אוניברסיטת
בן-גוריון בנגב

The Department of Mathematics

2022–23–A term

Course Name Applied probability and statistics for physics

Course Number 201.1.9691

Course web page
`https://www.math.bgu.ac.il//en/teaching/fall2023/courses/applied-prob-physics`

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Abstract

Requirements and grading[1]

Course topics

1. Counting states. Combinatorics. Distinguishable and indistinguishable particles. Ordered and unordered arrangements. Permutations without replacement and with replacement. Combinations without and with replacement. Multisets. N 1/2 spins. Cell gas. Fermions, para-fermions, bosons.

2. Repeated experiments, outcomes. Frequentist, Bayesian, and Kolmogorov probability, interrelation. Reproducible and irreproducible experiments. Probability in a finite universe. Expanding universe. Time dependent probability. Laws of probability. Mutually exclusive events/outcomes. Conditional probability. Bayes rule. Geometric probability, Betrand paradox.

3. Random variables. Discrete random variables. Probability of a random variable. Functions of random variables. Mean, variance, moments in general. Spin 1/2. Paramagnetism. Binomial distribution. Large numbers. Most probable state. Rare events. Radioactive decay. Poisson distribution. Information entropy. Maximum entropy principle without constraints. Uniform distribution. Maximum entropy principle with energy constraint. Boltzmann distribution.

[1] Information may change during the first two weeks of the term. Please consult the webpage for updates

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4. Gas of particles in the velocity space. Continuous random variable. Probability density. Mean, variance, moments. Delta-function. Maxwellian (normal, gaussian) distribution. Localized magnetic moment in a magnetic field. Classical paramagnetism. Fluctuations of magnetization. Other observed distributions: merging black holes. Line width: Breit? Wigner distribution. Entropy. Uniform distribution. Particle size distribution of aerosols and mass distribution in the Universe: log-normal distribution. Collisions in accelerators: from binomial distribution to Poisson.

5. Multivariate continuous distributions. Joint and marginal distribution. Gas in 3D. Most probable components and most probable magnitude of the velocity. Isotropic and anisotropic distributions. Plasma pressure tensor. Covariance, correlation. Transformation of variables in joint distributions. Beams in plasmas. Cosmic rays: energy spectrum and pitch-angle distribution. Covariance vs independence.

6. Laws of large numbers. Gaussian as the limiting distribution for the Binomial and and Poisson distributions. Chebyshev's inequality. Independent random variables. Sum of random variables. Convolution. Convolution of Gaussians. Central limit theorem. Applications and limitations of the theorem: velocity component of air molecules, Coulomb scattering, energy loss of charged particle traversing thin gas layer (Landau distribution).

7. Statistics in physics: from data to hypothesis. Main sequence: assume theory, devise an experiment, measure relevant parameters, estimate uncertainties, quantify agreement with theory, accept of reject. Examples: search for Higgs in LHC, dark matter in the Universe. More examples: CP violation.

8. Measurements and errors. Propagation of errors. Measured distribution vs true distribution: convolution with the resolution function (detector). Assumption of normal distribution of measurement uncertainties. Distortion of measured distribution: line width.

9. Measurements, samples, population, sample statistics. Sample mean and variance. Central limit theorem in statistics. Parameter estimates: frequentist and Bayesian approach. Prior and posterior probabilities. Basic estimators. Maximum-likelihood method: distance from the Sun to the center of the galaxy, mass distribution from LIGO.

10. LHC experiments: application of Chi-squared. Degrees of freedom. Nuisance parameters. Role of uncertainties (overestimate vs underestimate).

Unbiased estimators. Correlation functions.

11. Hypothesis testing. Simple and composite hypotheses; statistical tests; Neyman?Pearson; generalised likelihood-ratio; Student?s t; Fisher?s F; goodness of fit.

12. (Optional) Random walk. Diffusion processes.

13. (Optional) Monte-Carlo methods.