NATIONAL EXAMINATIONS MAY 2017

98-Mar-A1, Applied Thermodynamics and Heat Transfer

3 Hours Duration

Notes :

1. If doubt exists concerning the interpretation of any question, the candidate is urged to make assumptions and clearly explain what has been assumed along with the answer to the question.

2. The examination is open book. As a consequence, candidates are permitted to make use of any textbooks, references or notes.

3. Any non-communicating calculator is permitted. However, candidates must indicate the type of calculator(s) that they have used by writing the name and model designation of the calculator(s) on the inside of the cover of the first examination book.

4. It is expected that each candidate will have copies of both a thermodynamics text and a heat transfer text in order to make use of the information presented in the tables and graphs contained.

5. The answers to five questions, either three questions from Part A and two questions from Part B or two questions from Part A and three questions from Part B, comprise a complete examination.

6. Candidates must indicate the answers that they wish to have graded on the cover of the first examination book. Otherwise the answers will be graded in the order in which they appear in the examination book(s) up to a maximum of three answers per section.

7. The answer to any question carries the same value in the grading.

PART A   - THERMODYNAMICS

1. (a) Tank A which has a volume of 1.0 m³ is connected to tank B which has a volume of 0.3 m³. Initially, tank A contains air at 700 kPa and 20°C while tank B is evacuated. A connecting valve in the pipe connecting the tanks is opened and then closed when the tanks come to pressure equilibrium, The air in tank A may be assumed to have undergone a reversible process and there is no heat transfer with the surroundings as the pressures come to equilibrium. Determine the air mass and the temperature of the air in each of the tanks.

   (b) A blower supplying air to a diesel engine draws in air at 90 kPa and 20°C (u = 209.3 kJ/kg) with negligible velocity at the rate of 12.3 m³/min. The air is discharged into the engine at 106 kPa and 30°C (u = 303.4 kJ/kg) at a velocity of 24 m/s. Assuming that the process is adiabatic, calculate the power required by the blower to compress the air and the area through which the blower discharges the air into the engine.

2. The schematic diagrams at the right describe the air standard dual cycle, a combination of the Otto cycle and the Diesel cycle which is a better representation of an internal combustion engine.
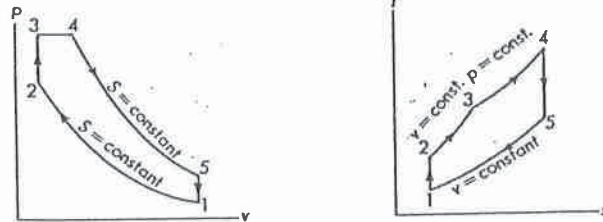

   Heat is transferred to the working fluid at constant volume and constant pressure. Fuel injection is started before the end of the compression stroke and is completed during the early part of the return stroke. The ratios $r_v = v_1/v_2$, $r_c = v_4/v_3$ and $r_p = p_3/p_2$ are the compression ratio, cut-off ratio and constant-volume pressure ratio respectively. In a particular air-standard dual cycle, the compression ratio is 16.5 and the pressure and temperature at the beginning of compression are 101.325 kPa and 25°C. The temperature after constant-volume combustion is 1170°C and the temperature after constant pressure combustion is 1595°C. Using the ideal gas property tables appended to the examination paper, determine the cut-off ratio, the constant volume pressure ratio, the heat added and rejected per unit mass of air and the thermal efficiency.

3. A gas turbine jet engine mounted on a stationary test bed is being tested for static thrust. Atmospheric pressure and temperature are 1 atmosphere and -20°C respectively. The compressor pressure ratio is 8 and the efficiency of both turbine and compressor is 0.88. The maximum temperature for the cycle is 1000°C and the nozzle efficiency is 90 %. What is the velocity of the air leaving the nozzle and the static thrust if the air flowrate through the nozzle is 25 kg/s ?

4.   A refrigeration plant uses ammonia as the working fluid. Before
      throttling, the pressure of the liquid ammonia is 1200 kPa and its
      temperature is 27°C. The evaporator pressure, which is assumed to
      be uniform, is 250 kPa and the ammonia leaves the evaporator at a
      temperature of -10°C. The work done by the compressor is 2.12 kW
      and the mass flowrate of the ammonia is 0.007 kg/s. Represent the
      refrigeration system on a T-s diagram and determine the following

          (a) The quality of the ammonia exiting from the throttling valve
          (b) The rate at which the ammonia in the evaporator absorbs heat
          (c) The coefficient of performance for the refrigeration system

PART B – HEAT TRANSFER

5.   A steel tube 150 mm inside diameter with a 10 mm wall thickness
      conveying steam at 200°C is surrounded by air at 25°C. The loss of
      heat under these conditions is 2000 W/m. Determine the loss of heat
      when the tube is covered with a 50 mm thick layer of insulation given
      that the thermal conductivities of the insulation and the tube are
      respectively 0.35 W/m°C and 46.7 W/m°C and that the heat transfer
      coefficient between the metal and the air is 40% greater than the
      heat transfer coefficient between the insulation and the air.

6.   Oil flowing at $\dot{m}$ = 0.025 kg/s enters a
      thin-walled tube 50 mm diameter by 6 m
      long at $T_{m,i}$ = 23°C where it is heated by
      a hot gas at T_∞ = 300°C moving in
      crossflow over the tube at V = 10 m/s. The
      gas may be assumed to have the same
      thermophysical properties as those of air.
      In order to prevent the oil overheating
      and decomposing, the temperature of the
      wall must not exceed T_t = 100°C anywhere along the tube. Will there
      be any problem associated with heating the oil under these conditions ?
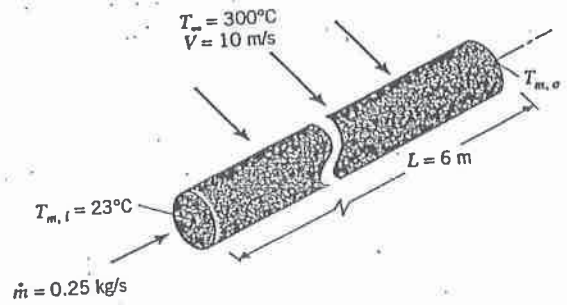
7.   An evacuated Dewar vessel comprised of thin
      spherical stainless steel shells is used for
      storing liquid oxygen at 90 K. The outer and
      inner shells are 610 mm diameter and 510 mm
      diameter respectively. Determine how much heat
      the liquified oxygen contained within the inner
      shell will gain with another spherical shell
      560 mm diameter placed between the inner and
      outer shell to act as a thermal radiation
      shield. The temperature of the outer shell is
      45°C. Neglect the opening in the Dewar vessel
      and assume that all stainless steel surfaces
      have an emissivity of 0.3.
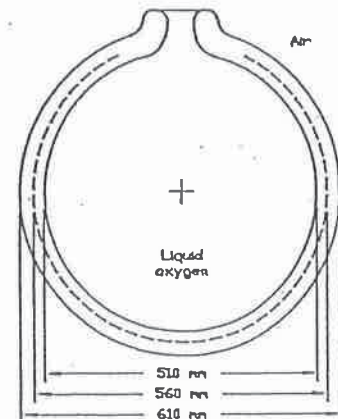
8.　The cooling system in an office building uses a crossflow finned tube heat exchanger like that depicted in the diagram to cool air flowing at 0.80 kg/s from 30°C to 7°C. The energy is transferred to water flowing at 0.76 kg/s which enters the heat exchanger at 3°C. Calculate the heat exchanger area required assuming an overall heat transfer coefficient of 55 W/m²°C. Assuming that the overall heat transfer coefficient is not affected, what percentage reduction in heat transfer rate will occur if the water flowrate is cut in half while the air flowrate is maintained constant ?

Water

Air
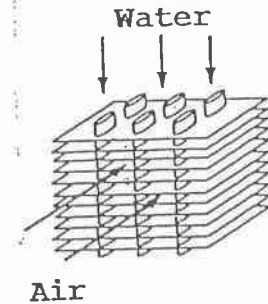
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Thermodynamic Properties of Ammonia[a]

Saturated Ammonia

Temp. °C	Abs. Press. kPa P	Specific Volume m³/kg			Enthalpy kJ/kg			Entropy kJ/kg K		
		Sat. Liquid v_f	Evap. v_{fg}	Sat. Vapor v_g	Sat. Liquid h_f	Evap. h_{fg}	Sat. Vapor h_g	Sat. Liquid s_f	Evap. s_{fg}	Sat. Vapor s_g
−50	40.88	0.001 424	2.6239	2.6254	−44.3	1416.7	1372.4	−0.1942	6.3502	6.1561
−48	45.96	0.001 429	2.3518	2.3533	−35.5	1411.3	1375.8	−0.1547	6.2696	6.1149
−46	51.55	0.001 434	2.1126	2.1140	−26.6	1405.8	1379.2	−0.1156	6.1902	6.0746
−44	57.69	0.001 439	1.9018	1.9032	−17.8	1400.3	1382.5	−0.0768	6.1120	6.0352
−42	64.42	0.001 444	1.7155	1.7170	−8.9	1394.7	1385.8	−0.0382	6.0349	5.9967
−40	71.77	0.001 449	1.5506	1.5521	0.0	1389.0	1389.0	0.0000	5.9589	5.9589
−38	79.80	0.001 454	1.4043	1.4058	8.9	1383.3	1392.2	0.0380	5.8840	5.9220
−36	88.54	0.001 460	1.2742	1.2757	17.8	1377.6	1395.4	0.0757	5.8101	5.8858
−34	98.05	0.001 465	1.1582	1.1597	26.8	1371.8	1398.5	0.1132	5.7372	5.8504
−32	108.37	0.001 470	1.0547	1.0562	35.7	1365.9	1401.6	0.1504	5.6652	5.8156
−30	119.55	0.001 476	0.9621	0.9635	44.7	1360.0	1404.6	0.1873	5.5942	5.7815
−28	131.64	0.001 481	0.8790	0.8805	53.6	1354.0	1407.6	0.2240	5.5241	5.7481
−26	144.70	0.001 487	0.8044	0.8059	62.6	1347.9	1410.5	0.2605	5.4548	5.7153
−24	158.78	0.001 492	0.7373	0.7388	71.6	1341.8	1413.4	0.2967	5.3864	5.6831
−22	173.93	0.001 498	0.6768	0.6783	80.7	1335.6	1416.2	0.3327	5.3188	5.6515
−20	190.22	0.001 504	0.6222	0.6237	89.7	1329.3	1419.0	0.3684	5.2520	5.6205
−18	207.71	0.001 510	0.5728	0.5743	98.8	1322.9	1421.7	0.4040	5.1860	5.5900
−16	226.45	0.001 515	0.5280	0.5296	107.8	1316.5	1424.4	0.4393	5.1207	5.5600
−14	246.51	0.001 521	0.4874	0.4889	116.9	1310.0	1427.0	0.4744	5.0561	5.5305
−12	267.95	0.001 528	0.4505	0.4520	126.0	1303.5	1429.5	0.5093	4.9922	5.5015
−10	290.85	0.001 534	0.4169	0.4185	135.2	1296.8	1432.0	0.5440	4.9290	5.4730
−8	315.25	0.001 540	0.3863	0.3878	144.3	1290.1	1434.4	0.5785	4.8664	5.4449
−6	341.25	0.001 546	0.3583	0.3599	153.5	1283.3	1436.8	0.6128	4.8045	5.4173
−4	368.90	0.001 553	0.3328	0.3343	162.7	1276.4	1439.1	0.6469	4.7432	5.3901
−2	398.27	0.001 559	0.3094	0.3109	171.9	1269.4	1441.3	0.6808	4.6825	5.3633
0	429.44	0.001 566	0.2879	0.2895	181.1	1262.4	1443.5	0.7145	4.6223	5.3369
2	462.49	0.001 573	0.2683	0.2698	190.4	1255.2	1445.6	0.7481	4.5627	5.3108
4	497.49	0.001 580	0.2502	0.2517	199.6	1248.0	1447.6	0.7815	4.5037	5.2852
6	534.51	0.001 587	0.2335	0.2351	208.9	1240.6	1449.6	0.8148	4.4451	5.2599
8	573.64	0.001 594	0.2182	0.2198	218.3	1233.2	1451.5	0.8479	4.3871	5.2350
10	614.95	0.001 601	0.2040	0.2056	227.6	1225.7	1453.3	0.8808	4.3295	5.2104
12	658.52	0.001 608	0.1910	0.1926	237.0	1218.1	1455.1	0.9136	4.2725	5.1861
14	704.44	0.001 616	0.1789	0.1805	246.4	1210.4	1456.8	0.9463	4.2159	5.1621
16	752.79	0.001 623	0.1677	0.1693	255.9	1202.6	1458.5	0.9788	4.1597	5.1385
18	803.66	0.001 631	0.1574	0.1590	265.4	1194.7	1460.0	1.0112	4.1039	5.1151
20	857.12	0.001 639	0.1477	0.1494	274.9	1186.7	1461.5	1.0434	4.0486	5.0920
22	913.27	0.001 647	0.1388	0.1405	284.4	1178.5	1462.9	1.0755	3.9937	5.0692
24	972.19	0.001 655	0.1305	0.1322	294.0	1170.3	1464.3	1.1075	3.9392	5.0467
26	1033.97	0.001 663	0.1228	0.1245	303.6	1162.0	1465.6	1.1394	3.8850	5.0244
28	1098.71	0.001 671	0.1156	0.1173	313.2	1153.6	1466.8	1.1711	3.8312	5.0023
30	1166.49	0.001 680	0.1089	0.1106	322.9	1145.0	1467.9	1.2028	3.7777	4.9805
32	1237.41	0.001 689	0.1027	0.1044	332.6	1136.4	1469.0	1.2343	3.7246	4.9589
34	1311.55	0.001 698	0.0969	0.0986	342.3	1127.6	1469.9	1.2656	3.6718	4.9374
36	1389.03	0.001 707	0.0914	0.0931	352.1	1118.7	1470.8	1.2969	3.6192	4.9161
38	1469.92	0.001 716	0.0863	0.0880	361.9	1109.7	1471.5	1.3281	3.5669	4.8950
40	1554.33	0.001 726	0.0815	0.0833	371.7	1100.5	1472.2	1.3591	3.5148	4.8740
42	1642.35	0.001 735	0.0771	0.0788	381.6	1091.2	1472.8	1.3901	3.4630	4.8530
44	1734.09	0.001 745	0.0728	0.0746	391.5	1081.7	1473.2	1.4209	3.4112	4.8322
46	1829.65	0.001 756	0.0689	0.0707	401.5	1072.0	1473.5	1.4518	3.3595	4.8113
48	1929.13	0.001 766	0.0652	0.0669	411.5	1062.2	1473.7	1.4826	3.3079	4.7905
50	2032.62	0.001 777	0.0617	0.0635	421.7	1052.0	1473.7	1.5135	3.2561	4.7696

Superheated Ammonia

Abs. Press. kPa (Sat. Temp.) °C		−20	−10	0	10	20	30	40	50	60	70	80	100
50 (−46.54)	v	2.4474	2.5481	2.6482	2.7479	2.8473	2.9464	3.0453	3.1441	3.2427	3.3413	3.4397	
	h	1435.8	1457.0	1478.1	1499.2	1520.4	1541.7	1563.0	1584.5	1606.1	1627.8	1649.7	
	s	6.3256	6.4077	6.4865	6.5625	6.6360	6.7073	6.7766	6.8441	6.9099	6.9743	7.0372	
75 (−39.18)	v	1.6233	1.6915	1.7591	1.8263	1.8932	1.9597	2.0261	2.0923	2.1584	2.2244	2.2903	
	h	1433.0	1454.7	1476.1	1497.5	1518.9	1540.3	1561.8	1583.4	1605.1	1626.9	1648.9	
	s	6.1190	6.2028	6.2828	6.3597	6.4339	6.5058	6.5756	6.6434	6.7096	6.7742	6.8373	
100 (−33.61)	v	1.2110	1.2631	1.3145	1.3654	1.4160	1.4664	1.5165	1.5664	1.6163	1.6659	1.7155	1.8145
	h	1430.1	1452.2	1474.1	1495.7	1517.3	1538.9	1560.5	1582.2	1604.1	1626.0	1648.0	1692.6
	s	5.9695	6.0552	6.1366	6.2144	6.2894	6.3618	6.4321	6.5003	6.5668	6.6316	6.6950	6.8177
125 (−29.08)	v	0.9635	1.0059	1.0476	1.0889	1.1297	1.1703	1.2107	1.2509	1.2909	1.3309	1.3707	1.4501
	h	1427.2	1449.8	1472.0	1493.9	1515.7	1537.5	1559.3	1581.1	1603.0	1625.0	1647.2	1691.8
	s	5.8512	5.9389	6.0217	6.1006	6.1763	6.2494	6.3201	6.3887	6.4555	6.5206	6.5842	6.7072
150 (−25.23)	v	0.7984	0.8344	0.8697	0.9045	0.9388	0.9729	1.0068	1.0405	1.0740	1.1074	1.1408	1.2072
	h	1424.1	1447.3	1469.8	1492.1	1514.1	1536.1	1558.0	1580.0	1602.0	1624.1	1646.3	1691.1
	s	5.7526	5.8424	5.9266	6.0066	6.0831	6.1568	6.2280	6.2970	6.3641	6.4295	6.4933	6.6167
200 (−18.86)	v		0.6199	0.6471	0.6738	0.7001	0.7261	0.7519	0.7774	0.8029	0.8282	0.8533	0.9035
	h		1442.0	1465.5	1488.4	1510.9	1533.2	1555.5	1577.7	1599.9	1622.2	1644.6	1689.6
	s		5.6863	5.7737	5.8559	5.9342	6.0091	6.0813	6.1512	6.2189	6.2849	6.3491	6.4732
250 (−13.67)	v		0.4910	0.5135	0.5354	0.5568	0.5780	0.5989	0.6196	0.6401	0.6605	0.6809	0.7212
	h		1436.6	1461.0	1484.5	1507.6	1530.3	1552.9	1575.4	1597.8	1620.3	1642.8	1688.2
	s		5.5609	5.6517	5.7365	5.8165	5.8928	5.9661	6.0368	6.1052	6.1717	6.2365	6.3613
300 (−9.23)	v			0.4243	0.4430	0.4613	0.4792	0.4968	0.5143	0.5316	0.5488	0.5658	0.5997
	h			1456.3	1480.6	1504.2	1527.4	1550.3	1573.0	1595.7	1618.4	1641.1	1686.7
	s			5.5493	5.6366	5.7186	5.7963	5.8707	5.9423	6.0114	6.0785	6.1437	6.2693
350 (−5.35)	v			0.3605	0.3770	0.3929	0.4086	0.4239	0.4391	0.4541	0.4689	0.4837	0.5129
	h			1451.5	1476.5	1500.7	1524.4	1547.6	1570.7	1593.6	1616.5	1639.3	1685.2
	s			5.4600	5.5502	5.6342	5.7135	5.7890	5.8615	5.9314	5.9990	6.0647	6.1910
400 (−1.89)	v			0.3125	0.3274	0.3417	0.3556	0.3692	0.3826	0.3959	0.4090	0.4220	0.4478
	h			1446.5	1472.4	1497.2	1521.3	1544.9	1568.3	1591.5	1614.5	1637.6	1683.7
	s			5.3803	5.4735	5.5597	5.6405	5.7173	5.7907	5.8613	5.9296	5.9957	6.1228
450 (1.26)	v			0.2752	0.2887	0.3017	0.3143	0.3266	0.3387	0.3506	0.3624	0.3740	0.3971
	h			1441.3	1468.1	1493.6	1518.2	1542.2	1565.9	1589.3	1612.6	1635.8	1682.2
	s			5.3078	5.4042	5.4926	5.5752	5.6532	5.7275	5.7989	5.8678	5.9345	6.0623

Abs. Press. kPa (Sat. Temp.) °C		20	30	40	50	60	70	80	100	120	140	160	180
500 (4.14)	v	0.2698	0.2813	0.2926	0.3036	0.3144	0.3251	0.3357	0.3565	0.3771	0.3975		
	h	1489.9	1515.0	1539.5	1563.4	1587.1	1610.6	1634.0	1680.7	1727.5	1774.7		
	s	5.4314	5.5157	5.5950	5.6704	5.7425	5.8120	5.8793	6.0079	6.1301	6.2472		
600 (9.29)	v	0.2217	0.2317	0.2414	0.2508	0.2600	0.2691	0.2781	0.2957	0.3130	0.3302		
	h	1482.4	1508.6	1533.8	1558.5	1582.7	1606.6	1630.4	1677.7	1724.9	1772.4		
	s	5.3222	5.4102	5.4923	5.5697	5.6436	5.7144	5.7826	5.9129	6.0363	6.1541		
700 (13.81)	v	0.1874	0.1963	0.2048	0.2131	0.2212	0.2291	0.2369	0.2522	0.2672	0.2821		
	h	1474.5	1501.9	1528.1	1553.4	1578.2	1602.6	1626.8	1674.6	1722.4	1770.2		
	s	5.2259	5.3179	5.4029	5.4826	5.5582	5.6303	5.6997	5.8316	5.9562	6.0749		
800 (17.86)	v	0.1615	0.1696	0.1773	0.1848	0.1920	0.1991	0.2060	0.2196	0.2329	0.2459	0.2589	
	h	1466.3	1495.0	1522.2	1548.3	1573.7	1598.6	1623.1	1671.6	1719.8	1768.0	1816.4	
	s	5.1387	5.2351	5.3232	5.4053	5.4827	5.5562	5.6268	5.7603	5.8861	6.0057	6.1202	
900 (21.54)	v		0.1488	0.1559	0.1627	0.1693	0.1757	0.1820	0.1942	0.2061	0.2178	0.2294	
	h		1488.0	1516.2	1543.0	1569.1	1594.4	1619.4	1668.5	1717.1	1765.7	1814.4	
	s		5.1593	5.2508	5.3354	5.4147	5.4897	5.5614	5.6968	5.8237	5.9442	6.0594	
1000 (24.91)	v		0.1321	0.1388	0.1450	0.1511	0.1570	0.1627	0.1739	0.1847	0.1954	0.2058	0.2162
	h		1480.6	1510.0	1537.7	1564.4	1590.3	1615.6	1665.4	1714.5	1763.4	1812.4	1861.7
	s		5.0889	5.1840	5.2713	5.3525	5.4292	5.5021	5.6392	5.7674	5.8888	6.0047	6.1159
1200 (30.96)	v			0.1129	0.1185	0.1238	0.1289	0.1338	0.1434	0.1526	0.1616	0.1705	0.1792
	h			1497.1	1526.6	1554.7	1581.7	1608.0	1659.2	1709.2	1758.9	1808.5	1858.2
	s			5.0629	5.1560	5.2416	5.3215	5.3970	5.5379	5.6687	5.7919	5.9091	6.0214

Ideal Gas Properties of Air

T(K), h and u(kJ/kg), s°(kJ/kg·K)

T	h	p_r	u	v_r	s°	T	h	p_r	u	v_r	s°
200	199.97	0.3363	142.56	1707.	1.29559	750	767.29	37.35	551.99	57.63	2.64737
210	209.97	0.3987	149.69	1512.	1.34444	760	778.18	39.27	560.01	55.54	2.66176
220	219.97	0.4690	156.82	1346.	1.39105	770	789.11	41.31	568.07	53.39	2.67595
230	230.02	0.5477	164.00	1205.	1.43557	780	800.03	43.35	576.12	51.64	2.69013
240	240.02	0.6355	171.13	1084.	1.47824	790	810.99	45.55	584.21	49.86	2.70400
250	250.05	0.7329	178.28	979.	1.51917	800	821.95	47.75	592.30	48.08	2.71787
260	260.09	0.8405	185.45	887.8	1.55848	820	843.98	52.59	608.59	44.84	2.74504
270	270.11	0.9590	192.60	808.0	1.59634	840	866.08	57.60	624.95	41.85	2.77170
280	280.13	1.0889	199.75	738.0	1.63279	860	888.27	63.09	641.40	39.12	2.79783
285	285.14	1.1584	203.33	706.1	1.65055	880	910.56	68.98	657.95	36.61	2.82344
290	290.16	1.2311	206.91	676.1	1.66802	900	932.93	75.29	674.58	34.31	2.84856
295	295.17	1.3068	210.49	647.9	1.68515	920	955.38	82.05	691.28	32.18	2.87324
300	300.19	1.3860	214.07	621.2	1.70203	940	977.92	89.28	708.08	30.22	2.89748
305	305.22	1.4686	217.67	596.0	1.71865	960	1000.55	97.00	725.02	28.40	2.92128
310	310.24	1.5546	221.25	572.3	1.73498	980	1023.25	105.2	741.98	26.73	2.94468
315	315.27	1.6442	224.85	549.8	1.75106	1000	1046.04	114.0	758.94	25.17	2.96770
320	320.29	1.7375	228.42	528.6	1.76690	1020	1068.89	123.4	776.10	23.72	2.99034
325	325.31	1.8345	232.02	508.4	1.78249	1040	1091.85	133.3	793.36	22.39	3.01260
330	330.34	1.9352	235.61	489.4	1.79783	1060	1114.86	143.9	810.62	21.14	3.03449
340	340.42	2.149	242.82	454.1	1.82790	1080	1137.89	155.2	827.88	19.98	3.05608
350	350.49	2.379	250.02	422.2	1.85708	1100	1161.07	167.1	845.33	18.896	3.07732
360	360.58	2.626	257.24	393.4	1.88543	1120	1184.28	179.7	862.79	17.886	3.09585
370	370.67	2.892	264.46	367.2	1.91313	1140	1207.57	193.1	880.35	16.946	3.11883
380	380.77	3.176	271.69	343.4	1.94001	1160	1230.92	207.2	897.91	16.064	3.13916
390	390.88	3.481	278.93	321.5	1.96633	1180	1254.34	222.2	915.57	15.241	3.15916
400	400.98	3.806	286.16	301.6	1.99194	1200	1277.79	238.0	933.33	14.470	3.17888
410	411.12	4.153	293.43	283.3	2.01699	1220	1301.31	254.7	951.09	13.747	3.19834
420	421.26	4.522	300.69	266.6	2.04142	1240	1324.93	272.3	968.95	13.069	3.21751
430	431.43	4.915	307.99	251.1	2.06533	1260	1348.55	290.8	986.90	12.435	3.23638
440	441.61	5.332	315.30	236.8	2.08870	1280	1372.24	310.4	1004.76	11.835	3.25510
450	451.80	5.775	322.62	223.6	2.11161	1300	1395.97	330.9	1022.82	11.275	3.27345
460	462.02	6.245	329.97	211.4	2.13407	1320	1419.76	352.5	1040.88	10.747	3.29160
470	472.24	6.742	337.32	200.1	2.15604	1340	1443.60	375.3	1058.94	10.247	3.30959
480	482.49	7.268	344.70	189.5	2.17760	1360	1467.49	399.1	1077.10	9.780	3.32724
490	492.74	7.824	352.08	179.7	2.19876	1380	1491.44	424.2	1095.26	9.337	3.34474
500	503.02	8.411	359.49	170.6	2.21952	1400	1515.42	450.5	1113.52	8.919	3.36200
510	513.32	9.031	366.92	162.1	2.23993	1420	1539.44	478.0	1131.77	8.526	3.37901
520	523.63	9.684	374.36	154.1	2.25997	1440	1563.51	506.9	1150.13	8.153	3.39586
530	533.98	10.37	381.84	146.7	2.27967	1460	1587.63	537.1	1168.49	7.801	3.41247
540	544.35	11.10	389.34	139.7	2.29906	1480	1611.79	568.8	1186.95	7.468	3.42892
550	554.74	11.86	396.86	133.1	2.31809	1500	1635.97	601.9	1205.41	7.152	3.44516
560	565.17	12.66	404.42	127.0	2.33685	1520	1660.23	636.5	1223.87	6.854	3.46120
570	575.59	13.50	411.97	121.2	2.35531	1540	1684.51	672.8	1242.43	6.569	3.47712
580	586.04	14.38	419.55	115.7	2.37348	1560	1708.82	710.5	1260.99	6.301	3.49276
590	596.52	15.31	427.15	110.6	2.39140	1580	1733.17	750.0	1279.65	6.046	3.50829
600	607.02	16.28	434.78	105.8	2.40902	1600	1757.57	791.2	1298.30	5.804	3.52364
610	617.53	17.30	442.42	101.2	2.42644	1620	1782.00	834.1	1316.96	5.574	3.53879
620	628.07	18.36	450.09	96.92	2.44356	1640	1806.46	878.9	1335.72	5.355	3.55381
630	638.63	19.84	457.78	92.84	2.46048	1660	1830.96	925.6	1354.48	5.147	3.56867
640	649.22	20.64	465.50	88.99	2.47716	1680	1855.50	974.2	1373.24	4.949	3.58335
650	659.84	21.86	473.25	85.34	2.49364	1700	1880.1	1025	1392.7	4.761	3.5979
660	670.47	23.13	481.01	81.89	2.50985	1750	1941.6	1161	1439.8	4.328	3.6336
670	681.14	24.46	488.81	78.61	2.52589	1800	2003.3	1310	1487.2	3.944	3.6684
680	691.82	25.85	496.62	75.50	2.54175	1850	2065.3	1475	1534.9	3.601	3.7023
690	702.52	27.29	504.45	72.56	2.55731	1900	2127.4	1655	1582.6	3.295	3.7354
700	713.27	28.80	512.33	69.76	2.57277	1950	2189.7	1852	1630.6	3.022	3.7677
710	724.04	30.38	520.23	67.07	2.58810	2000	2252.1	2068	1678.7	2.776	3.7994
720	734.82	32.02	528.14	64.53	2.60319	2050	2314.6	2303	1726.8	2.555	3.8303
730	745.62	33.72	536.07	62.13	2.61803	2100	2377.4	2559	1775.3	2.356	3.8605
740	756.44	35.50	544.02	59.82	2.63280	2150	2440.3	2837	1823.8	2.175	3.8901