1. Diameters of holes and shafts have been measured as follows (unit: inches).

Shaft	0.995	0.992	0.994	0.996	0.999	0.995	0.996	0.99	0.994	0.997
Hole	1.001	1.005	1.003	1.004	1.005	0.998	1.01	1.002	1.005	1

(a) Show the tolerance of the hole and shaft using the unilateral and bilateral notations. For the unilateral specification, use 0 as the lower tolerance limit for the holes and as the upper tolerance limit for the shafts.

(b) Determine the allowance (interference or clearance).

(c) The tolerance of an assembled length T_s equals $\sqrt{(T_A)^2+(T_B)^2+\ldots}$ where T_A etc. equals the tolerance of the individual parts. What is the tolerance on the assembled part?

2. Surface roughness measurements were taken from the surface of a machined workpiece as shown in Table 1. Answer the following questions.

Point	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Value	0.35	0.95	0.2	-0.55	-0.83	-0.22	0.75	0.12	0.33	-0.68	-0.85	0.22

(a) Calculate the arithmetic average of the roughness.

(b) Calculate the root mean square value.

(c) Draw a surface finish symbol which will show the arithmetic average calculated above with a cutoff length of 0.030 in. when the measurement was taken in the direction normal to the machining paths.

3. Parts made in a production system have been measured as shown in the table below.

sample number	x1	x2	x3	x4	x5	**Average**	**R**
1	0.55	0.56	0.57	0.55	0.57	0.560	0.02
2	0.59	0.56	0.6	0.58	0.56	0.578	0.04
3	0.55	0.52	0.55	0.54	0.53	0.538	0.03
4	0.54	0.57	0.55	0.56	0.53	0.550	0.04
5	0.58	0.58	0.6	0.56	0.58	0.580	0.04
6	0.6	0.61	0.55	0.61	0.58	0.590	0.06
7	0.58	0.55	0.59	0.53	0.57	0.564	0.06

(a) Determine the values of center, *LCL*, and *UCL* for the $\bar{x}$ and R using the first part of eqs. (36.6) and (36.7) of the textbook.

(b) Construct the control charts and plot the sample data on the charts.

(c) Calculate the process capabilities parameters, *Cp* and *Cpk* using the $UCL_{\bar{x}}$ and $LCL_{\bar{x}}$ obtained in part (a) as USL and LSL.

(d) Repeat the part (c) using the $UCL_{\bar{x}}$ and $LCL_{\bar{x}}$ values shown in the second part of eqs. (36.6) and (36.7) in the book as USL and LSL, respectively.

(e) Repeat the part (c) assuming the *USL* and *LSL* are set as 0.62 and 0.52.

4 Two lathes are used to machine 1 inch bars. The diameters of five parts machined on each machine were measured with a vernier caliper. For machine A, the five measurements were 1.01, 0.95, 1.03, 0.98, 1.02 and 1.02 inches. For machine B, the five measurements were 1.02, 1.01, 1.03, 1.01, 1.02 and 0.97 inches. Which machine has the better accuracy and which one has the better precision?