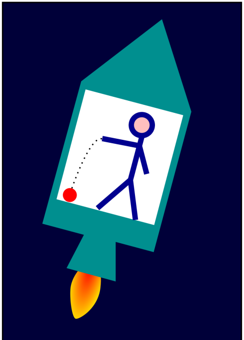
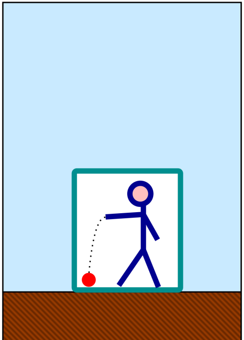
Theoretical Bachelor Projects

Klaus Bering

February 24th, 2023





1. General remarks
2. Topics in theoretical physics & previous bachelor students
3. Example: Schrödinger equation solved via path integral & Feynman diagrams

Theoretical diploma & PhD project?

- I do supervise them, but today I will focus on bachelor projects.

How to sign up?

- Come to my office.
- I sometimes have camera-ready projects, but usually the project topic is not fixed on the very first day, and is a result of what fits student and superviser best.
- Since many projects use Lagrangian or Hamiltonian formulations, my course F5500 Analytic Mechanics is recommended (possibly concurrently).

Lagrangian & Hamiltonian formulations, symplectic geometry

- Ondrej Hulik: WKB approximation & Maslov index in QM.
- Samuel Valach: Contact geometry (opponent).

Symmetry, group theory & conservation laws

- David Svoboda: QED Ward identity.
- Martin Skorna: Non-relativistic Goldstone theorem.

QM/QFT/path integral

- Michal Pazderka: Non-commutative QM & Seiberg-Witten map.
- Nikolas Masnicak: Casimir effect.
- Ondrej Kovanda & Radek Slama: Batalin-Vilkovisky (BV) formulation of relativistic point particle.
- Jan Merta: Shor algorithm for quantum computers & number theory.
- Matus Liptak: Schrödinger equation solved via path integral.

String theory

- Paulina Karlubikova: Regularize string oscillator modes to derive anomaly cancellation in $D = 26$ bosonic string theory.

Supermathematics

-

General relativity

- Tomas Michalik: General relativity modeled over the de-Sitter group $SO(1, 4)$.
- Darek Cidlinsky & Nino Lomtatidze: The mass parameter in the Schwarzschild solution has an interpretation as the total energy.

NB

- Just because a topic already became a thesis, it is usually far from exhausted.

Example: Schrödinger equation solved via path integral & Feynman diagrams

Ongoing bachelor project with Matus Liptak

1D Schrödinger equation: Oscillator with cubic interaction

$$\left(-\frac{\hbar^2}{2}\frac{d^2}{dx^2} + \frac{\omega^2}{2}x^2 + gx^3\right)\psi(x) = E_0\psi(x).$$

Perturbative ground state energy

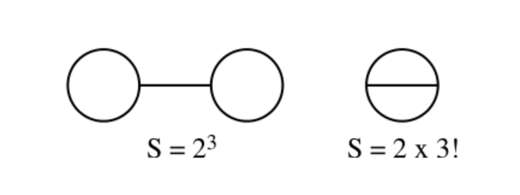
$$E_0 = \frac{\hbar\omega}{2} - \frac{11\hbar^2}{8\omega^4}g^2 - \frac{465\hbar^3}{32\omega^9}g^4 - \frac{39708\hbar^4}{128\omega^{14}}g^6 + \mathcal{O}(g^8)$$

Path integral

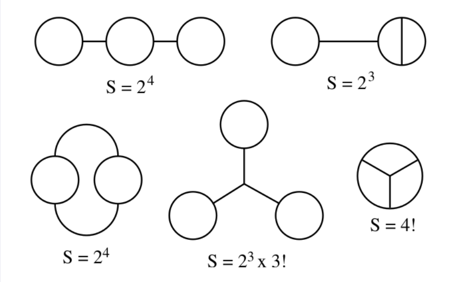
$$Z[J] = \int_{x(0)=x(T)}^{\dot{x}(0)=\dot{x}(T)} \mathcal{D}x \, \exp\left\{-\frac{1}{\hbar}\int_0^T dt \, (\frac{1}{2}\dot{x}^2 + \frac{\omega^2}{2}x^2 + gx^3 - Jx)\right\}$$

Vacuum Feynman diagrams with symmetry factor S

2-loop: $\mathcal{O}(g^2)$



3-loop: $\mathcal{O}(g^4)$



Děkuji!