Physics 60 Final Exam REVIEW
10:30 - 12:30 Monday of finals week

You may use a 3"x5" card of notes, both sides. No phones.

There is no acceptable reason for your work to look exactly like someone else's work.

"Someone else" includes other people, the textbook, anything on the web, and handed out solutions.

Present clear and complete solutions

Start solutions with definitions (e.g. $\vec{v} \equiv \frac{d\vec{r}}{dt}$), theorems (e.g. Newton's laws), and commonly used equations (e.g. constant acceleration equations).

Any physics/engineering major should be able to understand what you did just by reading your solution. A diagram and words usually help. A correct final answer without a reasonably organized justification will earn no credit.

Leave some values and integrals uncalculated.

Do all derivatives.

Do simple integrals: $\int \mathrm{a}z^n dz$, $\int \mathrm{a}e^x dx$, $\int \mathrm{a}(\cos\theta)d\theta$, $\int \mathrm{a}(\sin\phi)d\phi$, and $\int \mathrm{a}\ln(g)dg$.

Leave other integrals unintegrated. Include the limits of integration, move constants out of the integral, and simplify.

Do simple calculations: (1) multiply, divide, subtract and add integers with powers of 10, (2) simple fractions and square roots, and (3) sine and cosine of common angles such as $0, \pi, \pi/4, \pi/3, \ldots$.

Leave other calculations uncalculated. Provide an expression that requires a single calculation from your calculator. This means using the correct units.

1. Tell us (or write me) a quantum or special relativity related joke. If yours is the same as another person's, no points for either of you.

2. Given a wavefunction $\Psi(x,t)$ calculate the

   - expectation value of position
   - uncertainty in position
   - most likely position
   - expectation value of momentum
   - uncertainty in momentum

3. Given $\Psi(x,t)$, show that it satisfies the uncertainty principle for position and momentum.

4. Identify if an integral is equal to zero. No calculation required; you should be able to do this by considering the even-ness of the function.

5. Consider a beam of particles traveling towards

   (a) a potential barrier with an energy less than the barrier, $E < U_0$

   (b) a potential step with an energy greater than the step, $E > U_0$

   Draw an energy diagram for each of these situations. What is expected classically in each case? What is the quantum result?

6. Use the transmission and reflection coefficient equations correctly.

7. Consider a given $U(x)$ and E. For each region,

   - write the TISE,
   - write the general solution $\psi(x)$
   - discard terms, if necessary

8. Consider the spherically symmetric solutions to the hydrogen atom, $R(r)$. Calculate the

   (a) most likely position the electron will be found
   (b) expectation value of the electron's position
   (c) probability that the electron will be found between r_a and r_b.

   (d) What is the Bohr radius, a_o? Use words.

9. Calculate the photon wavelengths associated with transitions between states in the hydrogen atom.

10. In the hydrogen atom, what are the possible values

    (a) of the electron's orbital angular momentum? Give this in terms of $\hbar$.

    (b) the z-component of the orbital angular momentum, L_z.

    (c) of the angle that the angular momentum vector makes with the $z-$axis.

11. What is intrinsic angular momentum? Compare and contrast it with orbital angular momentum.

12. How are intrinsic angular momentum and intrinsic magnetic dipole moment related? Use text, equations and/or diagrams.

13. What is the Stern-Gerlach experiment? What do the results say about angular momentum? Use text, equations and/or diagrams.

14. Consider a spin-$\frac{1}{2}$ particle. What are the possible values of $|\vec{S}|$ and S_z.

    Repeat for a spin-$\frac{3}{2}$ and a spin-1 particle.

15. An electron is in a magnetic field $\vec{B} = B(z)\hat{z}$.

    (a) Use $\vec{F} = -\nabla U$, $U = -\vec{\mu}\cdot\vec{B}$, and the relationship (equation!) between $\vec{\mu}$ and $\vec{S}$, to derive the following expression for the force:

    $$\vec{F} = -\frac{e}{m_e} m_s \hbar \frac{\partial B}{\partial z}\hat{z}$$

    (b) How many possible values of the force are there? What are they?

16. Consider a particle with magnetic moment, $\vec{\mu}$ and spin s. It sits in a uniform magnetic field $B_0\hat{z}$.

    (a) Determine the possible energies of the particle.

    (b) Calculate the photon frequencies that the particle can absorb or emit while in this field.

17. Show, by explicit calculation, that the symmetric wave function is symmetric under label exchange. That is, $\psi_S(x_1, x_2) = +\psi_S(x_2, x_1)$.

    Show, by explicit calculation, that the antisymmetric wave function is antisymmetric under label exchange. That is, $\psi_A(x_1, x_2) = -\psi_A(x_2, x_1)$.

    How are the probability densities, $|\psi_S|^2$ or $|\psi_A|^2$, affected by label exchange?

18. From a graph of $P(x_1, x_2)$, determine whether the system consists of distinguishable particles, indistinguishable bosons, or indistinguishable fermions.

19. What is the Pauli Exclusion Principle? Include text, equations, and possibly an example.

20. Write the possible configurations (total energy E and state ψ) for N particles if the particles are

    (a) distinguishable
    (b) fermions
    (c) bosons.