ISE 315: Engineering Statistics

Homework 3 – Set B

Class Section: F-04
Instructor: Mansur M. Arief

Due: Wednesday, 18 February 2026, 12:00 PM (Gradescope)
Department of Industrial and Systems Engineering, KFUPM

Instructions

- Show all work for full credit. Clear procedure and reasoning is needed for correct answers.
- You may use a calculator or other software to assist with calculations.
- You may also use gen AI (if you want), but **only after** you have formulated and calculated your own answers. Any work submitted must be your own and you will be responsible for it.
- Submit your solutions via Gradescope, with each subproblem marked properly.
- Statistical tables (Standard Normal, t-distribution, Chi-Square) are provided in the Appendix.

Problem Sets

1. **(12 points)** A petrochemical plant monitors the benzene concentration (in mg/L) in wastewater discharge. A random sample of $n = 40$ measurements yields a sample mean of $\bar{x} = 0.85$ mg/L with a sample standard deviation of $s = 0.15$ mg/L. Using the large-sample approach, construct a 95% confidence interval for the true mean benzene concentration.

2. **(15 points)** The torque output (in N·m) of a servo motor in a collaborative robot is being characterized. A sample of $n = 18$ measurements yields a sample standard deviation of $s = 2.4$ N·m.

   (a) Construct a 95% confidence interval for the population variance σ^2.

   (b) Construct a 95% confidence interval for the population standard deviation σ.

3. **(12 points)** An autonomous vehicle company conducts lane-keeping tests. In a sample of $n = 180$ highway segments, the vehicle maintained proper lane position in 171 segments. Construct a 99% confidence interval for the true proportion of successful lane-keeping.

4. **(10 points)** A refinery engineer wants to estimate the mean flash point temperature of a diesel fuel blend. Previous testing indicates the flash point follows a normal distribution with $\sigma = 3.5$ degrees Celsius. How many samples must be tested to be 90% confident that the estimated mean is within ± 1 degree of the true mean?

5. **(12 points)** The lateral acceleration (in m/s^2) during autonomous vehicle cornering maneuvers follows a normal distribution. A sample of $n = 10$ tests yields $\bar{x} = 4.2$ m/s^2 and $s = 0.6$ m/s^2. Construct a 99% confidence interval for the true mean lateral acceleration.

6. **(15 points)** The flow rate (in barrels per day) through a pipeline segment is normally distributed with a known standard deviation of $\sigma = 450$ bbl/day. A sample of $n = 25$ daily readings yields $\bar{x} = 12{,}500$ bbl/day.

   (a) Construct a 95% confidence interval for the true mean flow rate.

   (b) Construct a 95% lower confidence bound for the true mean flow rate.

7. **(12 points)** A semiconductor fab uses mobile robots for wafer transport. Out of 95 transport missions in a shift, 7 required manual intervention due to navigation errors. Construct a 90% confidence interval for the true proportion of missions requiring intervention.

8. **(12 points)** The response time (in milliseconds) of a LiDAR sensor on an autonomous vehicle is known to follow a normal distribution with variance $\sigma^2 = 100$ ms^2. An engineer wants to estimate the mean response time within ± 3 ms with 99% confidence. What is the minimum sample size required?

Reference: Problems adapted from Montgomery & Runger, *Applied Statistics and Probability for Engineers*, Chapter 8.

AI Usage Statement: Generative AI (Claude Opus 4.5) assisted in the refinement of wording in this document. The instructor has revised, fully reviewed, and approved the content. (MMA)

Appendix: Statistical Tables

Table A.1: Standard Normal Distribution (Cumulative Probabilities)

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5359
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
1.0	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.9015
1.3	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9131	0.9147	0.9162	0.9177
1.4	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9279	0.9292	0.9306	0.9319
1.5	0.9332	0.9345	0.9357	0.9370	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
1.7	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
1.8	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706
1.9	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.9750	0.9756	0.9761	0.9767
2.0	0.9772	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
2.1	0.9821	0.9826	0.9830	0.9834	0.9838	0.9842	0.9846	0.9850	0.9854	0.9857
2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.9890
2.3	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
2.4	0.9918	0.9920	0.9922	0.9925	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
2.8	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
2.9	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986
3.0	0.9987	0.9987	0.9987	0.9988	0.9988	0.9989	0.9989	0.9989	0.9990	0.9990

Common Critical Values: $z_{0.10} = 1.282$, $z_{0.05} = 1.645$, $z_{0.025} = 1.96$, $z_{0.01} = 2.326$, $z_{0.005} = 2.576$

Table A.2: Critical Values of the t-Distribution

ν (df)	Upper-Tail Area α						
	0.40	0.25	0.10	0.05	0.025	0.01	0.005
1	0.325	1.000	3.078	6.314	12.706	31.821	63.657
2	0.289	0.816	1.886	2.920	4.303	6.965	9.925
3	0.277	0.765	1.638	2.353	3.182	4.541	5.841
4	0.271	0.741	1.533	2.132	2.776	3.747	4.604
5	0.267	0.727	1.476	2.015	2.571	3.365	4.032
6	0.265	0.718	1.440	1.943	2.447	3.143	3.707
7	0.263	0.711	1.415	1.895	2.365	2.998	3.499
8	0.262	0.706	1.397	1.860	2.306	2.896	3.355
9	0.261	0.703	1.383	1.833	2.262	2.821	3.250
10	0.260	0.700	1.372	1.812	2.228	2.764	3.169
11	0.260	0.697	1.363	1.796	2.201	2.718	3.106
12	0.259	0.695	1.356	1.782	2.179	2.681	3.055
13	0.259	0.694	1.350	1.771	2.160	2.650	3.012
14	0.258	0.692	1.345	1.761	2.145	2.624	2.977
15	0.258	0.691	1.341	1.753	2.131	2.602	2.947
16	0.258	0.690	1.337	1.746	2.120	2.583	2.921
17	0.257	0.689	1.333	1.740	2.110	2.567	2.898
18	0.257	0.688	1.330	1.734	2.101	2.552	2.878
19	0.257	0.688	1.328	1.729	2.093	2.539	2.861
20	0.257	0.687	1.325	1.725	2.086	2.528	2.845
21	0.257	0.686	1.323	1.721	2.080	2.518	2.831
22	0.256	0.686	1.321	1.717	2.074	2.508	2.819
23	0.256	0.685	1.319	1.714	2.069	2.500	2.807
24	0.256	0.685	1.318	1.711	2.064	2.492	2.797
25	0.256	0.684	1.316	1.708	2.060	2.485	2.787
26	0.256	0.684	1.315	1.706	2.056	2.479	2.779
27	0.256	0.684	1.314	1.703	2.052	2.473	2.771
28	0.256	0.683	1.313	1.701	2.048	2.467	2.763
29	0.256	0.683	1.311	1.699	2.045	2.462	2.756
30	0.256	0.683	1.310	1.697	2.042	2.457	2.750
40	0.255	0.681	1.303	1.684	2.021	2.423	2.704
60	0.254	0.679	1.296	1.671	2.000	2.390	2.660
120	0.254	0.677	1.289	1.658	1.980	2.358	2.617
∞	0.253	0.674	1.282	1.645	1.960	2.326	2.576

Table A.3: Critical Values of the Chi-Square Distribution

ν (df)	Upper-Tail Area α						
	0.995	0.99	0.975	0.95	0.05	0.025	0.01
1	0.000	0.000	0.001	0.004	3.841	5.024	6.635
2	0.010	0.020	0.051	0.103	5.991	7.378	9.210
3	0.072	0.115	0.216	0.352	7.815	9.348	11.345
4	0.207	0.297	0.484	0.711	9.488	11.143	13.277
5	0.412	0.554	0.831	1.145	11.070	12.833	15.086
6	0.676	0.872	1.237	1.635	12.592	14.449	16.812
7	0.989	1.239	1.690	2.167	14.067	16.013	18.475
8	1.344	1.646	2.180	2.733	15.507	17.535	20.090
9	1.735	2.088	2.700	3.325	16.919	19.023	21.666
10	2.156	2.558	3.247	3.940	18.307	20.483	23.209
11	2.603	3.053	3.816	4.575	19.675	21.920	24.725
12	3.074	3.571	4.404	5.226	21.026	23.337	26.217
13	3.565	4.107	5.009	5.892	22.362	24.736	27.688
14	4.075	4.660	5.629	6.571	23.685	26.119	29.141
15	4.601	5.229	6.262	7.261	24.996	27.488	30.578
16	5.142	5.812	6.908	7.962	26.296	28.845	32.000
17	5.697	6.408	7.564	8.672	27.587	30.191	33.409
18	6.265	7.015	8.231	9.390	28.869	31.526	34.805
19	6.844	7.633	8.907	10.117	30.144	32.852	36.191
20	7.434	8.260	9.591	10.851	31.410	34.170	37.566
21	8.034	8.897	10.283	11.591	32.671	35.479	38.932
22	8.643	9.542	10.982	12.338	33.924	36.781	40.289
23	9.260	10.196	11.689	13.091	35.172	38.076	41.638
24	9.886	10.856	12.401	13.848	36.415	39.364	42.980
25	10.520	11.524	13.120	14.611	37.652	40.646	44.314
26	11.160	12.198	13.844	15.379	38.885	41.923	45.642
27	11.808	12.879	14.573	16.151	40.113	43.195	46.963
28	12.461	13.565	15.308	16.928	41.337	44.461	48.278
29	13.121	14.256	16.047	17.708	42.557	45.722	49.588
30	13.787	14.953	16.791	18.493	43.773	46.979	50.892
40	20.707	22.164	24.433	26.509	55.758	59.342	63.691
50	27.991	29.707	32.357	34.764	67.505	71.420	76.154
60	35.534	37.485	40.482	43.188	79.082	83.298	88.379

Note: For a two-sided $(1-\alpha)$ confidence interval on variance, use $\chi^2_{\alpha/2,\nu}$ (upper) and $\chi^2_{1-\alpha/2,\nu}$ (lower).