### Exercises in Probability

# A Guided Tour from Measure Theory to Random Processes, via Conditioning

L. Chaumont and M. Yor Universite Pierre et Marie Curie, Paris VI

> UNIVERSITAT LIECHTENSTEIN Bfbliothek

#### CAMBRIDGE UNIVERSITY PRESS

	Pref	face	xiii
	Son	ne frequently used notations	XV
1	Me	asure theory and probability	1
	1.1	Sets which do not belong in a strong sense, to a (T-field	.1
	1.2	Some criteria for uniform integrabilityT.	.3
	1.3	When does weak convergence imply the convergence of expectations?.	4
	1.4	Conditional expectation and the Monotone Class Theorem	.5
	1.5	//-convergence of conditional expectations.	.5
	1.6	Measure preserving transformations.	.6
	1.7	Ergodic transformations.	.6
	1.8	Invariant a-fields.	.7
	1.9	Extremal solutions of (general) moments problems.	.8
	1.10	The log normal distribution is moments indeterminate	.9
	1.11	Conditional expectations and equality in law.	.10
	1.12	Simplihable random variables.	.11
	113	Mellin transform and simplification	.12
	Solu	itions for Chapter 1.	.13
2	Ind	ependence and conditioning -	25
	2.1	Independence does not imply measurability with respect to an independent complement.	.26

	2.2	Complement to Exercise 2.1: further statements of independence versus measurability.	.27
	2.3	Independence and mutual absolute continuity.	.27
	2.4	Size-biased sampling and conditional laws	28
	2.5	Think twice before exchanging the order of taking the supremum and intersection of cr-fields!	.29
	2.6	Exchangeability and conditional independence: de Finetti's theorem .	30
	2.7	Too much independence implies constancy.	.31
	2.8	A double paradoxical inequality.	.32
	2.9	Euler's formula for primes and probability.	.33
	2.10	The probability, for integers; of being relatively prime.	.34
	2.11	Bernoulli random walks considered at some stopping time.	35
	2.12	cosh, sinh, the Fourier transform and conditional independence	36
	2.13	cosh, sinh, and the Laplace transform	.37
	2.14	Conditioning and changes of probabilities	.38
	2.15	Radon-Nikodym density and the Acceptance-Rejection Method of	
		von Neumann	.39
	2.16	Negligible sets and conditioning.	.39
	2.17	Gamma laws and conditioning.	41
	2.18	Random variables with independent fractional and integer parts	42
	Solu	tions for Chapter 2	.43
3	Gau	issian variables	67
	3.1	Constructing Gaussian variables from, but not belonging to, a Gaussian space	.68
	3.2	A complement to Exercise 3.1.	.68
	3.3	On the negative moments of norms of Gaussian vectors.	.69
	3.4	Quadratic functionals of Gaussian vectors and continued fractions	70
	3.5	Orthogonal but non-independent Gaussian variables	.72

	3.6	Isotropy property of multidimensional Gaussian laws	73
	3.7	The Gaussian distribution and matrix transposition	73
	3.8	A law whose ra-samples are preserved by every orthogonal transfor- mation is Gaussian.	74
	3.9	Non-canonical representation of Gaussian random walks	74
	3.10	Concentration inequality for Gaussian vectors	76
	3.11	Determining a jointly Gaussian distribution from its conditional marginals.	77
	Solu	tions for Chapter 3	п
4	Dist	ributional computations 9	91
	4.1	Hermite polynomials and Gaussian variables	92
	4.2	The beta-gamma algebra and Poincare's Lemma	<del>)</del> 3
	4.3	An identity in law between reciprocals of gamma variables.	96
	4.4	The Gamma process and its associated Dirichlet processes.	97
	4.5	Gamma variables and Gauss multiplication formulae	<del>)</del> 8
	4.6	The beta-gamma algebra and convergence in law.	00
	4.7	Beta-gamma variables and changes of probability measures	00
	4.8	Exponential variables and powers of Gaussian variables	01
	4.9	Mixtures of exponential distributions.	)2
	4.10		03
	4.11	Some identities in law between Gaussian and exponential variables . 10	)4
	4.12	Some functions which preserve the Cauchy law.	)5
	4.T3	Uniform laws on the circle	)5
	4.14	Trigonometric formulae and probability.	)6
	4.15	A multidimensional version of the Cauchy distribution	)6
	4.16	Some properties of the Gauss transform.	)8
	4.17	Unilateral stable distributions (1)	10

	4.18	Unilateral stable distributions (2)	.I11
	4.19	Unilateral stable distributions (3)	.112
	4.20	A probabilistic translation of Selberg's integral formulae.	.115
	4.21	Mellin and Stieltjes transforms of stable variables.	.116
	4.22	Solving certain moment problems via simplification	.117
	Solu	tions for Chapter 4	.119
5	Cor	vergence of random variables	149
	5.1	Convergence of sum of squares of independent Gaussian variables	150
	5.2	Convergence of moments and convergence in law	.150
	5.3	Borel test functions and convergence in law	.150
	5.4	Convergence in law of the normalized "maximum of Cauchy variables .	151
	5.5	Large deviations for the maximum of Gaussian vectors.	.151
	5.6	A logarithmic normalization	.152
	5.7	A $\setminus$ Jn log n normalization	.152
	5.8	The Central Limit Theorem involves convergence in law, not in probability	.153
	5.9	Changes of probabilities and the Central Limit Theorem	.154
	5.10	Convergence in law of stablest) variables, as $fi \rightarrow 0$	.154
	5.11	Finite dimensional convergence in law towards Brownian motion	155
-	5.12	The empirical process and the Brownian bridge	.157
	5.13	The Poisson process and Brownian motion	.157
	5.14	Brownian bridges converging in law to Brownian motions	.158
	5.15	An almost sure convergence result for sums of stable random variable	s 159
i	Solu	tions for Chapter 5.	.161
6	Ran	ndom processes	175
	6.1	Solving a particular SDE	.177

,

6.2	The range process of Brownian motion	.178
6.3	Symmetric Levy processes reflected at their minimum and maximum;	
	E. Csaki's formulae for the ratio of Brownian extremes	.178
6.4	A toy example for West/water's renormalization	.180
6.5	Some asymptotic laws of planar Brownian motion	.182
6.6 6.7	Windings of the three-dimensional Brownian motion around a line Cyclic exchangeability property and uniform law related to the Brownian bridge.	
6.8	Local time and hitting time distributions for the Brownian bridge	185
6.9	Partial absolute continuity of the. Brownian bridge distribution with respect to the Brownian distribution	.187
6.10		.188
6.11	Sqme deterministic time-changes of Brownian motion	.189
6.12	Random scaling of the Brownian bridge	.190
6.13	Time-inversion and quadratic functional of Brownian motion; Levy's stochastic area formula	.191
6.14	Quadratic variation and local time of semimartingales	.193
6.15	Geometric Brownian motion.	.193
6.16	0-self similar processes and conditional expectation	.195
6.17	A Taylor formula for semimartingales: Markov martingales and iter- ated infinitesimal generators.	.196
6.18	A remark of D. Williams: the optional stopping theorem may hold	
	for certain "non-stopping times".	.197
6.19	Stochastic affine processes, also known as "Harnesses"	.198
6.20	A martingale "in the mean over time" is a martingale	.200
6.21	A reinforcement of Exercise 6.20	.201
Solu	tions for Chapter 6.	.202

Where is the notion JV discussed ?	.226
Final suggestions: how to go further ?	.227
References	.229
Index	.235