Exercise 5

1. Derive the probability that the insulation structure will pass the 15/2 test (2 flashovers in 15 impulses). What is the probability with 125 kV test voltage when 50% breakdown voltage is 130 kV and standard deviation of breakdown is 3 %.

2. In order to determine an insulator's 50% breakdown voltage, a series of tests were conducted where voltage was increased steadily from 200 kV until breakdown occurred. The following breakdown values were obtained (in kV): 478, 487, 503, 499, 481, 518, 530, 512, 495, 480, 471, 535, 505, 507, 491, 498, 506, 521, 482, 493. Determine the insulator's 50% breakdown voltage and its standard deviation using the probability sheet. Also, calculate the mean and experimental standard deviation using the measured data.

3. For the purchase of a 123 kV air insulating device, the impulse test voltage was set according to IEC as 450 kV. According to IEC, a 450 kV test voltage for an impulse voltage test correlates to 10 % breakdown probability. Acceptance testing was conducted using up and down method. The test produces the following document (x = breakdown, o = no breakdown):

494 kV	x x
480 kV	x o o x
466 kV	x o o x x x
452 kV	x o o o x o o
438 kV	o o o
424 kV	o
410 kV	o

Withstand strength is assumed to follow normal distribution when standard deviation $\sigma = 3\%$. Did the device pass the test?

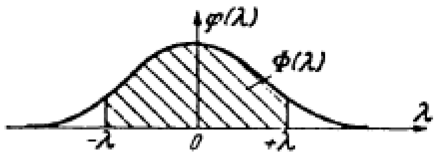
Hint: Respective breakdown voltage U_p for breakdown probability p can be estimated using the mean and standard deviation according to the following table.

$$U_p = U_{50} - k\sigma$$

p/%	50	15,9	10	2,3	0,13
k	0	1	1,3	2,0	3,0

The table shows (0,1) normal distribution function:

$$\Phi(\lambda) = \frac{1}{\sqrt{2\pi}} \int_{-\lambda}^{+\lambda} e^{-\frac{\lambda^2}{2}} d\lambda$$



λ	Φ(λ)	λ	Φ(λ)	λ	Φ(λ)	λ	Φ(λ)	λ	Φ(λ)
0,00	0,0000	0,30	0,2358	0,90	0,6318	1,50	0,8664	3,00	0,9973
0,01	0,0080	0,32	0,2510	0,92	0,6424	1,55	0,8788	3,05	0,9978
0,02	0,0160	0,34	0,2662	0,94	0,6528	1,60	0,8904	3,10	0,9981
0,03	0,0240	0,36	0,2812	0,96	0,6630	1,65	0,9010	3,15	0,9984
0,04	0,0320	0,38	0,2960	0,98	0,6730	1,70	0,9108	3,20	0,9986
0,05	0,0398	0,40	0,3108	1,00	0,6826	1,75	0,9198	3,25	0,9988
0,06	0,0478	0,42	0,3256	1,02	0,6922	1,80	0,9282	3,30	0,9990
0,07	0,0558	0,44	0,3400	1,04	0,7016	1,85	0,9356	3,35	0,9992
0,08	0,0638	0,46	0,3544	1,06	0,7108	1,90	0,9426	3,40	0,9993
0,09	0,0718	0,48	0,3688	1,08	0,7198	1,95	0,9488	3,45	0,9994
0,10	0,0786	0,50	0,3830	1,10	0,7286	2,00	0,9544	3,50	0,9995
0,11	0,0876	0,52	0,3970	1,12	0,7372	2,05	0,9596	3,60	0,9997
0,12	0,0956	0,54	0,4108	1,14	0,7458	2,10	0,9642	3,70	0,9998
0,13	0,1034	0,56	0,4246	1,16	0,7540	2,15	0,9684	3,80	0,9999
0,14	0,1114	0,58	0,4380	1,18	0,7620	2,20	0,9722		
0,15	0,1192	0,60	0,4514	1,20	0,7698	2,25	0,9756		
0,16	0,1278	0,62	0,4648	1,22	0,7776	2,30	0,9786		
0,17	0,1350	0,64	0,4778	1,24	0,7850	2,35	0,9812		
0,18	0,1428	0,66	0,4908	1,26	0,7924	2,40	0,9836		
0,19	0,1506	0,68	0,5034	1,28	0,7994	2,45	0,9858		
0,20	0,1586	0,70	0,5160	1,30	0,8064	2,50	0,9876		
0,21	0,1664	0,72	0,5284	1,32	0,8132	2,55	0,9892		
0,22	0,1742	0,74	0,5408	1,34	0,8198	2,60	0,9906		
0,23	0,1818	0,76	0,5528	1,36	0,8262	2,65	0,9920		
0,24	0,1896	0,78	0,5646	1,38	0,8324	2,70	0,9930		
0,25	0,1974	0,80	0,5762	1,40	0,8384	2,75	0,9940		
0,26	0,2052	0,82	0,5878	1,42	0,8444	2,80	0,9949		
0,27	0,2128	0,84	0,6010	1,44	0,8502	2,85	0,9956		
0,28	0,2206	0,86	0,6102	1,46	0,8558	2,90	0,9963		
0,29	0,2282	0,88	0,6212	1,48	0,8612	2,95	0,9968		

λ	100 · Φ(λ)
0,675	50,00
1,645	90,00
1,960	95,00
2,282	97,50
2,326	98,00
2,576	99,00
2,878	99.60
3,090	99,80
3,291	99,90
3,719	99,98
3,891	99.99

$\Phi(\lambda) \triangleq$ probability that (0,1) distributed random value falls within $-\lambda ... \lambda$.

(μ, σ) normal and (0,1) normal random value is correlated as:

$$\lambda = \frac{x - \mu}{\sigma}$$

where $x \triangleq$ (μ, σ) distribution random value.