Birla Institute of Technology & Science, Pilani
First Semester 2022-23 (Mid-term Examination - Regular)

ME F443 (QCAR)   **Total Marks: 30**
Date: 01/11/2022   **Duration 1.5hrs**

You are required to be very brief and specific in your answers   **[Each 2Mark]**

Question 1.
(a) If a process is in a state of statistical control, does it necessarily follow that all or nearly all of the units of product produced will be within the specification limits?
(b) Discuss the logic underlying the use of three-sigma limits on Shewhart control charts. How will the chart respond if narrower limits are chosen? How will it respond if wider limits are chosen?
(c) Sketch the extended process in Deming philosophy
(d) State one of the seven deadly sins and one of the fourteen points from Deming's philosophy
(e) What are eight dimensions of Quality defined by Garvin?
(f) What are the tools used for Quality Improvement activities? Justify your answer.
(g) What is Hidden failure cost? How is it different from Failure Quality cost?
(h) Discuss the differences between service and product quality characteristics.
(i) List down three important similarities between Juran's and Deming's philosophies.
(j) Why errors are part and parcel of every sampling process and how do you minimize it?
(k) How level of significance is linked with p-value used in hypothesis testing? **[Bonus]**

Question 2.
Two parts are assembled as shown in Fig. 1. Assume that the dimensions X and Y are normally distributed with means μ_x and μ_y and standard deviations σ_x and σ_y respectively. The parts are produced on different machines and are assembled at random.
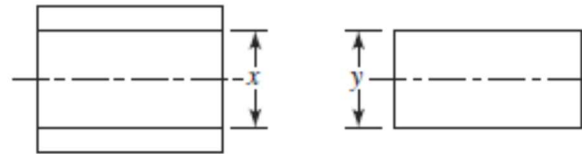
(a) Determine the distribution for X+Y and X-Y, with mean and variance.
(b) The mean of outside diameter of shaft and inside diameter of journal are 9.0 cm and 9.1 cm respectively. And the SD of shaft and hole are 0.033 cm and 0.043 cm. Determine the proportion of nonconforming assemblies.
(c) If it is desired that the probability of a smaller clearance than 0.09 should be 0.006, what distance between the average dimensions should be specified?   **[2+2 +2]**

Question 3.
Two machinist measured the surface finish of metal part manufactured by them and the data is shown in Table 1. Assume that the measurements are normally distributed. (a) Test the hypothesis that the mean surface finish measurements made by the two technicians are equal. Use $\alpha = 0.05$ and assume equal variances. Discuss the practical implications of the test.
(b) Test the hypothesis that the variances of the measurements made by the two machinist are equal. Use $\alpha = 0.05$ and discuss the implication. What changes will we need to take care in (a) when the variances are not equal?   **[2+2]**

Machinist 1	Machinist 2
1.45	1.54
1.37	1.41
1.21	1.56
1.54	1.37
1.48	1.20
1.29	1.31
1.34	1.27
	1.35

Formulas Sheet

(a) $P(x) = \dfrac{\dbinom{D}{x}\dbinom{N-D}{n-x}}{\dbinom{N}{n}}$ $\quad x = 0,1\ldots\ldots,\min(n,D)$, (b) $p(x) = \dbinom{n}{x}p^x(1-p)^{n-x}$, $\quad x = 0,1,2\ldots\ldots n$

(c) $P(x) = \dfrac{e^{-\lambda}\lambda^x}{x!}$, $\qquad x = 0,1,2\ldots\ldots$, (d) $f(x) = \dfrac{1}{\sqrt{2\pi}\sigma}\exp\left[\dfrac{-(x-\mu)^2}{2\sigma^2}\right]$, $\qquad \infty \le x \le \infty$

(e) $f(z) = \dfrac{1}{\sqrt{2\pi}}e^{-z^2/2}$, $\quad -\infty < z < \infty$, (f) $f(x) = \left(\dfrac{\beta}{\theta}\right)\left(\dfrac{x}{\theta}\right)^{\beta-1}\exp\left[-\left(\dfrac{x}{\theta}\right)^{\beta}\right]$

(g) $\overline{X} - Z_{\alpha/2}\dfrac{\sigma}{\sqrt{n}} \le \mu \le \overline{X} + Z_{\alpha/2}\dfrac{\sigma}{\sqrt{n}}$, (h) $\overline{X} - t_{\alpha/2,\,n-1}\dfrac{s}{\sqrt{n}} \le \mu \le \overline{X} + t_{\alpha/2,\,n-1}\dfrac{s}{\sqrt{n}}$

(i) $(\overline{X}_1 - \overline{X}_2) - Z_{\alpha/2}\sqrt{\dfrac{\sigma_1^2}{n_1} + \dfrac{\sigma_2^2}{n_2}} \le \mu_1 - \mu_2 \le (\overline{X}_1 - \overline{X}_2) + Z_{\alpha/2}\sqrt{\dfrac{\sigma_1^2}{n_1} + \dfrac{\sigma_2^2}{n_2}}$

(j) $\hat{p} - Z_{\alpha/2}\sqrt{\dfrac{\hat{p}(1-\hat{p})}{n}} \le p \le \hat{p} + Z_{\alpha/2}\sqrt{\dfrac{\hat{p}(1-\hat{p})}{n}}$ (l) $\dfrac{(n-1)s^2}{\chi^2_{\alpha/2,\,n-1}} \le \sigma^2 \le \dfrac{(n-1)s^2}{\chi^2_{1-\alpha/2,\,n-1}}$

(k) $(\hat{p}_1 - \hat{p}_2) - Z_{\alpha/2}\sqrt{\dfrac{\hat{p}_1(1-\hat{p}_1)}{n_1} + \dfrac{\hat{p}_2(1-\hat{p}_2)}{n_2}} \le p_1 - p_2 \le (\hat{p}_1 - \hat{p}_2) + Z_{\alpha/2}\sqrt{\dfrac{\hat{p}_1(1-\hat{p}_1)}{n_1} + \dfrac{\hat{p}_2(1-\hat{p}_2)}{n_2}}$

(m) $(\overline{X}_1 - \overline{X}_2) - t_{\alpha/2,\,n_1+n_2-2}\,S_p\sqrt{\dfrac{1}{n_1} + \dfrac{1}{n_2}} \le \mu_1 - \mu_2 \le (\overline{X}_1 - \overline{X}_2) + t_{\alpha/2,\,n_1+n_2-2}\,S_p\sqrt{\dfrac{1}{n_1} + \dfrac{1}{n_2}}$

(n) $\dfrac{s_1^2}{s_2^2}\left(\dfrac{1}{F_{\alpha/2,\,v_1,v_2}}\right) \le \dfrac{\sigma_1^2}{\sigma_2^2} \le \dfrac{s_1^2}{s_2^2}\left(\dfrac{1}{F_{1-\alpha/2,\,v_1,v_2}}\right)$, $F_0 = \dfrac{s_1^2}{s_2^2}$, (o) $\beta = \Phi\left(Z_{\frac{\alpha}{2}} - \dfrac{\delta\sqrt{n}}{\sigma}\right) - \Phi\left(-Z_{\frac{\alpha}{2}} - \dfrac{\delta\sqrt{n}}{\sigma}\right)$

(p) $[UCL_{\overline{x}}\ LCL_{\overline{x}}] = \overline{\overline{X}} \pm 3\dfrac{\overline{R}}{d_2.\sqrt{n}}$ $= \overline{\overline{X}} \pm A_2\overline{R}$, $\hat{\sigma} = \dfrac{\overline{R}}{d_2}$, $\dfrac{UCL_R}{LCL_R} = \overline{R}\left(1 \pm 3\dfrac{d_3}{d_2}\right) = (D_3\overline{R}, D_4\overline{R})$

(r) $[LCL_{\overline{X}}\quad UCL_{\overline{X}}] = \overline{\overline{X}} \pm 3.\dfrac{\overline{s}}{c_4\sqrt{n}}$ $= \overline{\overline{X}} \pm A_3\overline{s}$, $\hat{\sigma} = \dfrac{\overline{s}}{c_4}$, $\dfrac{UCL_s}{LCL_s} = \overline{s} \pm 3.\dfrac{\overline{s}}{c_4}.\sqrt{1-c_4^2} = \dfrac{B_4\overline{s}}{B_3\overline{s}}$

(s) $[UCL_{\overline{X}}\quad LCL_{\overline{X}}] = \overline{X}_0 \pm 3.\dfrac{\sigma_0}{\sqrt{n}}$ $= \overline{X}_0 \pm A.\sigma_0$, (l) $S_p^2 = \dfrac{(n_1-1)s_1^2 + (n_2-1)s_2^2}{n_1 + n_2 - 2}$

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Cumulative standard Normal distribution chart

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.500000	0.503989	0.507978	0.511967	0.515953	0.519939	0.532922	0.527903	0.531881	0.535856
0.1	0.539828	0.543795	0.547758	0.551717	0.555760	0.559618	0.563559	0.567495	0.571424	0.575345
0.2	0.579260	0.583166	0.587064	0.590954	0.594835	0.598706	0.602568	0.606420	0.610261	0.614092
0.3	0.617911	0.621719	0.625516	0.629300	0.633072	0.636831	0.640576	0.644309	0.648027	0.651732
0.4	0.655422	0.659097	0.662757	0.666402	0.670031	0.673645	0.677242	0.680822	0.684386	0.687933
0.5	0.691462	0.694974	0.698468	0.701944	0.705401	0.708840	0.712260	0.715661	0.719043	0.722405
0.6	0.725747	0.729069	0.732371	0.735653	0.738914	0.742154	0.745373	0.748571	0.751748	0.754903
0.7	0.758036	0.761148	0.764238	0.767305	0.770350	0.773373	0.776373	0.779350	0.782305	0.785236
0.8	0.788145	0.791030	0.793892	0.796731	0.799546	0.802338	0.805106	0.807850	0.810570	0.813267
0.9	0.815940	0.818589	0.821214	0.823815	0.826391	0.828944	0.831472	0.833977	0.836457	0.838913
1.0	0.841345	0.843752	0.846136	0.848495	0.850830	0.853141	0.855428	0.857690	0.859929	0.862143
1.1	0.864334	0.866500	0.868643	0.870762	0.872857	0.874928	0.876976	0.878999	0.881000	0.882977
1.2	0.884930	0.886860	0.888767	0.890651	0.892512	0.894350	0.896165	0.897958	0.899727	0.901475
1.3	0.903199	0.904902	0.906582	0.908241	0.909877	0.911492	0.913085	0.914657	0.916207	0.917736
1.4	0.919243	0.920730	0.922196	0.923641	0.925066	0.926471	0.927855	0.929219	0.930563	0.931888
1.5	0.933193	0.934478	0.935744	0.936992	0.938220	0.939429	0.940620	0.941792	0.942947	0.944083
1.6	0.945201	0.946301	0.947384	0.948449	0.949497	0.950529	0.951543	0.952540	0.953521	0.954486
1.7	0.955435	0.956367	0.957284	0.958185	0.959071	0.959941	0.960796	0.961636	0.962462	0.963273
1.8	0.964070	0.964852	0.965621	0.966375	0.967116	0.967843	0.968557	0.969258	0.969946	0.970621
1.9	0.971283	0.971933	0.972571	0.973197	0.973810	0.974412	0.975002	0.975581	0.976148	0.976705
2.0	0.977250	0.977784	0.978308	0.978822	0.979325	0.979818	0.980301	0.980774	0.981237	0.981691
2.1	0.982136	0.982571	0.982997	0.983414	0.983823	0.984222	0.984614	0.984997	0.985371	0.985738
2.2	0.986097	0.986447	0.986791	0.987126	0.987455	0.987776	0.988089	0.988396	0.988696	0.988989
2.3	0.989276	0.989556	0.989830	0.990097	0.990358	0.990613	0.990863	0.991106	0.991344	0.991576
2.4	0.991802	0.992024	0.992240	0.992451	0.992656	0.992857	0.993053	0.993244	0.993431	0.993613
2.5	0.993790	0.993963	0.994132	0.994297	0.994457	0.994614	0.994766	0.994915	0.995060	0.995201
2.6	0.995339	0.995473	0.995604	0.995731	0.995855	0.995975	0.996093	0.996207	0.996319	0.996427
2.7	0.996533	0.996636	0.996736	0.996833	0.996928	0.997020	0.997110	0.997197	0.997282	0.997365
2.8	0.997445	0.997523	0.997599	0.997673	0.997744	0.997814	0.997882	0.997948	0.998012	0.998074
2.9	0.998134	0.998193	0.998250	0.998305	0.998359	0.998411	0.998462	0.998511	0.998559	0.998605
3.0	0.998650	0.998694	0.998736	0.998777	0.998817	0.998856	0.998893	0.998930	0.998965	0.998999
3.1	0.999032	0.999065	0.999096	0.999126	0.999155	0.999184	0.999211	0.999238	0.999264	0.999289
3.2	0.999313	0.999336	0.999359	0.999381	0.999402	0.999423	0.999443	0.999462	0.999481	0.999499
3.3	0.999517	0.999533	0.999550	0.999566	0.999581	0.999596	0.999610	0.999624	0.999638	0.999650
3.4	0.999663	0.999675	0.999687	0.999698	0.999709	0.999720	0.999730	0.999740	0.999749	0.999758
3.5	0.999767	0.999776	0.999784	0.999792	0.999800	0.999807	0.999815	0.999821	0.999828	0.999835
3.6	0.999841	0.999847	0.999853	0.999858	0.999864	0.999869	0.999874	0.999879	0.999883	0.999888
3.7	0.999892	0.999896	0.999900	0.999904	0.999908	0.999912	0.999915	0.999918	0.999922	0.999925
3.8	0.999928	0.999931	0.999933	0.999936	0.999938	0.999941	0.999943	0.999946	0.999948	0.999950
3.9	0.999952	0.999954	0.999956	0.999958	0.999959	0.999961	0.999963	0.999964	0.999966	0.999967

Chi-squared value for a specified Right hand area

Degrees of Freedom v	α = Right-Hand Tail Area											
	.999	.995	.99	.975	.95	.90	.10	.05	.025	.01	.005	.001
1	.00	.00	.00	.00	.00	.02	2.71	3.84	5.02	6.63	7.88	10.83
2	.00	.01	.02	.05	.10	.21	4.61	5.99	7.38	9.21	10.60	13.81
3	.02	.07	.11	.22	.35	.58	6.25	7.81	9.35	11.34	12.84	16.25
4	.09	.21	.30	.48	.71	1.06	7.78	9.49	11.14	13.28	14.86	18.45
5	.21	.41	.55	.83	1.15	1.61	9.24	11.07	12.83	15.09	16.75	20.50
6	.38	.68	.87	1.24	1.64	2.20	10.64	12.59	14.45	16.81	18.54	22.44
7	.60	.99	1.24	1.69	2.17	2.83	12.02	14.07	16.01	18.48	20.28	24.30
8	.86	1.34	1.65	2.18	2.73	3.49	13.36	15.51	17.53	20.09	21.95	26.11
9	1.15	1.74	2.09	2.70	3.33	4.17	14.68	16.92	19.02	21.67	23.59	27.86
10	1.48	2.16	2.56	3.25	3.94	4.87	15.99	18.31	20.48	23.21	25.19	29.57
11	1.83	2.60	3.05	3.82	4.57	5.58	17.27	19.68	21.92	24.72	26.76	31.25
12	2.22	3.07	3.57	4.40	5.23	6.30	18.55	21.03	23.34	26.22	28.30	32.90
13	2.62	3.57	4.11	5.01	5.89	7.04	19.81	22.36	24.74	27.69	29.82	34.52
14	3.05	4.07	4.66	5.63	6.57	7.79	21.06	23.68	26.12	29.14	31.32	36.12
15	3.48	4.60	5.23	6.26	7.26	8.55	22.31	25.00	27.49	30.58	32.80	37.69

T -table

v	0.40	0.25	0.10	0.05	0.025	0.01	0.005	0.0025	0.001	0.0005
1	0.325	1.000	3.078	6.314	12.706	31.821	63.657	127.32	318.31	636.62
2	0.289	0.816	1.886	2.920	4.303	6.965	9.925	14.089	23.326	31.598
3	0.277	0.765	1.638	2.353	3.182	4.541	5.841	7.453	10.213	12.924
4	0.271	0.741	1.533	2.132	2.776	3.747	4.604	5.598	7.173	8.610
5	0.267	0.727	1.476	2.015	2.571	3.365	4.032	4.773	5.893	6.869
6	0.265	0.727	1.440	1.943	2.447	3.143	3.707	4.317	5.208	5.959
7	0.263	0.711	1.415	1.895	2.365	2.998	3.49	4.019	4.785	5.408
8	0.262	0.706	1.397	1.860	2.306	2.896	3.355	3.833	4.501	5.041
9	0.261	0.703	1.383	1.833	2.262	2.821	3.250	3.690	4.297	4.781
10	0.260	0.700	1.372	1.812	2.228	2.764	3.169	3.581	4.144	4.587
11	0.260	0.697	1.363	1.796	2.20	2.718	3.106	3.497	4.025	4.437
12	0.259	0.695	1.356	1.782	2.179	2.681	3.055	3.428	3.930	4.318
13	0.259	0.694	1.350	1.771	2.160	2.650	3.012	3.372	3.852	4.221
14	0.258	0.692	1.345	1.761	2.145	2.624	2.977	3.326	3.787	4.140
15	0.258	0.691	1.341	1.753	2.131	2.602	2.947	3.286	3.733	4.073
16	0.258	0.690	1.337	1.746	2.120	2.583	2.921	3.252	3.686	4.015
17	0.257	0.689	1.333	1.740	2.110	2.567	2.898	3.222	3.646	3.965
18	0.257	0.688	1.330	1.734	2.101	2.552	2.878	3.197	3.610	3.992
19	0.257	0.688	1.328	1.729	2.093	2.539	2.861	3.174	3.579	3.883
20	0.257	0.687	1.325	1.725	2.086	2.528	2.845	3.153	3.552	3.850

Values of F for specified Right Tail area

$F_{0.25,\ v_1,\ v_2}$

v_2 \ v_1	Degrees of freedom for the numerator (v_1)											
	1	2	3	4	5	6	7	8	9	10	12	15
1	5.83	7.50	8.20	8.58	8.82	8.98	9.10	9.19	9.26	9.32	9.41	9.49
2	2.57	3.00	3.15	3.23	3.28	3.31	3.34	3.35	3.37	3.38	3.39	3.41
3	2.02	2.28	2.36	2.39	2.41	2.42	2.43	2.44	2.44	2.44	2.45	2.46
4	1.81	2.00	2.05	2.06	2.07	2.08	2.08	2.08	2.08	2.08	2.08	2.08
5	1.69	1.85	1.88	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89
6	1.62	1.76	1.78	1.79	1.79	1.78	1.78	1.78	1.77	1.77	1.77	1.76
7	1.57	1.70	1.72	1.72	1.71	1.71	1.70	1.70	1.70	1.69	1.68	1.68
8	1.54	1.66	1.67	1.66	1.66	1.65	1.64	1.64	1.63	1.63	1.62	1.62
9	1.51	1.62	1.63	1.63	1.62	1.61	1.60	1.60	1.59	1.59	1.58	1.57
10	1.49	1.60	1.60	1.59	1.59	1.58	1.57	1.56	1.56	1.55	1.54	1.53
11	1.47	1.58	1.58	1.57	1.56	1.55	1.54	1.53	1.53	1.52	1.51	1.50
12	1.46	1.56	1.56	1.55	1.54	1.53	1.52	1.51	1.51	1.50	1.49	1.48
13	1.45	1.55	1.55	1.53	1.52	1.51	1.50	1.49	1.49	1.48	1.47	1.46
14	1.44	1.53	1.53	1.52	1.51	1.50	1.49	1.48	1.47	1.46	1.45	1.44
15	1.43	1.52	1.52	1.51	1.49	1.48	1.47	1.46	1.46	1.45	1.44	1.43
16	1.42	1.51	1.51	1.50	1.48	1.47	1.46	1.45	1.44	1.44	1.43	1.41
17	1.42	1.51	1.50	1.49	1.47	1.46	1.45	1.44	1.43	1.43	1.41	1.40
18	1.41	1.50	1.49	1.48	1.46	1.45	1.44	1.43	1.42	1.42	1.40	1.39
19	1.41	1.49	1.49	1.47	1.46	1.44	1.43	1.42	1.41	1.41	1.40	1.38
20	1.40	1.49	1.48	1.47	1.45	1.44	1.43	1.42	1.41	1.40	1.39	1.37
21	1.40	1.48	1.48	1.46	1.44	1.43	1.42	1.41	1.40	1.39	1.38	1.37
22	1.40	1.48	1.47	1.45	1.44	1.42	1.41	1.40	1.39	1.39	1.37	1.36
23	1.39	1.47	1.47	1.45	1.43	1.42	1.41	1.40	1.39	1.38	1.37	1.35
24	1.39	1.47	1.46	1.44	1.43	1.41	1.40	1.39	1.38	1.38	1.36	1.35
25	1.39	1.47	1.46	1.44	1.42	1.41	1.40	1.39	1.38	1.37	1.36	1.34