Physics 215 – Elementary Modern Physics

Equations for Final Exam

Cosmology and the Big Bang Theory are not on the 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: $M \approx A$ u

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

Types of radioactive decay:

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

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

Particle Physics Things to know:

- How are anti-particles related to particles? What's their mass, charge, strangeness, baryon number, spin, etc.?
- What distinguishes fermions and bosons?
- What are the four forces of nature? Which one isn't part of particle physics?
  - Electromagnetism + Weak = electroweak
  - How can tell which of the three forces is involved (memorize the chart)
- What are the conservation laws for particles? Are they always conserved?
  - How many quarks/anti-quarks there are in baryons, anti-baryons, and mesons?
  - What's the name of the three most common types of quarks?
  - What are the charges of the three most common types of quarks?
  - How to tell what quarks something is made of based on type of particle and strangeness
- Which particles carry the three forces? (there are two for the weak force)

The following review equations you should also memorize:

Speed of light: $c \simeq 3\times10^8$ 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: $E = \gamma mc^2$, $\quad \gamma = \frac{1}{\sqrt{1 - u^2/c^2}}$

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 $e^{i(kx-\omega t)}$

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:

$$i\hbar\frac{\partial}{\partial t}\Psi(x,t) = -\frac{\hbar^2}{2m}\frac{\partial^2}{\partial x^2}\Psi(x,t) + V(x,t)\Psi(x,t)$$

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

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: $n = 1, 2, 3, \ldots$ $l = 0, 1, 2, 3, \ldots, n-1$

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

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

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

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

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

Planck's Constants:
$$h = 6.626\times10^{-34}\ \text{J}\cdot\text{s} = 4.136\times10^{-15}\ \text{eV}\cdot\text{s}$$
$$\hbar = 1.055\times10^{-34}\ \text{J}\cdot\text{s} = 6.582\times10^{-16}\ \text{eV}\cdot\text{s}$$

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

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

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

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]

The exam will be in the usual room where we meet on
Monday, December 6, at 2:00 PM

You will have 2 hours and 40 minutes for the final exam
Those with accommodations will have 4 hours for the final exam