1. Annotation

Course Description

Advanced course in quantum mechanics, in which the basic principles of quantum theory are supplemented and applied to the study of specific physical systems. Modern methods of research of quantum systems are proposed - the construction of integrable potentials, the integral along trajectories, and the concepts of density matrix and effective action are introduced. The course involves a transition to the consideration of free field theories, their canonical quantization, and discussion of differences between quantum mechanics and quantum field theory.

The purpose of the course is to consolidate the basic principles and methods of quantum theory, study the transition from quantum mechanics to quantum field theory. The course introduces the basic concepts necessary for studying the courses of the program "Mathematical physics".

The course is designed as a solution to specific problems in quantum theory (see the course content). The course involves significant independent work on solving problems. I would like the results of the course to coincide with the goals.

Course Prerequisites / Recommendations

Course "Introduction to quantum theory" or completed course "Quantum mechanics" in a good University's undergraduate program.

2. Structure and Content
### Course Academic Level

Master-level course suitable for PhD students

### Number of ECTS credits

6

<table>
<thead>
<tr>
<th>Topic</th>
<th>Summary of Topic</th>
<th>Lectures (# of hours)</th>
<th>Seminars (# of hours)</th>
<th>Labs (# of hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction.</td>
<td>Basic principles of quantum theory.</td>
<td>2</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Quantum mechanics in external fields.</td>
<td>The motion of an electron in external electromagnetic fields. Pauli’s Equation.</td>
<td>1</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Integration of one-dimensional quantum mechanics.</td>
<td>Soliton potentials, their construction and properties. Communication with integrated systems.</td>
<td>1</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Motion of a particle in a periodic potential.</td>
<td>Band structure.</td>
<td>1</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Systems of identical particles.</td>
<td>Bosons and fermions. The Fock space for fermions and bosons.</td>
<td>1</td>
<td>5</td>
<td></td>
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<tr>
<td>Quantum system in the environment.</td>
<td>The concept of the density matrix, its calculation using path integral.</td>
<td>1</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Quantization of the field.</td>
<td>Quantization of the free electromagnetic field as a gauge theory. Radiation of absolutely black body.</td>
<td>2</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

### 3. Assignments

<table>
<thead>
<tr>
<th>Assignment Type</th>
<th>Assignment Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homework</td>
<td>Solving problems by topic 1,2,3</td>
</tr>
<tr>
<td>Homework</td>
<td>Solving problems by topic 4,5,6</td>
</tr>
<tr>
<td>Homework</td>
<td>Solving problems on topics 7,8 and preparing a question of choice for the exam.</td>
</tr>
</tbody>
</table>

### 4. Grading

| Type of Assessment | Graded |
Grade Structure

<table>
<thead>
<tr>
<th>Activity Type</th>
<th>Activity weight, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homework Assignments</td>
<td>30</td>
</tr>
<tr>
<td>Homework Assignments</td>
<td>30</td>
</tr>
<tr>
<td>Homework Assignments</td>
<td>30</td>
</tr>
<tr>
<td>Final Exam</td>
<td>10</td>
</tr>
</tbody>
</table>

Grading Scale

<table>
<thead>
<tr>
<th>Grade</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>86</td>
</tr>
<tr>
<td>B</td>
<td>76</td>
</tr>
<tr>
<td>C</td>
<td>66</td>
</tr>
<tr>
<td>D</td>
<td>56</td>
</tr>
<tr>
<td>E</td>
<td>46</td>
</tr>
<tr>
<td>F</td>
<td>0</td>
</tr>
</tbody>
</table>

Attendance Requirements
Optional with Exceptions

5. Basic Information

Maximum Number of Students

<table>
<thead>
<tr>
<th></th>
<th>Maximum Number of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>12</td>
</tr>
<tr>
<td>Per Group (for seminars and labs):</td>
<td>12</td>
</tr>
</tbody>
</table>

Course Stream
Science, Technology and Engineering (STE)

Course Term (in context of Academic Year)
Term 1
Term 2

Course Delivery Frequency
Every year

Students of Which Programs do You Recommend to Consider this Course as an Elective?

<table>
<thead>
<tr>
<th>Masters Programs</th>
<th>PhD Programs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematical and Theoretical Physics</td>
<td></td>
</tr>
</tbody>
</table>
6. Textbooks and Internet Resources

<table>
<thead>
<tr>
<th>Required Textbooks</th>
<th>ISBN-13 (or ISBN-10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>П. Дирак, Принципы квантовой механики, 1979, М., Наука</td>
<td></td>
</tr>
<tr>
<td>Р. Фейнман, Статистическая механика, 1978, М., Мир</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recommended Textbooks</th>
<th>ISBN-13 (or ISBN-10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>П.В.Елютин, В.Д.Кривченков, Квантовая механика с задачами.</td>
<td></td>
</tr>
</tbody>
</table>

7. Facilities

8. Learning Outcomes

**Knowledge**

Fixing the basic principles and methods of quantum theory, studying the transition from quantum mechanics to quantum field theory. Introduction of the basic concepts necessary for studying the courses of the program "mathematical physics".

**Skill**

Ability to solve problems of quantum mechanics.

**Experience**

Using images and principles of quantum theory to solve specific problems.

9. Assessment Criteria
<table>
<thead>
<tr>
<th>Assignment 1 Type</th>
<th>Homework Assignments</th>
</tr>
</thead>
</table>
| Input Example(s) of Assignment 1 (preferable) | 1. To find the variance the square of coordinates is real one dimensional generator (frequency - $\omega$, mass $m$) in the state with the energy is definitely $\frac{3\hbar\omega}{2}$.
2. Find the average kinetic energy of an electron in the Coulomb field of attraction in the 2p-state with the minimum projection of the moment of momentum on the selected axis.
3. Two neutrons can only move along a straight line and they interact with each other as follows: $U(q_{1,2})=m\omega^2 (q_{1}-q_{2})^2/4$ (here $q_{1,2}$ - coordinates of neutrons on a straight line, $\omega$ - characteristic potential, $m$ - the mass of the neutron). The system is placed in a uniform magnetic field $\vec{B}$. What is the main magnetic field the state of this system is singlet?
4. Find the splitting of the first excited level of hydrogen in a linear magnetic field approximation.
5. The electron is located near an ideal metal surface. The surface is impervious to the electron. The electron is in the ground state. What is the distance from this surface at which this electron can be detected? |

| Assessment Criteria for Assignment 1 | The score is set according to the percentage of correct decisions. |

<table>
<thead>
<tr>
<th>Assignment 2 Type</th>
<th>Homework Assignments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input or Upload Example(s) of Assignment 2:</td>
<td></td>
</tr>
</tbody>
</table>

| Assessment Criteria for Assignment 2 | The score is set according to the percentage of correct decisions. |

| Assignment 3 Type | |
|-------------------| |
| Input or Upload Example(s) of Assignment 3: | |

| Assignment 4 Type | |
|-------------------| |
| Input or Upload Example(s) of Assignment 4: | |

| Assignment 5 Type | |
|-------------------| |
| Input or Upload Example(s) of Assignment 5: | |

| Additional Notes | 10. Additional Notes |