Physics 215 – Elementary Modern Physics

Equations for Final Exam

The following <u>new</u> 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: $M \simeq A$ u

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

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

Types of Radioactive decay:

Type	ΔZ	ΔA	Q
α	-2	-4	$\left(M_P - M_D - M_{\text{He}}\right)c^2$
β^-	+1	0	$\left(M_P - M_D\right)c^2$
e. c.	-1	0	$\left(M_P - M_D\right)c^2$
β^+	-1	0	$\left(M_P - M_D - 2m_e\right)c^2$
γ	0	0	$\left(M_P - M_D\right)c^2$

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

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

The following review equations you should also memorize:

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

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

Time dilation: $\Delta t = \gamma\tau$ Length contraction: $L = L_p/\gamma$

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

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

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

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

For light waves: $c = \lambda f$

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

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

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

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

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

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

$$E\psi\left(x\right) = -\frac{\hbar^2}{2m}\frac{\partial^2}{\partial x^2}\psi\left(x\right) + V\left(x\right)\psi\left(x\right)$$

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

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

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

Restrictions on quantum numbers: $n = 1, 2, 3, \ldots$ $l = 0, 1, 2, 3, \ldots, n-1$

$m = -l, -l+1, \ldots, 0, \ldots, l$ $m_s = \pm\frac{1}{2}$

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

Basic Masses: $\mathrm{u} = 931.494\ \mathrm{MeV}/c^2 = 1.661\times10^{-27}\,\mathrm{kg}$ $\qquad N_A = 6.022\times10^{23}$

Nuclear Decay: $\qquad 2m_ec^2 = 1.02200\ \mathrm{MeV}, \qquad M_{\mathrm{He}} = 4.002602\ \mathrm{u}$

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

Planck's Constants: $\qquad h = 6.626\times10^{-34}\ \mathrm{J\cdot s} = 4.136\times10^{-15}\ \mathrm{eV\cdot s}$

$\qquad\qquad\qquad\qquad \hbar = 1.055\times10^{-34}\ \mathrm{J\cdot s} = 6.582\times10^{-16}\ \mathrm{eV\cdot s}$

Newton's Constant: $\qquad G = 6.673\times10^{-11}\,\mathrm{m^3/kg/s^2}$

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

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

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

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

Schwarzschild radius of a black hole: $\qquad R_S = \dfrac{2GM}{c^2}$

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 Thursday, December 11 at 6:30 PM

The exam will be in the usual room where we meet on Friday, December 12, at 2:00 PM