

- 1 Potato chips are being produced and packed in a factory. On the bags it says “160 g”. From yesterday’s production of chips, the company’s quality technician Erica took out 19 randomly selected bags of chips and weighted the content. The result is seen in Table 1.

*Table 1: The net weight of 19 tested potato chips bags (in the unit g)*

166,6	167,2	164,8	162,3	161,9	160,5	165,1	164,4	165,3	166,3
167,7	165,0	165,9	163,9	163,3	166,0	161,1	169,7	165,8	

- Calculate analytically (by calculator, using the built-in statistical function is OK) the sample *median*, *mean*, *range*, *variance*, and *standard deviation*, based on the measurements in Table1. (1p)
- Estimate the proportion (percentage) of bags that during the next couple of days of production can be expected to contain *less* than 160 g of chips. *Hint: Assume normal distribution and make use of the normal probability table for  $N(0,1)$ .* (2,5p)
- Construct a boxplot (box-and-whisker-plot) based on Table 1. (1,5p)
- Can the data in Table 1 be considered to come from a normal distribution? Use a *Normal probability paper* (see appendix at the end of the exam) to answer that question. Also, estimate graphically (using the normal probability paper) the parameters  $\mu$  (mu) and  $\sigma$  (sigma) for a normal distribution that best would fit to the data we have in Table 1. (3,5p)
- Estimate the proportion (percentage) of bags that during the next couple of days production can be expected to contain *less* than 160 g of chips, using graphical method (the used normal probability paper from 1d). (1p)
- Estimate a 98% confidence interval for the true mean of the distribution, based on the sample of 19 measurements in Table 1. (1,5p)
- What are your thoughts and conclusions about the production of potato chips at this company? Which suggestions would you give Erica? Discuss and motivate. (1p)
- If 40% of the workers in the chips company are women, and 20% of the workers in the chips factory are left-handed, what is the probability that a randomly chosen worker in the chips factory will be a woman, or left-handed, or both? (1p)

- 2 A company produces different electrical resistors. One of the products has the specifications  $40 \pm 1,5$  ohm. Over the last 10 days the company quality technician Mary has taken out the four first produced resistors of the day and measured their resistance. The result is seen in Table 2.

*Table 2: The resistance of measured resistors (in the unit ohm)*

<b>Day 1</b>	40,3	40,0	40,1	39,9
<b>Day 2</b>	40,6	41,5	40,7	40,7
<b>Day 3</b>	40,6	40,5	40,2	39,8
<b>Day 4</b>	40,4	40,4	40,0	40,1
<b>Day 5</b>	40,3	40,2	40,0	40,5
<b>Day 6</b>	40,3	40,5	40,2	40,6
<b>Day 7</b>	40,4	40,6	40,3	40,1
<b>Day 8</b>	40,6	40,6	40,6	40,6
<b>Day 9</b>	39,9	39,9	40,5	40,4
<b>Day 10</b>	40,2	40,1	40,4	40,6

- a) Set up an  $\bar{x}$  chart and an R chart and analyze the process. Can the process be considered in statistical control? Comment and motivate. Also discuss (speculate) possible causes for the looks of the control charts and any suspected alarm situations. What are your suggestions to Mary and to the company? (6p)
- b) Conduct a process capability analysis based on the given data. Estimate and comment on  $C_p$ ,  $C_M$  and  $C_{pk}$ . Also establish a 95% confidence interval for  $C_p$  and  $C_{pk}$  and comment on the results. What are your conclusions? What are your suggestions to Mary and to the company? (6p)
- c) Mary decides to do a simplified MSA (Measurement System Analysis) by taking the same resistor (which is known to have exactly 42,000 ohm) and measure it ten times, with the same instrument that she normally uses in the process as she checks the resistance (also used for the measurements in Table 1). The ten measurements are seen in Table 3.

*Table 3: Results of ten times measuring the same resistor (in the unit ohm)*

41,8	41,9	41,8	41,7	41,9	41,6	41,8	41,7	42,0	41,9
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Help Mary by evaluating the measuring system. What can you say about the accuracy (calibration needed?) of the measuring instrument? What can you say about the precision (reduced spread needed?) What are your conclusions? What are your suggestions to Mary and to the company? (3p)

- d) Now recalculate the point estimates of  $C_p$  and  $C_{pk}$  based on your “new” knowledge about the measuring system, i.e. taking the results of 1c into account. Comment and motivate. What are your conclusions? *Hint: You only need to calculate the point estimates this time, not the confidence intervals.* (2p)
- e) What do you think of the sampling procedure Mary was using in 2a? Which pros and cons (positives and negatives) do you see with that? What practical changes would you suggest and why? (1p)

- 3 An industrial laundry has experienced some complaints from customers lately, about clothes not always being clean enough after being washed and delivered back to the customer. In order to investigate the problem, each week over 10 weeks' time, 150 batches (washing runs) were inspected after the washing procedure. The number of batches (of the 150) that were found to have some dirty clothes was noticed. The result is seen in Table 4.

Table 4: Number of "dirty" batches (of 150 tested) every week for 10 weeks

	Week									
	1	2	3	4	5	6	7	8	9	10
Number of "dirty" batches	5	2	8	3	3	1	6	0	4	2

- a) Evaluate the stability of the process, by setting up a suitable control chart and analyze it. Can the process be considered in statistical control? Comment and motivate. What are your conclusions? What are your suggestions to the company? (3p)
- b) Let us now say that the data in Table 4 is NOT the number of batches that contain dirty clothes, but instead we assume that the data show the *number of stains* found on the clothes during each inspection. For example, the first week revealed 5 stains in total, on the clothes in the 150 batches of clothes inspected that week. Now set up a suitable control chart for *this* situation and analyze it. Comment and reflect on similarities and differences compared to what you found in 3a. (3p)

- 4 In a chemical factory there is a climate chamber used in one of the processes. According to working procedures, the chamber should ideally have an air pressure of 945 hPa. For twelve days in a row, every morning before the production started, the quality technician Billy measured the air pressure in the chamber. The result is shown in Table 5.

Table 5: Air pressure in the process climate chamber (in the unit hPa)

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12
953	945	972	945	975	970	959	973	940	936	985	973

Your task:

Analyze the process by setting up an EWMA control chart for these 12 days. Can the process be considered in statistical control, relative to the target value? Comment and motivate. What are your conclusions? What are your suggestions to Billy and to the company? *Hint: You need to plot all twelve days, only you only need to estimate the exact control limits for the first three days. For day 4-12 you can instead approximate with the steady-state control limits.* (6p)



