

Physics 215 – Elementary Modern Physics  
**Equations for Final Exam**

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

Atomic Mass, Charge, Neutron Number:  $Q = Ze \quad A = Z + N$

Approximate mass of an atom:  $M \simeq A \text{ u}$

Avogadro's number:  $N_A = \frac{1 \text{ g}}{1 \text{ u}}$

Radioactivity:  $R = \lambda N$ ,  $N = N_0 e^{-\lambda t}$ ,  $R = R_0 e^{-\lambda t}$ ,  $\lambda = \frac{\ln 2}{t_{1/2}}$ .

Types of Radioactive decay:

Type	$\Delta Z$	$\Delta A$	$Q$
$\alpha$	-2	-4	$(M_P - M_D - M_{\text{He}})c^2$
$\beta$	+1	0	$(M_P - M_D)c^2$
e. c.	-1	0	$(M_P - M_D)c^2$
$\beta^+$	-1	0	$(M_P - M_D - 2m_e)c^2$
$\gamma$	0	0	$(M_P - M_D)c^2$

Red Shift:  $1 + z = \frac{\lambda}{\lambda_0} = \frac{f_0}{f}$ , also,  $z \approx \frac{v}{c}$  (non relativistic)

Maximum size of object based on how fast it varies:  $d \leq ct$ .

**The following review equations you should also memorize:**

Speed of light:  $c \simeq 3 \times 10^8 \text{ m/s}$

Lorentz factor:  $\gamma = \frac{1}{\sqrt{1 - v^2/c^2}}$

Time dilation:  $\Delta t = \gamma \tau$

Length contraction:  $L = L_p / \gamma$

Energy:  $E = \gamma mc^2$ ,  $\gamma = \frac{1}{\sqrt{1-u^2/c^2}}$

Math with complex numbers:  $i^2 = -1$ ,  $e^{i\theta} = \cos \theta + i \sin \theta$   $(x + iy)^* = x - iy$

Basic waves:  $\cos(kx - \omega t)$  or  $\sin(kx - \omega t)$  or  $e^{i(kx - \omega t)}$

Wave relationships:  $\lambda = \frac{2\pi}{k}$   $\frac{\omega}{2\pi} = f = \frac{1}{T}$

For light waves:  $c = \lambda f$

Quantum waves:  $E = hf = \hbar \omega$   $p = \frac{h}{\lambda} = \hbar k$

Planck's constants:  $\hbar = h/2\pi$

Size of atoms and nuclei:  $a \approx 10^{-10}$  m  $R \approx 10^{-15}$  m

Uncertainty relations:  $\Delta x \Delta p \geq \frac{1}{2} \hbar$

Momentum operator in 1D:  $p = \frac{\hbar}{i} \frac{\partial}{\partial x}$  in 3D:  $p_x = \frac{\hbar}{i} \frac{\partial}{\partial x}$ ,  $p_y = \frac{\hbar}{i} \frac{\partial}{\partial y}$ ,  $p_z = \frac{\hbar}{i} \frac{\partial}{\partial z}$

Schrödinger's Equation in 1D:  $i\hbar \frac{\partial}{\partial t} \Psi(x,t) = -\frac{\hbar^2}{2m} \frac{\partial^2}{\partial x^2} \Psi(x,t) + V(x,t) \Psi(x,t)$   
 $E\psi(x) = -\frac{\hbar^2}{2m} \frac{\partial^2}{\partial x^2} \psi(x) + V(x)\psi(x)$

Probability of finding a particle in a range:  $P(a < x < b) = \int_a^b |\psi(x)|^2 dx$

Angular momentum values:  $L^2 = \hbar^2(l^2 + l)$ ,  $L_z = \hbar m$

Spin values:  $s = \frac{1}{2}$   $S^2 = \hbar^2(s^2 + s) = \frac{3}{4} \hbar^2$   $S_z = \hbar m_s$

Restrictions on quantum numbers:  $n = 1, 2, 3, \dots$   $l = 0, 1, 2, 3, \dots, n-1$   
 $m = -l, -l+1, \dots, 0, \dots, l$   $m_s = \pm \frac{1}{2}$

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

Basic Masses:  $u = 931.494 \text{ MeV}/c^2 = 1.661 \times 10^{-27} \text{ kg}$        $N_A = 6.022 \times 10^{23}$

Nuclear Decay:       $2m_e c^2 = 1.02200 \text{ MeV}$ ,       $M_{\text{He}} = 4.002602 \text{ u}$

Range of forces:       $d = \frac{\hbar c}{mc^2}$

Planck's Constants:       $h = 6.626 \times 10^{-34} \text{ J} \cdot \text{s} = 4.136 \times 10^{-15} \text{ eV} \cdot \text{s}$   
                                  $\hbar = 1.055 \times 10^{-34} \text{ J} \cdot \text{s} = 6.582 \times 10^{-16} \text{ eV} \cdot \text{s}$

Newton's Constant:       $G = 6.673 \times 10^{-11} \text{ m}^3/\text{kg}/\text{s}^2$

Orbital Velocity:  $v = \sqrt{\frac{GM}{r}}$

Red shift formulas:       $\frac{v_r}{c} = \frac{(1+z)^2 - 1}{(1+z)^2 + 1}$

Gravitational time dilation & Red-shift:       $\tau = t \sqrt{1 - \frac{2GM}{c^2 r}}$

Gravitational Red-shift:       $\lambda = \lambda_0 \left(1 - \frac{2GM}{c^2 r}\right)^{-1/2}$

Schwarzschild radius of a black hole:       $R_s = \frac{2GM}{c^2}$

**In addition to these equations, any equation that appeared on a previous exam may be tested on this exam. But if it isn't listed here, you don't need to memorize it.**

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

This test consists of five parts. Please note that in parts II through V, you can skip one question of those offered.

**Part I: Multiple Choice (mixed new and review questions) [50 points]**

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

[questions 1-25]

**Part II: Short answer (review material) [20 points]**

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

[questions 26-28]

**Part III: Short answer (new material) [30 points]**

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

[questions 29-32]

**Part IV: Calculation (review material) [40 points]**

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

[questions 33-35]

**Part V: Calculation (new material): [60 points]**

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

[questions 36-39]

**Review Session on Monday, December 12 at 5:30 PM**

**The exam will be in the usual room where we meet on  
Wednesday, December 14, at 9:00 AM**