

A VARIATIONAL PROOF OF BIRKHOFF'S THEOREM ON DOUBLY STOCHASTIC MATRICES

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Abstract. This note provides a short variational proof of the Birkhoff's theorem asserting that the extreme points of the convex set of doubly stochastic matrices are the permutation matrices.

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REFERENCES

- [1] T. ANDO, *Majorization, doubly stochastic matrices and comparison of eigenvalues*, Linear Algebra and Its Applications, **118** (1989) 163–248.
- [2] R. BHATIA, *Matrix Analysis*. Springer–Verlag, New York, 1997.
- [3] J. M. BORWEIN AND A. S. LEWIS, *Convex Analysis and Nonlinear Optimization: Theory and Examples*, Springer, New York, 2000.
- [4] J. M. BORWEIN, A. S. LEWIS, AND R. NUSSBAUM, *Entropy minimization, DAD problems and doubly-stochastic kernels*, Journal of Functional Analysis, **123** (1994), 264–307.
- [5] J. M. BORWEIN AND D. PREISS, *A smooth variational principle with applications to subdifferentiability and to differentiability of convex functions*, Trans. Amer. Math. Soc., **303** (1987), 517–527.
- [6] I. EKELAND, *On the variational principle*, J. Math. Anal. Appl., **47** (1974), 324–353.
- [7] R. A. HORN AND C. R. JOHNSON, *Topics in Matrix Analysis*, Cambridge University Press, Cambridge, 1991.