Biological Physics

Instructor: Dr. Peter M. Hoffmann, Associate Professor of Physics & Materials Science
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Office hours: W 11-12, TH 2-3, or by appointment (e-mail)
Website: Blackboard

Time & Place: Tuesdays and Thursdays, 10:40 am - 12:30 pm, Room 0058 Mannogian Hall.
Lecture: TU, 10:40-12:30, TH 10:40 - 11:30
Problem solving: TH 11:30 - 12:30

Textbook:

What is Biological Physics?
Biological Physics deals with fundamental physical principles at the center of life’s processes. In this course, we concentrate on the physics of cellular processes. Biological Physics touches on many areas of physics, including thermodynamics, electrodynamics, kinetics and statistical mechanics. Thus, in addition to learning about the physics of life, this course will also serve as an introduction to these important areas of physics. We will also learn new mathematical techniques in this course, as needed.

Level of course:
This course is a senior level undergraduate course. As such, we will learn how to analyze complex physical situations and use modestly advanced calculus. Students need to be aware this is not an easy course and a high level of attention and dedication is expected from students who want to achieve a grade of A or B. Understanding the course material will be assisted by weekly problem solving sessions, as well as quizzes and regular homework assignments.

Grading & Assignments:

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attendance</td>
<td>5%</td>
<td>A-, A</td>
</tr>
<tr>
<td>Homework</td>
<td>10%</td>
<td>B-, B, B+</td>
</tr>
<tr>
<td>Problem solving</td>
<td>15%</td>
<td>C-, C, C+</td>
</tr>
<tr>
<td>Reading quizzes</td>
<td>5%</td>
<td>D-, D, D+</td>
</tr>
<tr>
<td>Review Exam</td>
<td>5%</td>
<td>F</td>
</tr>
<tr>
<td>Exams (2 x 20%)</td>
<td>40%</td>
<td></td>
</tr>
<tr>
<td>Final Exam</td>
<td>20%</td>
<td></td>
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A-, A  85 - 100
B-, B, B+  70 - 84
C-, C, C+  55 - 69
D-, D, D+  40 - 54
F  < 40

Attendance will be taken at least once a week unannounced.

Homework will be given weekly. Students will present their homework solutions during our weekly problem solving sessions. Handing in a problem as a homework, but not understanding the solution, will result in a loss of points for both the problem solving session and the handed-in homework. Problem solving will be graded on an honest effort basis, not on absolute correctness of solution presented. It is important to demonstrate you have spent effort and time to think about the problem and can explain how you arrive at your solution. Therefore, do not copy solutions from others. Instead, if you need help, discuss problems with your fellow students or with me.
**Reading quizzes** will be short quizzes given weekly to ensure students read the textbook.

The **Review Exam** is based on material from the text book already covered in PHY 4700. These previously covered topics are needed to understand the more advanced chapters in the book.

**Exams** will be 1 hour, except for the final which will be two hours.

Tentative content of course:

<table>
<thead>
<tr>
<th>Week of</th>
<th>Topics</th>
<th>Reading (pages)</th>
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</thead>
<tbody>
<tr>
<td>Sept. 7</td>
<td>Review of Chapters 1 - 3: thermodynamics, probability, statistics, Boltzmann, ideal gas law</td>
<td>3-29, 35-62, 69-103</td>
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<tr>
<td>Sept. 14</td>
<td>Chapter 4: Random walk, diffusion, friction, Einstein relation, Polymer conformation, membrane diffusion, Nernst relation, <strong>REVIEW EXAM (Ch. 1, 3 &amp; 4)</strong></td>
<td>108-146</td>
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<tr>
<td>Sept. 21</td>
<td>Chapter 6: Entropy, Sackur-Tetrode, Second Law, Shannon’s formula, entropic forces, free energy</td>
<td>195-217</td>
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<td>Sept. 28</td>
<td>Chapter 6: Review &amp; new topics: microscopic systems, Boltzmann distribution, kinetics, partition function, 2-state systems <strong>EXAM 1 (Ch. 4-6)</strong></td>
<td>217-231</td>
</tr>
<tr>
<td>Oct. 5</td>
<td>Chapter 7: Entropic forces, osmotic pressure, depletion forces, osmotic flow</td>
<td>245-260</td>
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<td>Oct. 12</td>
<td>Chapter 7: Electrostatics, Gauss law, charged surfaces, Poisson-Boltzmann equation, double layers, properties of water</td>
<td>260-282</td>
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<tr>
<td>Oct. 19</td>
<td>Chapter 8: Chemical Potential, grand partition function, chemical equilibrium, Gibbs free energy, reaction kinetics, ions &amp; dissociation, amphiphiles and self-assembly</td>
<td>294-334</td>
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<td>Oct. 26</td>
<td>Chapter 9: polymer elasticity, stretching single molecules, Eigen values, cooperativity</td>
<td>341-363</td>
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<td>Nov. 2</td>
<td>Chapter 9: molecular switching, helix-coil transition, DNA ‘melting’, applied forces, allostery, <strong>EXAM 2 (Ch. 7 - 9)</strong></td>
<td>363-383</td>
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<tr>
<td>Nov. 9</td>
<td>Chapter 10: Molecular devices in cells, enzymes, cyclic motors, energy landscapes, Smoluchowski equation, Feynman’s ratchet</td>
<td>401-432</td>
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<td>Nov. 16</td>
<td>Chapter 10: Real machines, Michaelis-Menten rule, kinesin, diffusing (Brownian) ratchet</td>
<td>432-453</td>
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<tr>
<td>Nov. 23</td>
<td>Chapter 11: electro-osmotic effects, ohmic conductance, Donnan equilibrium, ion pumps, mitochondria, <strong>Thanksgiving week</strong></td>
<td>469-500</td>
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<tr>
<td>Nov. 30</td>
<td>Chapter 12: Nerve Impulses, Action potentials</td>
<td>505-551</td>
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<td>Dec. 7</td>
<td>Review, End of class</td>
<td>Review</td>
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<tr>
<td>Dec. 16</td>
<td><strong>FINAL EXAM (comprehensive, emphasis on Ch. 10-12)</strong>, Wednesday, Dec. 16, 10:40 am</td>
<td>Review</td>
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