

Physics 215– Elementary Modern Physics
Equations for Test 3

The following equations you should have memorized, and understand how to use them:

For one dimension

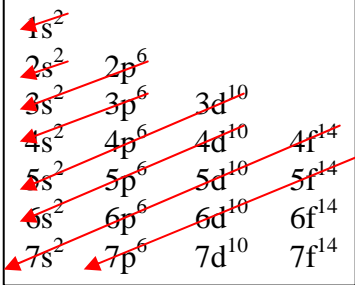
<u>Expectation Value of Operator</u> $\langle \mathcal{O} \rangle = \int_{-\infty}^{\infty} \psi^*(x) \mathcal{O} \psi(x) dx$	<u>Uncertainty</u> $(\Delta \mathcal{O})^2 = \langle \mathcal{O}^2 \rangle - \langle \mathcal{O} \rangle^2$	<u>Time-dependence</u> $\Psi(x, t) = e^{-iEt/\hbar} \psi(x)$
<u>Schrödinger Equations</u> $i\hbar \frac{\partial}{\partial t} \Psi = -\frac{\hbar^2}{2m} \frac{\partial^2}{\partial x^2} \Psi + V\Psi$ or $i\hbar \frac{\partial}{\partial t} \Psi = H\Psi$ $E\psi = -\frac{\hbar^2}{2m} \frac{d^2}{dx^2} \psi + V\psi$ or $E\psi = H\psi$		<u>Momentum Operator</u> $p_{op} = \frac{\hbar}{i} \frac{\partial}{\partial x}$
<u>Hamiltonian</u> $H = \frac{1}{2m} p_{op}^2 + V$ $\bar{E} = \langle H \rangle$		

For three dimensions

<u>Momentum Operators (3D):</u> $p_x = \frac{\hbar}{i} \frac{\partial}{\partial x}$ $p_y = \frac{\hbar}{i} \frac{\partial}{\partial y}$ $p_z = \frac{\hbar}{i} \frac{\partial}{\partial z}$	<u>Schrödinger Equations in 3D:</u> $i\hbar \frac{\partial}{\partial t} \Psi = -\frac{\hbar^2}{2m} \left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2} \right) \Psi + V\Psi$ or $i\hbar \frac{\partial}{\partial t} \Psi = H\Psi$ $E\psi = -\frac{\hbar^2}{2m} \left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2} \right) \psi + V\psi$ or $E\psi = H\psi$	
<u>Angular Momentum Values:</u> $L^2 = \hbar^2(l^2 + l)$ $L_z = \hbar m$	<u>The Hamiltonian</u> $H = \frac{1}{2m} \vec{p}_{op}^2 + V$ $\bar{E} = \langle H \rangle$	<u>Restrictions on Quantum Numbers:</u> $n = 1, 2, 3, \dots$ $l = 0, 1, 2, 3, \dots, n-1$ $m = -l, -l+1, \dots, 0, \dots, l$ $m_s = \pm \frac{1}{2}$
<u>Spin Values</u> $s = \frac{1}{2}$ $S^2 = \hbar^2(s^2 + s)$ $= \frac{3}{4} \hbar^2$ $S_z = \hbar m_s$		<u>Hydrogen Wave Functions</u> $\psi_{n,l,m}(r, \theta, \phi) = R_{n,l}(r) Y_{l,m}(\theta, \phi)$

Filling up Atoms:

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 \dots$



The following equations you need not memorize, but you should know how to use them if given to you:

$h = 6.626 \times 10^{-34} \text{ J}\cdot\text{s} = 4.136 \times 10^{-15} \text{ eV}\cdot\text{s}$ $\hbar = 1.055 \times 10^{-34} \text{ J}\cdot\text{s} = 6.582 \times 10^{-16} \text{ eV}\cdot\text{s}$	<p>Harmonic Osc.</p> $E_n = \hbar\omega\left(n + \frac{1}{2}\right)$ $n = 0, 1, 2, \dots$	<p>Hydrogen</p> $E_n = -\frac{(13.6 \text{ eV})Z^2}{n^2}$
<p>1D square well:</p> $E_n = \frac{\pi^2 \hbar^2 n^2}{2mL^2}$ $\psi_n(x) = \sqrt{\frac{2}{L}} \sin\left(\frac{\pi nx}{L}\right)$ $n = 1, 2, 3, \dots$	<p>Barrier penetration:</p> $T \approx 16 \frac{E}{V_0} \left(1 - \frac{E}{V_0}\right) e^{-2\alpha L},$ $\alpha = \frac{\sqrt{2m(V_0 - E)}}{\hbar}$	<p>Reflection off a step:</p> $R = \begin{cases} \left(\frac{\sqrt{E} - \sqrt{E - V_0}}{\sqrt{E} + \sqrt{E - V_0}}\right)^2 & \text{if } E > V_0 \\ 1 & \text{if } E < V_0 \end{cases}$

Layout of the exam: Below is an outline of the exam

This test consists of three parts. Please note that in parts II and III, you can skip one question of those offered.

Part I: Multiple Choice [20 points]

For each question, choose the best answer (2 points each)

[questions 1-10]

Part II: Short answer [20 points]

Choose **two** of the following three questions and give a short answer (1-3 sentences) (10 points each).

[questions 11-13]

Part III: Calculation: [60 points]

Choose **three** of the following four questions and perform the indicated calculations (20 points each)

[questions 14-17]