Physics 1201 Final Exam information – Spring 2013

1) Format: 35 multiple-choice questions, 5 points each → 175 points total

2) Closed book and closed notes

3) Equations and constants are provided on the final exam

4) Cumulative – it covers all of the material covered in the course

5) Approximate weightings of material:
   ~10 questions from material covered for midterm 1
   ~10 questions from material covered for midterm 2
   ~15 questions on material covered since midterm 2

6) See the Assignment Sheet for the date and time of your final exam
Final Exam -- Physics 1201
Spring 2013 -- X:XX pm lecture section --Humanic
April XX, 2013

Name ___________________________ Rec. Instructor _______________________

* Exam is closed book and closed notes.
* Write your name and the name of your recitation instructor on every page of the exam.
* This exam consists of 35 multiple-choice questions (5 points each, 175 points total)
* You have 1 hr 45 minutes to complete the exam.

\[
\begin{align*}
    m_{\text{proton}} &= 1.67 \times 10^{-27} \text{ kg} & e &= 1.60 \times 10^{-19} \text{ C} & 1 \text{ T} &= 10^4 \text{ G} \\
    k &= 8.99 \times 10^9 \text{ N m}^2/\text{C}^2 & \varepsilon_0 &= 8.85 \times 10^{-12} \text{ C}^2/(\text{Nm}^2) & c &= 3.00 \times 10^8 \text{ m/s} \\
    m_{\text{electron}} &= 9.11 \times 10^{-31} \text{ kg} & \mu_0 &= 4\pi \times 10^{-7} \text{ Tm/A} & \kappa &= 1.00 \text{ for air} \\
    F &= k \frac{|q_1||q_2|}{r^2} & E &= \frac{F}{q} & E &= k \frac{|q|}{r^2} & V &= \frac{EPE}{q} & V_B - V_A &= -\frac{W_{BA}}{q} & Q &= CV & C &= \frac{\kappa \varepsilon_0 A}{d} & V &= Ed \\
    R &= \frac{\rho L}{A} & I &= \frac{\Delta q}{\Delta t} & E_0 &= \frac{q}{\varepsilon_0 A} & \kappa &= \frac{E_0}{E} & E &= -\frac{\Delta V}{\Delta s} & W_{BA} &= EPE_A - EPE_B & W &= \Delta KE \\
    M &= \text{NIA} & KE &= \frac{1}{2}mv^2 & \bar{P} &= I_{\text{rms}} V_{\text{rms}} & V_{\text{rms}} &= IR & q &= q_0 e^{-\frac{r}{\tau}} & \tau &= RC & W &= F\Delta s \cos \theta \\
    V_{\text{rms}} &= \frac{V_0}{\sqrt{2}} & I_{\text{rms}} &= \frac{I_0}{\sqrt{2}} & P &= IV & V &= IR & Q &= CV & C_{eq} &= C_1 + C_2 & \frac{1}{C_{eq}} &= \frac{1}{C_1} + \frac{1}{C_2} \\
    P &= I^2R & P &= \frac{V^2}{R} & \text{Energy} &= \frac{1}{2}qV & \text{Energy} &= \frac{1}{2}CV^2 & \text{Energy} &= \frac{q^2}{2C} & R_{eq} &= R_1 + R_2 & \frac{1}{R_{eq}} &= \frac{1}{R_1} + \frac{1}{R_2} \\
    F &= \mu LI \sin \theta & F &= qvB \sin \theta & B &= \frac{\mu_0 I}{2\pi r} & B &= \mu_0 nI & \tau &= NIAB \sin \phi & r &= \frac{mv}{qB} & F &= \frac{\mu_0 LI}{2\pi r} \sin \theta
\end{align*}
\]
\[
\varepsilon = -N \frac{\Delta \Phi}{\Delta t} \quad \Phi = BA \cos \phi \quad \varepsilon = \varepsilon_0 \sin \omega t \quad \varepsilon_0 = NA \alpha \omega \quad \omega = 2\pi f \quad V - \varepsilon = IR \quad \frac{I_p}{I_p} = \frac{V_p}{V_s} = \frac{N_p}{N_s}
\]

\[
c = \frac{f \lambda}{d_o + \frac{1}{d_i}} \quad f = \frac{1}{2} R \quad m = \frac{h}{d} \quad n = \frac{c}{\nu} \quad \sin \theta_c = \frac{n}{n_i} \quad n_i \sin \theta_i = n_2 \sin \theta_2
\]

\[
\sin \theta = \frac{m}{d} \lambda \quad \sin \theta = (m + \frac{1}{2}) \frac{\lambda}{d} \quad \sin \theta = \frac{m \lambda}{W} \quad S = S_0 \cos^2 \theta \quad \tan \theta_p = \frac{n_2}{n_1} \quad S_{\text{polarized}} = \frac{S_{\text{regularized}}}{2}
\]

\[
\theta = \frac{h}{d_o} \quad M = \frac{N}{f} \quad M = \frac{N}{f} + 1 \quad P = \frac{1}{f} \quad M = \frac{L \nu}{f_o f_s} \quad N = 25.0 \text{ cm} \quad M = \frac{f_e}{f_o}
\]

\[
\theta_{\text{aim}} = 1.22 \frac{\lambda}{D} \quad m \lambda = 2d \sin \theta \quad f - \text{stop} = \frac{f}{D}
\]

\[
\Delta t = \gamma \Delta t_0 \quad \frac{L}{\gamma} \quad m = \gamma m_0 \quad p = \gamma m_0 \nu \quad E = \gamma m_0 c^2 \quad E_0 = m_0 c^2 \quad c = 3.00 \times 10^8 \frac{m}{s}
\]

\[
KE = E - E_0 = m_0 c^2 (\gamma - 1) \quad \gamma = \frac{1}{\sqrt{1 - \nu^2 \frac{c^2}{E}}}
\]

\[
\frac{1}{E} = \sqrt{p^2 c^2 + m_0^2 c^4} \quad 1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}
\]

\[
\lambda_{\text{max}} T = 2.898 \times 10^{-3} m \cdot K \quad E = hf \quad h = 6.63 \times 10^{-34} \text{ J} \cdot \text{s} \quad KE_{\text{max}} = e \Delta V \quad KE_{\text{max}} = hf - W_0 \quad p = \frac{h}{\lambda}
\]

\[
\lambda = \frac{h}{p} \quad E = pc \quad \lambda' = \lambda = (2.43 \times 10^{-12} m)(1 - \cos \theta) \quad E_i - E_f = hf \quad r = \left(5.29 \times 10^{-11} m\right) \frac{n^2}{Z}
\]

\[
E_n = -(13.6 \text{ eV}) \frac{Z^2}{n^2} \frac{1}{\lambda} = \left(1.097 \times 10^7 \text{ m}^{-1}\right) \frac{1}{\lambda} \left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)
\]

\[
r = (1.2 \times 10^{-15} m)^{\frac{1}{3}} \quad 1 \mu = 931.5 \frac{MeV}{c^2} \quad BE = (\Delta m)c^2 \quad \Delta m = Zm(\frac{1}{H}) + Nm(\frac{1}{n}) - m(\frac{1}{X})
\]

\[
A = N + Z \quad Q = m_{\text{parent}}c^2 - m_{\text{daughter}}c^2 - m_Z c^2 \quad \frac{\Delta N}{\Delta t} = -\lambda N \quad N = N_0 e^{-\lambda t} \quad T_{1/2} = \frac{0.693}{\lambda} \quad Bq = \frac{1}{s} \frac{\text{decay}}{s}
\]
Chapter 30

Nuclear Physics and Radioactivity
The atomic nucleus consists of positively charged protons and neutral neutrons.

Table 31.1 Properties of Select Particles

<table>
<thead>
<tr>
<th>Particle</th>
<th>Electric Charge (C)</th>
<th>Kilograms (kg)</th>
<th>Atomic Mass Units (u)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electron</td>
<td>(-1.60 \times 10^{-19})</td>
<td>(9.109382 \times 10^{-31})</td>
<td>(5.485799 \times 10^{-4})</td>
</tr>
<tr>
<td>Proton</td>
<td>(+1.60 \times 10^{-19})</td>
<td>(1.672622 \times 10^{-27})</td>
<td>(1.007276)</td>
</tr>
<tr>
<td>Neutron</td>
<td>0</td>
<td>(1.674927 \times 10^{-27})</td>
<td>(1.008665)</td>
</tr>
<tr>
<td>Hydrogen atom</td>
<td>0</td>
<td>(1.673534 \times 10^{-27})</td>
<td>(1.007825)</td>
</tr>
</tbody>
</table>

1 atomic mass unit \(\equiv 1 \, u \equiv 931.5 \, \frac{MeV}{c^2}\)
Nuclear Structure

atomic mass number

\[ A = Z + N \]

Number of protons and neutrons

Number of protons

Number of neutrons

i.e. number of nucleons

atomic number

[i.e. number of nucleons]
Nuclear Structure

Nuclei that contain the same number of protons but a different number of neutrons are known as **isotopes**.

For example, two isotopes of carbon are $^{12}\text{C}$ and $^{14}\text{C}$. 
Approximate empirical radius of a nucleus of mass number, $A$

$$ r \approx r_0 A^{1/3}, \quad r_0 \approx 1.2 \times 10^{-15} \text{ m} = 1.2 \text{ fm} $$

1 fermi $\equiv$ 1 fm $\equiv$ $10^{-15}$ m

$$ r \approx \left(1.2 \times 10^{-15} \text{ m}\right) A^{1/3} $$
Nuclear Structure

Example: Nuclear radius and density
Find the radii of $^{16}$O and $^{208}$Pb nuclei. Estimate and compare their densities.

\[ r \approx r_0 A^{1/3} \approx \left(1.2 \times 10^{-15} \text{ m}\right) A^{1/3} \]

\[ r\left(^{16}\text{O}\right) = \left(1.2 \times 10^{-15}\right)(16)^{1/3} = 3.0 \times 10^{-15} \text{ m} = 3.0 \text{ fm} \]

\[ r\left(^{208}\text{Pb}\right) = \left(1.2 \times 10^{-15}\right)(208)^{1/3} = 7.1 \times 10^{-15} \text{ m} = 7.1 \text{ fm} \]

\[ \rho_{\text{nucleus}} = \frac{M_{\text{nucleus}}}{V_{\text{nucleus}}} \approx \frac{A m_{\text{nucleon}}}{\left(\frac{4}{3} \pi r^3\right)} \approx \frac{A m_{\text{nucleon}}}{\left(\frac{4}{3} \pi r_0^3 A\right)} \]

\[ \approx \frac{m_{\text{nucleon}}}{\left(\frac{4}{3} \pi r_0^3\right)} \quad \rightarrow \text{Nuclear densities are approximately the same for all } A \]
The mutual repulsion of the protons tends to push the nucleus apart. What then, holds the nucleus together?

*The strong nuclear force.*
The Strong Nuclear Force and the Stability of the Nucleus

As nuclei get larger, more neutrons are required for stability.

The neutrons act like glue without adding more repulsive force.
The Mass Deficit of the Nucleus and Nuclear Binding Energy

Binding energy of $^{A\,Z}_X \, = \, (\text{Mass deficit}) \, c^2 \, = \, (\Delta m) \, c^2$

$\Delta m \, = \, Z \times m( \frac{1}{1} H ) + N \times m( \frac{1}{0} n ) - m( \frac{A}{Z} X )$
The Mass Deficit of the Nucleus and Nuclear Binding Energy

Example: The Binding Energy of the Helium Nucleus

The atomic mass of helium is 4.0026u and the atomic mass of hydrogen is 1.0078u. Using atomic mass units, obtain the binding energy of the helium nucleus.
The Mass Deficit of the Nucleus and Nuclear Binding Energy

\[ \Delta m = Z \times m\left( ^1_1H \right) + N \times m\left( ^1_0n \right) - m\left( ^A_ZX \right) \]

\[ \Delta m = 2 \times (1.0078 \text{ u}) + 2 \times (1.0087 \text{ u}) - 4.0026 \text{ u} \\
= 4.0330 \text{ u} - 4.0026 \text{ u} = 0.0304 \text{ u} \]

\[ 1 \text{ u} = 931.5 \ \frac{MeV}{c^2} \]

Binding energy \( = (\Delta m) c^2 = (0.0304) \left( 931.5 \ \frac{MeV}{c^2} \right) c^2 = 28.3 \ \text{MeV} \)
The Mass Deficit of the Nucleus and Nuclear Binding Energy

![Graph showing the mass deficit and nuclear binding energy.](image)

- The x-axis represents the nucleon number $A$.
- The y-axis represents the binding energy per nucleon (MeV/nucleon).
- Data points for various elements are marked.

The graph illustrates how the binding energy per nucleon decreases as the nucleon number increases, reflecting the mass deficit and nuclear binding energy trends in atomic nuclei.
Radioactivity

A magnetic field separates three types of particles emitted by radioactive nuclei. The decay takes the general form:

\[ \text{parent} \rightarrow \text{daughter} + x \]

\[ Q \equiv m_{\text{parent}} c^2 - \left( m_{\text{daughter}} + m_x \right) c^2 \quad \Rightarrow \quad Q - \text{value} \rightarrow \text{KE released} \]

\[ Q > 0 \Rightarrow \text{exothermic} \quad Q < 0 \Rightarrow \text{endothermic} \]
Radioactivity

$^{238}_{92}U \rightarrow ^{234}_{90}Th + ^{4}_{2}He$

\[ Q = m_p c^2 - (m_D + m_\alpha) c^2 \]

\[ = [238.0508 \text{ } u - (234.0436 \text{ } u + 4.0026 \text{ } u)] \left( 931.5 \frac{\text{MeV}}{\text{u}} \right) \]

\[ = 4.3 \text{ MeV} \]
Radioactivity

A smoke detector

- $\alpha$ particles
- Radioactive material
- Battery
- Current
Radioactivity

$\beta$ DECAY

$$\frac{A}{Z} P \rightarrow \frac{A}{Z+1} D + \frac{0}{-1} e$$

Thorium parent nucleus

144
90
234
90 Th

Protactinium daughter nucleus

143
91
234
91 Pa

$\beta^-$ particle (electron)
Radioactivity

\[
^A_Z P^* \rightarrow ^A_Z P + \gamma
\]

- excited energy state
- lower energy state

\[
^{226}_{88} Ra^* \rightarrow ^{226}_{88} Ra + \gamma \quad E_\gamma = 0.186 \text{ MeV}
\]

a photon that originates from the energy-level transition of the nucleus.
During beta decay, energy is released. However, it is found that most beta particles do not have enough kinetic energy to account for all of the energy released.

The additional energy is carried away by a neutrino → mass ≈ 0, q = 0

A free neutron beta decays in about 12 minutes,

\[ ^{234}_{90}Th \rightarrow ^{234}_{91}Pa + ^{0}_{-1}e + \bar{\nu} \]

\[ ^{1}_{0}n \rightarrow ^{1}_{1}p + ^{0}_{-1}e + \bar{\nu} \]