Practice Final Exam

ME 240: Fundamentals of Instrumentation & Measurement
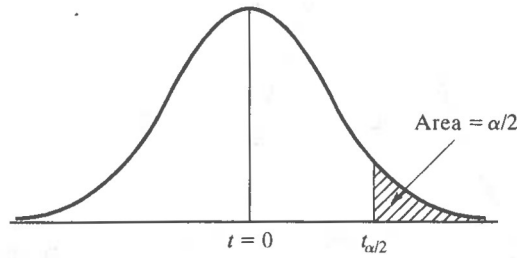
D. H. Kelley & I. Mohammad • 58 points

Please write the following sentence in the box below in your own handwriting and **SIGN**:
"I affirm that I have not given or received any unauthorized help on this assignment, and that this work will be my own."
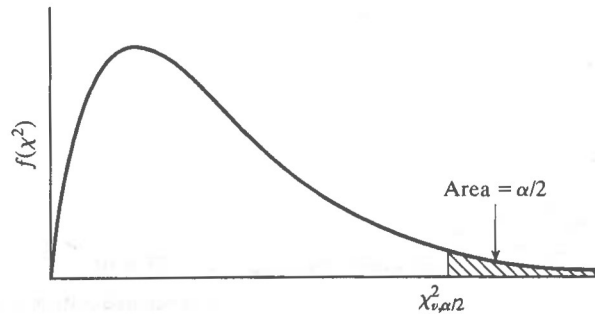
For multiple-choice problems below, please shade the circle or circles next to the correct responses. For other problems, please write in the boxed area following each problem. Please do not separate these stapled pages. For maximum partial credit, please make your work legible and clear. The answers to some problems may depend on prior answers; if you don't have the prior answers, you can still earn full credit by using a variable name or making up a number for the prior answer, as long as you make your thinking clear.

TABLE 6.3   Area Under the Normal Distribution From $z = 0$ to z

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	.0000	.0040	.0080	.0120	.0160	.0199	.0239	.0279	.0319	.0359
0.1	.0398	.0438	.0478	.0517	.0557	.0596	.0636	.0675	.0714	.0753
0.2	.0793	.0832	.0871	.0910	.0948	.0987	.1026	.1064	.1103	.1141
0.3	.1179	.1217	.1255	.1293	.1331	.1368	.1406	.1443	.1480	.1517
0.4	.1554	.1591	.1628	.1664	.1700	.1736	.1772	.1808	.1844	.1879
0.5	.1915	.1950	.1985	.2019	.2054	.2088	.2123	.2157	.2190	.2224
0.6	.2257	.2291	.2324	.2357	.2389	.2422	.2454	.2486	.2517	.2549
0.7	.2580	.2611	.2642	.2673	.2704	.2734	.2764	.2794	.2823	.2852
0.8	.2881	.2910	.2939	.2967	.2995	.3023	.3051	.3078	.3106	.3133
0.9	.3159	.3186	.3212	.3238	.3264	.3289	.3315	.3340	.3365	.3389
1.0	.3413	.3438	.3461	.3485	.3508	.3531	.3554	.3577	.3599	.3621
1.1	.3643	.3665	.3686	.3708	.3729	.3749	.3770	.3790	.3810	.3830
1.2	.3849	.3869	.3888	.3907	.3925	.3944	.3962	.3980	.3997	.4015
1.3	.4032	.4049	.4066	.4082	.4099	.4115	.4131	.4147	.4162	.4177
1.4	.4192	.4207	.4222	.4236	.4251	.4265	.4279	.4292	.4306	.4319
1.5	.4332	.4345	.4357	.4370	.4382	.4394	.4406	.4418	.4429	.4441
1.6	.4452	.4463	.4474	.4484	.4495	.4505	.4515	.4525	.4535	.4545
1.7	.4554	.4564	.4573	.4582	.4591	.4599	.4608	.4616	.4625	.4633
1.8	.4641	.4649	.4656	.4664	.4671	.4678	.4686	.4693	.4699	.4706
1.9	.4713	.4719	.4726	.4732	.4738	.4744	.4750	.4756	.4761	.4767
2.0	.4772	.4778	.4783	.4788	.4793	.4798	.4803	.4808	.4812	.4817
2.1	.4821	.4826	.4830	.4834	.4838	.4842	.4846	.4850	.4854	.4857
2.2	.4861	.4864	.4868	.4871	.4875	.4878	.4881	.4884	.4887	.4890
2.3	.4893	.4896	.4898	.4901	.4904	.4906	.4909	.4911	.4913	.4916
2.4	.4918	.4920	.4922	.4925	.4927	.4929	.4931	.4932	.4934	.4936
2.5	.4938	.4940	.4941	.4943	.4945	.4946	.4948	.4949	.4951	.4952
2.6	.4953	.4955	.4956	.4957	.4959	.4960	.4961	.4962	.4963	.4964
2.7	.4965	.4966	.4967	.4968	.4969	.4970	.4971	.4972	.4973	.4974
2.8	.4974	.4975	.4976	.4977	.4977	.4978	.4979	.4979	.4980	.4981
2.9	.4981	.4982	.4982	.4983	.4984	.4984	.4985	.4985	.4986	.4986
3.0	.4987	.4987	.4987	.4988	.4988	.4989	.4989	.4989	.4990	.4990
3.1	.4990	.4991	.4991	.4991	.4992	.4992	.4992	.4992	.4993	.4993
3.2	.4993	.4993	.4994	.4994	.4994	.4994	.4994	.4995	.4995	.4995
3.3	.4995	.4995	.4995	.4996	.4996	.4996	.4996	.4996	.4996	.4997
3.4	.4997	.4997	.4997	.4997	.4997	.4997	.4997	.4997	.4997	.4998
3.5	.4998	.4998	.4998	.4998	.4998	.4998	.4998	.4998	.4998	.4998
3.6	.4998	.4998	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999
3.7	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999
3.8	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999
3.9	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000
4.0	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000

TABLE 6.6   Student's t as a Function of α and v

v	0.100	0.050	0.025	0.010	0.005
1	3.078	6.314	12.706	31.823	63.658
2	1.886	2.920	4.303	6.964	9.925
3	1.638	2.353	3.182	4.541	5.841
4	1.533	2.132	2.776	3.747	4.604
5	1.476	2.015	2.571	3.365	4.032
6	1.440	1.943	2.447	3.143	3.707
7	1.415	1.895	2.365	2.998	3.499
8	1.397	1.860	2.306	2.896	3.355
9	1.383	1.833	2.262	2.821	3.250
10	1.372	1.812	2.228	2.764	3.169
11	1.363	1.796	2.201	2.718	3.106
12	1.356	1.782	2.179	2.681	3.054
13	1.350	1.771	2.160	2.650	3.012
14	1.345	1.761	2.145	2.624	2.977
15	1.341	1.753	2.131	2.602	2.947
16	1.337	1.746	2.120	2.583	2.921
17	1.333	1.740	2.110	2.567	2.898
18	1.330	1.734	2.101	2.552	2.878
19	1.328	1.729	2.093	2.539	2.861
20	1.325	1.725	2.086	2.528	2.845
21	1.323	1.721	2.080	2.518	2.831
22	1.321	1.717	2.074	2.508	2.819
23	1.319	1.714	2.069	2.500	2.807
24	1.318	1.711	2.064	2.492	2.797
25	1.316	1.708	2.060	2.485	2.787
26	1.315	1.706	2.056	2.479	2.779
27	1.314	1.703	2.052	2.473	2.771
28	1.313	1.701	2.048	2.467	2.763
29	1.311	1.699	2.045	2.462	2.756
30	1.310	1.697	2.042	2.457	2.750
∞	1.283	1.645	1.960	2.326	2.576

The header above the table columns reads $\alpha/2$. In the figure, Area $= \alpha/2$, with $t = 0$ and $t_{\alpha/2}$ marked.

TABLE 6.7   Critical Values of the Chi-Squared Distribution

$v\downarrow$	0.995	0.990	0.975	0.950	0.900	0.100	0.050	0.025	0.010	0.005
1	0.000039	0.000157	0.000982	0.003932	0.015791	2.706	3.841	5.024	6.635	7.879
2	0.0100	0.0201	0.0506	0.1026	0.2107	4.605	5.991	7.378	9.210	10.597
3	0.0717	0.1148	0.2158	0.3518	0.5844	6.251	7.815	9.348	11.345	12.838
4	0.2070	0.2971	0.4844	0.7107	1.0636	7.779	9.488	11.143	13.277	14.86
5	0.4118	0.5543	0.8312	1.1455	1.6103	9.236	11.070	12.832	15.086	16.750
6	0.6757	0.8721	1.2373	1.6354	2.2041	10.645	12.592	14.449	16.812	18.548
7	0.9893	1.2390	1.6899	2.1673	2.8331	12.017	14.067	16.013	18.475	20.278
8	1.3444	1.6465	2.1797	2.7326	3.4895	13.362	15.507	17.535	20.090	21.955
9	1.7349	2.0879	2.7004	3.3251	4.1682	14.684	16.919	19.023	21.666	23.589
10	2.1558	2.5582	3.2470	3.9403	4.8652	15.987	18.307	20.483	23.209	25.188
11	2.6032	3.0535	3.8157	4.5748	5.5778	17.275	19.675	21.920	24.725	26.757
12	3.0738	3.5706	4.4038	5.2260	6.3038	18.549	21.026	23.337	26.217	28.300
13	3.5650	4.1069	5.0087	5.8919	7.0415	19.812	22.362	24.736	27.688	29.819
14	4.0747	4.6604	5.6287	6.5706	7.7895	21.064	23.685	26.119	29.141	31.319
15	4.6009	5.2294	6.2621	7.2609	8.5468	22.307	24.996	27.488	30.578	32.801
16	5.1422	5.8122	6.9077	7.9616	9.3122	23.542	26.296	28.845	32.000	34.267
17	5.6973	6.4077	7.5642	8.6718	10.0852	24.769	27.587	30.191	33.409	35.718
18	6.2648	7.0149	8.2307	9.3904	10.8649	25.989	28.869	31.526	34.805	37.156
19	6.8439	7.6327	8.9065	10.1170	11.6509	27.204	30.144	32.852	36.191	38.582
20	7.4338	8.2604	9.5908	10.8508	12.4426	28.412	31.410	34.170	37.566	39.997
21	8.0336	8.8972	10.2829	11.5913	13.2396	29.615	32.671	35.479	38.932	41.401
22	8.6427	9.5425	10.9823	12.3380	14.0415	30.813	33.924	36.781	40.289	42.796
23	9.2604	10.1957	11.6885	13.0905	14.8480	32.007	35.172	38.076	41.638	44.181
24	9.8862	10.8563	12.4011	13.8484	15.6587	33.196	36.415	39.364	42.980	45.558
25	10.5196	11.5240	13.1197	14.6114	16.4734	34.382	37.652	40.646	44.314	46.928
26	11.1602	12.1982	13.8439	15.3792	17.2919	35.563	38.885	41.923	45.642	48.290
27	11.8077	12.8785	14.5734	16.1514	18.1139	36.741	40.113	43.195	46.963	49.645
28	12.4613	13.5647	15.3079	16.9279	18.9392	37.916	41.337	44.461	48.278	50.994
29	13.1211	14.2564	16.0471	17.7084	19.7677	39.087	42.557	45.722	49.588	52.335
30	13.7867	14.9535	16.7908	18.4927	20.5992	40.256	43.773	46.979	50.892	53.672
40	20.7066	22.1642	24.4331	26.5093	29.0505	51.805	55.758	59.342	63.691	66.766
50	27.9908	29.7067	32.3574	34.7642	37.6886	63.167	67.505	71.420	76.154	79.490
60	35.5344	37.4848	40.4817	43.1880	46.4589	74.397	79.082	83.298	88.379	91.952
70	43.2753	45.4417	48.7575	51.7393	55.3289	85.527	90.531	95.023	100.425	104.215
80	51.1719	53.5400	57.1532	60.3915	64.2778	96.578	101.879	106.629	112.329	116.321
90	59.1963	61.7540	65.6466	69.1260	73.2911	107.565	113.145	118.136	124.116	128.299
100	67.3275	70.0650	74.2219	77.9294	82.3581	118.498	124.342	129.561	135.807	140.170

Area of right hand tail $1 - \alpha/2$ and $\alpha/2$

TABLE 6.8 Values of Thompson's τ

Sample size		Sample size	
n	τ	n	τ
3	1.150	22	1.893
4	1.393	23	1.896
5	1.572	24	1.899
6	1.656	25	1.902
7	1.711	26	1.904
8	1.749	27	1.906
9	1.777	28	1.908
10	1.798	29	1.910
11	1.815	30	1.911
12	1.829	31	1.913
13	1.840	32	1.914
14	1.849	33	1.916
15	1.858	34	1.917
16	1.865	35	1.919
17	1.871	36	1.920
18	1.876	37	1.921
19	1.881	38	1.922
20	1.885	39	1.923
21	1.889	40	1.924

Source: ASME (1998).

1. (3 points) Fill in the blanks: A _____ is a random selection of items from a _____, usually made for evaluating its characteristics.

    ○ population, sample

    ○ sample, population

    ○ set, group

    ○ group, set

2. (3 points) The units of probability density are

    ○ the inverse of the units of the quantity whose probability is being considered.

    ○ the same as the units of the quantity whose probability is being considered.

    ○ count.

    ○ always dimensionless.

3. (3 points) According to the central limit theorem, any continuous, random variable whose value depends on many independent factors has a probability density function given by a

    ○ Poisson distribution.

    ○ binomial distribution.

    ○ chi-squared distribution.

    ○ normal distribution.

4. (3 points) A linear variable differential transformer is typically used for measuring

    ○ current.

    ○ magnetic field.

    ○ displacement.

    ○ stress.

5. (3 points) Manufacturers typically specify a strain gage's gain factor, which relates

    ○ strain to fractional change of thermoelectric voltage.

    ○ strain to fractional change of resistance.

    ○ strain to fractional change of magnetic field.

    ○ strain to fractional change of acoustic impedance.

6. (6 points) Sheets of glass used for manufacturing televisions or displays must be free of bubbles or other defects because each defect prevents diodes from properly bonding to the glass and therefore causes a faulty pixel, requiring the entire display to be discarded. In a particular manufacturing process, defects occur at random, at a rate of 1 per 1000 m^2 of glass sheet. What is the probability of having two or more defects in a glass sheet intended for a 98-inch display that has area 2.65 m^2?

7. With nine tests, the standard deviation of the tensile strength of a steel alloy is found to be 5750 psi.

   (a) (3 points) Determine the standard error of the mean.

   (b) (5 points) Determine the 99% uncertainty interval of the standard deviation (stating both its lower and upper bounds).

8. A dynamometer is used to determine the power transmitted to the wheels of an electric car by simultaneously measuring the torque T and angular rotation rate ω of the wheels. The power P is determined according to $P = T\omega$. With the car's settings held constant, the following measurements are made:

T (N·m)	407	388	408	414
ω (rad/s)	4757	4735	4777	4716

   (a) (2 points) Calculate the mean torque $\overline{T}$ and standard deviation of the torque, S_T.

   (b) (2 points) Determine the random uncertainty of the torque, with 95% confidence.

   (c) (2 points) Calculate the mean rotation rate $\overline{\omega}$ and standard deviation of the rotation rate S_ω.

   (d) (2 points) Determine the random uncertainty of the rotation rate, with 95% confidence.

   (e) (2 points) Calculate the mean power $\overline{P}$ and standard deviation of the power S_P.

   (f) (2 points) Determine the random uncertainty of the power, with 95% confidence.

   (g) (6 points) According to its manufacturer, the dynamometer measures both torque and rotation rate with accuracy 1% of the reading, with 95% confidence. Determine the systematic uncertainty in the power measurement.

   (h) (2 points) Determine the total uncertainty in the power measurement at 95% confidence.

   (i) (4 points) To reduce the total uncertainty, what would you do first?

   (j) (5 points) Which, if any, of the measurements of torque and rotation rate are outliers, according to Thompson's τ test?