21	2358.6	2383.8	25.21	2487.4	2512.6	0.0913	8.9102	9.0014
7	280.15	1.001	1.000	129100.	129100.	29.41	2355.8	2385.2	29.41	2485.0	2514.4	0.1063	8.8699	8.9762
8	281.15	1.072	1.000	121000.	121000.	33.60	2353.0	2386.6	33.60	2482.6	2516.2	0.1213	8.8300	8.9513
9	282.15	1.147	1.000	113400.	113400.	37.80	2350.1	2387.9	37.80	2480.3	2518.1	0.1362	8.7903	8.9265
10	283.15	1.227	1.000	106400.	106400.	41.99	2347.3	2389.3	41.99	2477.9	2519.9	0.1510	8.7510	8.9020
11	284.15	1.312	1.000	99910.	99910.	46.18	2344.5	2390.7	46.19	2475.5	2521.7	0.1658	8.7119	8.8776
12	285.15	1.401	1.000	93830.	93840.	50.38	2341.7	2392.1	50.38	2473.2	2523.6	0.1805	8.6731	8.8536
13	286.15	1.497	1.001	88180.	88180.	54.56	2338.9	2393.4	54.57	2470.8	2525.4	0.1952	8.6345	8.8297
14	287.15	1.597	1.001	82900.	82900.	58.75	2336.1	2394.8	58.75	2468.5	2527.2	0.2098	8.5963	8.8060
15	288.15	1.704	1.001	77980.	77980.	62.94	2333.2	2396.2	62.94	2466.1	2529.1	0.2243	8.5582	8.7826
16	289.15	1.817	1.001	73380.	73380.	67.12	2330.4	2397.6	67.13	2463.8	2530.9	0.2388	8.5205	8.7593
17	290.15	1.936	1.001	69090.	69090.	71.31	2327.6	2398.9	71.31	2461.4	2532.7	0.2533	8.4830	8.7363
18	291.15	2.062	1.001	65090.	65090.	75.49	2324.8	2400.3	75.50	2459.0	2534.5	0.2677	8.4458	8.7135
19	292.15	2.196	1.002	61340.	61340.	79.68	2322.0	2401.7	79.68	2456.7	2536.4	0.2820	8.4088	8.6908
20	293.15	2.337	1.002	57840.	57840.	83.86	2319.2	2403.0	83.86	2454.3	2538.2	0.2963	8.3721	8.6684
21	294.15	2.485	1.002	54560.	54560.	88.04	2316.4	2404.4	88.04	2452.0	2540.0	0.3105	8.3356	8.6462
22	295.15	2.642	1.002	51490.	51490.	92.22	2313.6	2405.8	92.23	2449.6	2541.8	0.3247	8.2994	8.6241
23	296.15	2.808	1.002	48620.	48620.	96.40	2310.7	2407.1	96.41	2447.2	2543.6	0.3389	8.2634	8.6023
24	297.15	2.982	1.003	45920.	45930.	100.6	2307.9	2408.5	100.6	2444.9	2545.5	0.3530	8.2277	8.5806
25	298.15	3.166	1.003	43400.	43400.	104.8	2305.1	2409.9	104.8	2442.5	2547.3	0.3670	8.1922	8.5592
26	299.15	3.360	1.003	41030.	41030.	108.9	2302.3	2411.2	108.9	2440.2	2549.1	0.3810	8.1568	8.5379
27	300.15	3.564	1.003	38810.	38810.	113.1	2299.5	2412.6	113.1	2437.8	2550.9	0.3949	8.1218	8.5168
28	301.15	3.778	1.004	36730.	36730.	117.3	2296.7	2414.0	117.3	2435.4	2552.7	0.4088	8.0870	8.4959
29	302.15	4.004	1.004	34770.	34770.	121.5	2293.8	2415.3	121.5	2433.1	2554.5	0.4227	8.0524	8.4751

101.325	V	1.044	1673.0	2604.2	2833.2	3061.9	3290.3	3518.7	3746.9	3975.0	4203.1
(100.00)	U	418.959	2506.5	2810.6	2888.5	2968.0	3048.9	3131.6	3215.9	3302.0	3389.8
	H	419.064	2676.0	3074.4	3175.6	3278.2	3382.3	3488.1	3595.6	3704.8	3815.7
	S	1.3069	7.3554	8.2105	8.3797	8.5381	8.6873	8.8287	8.9634	9.0922	9.2156
125	V	1.049	1374.6	2109.7	2295.6	2481.2	2666.5	2851.7	3036.8	3221.8	3406.7
(105.99)	U	444.224	2513.4	2810.2	2888.2	2967.7	3048.7	3131.4	3215.8	3301.9	3389.7
	H	444.356	2685.2	3073.9	3175.2	3277.8	3382.0	3487.9	3595.4	3704.6	3815.5
	S	1.3740	7.2847	8.1129	8.2823	8.4408	8.5901	8.7316	8.8663	8.9951	9.1188
150	V	1.053	1159.0	1757.0	1912.2	2066.9	2221.5	2375.9	2530.2	2684.5	2838.6
(111.37)	U	466.968	2519.5	2809.7	2887.9	2967.4	3048.5	3131.2	3215.6	3301.7	3389.5
	H	467.126	2693.4	3073.3	3174.7	3277.5	3381.7	3487.6	3595.1	3704.4	3815.3
	S	1.4336	7.2234	8.0280	8.1976	8.3562	8.5056	8.6472	8.7819	8.9108	9.0343
175	V	1.057	1003.34	1505.1	1638.3	1771.1	1903.7	2036.1	2168.4	2300.7	2432.9
(116.06)	U	486.815	2524.7	2809.3	2887.5	2967.1	3048.3	3131.0	3215.4	3301.6	3389.4
	H	487.000	2700.3	3072.7	3174.2	3277.1	3381.4	3487.3	3594.9	3704.2	3815.1
	S	1.4849	7.1716	7.9561	8.1259	8.2847	8.4341	8.5758	8.7106	8.8394	8.9630
200	V	1.061	885.44	1316.2	1432.8	1549.2	1665.3	1781.2	1897.1	2012.9	2128.6
(120.23)	U	504.489	2529.2	2808.8	2887.2	2966.9	3048.0	3130.8	3215.3	3301.4	3389.2
	H	504.701	2706.3	3072.1	3173.8	3276.7	3381.1	3487.0	3594.7	3704.0	3815.0
	S	1.5301	7.1268	7.8937	8.0638	8.2226	8.3722	8.5139	8.6487	8.7776	8.9012
225	V	1.064	792.97	1169.2	1273.1	1376.6	1479.9	1583.0	1686.0	1789.0	1891.9
(123.99)	U	520.465	2533.2	2808.4	2886.9	2966.6	3047.8	3130.6	3215.1	3301.2	3389.1
	H	520.705	2711.6	3071.5	3173.3	3276.3	3380.8	3486.8	3594.4	3703.8	3814.8
	S	1.5705	7.0873	7.8385	8.0088	8.1679	8.3175	8.4593	8.5942	8.7231	8.8467
250	V	1.068	718.44	1051.6	1145.2	1238.5	1331.5	1424.4	1517.2	1609.9	1702.5
(127.43)	U	535.077	2536.8	2808.0	2886.5	2966.3	3047.6	3130.4	3214.9	3301.1	3389.0
	H	535.343	2716.4	3070.9	3172.8	3275.9	3380.4	3486.5	3594.2	3703.6	3814.6
	S	1.6071	7.0520	7.7891	7.9597	8.1188	8.2686	8.4104	8.5453	8.6743	8.7980
275	V	1.071	657.04	955.45	1040.7	1125.5	1210.2	1294.7	1379.0	1463.3	1547.6
(130.60)	U	548.564	2540.0	2807.5	2886.2	2966.0	3047.3	3130.2	3214.7	3300.9	3388.8
	H	548.858	2720.7	3070.3	3172.4	3275.5	3380.1	3486.2	3594.0	3703.4	3814.4
	S	1.6407	7.0201	7.7444	7.9151	8.0744	8.2243	8.3661	8.5011	8.6301	8.7538
300	V	1.073	605.56	875.29	953.52	1031.4	1109.0	1186.5	1263.9	1341.2	1418.5
(133.54)	U	561.107	2543.0	2807.1	2885.8	2965.8	3047.1	3130.0	3214.5	3300.8	3388.7
	H	561.429	2724.7	3069.7	3171.9	3275.2	3379.8	3486.0	3593.7	3703.2	3814.2
	S	1.6716	6.9909	7.7034	7.8744	8.0338	8.1838	8.3257	8.4608	8.5898	8.7135

Table F.2. Superheated Steam, SI Units (Continued)

		TEMPERATURE: $t^{\circ}\text{C}$ (TEMPERATURE: T kelvins)									
P/kPa ($t^{\text{sat}}/^{\circ}\text{C}$)		sat. liq.	sat. vap.	175 (448.15)	200 (473.15)	220 (493.15)	240 (513.15)	260 (533.15)	280 (553.15)	300 (573.15)	325 (598.15)
750 (167.76)	V	1.112	255.43	260.88	279.05	293.03	306.65	320.01	333.17	346.19	362.32
	U	708.467	2573.3	2586.9	2632.1	2666.8	2700.6	2733.7	2766.4	2798.9	2839.3
	H	709.301	2764.8	2782.5	2841.4	2886.6	2930.6	2973.7	3016.3	3058.5	3111.0
	S	2.0195	6.6817	6.7215	6.8494	6.9429	7.0303	7.1128	7.1912	7.2662	7.3558
775 (169.10)	V	1.113	247.61	251.93	269.63	283.22	295.45	309.41	322.19	334.81	350.44
	U	714.326	2574.3	2585.4	2631.0	2665.9	2699.8	2733.1	2765.9	2798.4	2838.9
	H	715.189	2766.2	2780.7	2840.0	2885.4	2929.6	2972.9	3015.6	3057.9	3110.5
	S	2.0328	6.6705	6.7031	6.8319	6.9259	7.0137	7.0965	7.1751	7.2502	7.3400
800 (170.41)	V	1.115	240.26	243.53	260.79	274.02	286.88	299.48	311.89	324.14	339.31
	U	720.043	2575.3	2584.0	2629.9	2665.0	2699.1	2732.5	2765.4	2797.9	2838.5
	H	720.935	2767.5	2778.8	2838.6	2884.2	2928.6	2972.1	3014.9	3057.3	3109.8
	S	2.0457	6.6596	6.6851	6.8148	6.9094	6.9976	7.0807	7.1595	7.2348	7.3247
825 (171.69)	V	1.117	233.34	235.64	252.48	265.37	277.90	290.15	302.21	314.12	328.85
	U	725.625	2576.2	2582.5	2628.8	2664.1	2698.4	2731.8	2764.8	2797.5	2838.1
	H	726.547	2768.7	2776.9	2837.1	2883.1	2927.6	2971.2	3014.1	3056.6	3108.4
	S	2.0583	6.6491	6.6675	6.7982	6.8933	6.9819	7.0653	7.1443	7.2197	7.3098
850 (172.94)	V	1.118	226.81	228.21	244.66	257.24	269.44	281.37	293.10	304.68	319.00
	U	731.080	2577.1	2581.1	2627.7	2663.2	2697.6	2731.2	2764.3	2797.0	2837.7
	H	732.031	2769.9	2775.1	2835.7	2881.9	2926.6	2970.4	3013.4	3056.0	3108.8
	S	2.0705	6.6388	6.6504	6.7820	6.8777	6.9666	7.0503	7.1295	7.2051	7.2954
875 (174.16)	V	1.120	220.65	221.20	237.29	249.56	261.46	273.09	284.51	295.79	309.72
	U	736.415	2578.0	2579.6	2626.6	2662.3	2696.8	2730.6	2763.7	2796.5	2837.3
	H	737.394	2771.0	2773.1	2834.2	2880.7	2925.6	2969.5	3012.7	3055.3	3108.3
	S	2.0825	6.6289	6.6336	6.7662	6.8624	6.9518	7.0357	7.1152	7.1909	7.2813
900 (175.36)	V	1.121	214.81	.....	230.32	242.31	253.93	265.27	276.40	287.39	300.96
	U	741.635	2578.8	.....	2625.5	2661.4	2696.1	2729.9	2763.2	2796.1	2836.9
	H	742.644	2772.1	.....	2832.7	2879.5	2924.6	2968.7	3012.0	3054.7	3107.7
	S	2.0941	6.6192	.....	6.7508	6.8475	6.9373	7.0215	7.1012	7.1771	7.2676
925 (176.53)	V	1.123	209.28	.....	223.73	235.46	246.80	257.87	268.73	279.44	292.66
	U	746.746	2579.6	.....	2624.3	2660.5	2695.3	2729.3	2762.6	2795.8	2836.5
	H	747.784	2773.2	.....	2831.3	2878.3	2923.6	2967.8	3011.2	3054.1	3107.2
	S	2.1055	6.6097	.....	6.7357	6.8329	6.9231	7.0076	7.0875	7.1636	7.2543

Table E.2. Superheated Steam, SI Units (Continued)

		TEMPERATURE: $t^{\circ}\text{C}$ (TEMPERATURE: T kelvins)									
P/kPa ($t^{\text{sat}}/^{\circ}\text{C}$)		sat. liq.	sat. vap.	350 (623.15)	375 (648.15)	400 (673.15)	450 (723.15)	500 (773.15)	550 (833.15)	600 (873.15)	650 (923.15)
750 (167.76)	V	1.112	255.43	378.31	394.22	410.05	441.55	472.90	504.15	535.30	566.40
	U	708.467	2573.3	2879.6	2920.1	2960.7	3042.9	3126.3	3211.4	3298.0	3386.2
	H	709.301	2764.8	3163.4	3215.7	3268.3	3374.0	3481.0	3589.5	3699.5	3811.0
	S	2.0195	6.6817	7.4416	7.5240	7.6035	7.7550	7.8981	8.0340	8.1637	8.2880
775 (169.10)	V	1.113	247.61	365.94	381.35	396.69	427.20	457.56	487.81	517.97	548.07
	U	714.326	2574.3	2879.3	2919.8	2960.4	3042.6	3126.1	3211.2	3297.8	3386.1
	H	715.189	2766.2	3162.9	3215.3	3267.9	3373.7	3480.8	3589.2	3699.3	3810.9
	S	2.0328	6.6705	7.4259	7.5084	7.5890	7.7396	7.8827	8.0187	8.1484	8.2727
800 (170.41)	V	1.115	240.26	354.34	369.29	384.16	413.74	443.17	472.49	501.72	530.89
	U	720.043	2575.3	2878.9	2919.5	2960.2	3042.4	3125.9	3211.0	3297.7	3386.0
	H	720.935	2767.5	3162.4	3214.9	3267.5	3373.4	3480.5	3589.0	3699.1	3810.7
	S	2.0457	6.6596	7.4107	7.4932	7.5729	7.7246	7.8678	8.0038	8.1336	8.2579
825 (171.69)	V	1.117	233.34	343.45	357.96	372.39	401.10	429.65	458.10	486.46	514.76
	U	725.625	2576.2	2878.6	2919.1	2959.9	3042.2	3125.7	3210.8	3297.5	3385.8
	H	726.547	2768.7	3161.9	3214.5	3267.1	3373.1	3480.2	3588.8	3698.8	3810.5
	S	2.0583	6.6491	7.3959	7.4786	7.5583	7.7101	7.8533	7.9894	8.1192	8.2436
850 (172.94)	V	1.118	226.81	333.20	347.29	361.31	389.20	416.93	444.56	472.09	499.57
	U	731.080	2577.1	2878.2	2918.8	2959.6	3041.9	3125.5	3210.7	3297.4	3385.7
	H	732.031	2769.9	3161.4	3214.0	3266.7	3372.7	3479.9	3588.5	3698.6	3810.3
	S	2.0705	6.6388	7.3815	7.4643	7.5441	7.6960	7.8393	7.9754	8.1053	8.2296
875 (174.16)	V	1.120	220.65	323.53	337.24	350.87	377.98	404.94	431.79	458.55	485.25
	U	736.415	2578.0	2877.9	2918.5	2959.3	3041.7	3125.3	3210.5	3297.2	3385.6
	H	737.384	2771.0	3161.0	3213.6	3266.3	3372.4	3479.7	3588.3	3698.4	3810.2
	S	2.0825	6.6289	7.3676	7.4504	7.5303	7.6823	7.8257	7.9618	8.0917	8.2161
900 (175.36)	V	1.121	214.81	314.40	327.74	341.01	367.39	393.61	419.73	445.76	471.72
	U	741.635	2578.8	2877.5	2918.2	2959.0	3041.4	3125.1	3210.3	3297.1	3385.4
	H	742.644	2772.1	3160.5	3213.2	3266.0	3372.1	3479.4	3588.1	3698.2	3810.0
	S	2.0941	6.6192	7.3540	7.4370	7.5169	7.6689	7.8124	7.9486	8.0785	8.2030
925 (176.53)	V	1.123	209.28	305.76	318.75	331.68	357.36	382.90	408.32	433.66	458.93
	U	746.746	2579.6	2877.2	2917.9	2958.8	3041.2	3124.9	3210.1	3296.9	3385.3
	H	747.784	2773.2	3160.0	3212.7	3255.5	3371.8	3479.1	3587.8	3698.0	3809.8
	S	2.1055	6.6097	7.3408	7.4238	7.5038	7.6560	7.7995	7.9357	8.0657	8.1902