UNIVERSITY OF JORDAN
CHEMICAL ENGINEERING DEPARTMENT

0905331 – PROCESS MODELING BY STATISTICAL METHODS

Name	
University ID	

Course Process modeling by statistical methods (0905331)	
Exam	Final
Date	Wednesday, 17/1/2007
Time	120 minutes (open book)
Instructor	Dr. Ali Al-matar

Problem	Full Mark	Mark
1	35	
2 or 3	20	
4	15	
5	30	
Total	**100**	

وقّع على القسَم التالي المتعلق بالغش الأكاديمي:

اقسم بالله أنني لم أغش في هذا الامتحان ولم أساعد أي شخص على الغش سواءً لمنفعتي الشخصية أو لمنفعة الآخرين، وعلى هذا أوقّع.

التوقيع:

1. **(35 points)** Kumar, Muajumder, Kundu, and Mukherjee (*Bubble size distribution and gas–liquid interfacial area in a modified downflow bubble column, Chemical Engineering Journal, Volume 122, Issues 1-2, 1 September 2006, Pages 1-10*) measured the bubble size distribution in a gas-liquid contactor at three different locations: A, B, and C. Their results at the three different locations are given in Table 1 below.

Table 1 Bubble size distribution at various locations.

Class i	Center of Class	N_i			Cumulative frequency			Relative frequency, $p_i = N_i / \sum N_i$		
(mm)	(mm)	Location			Location			Location		
		A	B	C	A	B	C	A	B	C
0–0.125		103	0	0						
0.125–0.375		187	0	0						
0.375–0.625		96	0	0						
0.625–0.875		87	78	26						
0.875–1.125		31	255	259						
1.125–1.375		2	123	155						
1.375–1.625		1	41	63						
1.625–1.875		0	16	27						
1.875–2.125		0	6	10						
2.125–2.375		0	2	3						
2.375–2.625		0	0	1						

Class i	Center of Class									
(mm)	(mm)	Location			Location			Location		
		A	B	C	A	B	C	A	B	C
0–0.125										
0.125–0.375										
0.375–0.625										
0.625–0.875										
0.875–1.125										
1.125–1.375										
1.375–1.625										
1.625–1.875										
1.875–2.125										
2.125–2.375										
2.375–2.625										

a. Fill in the empty columns in the table.
b. Provide a point estimate for the mean bubble size of the population represented by the results of location A, B and C. What can you say about these values?
c. Provide a point estimate for the standard deviation for the bubble size of the population represented by the results of location B.
d. What is the standard error for the sample mean of B?
e. What is the median for C?
f. What is the mode for C?
g. Determine the CV for B.

h. Determine coefficient of skewness for location C.

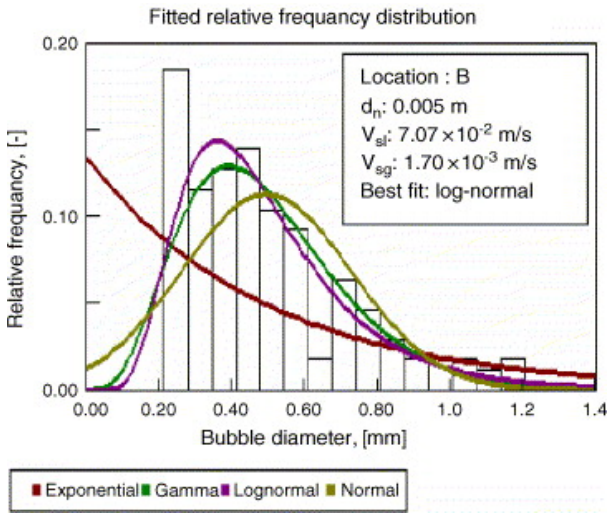
i. Determine the following probabilities

   i. $P(X \leq 0.5)$ for location A.

   ii. $P(0.75 \leq X \leq 1.25)$ for location C.

   iii. $P(X > 1.25)$ for location B.

j. The authors fitted four distributions to their results at location B. The results of fitting are shown in the figure provided. Which distribution in your opinion best describes the experimental data? Justify your answer.



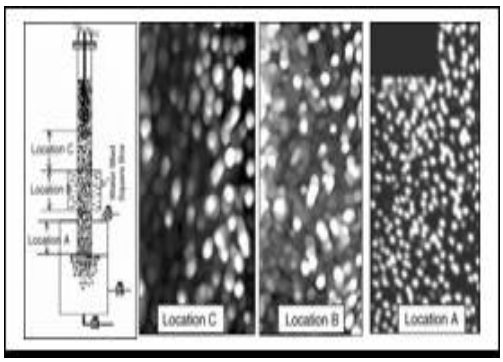


Figure 1 Fitted different distributions of bubble sizes at location B.

Solve either question 2 or 3. Don't attempt both; the solution with the lower grade will be factored in your final mark if you attempted both questions!

2. **(20 points)** The following data shows the per capita carbon dioxide emissions from the consumption and flaring of fossil fuels during the period 1997-2004 in metric tons of carbon dioxide (*Source: US DOE, Energy Information Administration, International Energy Annual 2004.*) Is there any strong evidence suggesting that the Israel's per capita emissions are higher than those of Jordan's per capita emissions? Comment on your conclusion.

Year	1997	1998	1999	2000	2001	2002	2003	2004
Israel	9.94	10.36	10.37	10.64	11.21	11.38	10.48	10.69
Jordan	3.02	3.14	3.10	3.10	2.95	2.99	3.11	3.32

3. **(20 points)** The following are the average population IQ in the states during the 2004 election between Bush and Kerry (*source: http://chrisevans3d.com/files/iq.htm*). Is there any strong evidence that the average population IQ for people voting for Kerry is different than those voting for Bush?

	Bush	Kerry
Mean	93.16	104.2
Variance	16.74	18.40
Observations	31	19

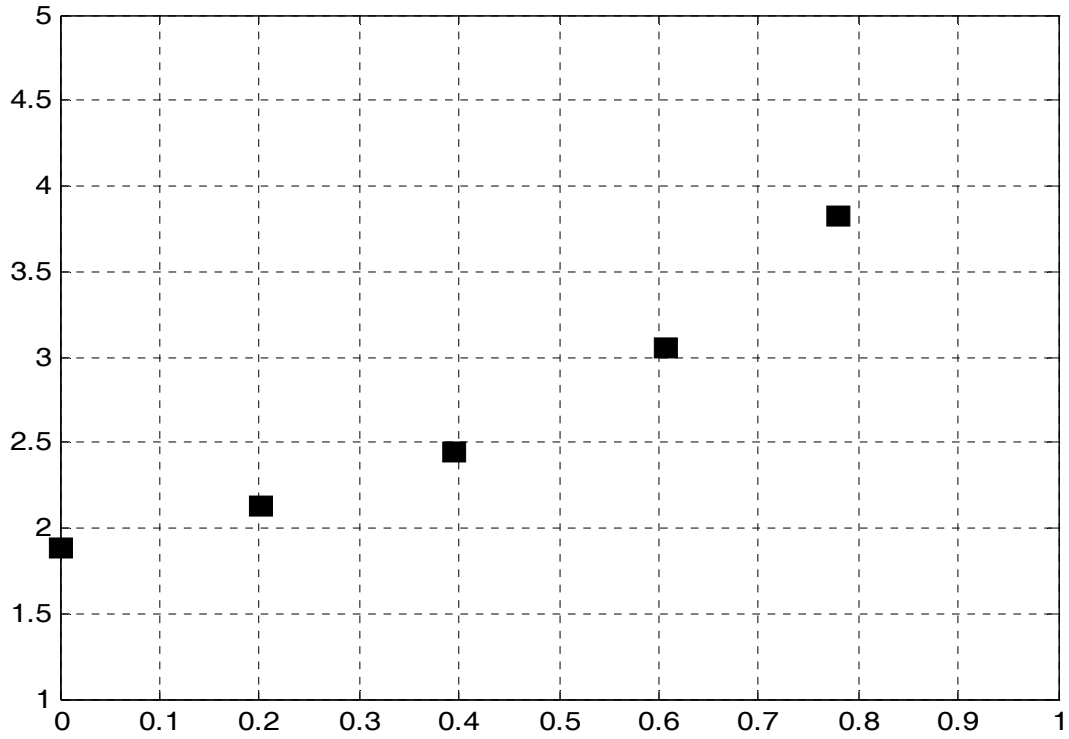
4. **(15 points)** Cast iron is an alloy composed primarily of iron together with smaller amounts of other elements, including carbon, silicon, sulfur, and phosphorous. The carbon occurs as graphite, which is soft, or iron carbide, which is very hard and brittle. The type of cast iron produced is determined by the amount and distribution of carbon in the iron. Five types of cast iron are identifiable. These are gray, compacted graphite, ductile, malleable, and white. In malleable cast iron the carbon is present as discrete graphite particles. Assume that in a particular casting these particles average 20 per square inch. Would it be unusual to see a 1/4-inch-square area of this casting with fewer than two graphite particles? Explain, based on the probability involved.

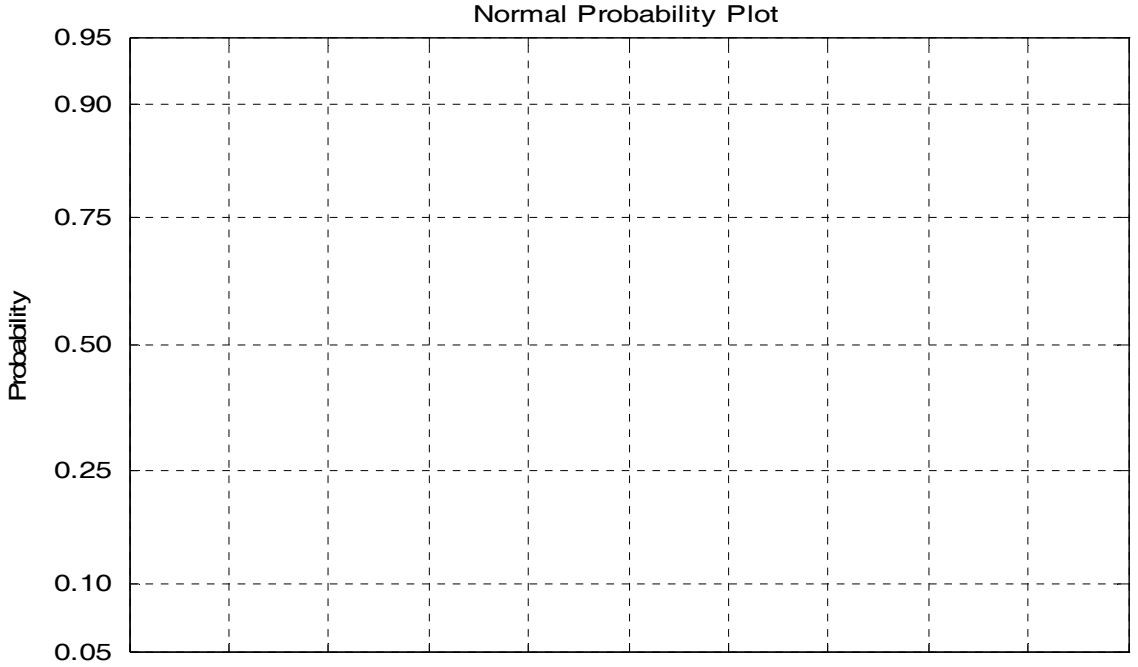
5. **(30 points)** Safi, Nicolas, Neau, and Chevalier measured the diffusion coefficients of aromatic compounds at infinite dilution in binary mixtures at 298.15 K (*Source: Amor Safi, Christophe Nicolas, Evelyne Neau, and Jean-Louis Chevalier, Diffusion Coefficients of Aromatic Compounds at Infinite Dilution in Binary Mixtures at 298.15 K, J. Chem. Eng. Data, 52 (1), 126 -130, 2007*). An excerpt of their results of the infinite dilution diffusion coefficients of benzene (1) in mixtures of hexane (2) + ethanol (3) are given in below.

Table 2 infinite dilution diffusion coefficients of benzene (1) in mixtures of hexane (2) + ethanol (3)

i	$x = x_2$	$y = 10^5 D_{1,m}^{\infty}$ ($cm^2.s^{-1}$)				
1	0.0000	1.88				
2	0.2024	2.13				
3	0.3942	2.45				
4	0.6082	3.05				
5	0.7796	3.82				
Σ						

   a. Fit a simple linear regression model for the diffusion coefficient, $D_{1,m}^{\infty}$, with the mole fraction, x_2.
   b. Find the confidence intervals for the intercept and slope. Use 95% confidence level.
   c. Calculate R^2 and R for the model.
   d. Calculate RMSE.
   e. Predict the value at $x_2 = 1$ and compare it with the reported value of 4.70.
   f. Analyze the residuals and comment on model adequacy.


5
4.5
4
3.5
3
2.5
2
1.5
1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


Normal Probability Plot
Probability
0.95
0.90
0.75
0.50
0.25
0.10
0.05