

# The Quantum Mechanical Two-body Problem

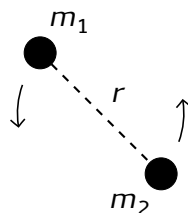
These are lecture notes by Apoorv Potnis of the lecture ‘Quantenmechanisches Zweikörperproblem’ or ‘The Quantum Mechanical Two-body Problem’, given by **Prof. Frederic Paul Schuller**, as the seventeenth lecture in the course ‘Theoretische Physik 2: Theoretische Quantenmechanik’ in 2014/15 at the Friedrich-Alexander-Universität Erlangen-Nürnberg. While the original lecture is in German, these notes are in English and have been prepared using YouTube’s automatic subtitle translation tool. The lecture is available at [https://www.youtube.com/watch?v=mcM4S3IMMvI&list=PLP05pgr\\_frzTeqa\\_thb1tYjyw8F9ehw7v&index=17](https://www.youtube.com/watch?v=mcM4S3IMMvI&list=PLP05pgr_frzTeqa_thb1tYjyw8F9ehw7v&index=17) and at <https://www.fau.tv/clip/id/44891>.

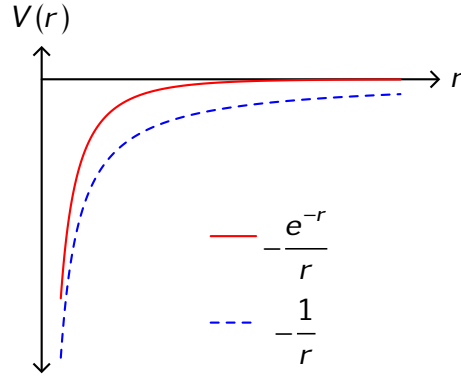
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## 1 Introduction

In this lecture, we shall consider a quantum-mechanical system consisting of two interacting particles of masses  $m_1$  and  $m_2$ , such that the interaction is completely determined by the potential  $V(r)$ , and the potential depends





only on the distance  $r$  between the particles. An example of such a potential would be the *Yukawa potential*, defined as

$$V_{\text{Yukawa}}(r) := a \frac{\exp(-kmr)}{r},$$

where  $k$ ,  $m$  and  $a$  are constants.  $a \in \mathbb{R} \setminus \{0\}$ ,  $m \geq 0$ . According to quantum field theory, very roughly speaking, interaction between particles takes place via a ‘mediating particle’. If the interaction is mediated by a ‘scalar field’<sup>1</sup>, then the mass associated to the particle of that scalar field is the mass  $m$  appearing in the Yukawa potential. If we plot a graph of the Yukawa potential for a massive scalar field, then we see that the magnitude of the potential becomes very close to zero after a certain distance. Thus, these interactions are short-ranged. If instead we have  $m = 0$ , corresponding to a photon, then we get the familiar long-range Coulomb potential

$$V_{\text{Coulomb}}(r) := a \frac{1}{r}.$$

## References

- [1] Frederic Schuller, Simon Rea, and Richie Dadhley. ‘Lectures on Quantum Theory’. Lecturer: Prof. Frederic Paul Schuller. 2019. URL: [https://docs.wixstatic.com/ugd/6b203f\\_a94140db21404ae69fd8b367d9fcd360.pdf](https://docs.wixstatic.com/ugd/6b203f_a94140db21404ae69fd8b367d9fcd360.pdf).
- [2] Frederic Schuller. *Lectures on Quantum Theory*. 2015. URL: [https://youtube.com/playlist?list=PLPH7f\\_7Z1zxQVx5jRjbfRGEzWY\\_upS5K6](https://youtube.com/playlist?list=PLPH7f_7Z1zxQVx5jRjbfRGEzWY_upS5K6).

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<sup>1</sup>Whatever that means

- [3] Philip Bowers. *Lectures on Quantum Mechanics*. Cambridge University Press, Cambridge, 2020. ISBN: 978-1-108-42976-4.
- [4] Michael Reed and Barry Simon. *Methods of Modern Mathematical Analysis I: Functional Analysis*. Revised and Enlarged edition. Vol. 1. Academic Press, Inc. London, 1980. ISBN: 978-0-080-57048-8.

The source code, updates and corrections to this document can be found on this GitHub repository: [https://github.com/apoorvpotnis/schuller\\_two-body\\_problem](https://github.com/apoorvpotnis/schuller_two-body_problem). The source code, along with the .bib file is embedded in this PDF. Comments and corrections can be mailed at [apoorvpotnis@gmail.com](mailto:apoorvpotnis@gmail.com).