

# Lecture Notes in Mathematics

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# Functional Analysis and Related Topics, 1991

Proceedings of the International Conference in  
Memory of Professor Kôzaku Yosida held at RIMS,  
Kyoto University, Japan, July 29-Aug. 2, 1991

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## Preface

These notes are a collection of papers presented at the International Conference on Functional Analysis and Related Topics, 1991, held at the Research Institute for Mathematical Sciences, Kyoto University, Japan, on July 29 - August 2, 1991. Approximately 180 mathematicians from 7 countries attended the conference.

The conference was organized by the Research Institute for Mathematical Sciences as a special conference of the institute, and supported by the ICM-90 Commemorative Meeting Fund of the Mathematical Society of Japan, and by the Inoue Foundation. It was held in memory of Professor Kôzaku Yosida who passed away a year before, on June 20, 1990 after a short illness. The Organizing Committee, consisting of M. Sato, H. Fujita, Y. Kôamura and H. Komatsu, invited 27 speakers who carry on Professor Yosida's research tradition.

As the attached list of publications shows, Professor Yosida had a very wide interest in analysis, and guided many students, not only through personal contact but also through his numerous books, including his famous textbook "Functional Analysis" of which six distinct editions appeared. His collected works in English will soon be published by Springer Verlag.

In 1969 an international conference of the same title was held in Tokyo on the occasion of his 60th anniversary. It covered Partial Differential Equations, Differential Equations on Manifolds, Hyperfunctions, Markov Processes and Potentials, and Ergodic Theory. This time the range of topics is more restricted, but we hope that some of these topics have deepened considerably since then. Professor Yosida was essentially a theorist but he always had applications in mind. Whenever he created a beautiful abstract theory, he was also the first to apply it to more concrete problems. The organizers of the conference will be delighted if the reader would recognize this flavor in the following pages.

Hikosaburo Komatsu

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## Program

### July 29 (Monday)

- 11:00 - 12:00 Jacques-Louis Lions (Collège de France)\*  
Distributed systems with incomplete data and uniqueness theorems
- 13:30 - 14:25 Kiyosi Itô (Kyoto Univ.)  
Semigroups in probability theory
- 14:30 - 15:25 Daisuke Fujiwara (Tokyo Inst. of Tech.)  
Some Feynman path integrals as oscillatory integrals over a Sobolev space
- 15:30 - 16:25 Hikosaburo Komatsu (Univ. of Tokyo)  
Operational calculus and semigroups of operators
- 16:30 - 16:45  
Donation of the Yosida Library
- 17:30 -  
Reception at Kyodai Kaikan

### July 30 (Tuesday)

- 9:50 - 10:50 Haïm Brezis (Univ. of Paris VI)  
Mathematical problems of liquid crystals
- 11:00 - 12:00 Yukio Kōmura - Kiyoko Furuya (Ochanomizu Univ.)  
Wave equations in non-reflexive spaces
- 13:30 - 14:25 Ken-iti Sato (Nagoya Univ.)  
Stochastic processes of Ornstein-Uhlenbeck type on Euclidean spaces
- 14:30 - 15:25 Takashi Suzuki (Tokyo Metropolitan Univ.)  
Symmetry breaking: a variational approach
- 15:30 - 16:25 Hisashi Okamoto (RIMS, Kyoto Univ.)  
Computer-assisted analysis of 2D Navier-Stokes equations
- 16:30 - 17:00 Yasuyuki Kawahigashi (Univ. of Tokyo)  
Solvable orbifold models and operator algebras

### July 31 (Wednesday)

- 9:50 - 10:50 Tosio Kato (Univ. of California, Berkeley)  
Abstract evolution equations, linear and quasilinear, revisited
- 11:00 - 12:00 Alberto Venni (Univ. of Bologna)  
Complex powers of operators and related problems of operator theory
- 13:30 - 14:25 Yoshikazu Giga (Hokkaido Univ.)  
 $L^p$  estimates for the Navier-Stokes system
- 14:30 - 15:25 Hitoshi Kitada (Univ. of Tokyo)  
Completeness of  $N$ -body wave operators — long-range quantum systems
- 15:30 - 16:25 Minoru Murata (Kumamoto Univ.)  
Nonnegative solutions of linear parabolic equations

16:30 - 17:00 Teruo Ushijima - Mihoko Matsuki (Univ. of Electro-Communications)  
Fully discrete approximation of a second order linear evolution equation related to the water wave problem

### August 1 (Thursday)

9:50 - 10:50 P. P. Narayanaswami (Memorial Univ. of Newfoundland)  
The separable quotient problem for Banach and  $(LF)$ -spaces  
11:00 - 12:00 D. C. Struppa (Univ. of Calabria) - T. Kawai (RIMS, Kyoto Univ.)  
Interpolating varieties and the Fabry-Ehrenpreis-Kawai gap theorem  
13:30 - 14:25 Shinnosuke Oharu (Hiroshima Univ.)  
Characterization of nonlinearly perturbed semigroups  
14:30 - 15:25 Yoshikazu Kobayashi (Niigata Univ.)  
Semigroups of locally Lipschitzian operators and applications  
15:30 - 16:25 Mitsuharu Otani (Waseda Univ.)  
A priori estimates for some nonlinear parabolic equations via Lyapunov functions  
16:30 - 17:00 Hiroko Morimoto (Meiji Univ.)  
Asymptotic behavior of solutions of the convection equation

### August 2 (Friday)

9:50 - 10:50 Philippe Clément (Delft Univ. of Technology)  
Maximal regularity  $L^p - L^q$  for a class of integro-differential equations  
11:00 - 12:00 Giovanni Dore (Univ. of Bologna)  
 $L^p$ -regularity for abstract differential equations  
13:30 - 14:25 Atsushi Yoshikawa (Kyushu Univ.)  
Quasilinear oscillations and geometric optics  
14:30 - 15:25 Atsushi Yagi (Himeji Inst. of Tech.)  
Global solution to some quasilinear parabolic system in mathematical biology  
15:30 - 16:25 Shigetake Matsuura (RIMS, Kyoto Univ.)  
On non-convex curves of constant angle

\*) Professor Lions was unable to attend the conference because of a minor accident.



## List of Publications of Kôzaku Yosida

### Books

- A. 連続群論 (= *Theory of Continuous Groups*), 岩波数学講座, Iwanami (岩波書店), Tokyo, 1934, iii+180 pp.
- B. リー環論 (= *Theory of Lie Rings*), 大阪帝国大学数学講演集 IV, Iwanami, Tokyo, 1939, 3+48 pp.
- C. 線型作用素 (= *Linear Operators*), 現代数学叢書, Iwanami, Tokyo, 1943, 2+118 pp.
- D. スペクトル解析 (= *Spectral Analysis*), 近代数学全書, Kyoritsu (共立出版), Tokyo, 1947, 1+2+125 pp.
- E. エルゴード諸定理 (= *Ergodic Theorems*), 確率統計叢書, Chubunkan (中文館書店), Tokyo, 1948, iii+82 pp.
- F. 物理数学概論 (= *Topics in Mathematical Physics*), Nihon Hyoron (日本評論社), Tokyo, 1949, 6+202+6 pp.
- G. 積分方程式論 (= *Theory of Integral Equations*), 岩波全書 117, Iwanami, Tokyo, 1950, 8+234 pp.
- H. 位相解析 I (= *Topological Analysis I*), 現代数学 8, Iwanami, Tokyo, 1951, 2+2+339 pp.
- I. ヒルベルト空間論 (= *Theory of Hilbert Spaces*), 共立全書 49, Kyoritsu, Tokyo, 1953, 2+4+215 pp.
- J. 微分方程式の解法 (= *Methods of Differential Equations*), 岩波全書 189, Iwanami, Tokyo, 1954, 9+263 pp.
- K. (With A. Amemiya, K. Itô, T. Kato, Y. Matsushima et al.) 応用数学便覧 (= *Handbook of Applied Mathematics*), Maruzen (丸善), Tokyo, 1954, 2+8+518 pp.
- L. 近代解析 (= *Modern Analysis*), 基礎数学講座 20, Kyoritsu, Tokyo, 1956, 1+3+121 pp.
- M. 超函数論 (= *Theory of Distributions*), 現代数学講座 13, Kyoritsu, Tokyo, 1956, v+169 pp.
- N. *Lectures on Semi-group Theory and its Application to Cauchy's Problem in Partial Differential Equations*, Lectures on Mathematics and Physics 8, Tata Inst. Fund. Research, Bombay, 1957, iv+127+iv pp.
- O. 位相解析 (= *Topological Analysis*), 岩波講座現代応用数学 A4, Iwanami, Tokyo, 1957, iv+234 pp.
- LII. 近代解析 第2版 (= *Modern Analysis, 2nd ed.*), 基礎数学講座 20, Kyoritsu, Tokyo, 1958, 2+4+219+4 pp.
- P. (With K. Kunugui, S. Nakanishi and S. Itô) 積分論・位相解析 (= *Theory of Integrals, Topological Analysis*), 数学演習講座 15, Kyoritsu, Tokyo, 1958, Part 2, 2+105 pp.
- GE. *Lectures on Differential and Integral Equations*, Pure and Applied Mathematics Vol. X, Interscience, New York-London, 1960, ix+220 pp.

- O<sub>II</sub>. (With Y. Kawada and T. Iwamura) 位相解析の基礎 (= *Fundamental of Topological Analysis*), Iwanami, Tokyo, 1960, pp. 95-330.
- Q. (With T. Kato) 大学演習応用数学 I (= *Exercises in Applied Mathematics I*), 大学演習新書, Shokabo (裳華房), Tokyo, 1961, vii+347 pp.
- R. *Functional Analysis*, Grundlehren Math. Wiss. Bd. 123, Springer, Berlin-Göttingen-Heidelberg, 1965, XI+458 pp.
- R<sub>R</sub>. *Funkcional'nyi Analiz*, Izdat. MIR, Moscow, 1967, 624 pp.
- K<sub>II</sub>. (With A. Amemiya, K. Itô, T. Kato, Y. Matsushima, S. Furuya et al.) 応用数学便覧 新版 (= *Handbook of Applied Mathematics, New ed.*), Maruzen, Tokyo, 1967, 2+9+603 pp.
- R<sub>II</sub>. *Functional Analysis, 2nd ed.*, Grundlehren Math. Wiss. Bd. 123, Springer, Berlin-Heidelberg-New York, 1968, XI+465 pp.
- R<sub>III</sub>. *Functional Analysis, 3rd ed.*, Grundlehren Math. Wiss. Bd. 123, Springer, Berlin-Heidelberg-New York, 1971, XI+475 pp.
- G<sub>F</sub>. *Equations Différentielles et Intégrals*, Dunod, Paris, 1971, xv+230 pp.
- F<sub>II</sub>. 物理数学概論 (= *Topics in Mathematical Physics*), 数理解析とその周辺 5, Sangyo Tosho (産業図書), 1974, 6+198 pp.
- R<sub>IV</sub>. *Functional Analysis, 4th ed.*, Grundlehren Math. Wiss. Bd. 123, Springer, Berlin-Heidelberg-New York, 1974, XI+496 pp.
- S. 測度と積分 (= *Measures and Integrals*), 岩波講座基礎数学, 解析学 (I) iii, Iwanami, Tokyo, 1976, vii+172 pp.
- T. (With S. Itô, A. Orihara and T. Muramatsu) 函数解析と微分方程式 (= *Functional Analysis and Differential Equations*), 現代数学演習叢書 4, Iwanami, Tokyo, 1976, xi+474 pp.
- R<sub>V</sub>. *Functional Analysis, 5th ed.*, Grundlehren Math. Wiss. Bd. 123, Springer, Berlin-Heidelberg-New York, 1978, XII+501 pp.
- G<sub>II</sub>. 積分方程式論 第2版 (= *Theory of Integral Equations, 2nd ed.*), 岩波全書 117, Iwanami, Tokyo, 1978, vi+292 pp.
- J<sub>II</sub>. 微分方程式の解法 第2版 (= *Methods of Differential Equations, 2nd ed.*), 岩波全書 189, Iwanami, Tokyo, 1978, xiv+307 pp.
- R<sub>VI</sub>. *Functional Analysis, 6th ed.*, Grundlehren Math. Wiss. Bd. 123, Springer, Berlin-Heidelberg-New York, 1980, XII+501 pp.
- U. 私の微分積分法 — 解析入門 (= *My Calculus — An Introduction to Analysis*), Kodansha (講談社), Tokyo, 1981, 250 pp.
- V. 演算子法 — 一つの超函数論 (= *Operational Calculus A Theory of Hyperfunctions*), UP 応用数学選書 5, Univ. of Tokyo Press (東京大学出版会), 1982, viii+171 pp.
- V<sub>E</sub>. *Operational Calculus A Theory of Hyperfunctions*, Applied Mathematical Sciences Vol. 55, Springer, New York-Berlin-Heidelberg-Tokyo, 1984, x+170 pp.
- W. 19世紀の数学 解析学 I (= *Analysis I Mathematics in the 19th Century*), 数学の歴史 9, Kyoritsu, Tokyo, 1986, xii+256 pp.
- S<sub>II</sub>. (With H. Fujita) 現代解析入門 (= *Introduction to Modern Analysis*), 岩波基礎数学選書, Iwanami, Tokyo, 1991, pp. 243-456.

1. *On the asymptotic property of the differential equation  $y'' + H(x)y = f(x, y, y')$* , Japan. J. Math. **9** (1932), 145-152.
2. *On the asymptotic property of the differential equation  $y'' + H(x)y = f(x, y, y')$ , II*, Japan. J. Math. **9** (1932), 227-230.
3. *A remark to a theorem due to Halphen*, Japan. J. Math. **9** (1932), 231-232.
4. *A generalisation of a Malmquist's theorem*, Japan. J. Math. **9** (1932), 253-256.
5. *Some remarks on the theory of Fredholm's integral equations*, Proc. Phys.-Math. Soc. Japan **14** (1932), 381-384.
6. *On the distribution of  $\alpha$ -points of solutions for linear differential equation of the second order*, Proc. Imp. Acad. Tokyo **8** (1932), 335-336.
7. *A note on Riccati's equation*, Proc. Phys.-Math. Soc. Japan **15** (1933), 227-232.
8. *On the characteristic function of a transcendental meromorphic solution of an algebraic differential equation of the first order and of the first degree*, Proc. Phys.-Math. Soc. Japan **15** (1933), 337-338.
9. *On algebroid-solutions of ordinary differential equations*, Japan. J. Math. **10** (1933), 199-208.
10. *On a class of meromorphic functions*, Proc. Phys.-Math. Soc. Japan **16** (1934), 227-235.
11. *Wronskian* = 就テ (= *On Wronskians*), Zenkoku Sizyo Sugaku Danwakai (全国紙上数学談話会) **3** (1934), 3-5.
12. *Algebroid function* = 就テ (= *On algebroid functions*), Zenkoku Sizyo Sugaku Danwakai **6** (1934), 2-6 and **10** (1934), d-e.
13. *Picard* の定理ニツイテ (= *On Picard's theorem*), Zenkoku Sizyo Sugaku Danwakai **18** (1934), 11-12.
14. *有理型函数ノ derivative* = 就テ (= *On derivatives of meromorphic functions*), Zenkoku Sizyo Sugaku Danwakai **21** (1934), 7-10.
15. (With T. Shimizu and S. Kakutani) *On meromorphic functions. I*, Proc. Phys.-Math. Soc. Japan **17** (1935), 1-10.
16. *Beurling* の定理ノ應用例 (= *An application of Beurling's theorem*), Zenkoku Sizyo Sugaku Danwakai **24** (1934), 28-30.
17. *Cartan-角谷-Selberg* の定理 = 就テ (= *On the Cartan-Kakutani-Selberg theorem*), Zenkoku Sizyo Sugaku Danwakai **25** (1935), 11-14 and **30** (1935), 9-11.
18. (With T. Shimizu and S. Kakutani) *Function group* = 就テ (= *On Function groups*), Zenkoku Sizyo Sugaku Danwakai **28** (1935), 2-8.
19. *Stone* の定理 = 就テ (= *On Stone's theorem*), Zenkoku Sizyo Sugaku Danwakai **35** (1935), 9-12.
20. *A theorem concerning the derivatives of meromorphic functions*, Proc. Phys.-Math. Soc. Japan **17** (1935), 170-173.
21. (With S. Kakutani) *in kleinen affine 寫像* = 就テ (= *On locally affine (quasi-conformal) mappings*), Zenkoku Sizyo Sugaku Danwakai **40**(1935), 5-8 and **41** (1935), 10-18.
22. *Fatou* の定理 = 對スル小サナ注意 (= *A short remark on Fatou's theorem*), Zenkoku Sizyo Sugaku Danwakai **45** (1935), 6-8.

23. 等角寫像ニ於ケル *metrical* ナ一定理 (= *A metrical theorem on conformal mappings*), *Zenkoku Sizyo Sugaku Danwakai* **47** (1935), 5-8.
24. *Picard-Vessiot* ノ理論ニ就テ (= *On the theory of Picard-Vessiot*), *Zenkoku Sizyo Sugaku Danwakai* **51** (1935), 8-14, **52** (1935), 1-3, **53** (1935), 9-10, **63** (1935), 28-33 and **67** (1935), 19-22.
25. *Closure* ニ関スル一問題ヘノ *Stone* ノ定理ノ應用 (= *An application of Stone's theorem to a problem of closure*), *Zenkoku Sizyo Sugaku Danwakai* **60** (1935), 15-17.
26. *On the groups of rationality for linear differential equations*, *Proc. Phys.-Math. Soc. Japan* **17** (1935), 498-510.
27. 距離付ケラレタ環ニ於テ閉ヂタ連續群 (= *Closed continuous groups in metrical rings*), *Zenkoku Sizyo Sugaku Danwakai* **68** (1935), 1-9, **69** (1935), 15-18, **70** (1935), 5-7 and **77** (1935), 4-9.
28. " $\det A \neq 0$  ナル *Matrix* ハ  $A = \exp B$ " ノ正田教授ニヨル証明其ノ他 (= *A matrix  $A = \exp B$  if  $\det A \neq 0$ ; Prof. Shoda's proof and other topics*), *Zenkoku Sizyo Sugaku Danwakai* **72** (1935), 1-6.
29. *On the group embedded in the metrical complete ring*, *Japan J. Math.* **13** (1936), 7-26.
30. *Locally compact* ナ *topological group* ノ連續表現 (= *Continuous representations of locally compact topological groups*), *Zenkoku Sizyo Sugaku Danwakai* **87** (1936), 1-8, **88** (1936), 6-8, **99** (1936), 1-3 and **101** (1936), 8-9.
31. *On the group embedded in the metrical complete ring, II*, *Japan J. Math.* **13** (1936), 459-472.
32. 距離付ケラレタ環ニ付イテ (= *On metrical rings*), *Zenkoku Sizyo Sugaku Danwakai* **101** (1936), 6-8.
33. *Topological group* ノ連續表現 (= *Continuous representations of topological groups*), *Zenkoku Sizyo Sugaku Danwakai* **107** (1936), 5-7.
34. *H. Auerbach* ノ定理ニツイテ (= *On a theorem of H. Auerbach*), *Zenkoku Sizyo Sugaku Danwakai* **110** (1936), 5-6.
35. *Homomorphie* ニヨル次元ノ關係 (= *Dimension relations under homomorphisms*), *Zenkoku Sizyo Sugaku Danwakai* **111** (1936), 16-18.
36. *A note on the continuous representation of topological groups*, *Proc. Imp. Acad. Tokyo* **12** (1936), 329-331.
37. *Riemann* 空間ノ等長變換ノ解析性 (= *Analyticity of isometric transformations of Riemannian spaces*), *Zenkoku Sizyo Sugaku Danwakai* **120** (1937), 33-35.
38. 完閉群ニ於ケル線狀移動可能微分演算子 (= *Linear translatable differential operators in compact groups*), *Zenkoku Sizyo Sugaku Danwakai* **123** (1937), 87-91 and **124** (1937), 118-119.
39. *A remark on a theorem of B. L. van der Waerden*, *Tôhoku Math. J.* **43** (1937), 411-413.
40. 單純群ノ一ツノ *class* ニ就テ (= *On a class of simple groups*), *Zenkoku Sizyo Sugaku Danwakai* **126** (1937), 143-146.
41. *Lie* ノ第二基本定理ニ關聯シタ一ツノ問題 (= *A problem concerning the second fundamental theorem of Lie*), *Zenkoku Sizyo Sugaku Danwakai* **128** (1937), 179-185.
42. *A problem concerning the second fundamental theorem of Lie*, *Proc. Imp. Acad. Tokyo* **13** (1937), 152-155.

43. 準單純りい群ニ関スル一定理 (= *A theorem on semi-simple Lie groups*), Zenkoku Sizyo Sugaku Danwakai **133** (1937), 267-272.
44. *Locally bicomact ナ topological group ノ 連続表現* (= *Continuous representations of locally bicomact topological groups*), Zenkoku Sizyo Sugaku Danwakai **135** (1937), 37-43.
45. *Lie ノ 第二基本定理ニ就テ* (= *On the second fundamental theorem of Lie*), Zenkoku Sizyo Sugaku Danwakai **137** (1937), 75-78.
46. *A theorem concerning the semi-simple Lie groups*, Tôhoku Math. J. **44** (1938), 81-84.
47. 豊田浩七氏ノ論文ヲ読ミテ (= *On a paper of Toyoda*), Zenkoku Sizyo Sugaku Danwakai **139** (1937), 138-140.
48. *Topological group ノ 微分可能性ニ就テ* (= *On the differentiability of topological groups*), Zenkoku Sizyo Sugaku Danwakai **141** (1937), 185-189.
49. *On the exponential-formula in the metrical complete ring*, Proc. Imp. Acad. Tokyo **13** (1937), 301-304.
50. *A note on the differentiability of the topological group*, Proc. Phys.-Math. Soc. Japan **20** (1938), 6-10.
51. *A characterisation of the adjoint representations of the semi-simple Lie-rings*, Japan J. Math. **14** (1938), 169-173.
52. 單純且準單純ナ環ノ表現ノ reduction ニ就テ (= *On the reduction of representations of simple and semi-simple Lie rings*), Zenkoku Sizyo Sugaku Danwakai **153** (1937), 56-60.
53. *Lie 環ノ derivation* (= *Derivations of Lie rings*), Zenkoku Sizyo Sugaku Danwakai **156** (1938), 125-129 and **157** (1938), 167-170.
54. *On the fundamental theorem of the tensor calculus*, Proc. Imp. Acad. Tokyo **14** (1938), 211-213.
55. 確率論ヘノ積分方程式ノ應用 (= *Applications of integral equations to probability theory*), Zenkoku Sizyo Sugaku Danwakai **160** (1938), 245-254, **161** (1938), 282-295, **162** (1938), 296-306, **163** (1938), 358-364, **164** (1938), 394-397 and **165** (1938), 429-441.
56. *Birkhoff-Khintchine ノ ergodic theorem* (= *The ergodic theorem of Birkhoff-Khintchine*), Zenkoku Sizyo Sugaku Danwakai **166** (1938), 476-485.
57. *Abstract integral equations and the homogeneous stochastic process*, Proc. Imp. Acad. Tokyo **14** (1938), 286-291.
58. *Mean ergodic theorem in Banach spaces*, Proc. Imp. Acad. Tokyo **14** (1938), 292-294.
59. *Mean ergodic theorem ノ 應用* (= *Applications of mean ergodic theorems*), Zenkoku Sizyo Sugaku Danwakai **167** (1938), 543-549.
60. (With Y. Mimura and S. Kakutani) 有界且ツ可測ナ核ニヨル積分 operator ニ就イテ (= *On integral operators with bounded measurable kernels*), Zenkoku Sizyo Sugaku Danwakai **168** (1938), 631-637 and **169** (1938), 681-684.
61. (With S. Kakutani) *Application of mean ergodic theorem to the problems of Markoff's process*, Proc. Imp. Acad. Tokyo **14** (1938), 333-339.
62. *Doebelin ノ 結果ノ 積分方程式の取扱* (= *A treatment of Doebelin's results by integral equations*), Zenkoku Sizyo Sugaku Danwakai **169** (1938), 656-666.

63. (With Y. Mimura and S. Kakutani) *Integral operator with bounded kernel*, Proc. Imp. Acad. Tokyo **14** (1938), 359-362.
64. *Operator-theoretical treatment of the Markoff's process*, Proc. Imp. Acad. Tokyo **14** (1938), 363-367.
65. 完全連続ナ對稱作用素ノ固有値存在ノ証明 (= *A proof of the existence of eigenvalues for completely continuous symmetric operators*), Zenkoku Sizyo Sugaku Danwakai **171** (1938), 756-758.
66. *Quasi-completely-continuous linear functional operations*, Japan. J. Math. **15** (1939), 297-301.
67. 可附番無限個ノ可能ナ状態ニ関スル *Markoff* 過程 (= *Markoff processes with countably infinite possible states*), Zenkoku Sizyo Sugaku Danwakai **172** (1939), 11-19, **173** (1939), 31-37 and **176** (1939), 170-173.
68. *F. Riesz* ノ *mean ergodic theorem* (= *F. Riesz's mean ergodic theorem*), Zenkoku Sizyo Sugaku Danwakai **176** (1939), 166-170.
69. (With S. Kakutani) *Markoff process with an enumerable infinite number of possible states*, Japan. J. Math. **16** (1940), 47-55.
70. 準完全連続線型作用素に就いて (= *On quasi-completely continuous linear operators*), Isô Sûgaku (位相数学) **1** No. 2 (1939), 32-34.
71. *Markoff* 過程ニ於ケルーツノ固有値問題 (= *An eigenvalue problem in Markoff processes*), Zenkoku Sizyo Sugaku Danwakai **177** (1939), 187-193.
72. *Operator-theoretical treatment of Markoff's process, II*, Proc. Imp. Acad. Tokyo **15** (1939), 127-130.
73. (With S. Kakutani) *Birkhoff ergodic theorem* ト *mazimal ergodic theorem* (= *Birkhoff's ergodic theorem and the mazimal ergodic theorem*), Zenkoku Sizyo Sugaku Danwakai **179** (1939), 216-221 and **181** (1939), 267-291.
74. (With S. Kakutani) *Birkhoff's ergodic theorem and the mazimal ergodic theorem*, Proc. Imp. Acad. Tokyo **15** (1939), 165-168.
75. 漸近的概週期性ト *ergodic theorems* (= *Asymptotic almost periodicities and ergodic theorems*), Zenkoku Sizyo Sugaku Danwakai **185** (1939), 407-414 and **186** (1939), 450-461.
76. *Asymptotic almost periodicities and ergodic theorems*, Proc. Imp. Acad. Tokyo **15** (1939), 255-259.
77. *Markoff chain* ノーツノ抽象化 (= *An abstraction of Markoff chains*), Zenkoku Sizyo Sugaku Danwakai **187** (1939), 481-490.
78. *P. Lévy* ノ定理ノ直接ナ証明 (by G. Ottaviani) (= *The direct proof of P. Lévy's theorem by G. Ottaviani*), Zenkoku Sizyo Sugaku Danwakai **188** (1939), 524-527.
79. (With S. Kakutani) *Operator-theoretical treatment of Markoff's Process and mean ergodic theorem*, Ann. Math. (2) **42** (1941), 188-228.
80. *Markoff process with stationary uniform distribution*, Zenkoku Sizyo Sugaku Danwakai **189** (1939), 534-541 and **191** (1939), 640-647.
81. *Markoff chain* と *H*-定理 (= *Markoff chains and the H-theorem*), Isô Sûgaku **2** No. 1 (1939), 41-42.
82. *An ergodic theorem of Birkhoff-Khinchine type*, Zenkoku Sizyo Sugaku Danwakai **193** (1940), 64-66 and **195** (1940), 100-107.
83. (With S. Kakutani) *Compact* ナ空間ニ於ケル *transition process* (= *Transition processes in compact spaces*), Zenkoku Sizyo Sugaku Danwakai **196** (1940), 139-147.

84. *Ergodic theorems of Birkhoff-Khinchine's type*, Japan. J. Math. **17** (1940), 31-36.
85. *The Markoff process with a stable distribution*, Proc. Imp. Acad. Tokyo **16** (1940), 43-48.
86. *Individual ergodic theorem* = 就テ (= *On the individual ergodic theorem*), Zenkoku Sizyo Sugaku Danwakai **199** (1940), 263-272.
87. *An abstract treatment of the individual ergodic theorem*, Proc. Imp. Acad. Tokyo **16** (1940), 280-284.
88. *Pythagorean ring* = 就テ (= *On Pythagorean rings*), Zenkoku Sizyo Sugaku Danwakai **200** (1940), 293-299, **201** (1940), 306-314 and **203** (1940), 368-374.
89. *On the theory of spectra*, Proc. Imp. Acad. Tokyo **16** (1940), 378-383.
90. *Hilbert 空間の Hermite 作用素の作る "環" に就て (Pythagorean ring)* (= *On "rings" of Hermitian operators in Hilbert spaces (Pythagorean rings)*), Isô Sûgaku **3** No. 1 (1940), 64-66.
91. *Regularly convex set* = 就テ (= *On regularly convex sets*), Zenkoku Sizyo Sugaku Danwakai **207** (1940), 473-478.
92. (With M. Fukamiya) *On regularly convex sets*, Proc. Imp. Acad. Tokyo **17** (1941), 49-52.
93. *On vector lattice with a unit*, Proc. Imp. Acad. Tokyo **17** (1941), 121-124.
94. 単位ヲ有スル *vector-lattice* = 就テ (= *On vector lattices with unit*), Zenkoku Sizyo Sugaku Danwakai **211** (1941), 94-98 and **212** (1941), 119.
95. *Spectral theorem* に就いて (= *On the spectral theorem*), Isô Sûgaku **3** No. 2 (1941), 47-49 and **4** No. 1 (1942), 62.
96. *Radon-Nikodym* ノ定理 = 就テ (= *On the Radon-Nikodym theorem*), Zenkoku Sizyo Sugaku Danwakai **217** (1941), 274-282 and **218** (1941), 328-330.
97. *Vector lattices and additive set functions*, Proc. Imp. Acad. Tokyo **17** (1941), 228-232.
98. アルキメデスの *vector lattice* ノ表現 (= *A representation of Archimedean vector lattices*), Zenkoku Sizyo Sugaku Danwakai **225** (1941), 499-502.
99. (With M. Fukamiya) 単位ヲ有スル *vector* 束 = 就テ, III (= *On vector lattices with unit*), Zenkoku Sizyo Sugaku Danwakai **226** (1941), 574-578 and **227** (1941), 643-644.
100. 平均エルゴード定理及び個別エルゴード定理 (= *The mean and the individual ergodic theorems*), Tokyo Buturi Gakko Zassi (東京物理學校雜誌) **50** (1941), 463-465.
101. (With M. Fukamiya) *On vector lattice with a unit, II*, Proc. Imp. Acad. Tokyo **17** (1941), 479-482.
102. *Vector* 束の表現に就て (= *On representations of vector lattices*), Isô Sûgaku **4** No. 1 (1942), 1-7 and **4** No. 2 (1942), 54-55.
103. *On the representation of the vector lattice*, Proc. Imp. Acad. Tokyo **18** (1942), 339-342.
104. *Spectral theorem* ノ証明 = 就テ (= *On a proof of the spectral theorem*), Zenkoku Sizyo Sugaku Danwakai **240** (1942), 1232-1237.
105. (With T. Nakayama) 準順序環及ビソノ應用ニツイテ (= *On semi-ordered rings and their application*), Zenkoku Sizyo Sugaku Danwakai **242** (1942), 1309-1320 and **250** (1943), 158-163.
106. (With T. Nakayama) *On the semi-ordered ring and its application to the spectral theorem*, Proc. Imp. Acad. Tokyo **18** (1942), 555-560.

107. 淡中氏相對定理ノ証明ニ就テ (= *On a proof of Tannaka's duality theorem*), *Zenkoku Sizyo Sugaku Danwakai* **246** (1942), 1591-1595.
108. (With T. Nakayama) *On the semi-ordered ring and its application to the spectral theorem. II*, *Proc. Imp. Acad. Tokyo* **19** (1943), 144-147.
109. *On the duality theorem of non-commutative compact groups*, *Proc. Imp. Acad. Tokyo* **19** (1943), 181-183.
110. *L. Pontrjagin ノ 双對定理ノ 証明ニツイテ* (= *On a proof of L. Pontrjagin's duality theorem*), *Zenkoku Sizyo Sugaku Danwakai* **254** (1943), 318-321.
111. のるむ環トスペクトル定理 (= *Normed rings and spectral theorems*), *Zenkoku Sizyo Sugaku Danwakai* **255** (1943), 362-364.
112. *Normed rings and spectral theorems*, *Proc. Imp. Acad. Tokyo* **19** (1943), 356-359.
113. 線型函數方程式の可解性 (= *Solvability of linear functional equations*), *Isô Sûgaku* **5** No. 1 (1943), 23.
114. *Normed rings and spectral theorems, II*, *Proc. Imp. Acad. Tokyo* **19** (1943), 466-470.
115. *Normed rings and spectral theorems, III*, *Proc. Imp. Acad. Tokyo* **20** (1944), 71-73.
116. *Normed rings and spectral theorems, IV*, *Proc. Imp. Acad. Tokyo* **20** (1944), 183-185.
117. *Normed rings and spectral theorems, V*, *Proc. Imp. Acad. Tokyo* **20** (1944), 269-273.
118. (With T. Iwamura) *Equivalence of two topologies of Abelian groups*, *Proc. Imp. Acad. Tokyo* **20** (1944), 451-453.
119. *Normed rings and spectral theorems, VI*, *Proc. Imp. Acad. Tokyo* **20** (1944), 580-583.
120. *On the representation of functions by Fourier integrals*, *Proc. Imp. Acad. Tokyo* **20** (1944), 655-660.
121. *On the unitary equivalence in general Euclid space*, *Proc. Japan Acad.* **22** (1946), 242-245.
122. *Unitary equivalence について* (= *On the unitary equivalence*), *Sûgaku (数学)* **1** (1948), 88-89.
123. *Simple Markoff process with a locally compact phase space*, *Math. Japon.* **1** (1948), 99-103.
124. *On the differentiability and the representation of one-parameter semi-group of linear operators*, *J. Math. Soc. Japan* **1** No. 1 (1948), 15-21.
125. 線型作用素の作る 1-parameter 準群 (= *One parameter semi-groups of linear operators*), *Sûgaku* **1** (1948), 201-203.
126. *An operator-theoretical treatment of temporally homogeneous Markoff process*, *J. Math. Soc. Japan* **1** No. 3 (1949), 244-253.
127. 三次元球面上の Brown 運動 (= *Brownian motion on the sphere in the 3-space*), *Sûgaku* **1** (1949), 327-329.
128. *Brownian motion on the surface of the 3-sphere*, *Ann. Math. Statist.* **20** (1949), 292-296.
129. *Compact Riemann 空間の上での Fokker-Planck 偏微分方程式の積分* (= *Integration of the Fokker-Planck equation on compact Riemannian spaces*), *Sûgaku* **2** (1949), 166-168.



130. *Integration of Fokker-Planck's equation in a compact Riemannian space*, Ark. Mat. **1** No. 9 (1949), 71-75.
131. *An extension of Fokker-Planck's equation*, Proc. Japan Acad. **25** No. 9 (1949), 1-3.
132. *On Titchmarsh-Kodaira's formula concerning Weyl-Stone's eigenfunction expansion*, Nagoya Math. J. **1** (1950), 49-58, Correction. *ibid.* **6** (1953), 187-188.
133. *Stochastic processes built from flows*, Proc. Japan Acad. **26** No. 8 (1950), 1-3.
134. *Integration of Fokker-Planck's equation with a boundary condition*, J. Math. Soc. Japan **3** (1951), 69-73.
135. *Integrability of the backward diffusion equation in a compact Riemannian space*, Nagoya Math. J. **3** (1951), 1-4.
136. (With E. Hewitt) *Finitely additive measures*, Trans. Amer. Math. Soc. **72** (1952), 46-66.
137. *Fokker-Planck 方程式およびその積分について (= On the Fokker-Planck equation and its integral)*, Sûgaku **3** (1951), 129-136.
138. *A theorem of Liouville's type for meson equation*, Proc. Japan Acad. **27** (1951), 214-215.
139. *On Brownian motion in a homogeneous Riemannian space*, Pacific J. Math. **2** (1952), 263-270.
140. *On the existence of the resolvent kernel for elliptic differential operator in a compact Riemann space*, Nagoya Math. J. **4** (1952), 63-72.
141. *An ergodic theorem associated with harmonic integrals*, Proc. Japan Acad. **27** (1951), 540-543.
142. *Homogeneous space の上の Brown 運動の定義 (= A definition of Brownian motions on homogeneous spaces)*, Sûgaku **4** (1952), 32-34.
143. *On the integration of diffusion equations in Riemannian spaces*, Proc. Amer. Math. Soc. **3** (1952), 864-873.
144. *Fokker-Planck 方程式およびその積分について, II*, Sûgaku **4** (1952), 145-150.
145. *On Cauchy's problem in the large for wave equations*, Proc. Japan Acad. **28** (1952), 396-403.
146. *On the fundamental solution of the parabolic equation in a Riemannian space*, Osaka Math. J. **5** (1953), 65-74.
147. *Titchmarsh-Kodaira の固有函数による展開定理の証明について (= On a proof of the eigenfunction expansion theorem of Titchmarsh-Kodaira)*, Sûgaku **5** (1952), 228.
148. *On the integration of the temporally inhomogeneous diffusion equation in a Riemannian space*, Proc. Japan Acad. **30** (1954), 19-23.
149. *On the integration of the temporally inhomogeneous diffusion equation in a Riemannian space, II*, Proc. Japan Acad. **30** (1954), 273-275.
150. *Semi-group theory and the integration problem of diffusion equations*, Proc. of Internat. Congress of Mathematicians, Amsterdam, 1954, Vol. 1, pp. 405-420.
151. *On the generating parametriz of the stochastic processes*, Proc. Nat. Acad. Sci. U. S. A. **41** (1955), 240-244.
152. *A characterization of the second order elliptic differential operators*, Proc. Japan Acad. **31** (1955), 406-409.
153. *An operator-theoretical integration of the wave equation*, J. Math. Soc. Japan **8** (1956), 79-92.

154. *Semi-group の理論による波動方程式の積分 (= Integration of the wave equation by the theory of semi-groups)*, *Sûgaku* **8** (1956), 65-71.
155. *An operator-theoretical integration of the temporally inhomogeneous wave equation*, *J. Fac. Sci. Univ. Tokyo Sect. I*, **7** (1957), 463-466.
156. *On the reflexivity of the space of distribution*, *Sci. Papers Coll. Gen. Ed. Univ. Tokyo* **7** (1957), 151-155.
157. *On the differentiability of semi-groups of linear operators*, *Proc. Japan Acad.* **34** (1958), 337-340.
158. *発展方程式に関連して (= Regarding the evolution equation)*, *Sûgaku* **10** (1959), 205-211.
159. *An abstract analyticity in time for solutions of a diffusion equation*, *Proc. Japan Acad.* **35** (1959), 109-113.
160. *Fractional powers of infinitesimal generators and the analyticity of the semi-groups generated by them*, *Proc. Japan Acad.* **36** (1960), 86-89.
161. *On a class of infinitesimal generators and the integration problem of evolution equations*, *Proc. Fourth Berkeley Sympos. on Math. Stat. and Prob.*, 1961, Vol. **II**, pp. 623-633.
162. *Ergodic theorems for pseudo-resolvents*, *Proc. Japan Acad.* **37** (1961), 422-425.
163. *Abelian ergodic theorems in locally convex spaces*, *Ergodic Theory, Proc. Internat. Sympos. Tulane Univ.* 1961, pp. 293-299.
164. *On the integration of the equation of evolution*, *J. Fac. Sci. Univ. Tokyo Sect. I*, **9** (1963), 397-402.
165. *Holomorphic semi-groups in a locally convex linear topological space*, *Osaka Math. J.* **15** (1963), 51-57.
166. *Holomorphic semi-groups*, *Séminaire sur les Équations aux Dérivées Partielles* (1963-1964), **II**, 68-76.
167. *Positive pseudo-resolvents and potentials*, *Proc. Japan Acad.* **41** (1965), 1-5.
168. *Time dependent evolution equations in a locally convex space*, *Math. Ann.* **162** (1965), 83-86.
169. *A perturbation theorem for semi-groups of linear operators*, *Proc. Japan Acad.* **41** (1965), 645-647.
170. *On holomorphic Markov processes*, *Proc. Japan Acad.* **42** (1966), 313-317.
171. *Positive resolvents and potentials (An operator-theoretical treatment of Hunt's theory of potentials)*, *Z. Wahrscheinlichkeitstheorie und Verw. Gebiete* **8** (1967), 210-218.
172. (With T. Watanabe and H. Tanaka) *On the pre-closedness of the potential operator*, *J. Math. Soc. Japan* **20** (1968), 419-421.
173. *The existence of the potential operator associated with an equicontinuous semigroup of class  $(C_0)$* , *Studia Math.* **31** (1968), 531-533.
174. *On the potential operators associated with Brownian motions*, *J. Analyse Math.* **23** (1970), 461-465.
175. *On the pre-closedness of Hunt's potential operators and its applications*, *Proc. Intern. Conf. on Functional Analysis and Related Topics, Tokyo, 1969*, Univ. of Tokyo Press, 1970, pp. 324-331..
176. *Abel 型エルゴード定理と Hunt のポテンシャル論 (= Abelian ergodic theorem and Hunt's theory of potentials)*, *Sûgaku* **22** (1970), 81-91.

177. *On the existence and a characterization of abstract potential operators*, Proc. Troisième Colloq. sur l'Analyse Fonctionnelle, Liège, 1970, pp.129-136.
178. *Abstract potential operators on Hilbert space*, Publ. Res. Inst. Math. Sci. **8** (1972), 201-205.
179. ブラウン運動と等速度運動 拡散方程式の一面 (= *Brownian motions and uniform motions An aspect of diffusion equations*), Sûrikagaku (数理科学) **146** (1975), 9-14.
180. *A note on Malmquist's theorem on first order algebraic differential equations*, Proc. Japan Acad. **53** (1977), 120-123.
181. (With S. Okamoto) *A note on Mikusiński's operational calculus*, Proc. Japan Acad. Ser. A Math. **56** (1980), 1-3.
182. *A brief biography on Takakazu Seki (1642?-1708)*, Math. Intelligencer **3** (1980/81), no.3, 121-122.
183. *A note on the fundamental theorem of calculus*, Proc. Japan Acad. Ser. A Math. **57** (1981), 241.
184. *Some aspects of E. Hille's contribution to semi-group theory*, Integral Equations Operator Theory **4** (1981), 311-329.
185. 函数解析 50 年 (= *50 years of functional analysis*), Sûgaku **34** (1982), 354-364.
186. *A simple complement to Mikusiński's operational calculus*, Studia Math. **77** (1983), 95-98.
187. 角谷静夫氏の学士院賞・恩賜賞の受賞に際して (= *Award of Academy-Imperial Prize to Shizuo Kakutani*), Sûgaku **34** (1982), 351-353.
188. (With S. Matsuura) *A note on Mikusiński's proof of the Titchmarsh convolution theorem*, Conference in Modern Analysis and Probability, New Haven, Conn., 1982, Contemp. Math., **26** (1984), 423-425.
189. *The algebraic derivative and Laplace's differential equation*, Proc. Japan Acad. Ser. A Math. **59** (1983), 1-4.
190. *Chaos からの距離* (= *A metric from the chaos*), Sûrikagaku Suppl. *Entropy and Chaos* (1984), 111-114.
191. *Sato, a perfectionist*, Algebraic Analysis Vol. 1, Academic Press, Boston, 1988, pp. 17-18.

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