Physics 60 Exam 2 - Front page
10:30 - 11:35am Friday Nov 10

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

Make-up exams will be arranged if you can provide (1) an approved and documentable excuse **and** (2) advance notice (an email or voicemail 30 minutes ahead of time is fine). If you cannot do **both**, you cannot make up the exam.

Review

1. Consider the double slit experiment for light.

   Calculate the rate that photons are detected at particular positions. Calculate the rate if one slit is closed.

   How do the results indicate that light has wave and particle characteristics?

2. Consider the double slit experiment for mono-energetic electrons.

   Describe the results. How do the results indicate that matter has wave and particle characteristics?

   Calculate the rate that electrons are detected at particular positions. Calculate the rate if one slit is closed.

3. Under what circumstances should we describe

   (a) light as a wave? as particles?
   (b) objects as waves? as particles?

4. (a) Calculate the wavelength of a particle.

   (b) Derive an expression for the wavelength of a particle that has a particular energy E. That is, if $E = 3/2k_bT$ or $E = q\Delta V$, for example, come up with an equation for λ in terms of the given parameters.

5. (a) Apply the momentum-position uncertainty principle to a particle.

   (b) Consider single slit diffraction of an electron beam. What are Δx and Δp_x in this experiment?

6. Apply the energy-time uncertainty principle.

7. Given a potential, $U(x)$, write the

   (a) Schrödinger equation
   (b) time-independent Schrödinger equation
   (c) temporal part of the Schrödinger equation

8. Show that a given function $g(z,t)$ satisfies a given partial differential equation.

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

   - normalization constant (or verify that it's normalized)
   - most likely position
   - probability the particle will be found within a specific interval

10. Consider a particle with potential energy $U(x)$ and total energy E, determine

    (a) the kinetic energy of a particle at position x
    (b) any turning points
    (c) if the particle is bound or unbound

11. For the infinite well

    (a) write the wave function, sketch the wavefunction, and calculate the energy associated with each state.

    (b) What is the ground state energy and wavefunction? Why can't we choose $n = 0$?

12. How are quantum expectations for the infinite well different from classical expectations? In particular address the

    (a) probability of finding a particle between x_a and x_b. Give a specific example.

    (b) energy of a particle

13. In what limit does quantum expectations recover classical expectations? In particular, for the infinite well, when

    (a) do we recover the classically expected probability?

    (b) does the difference between energy states become negligible? That is, $\frac{(E_{n+1}-E_n)}{E_n} \to 0$?

    Provide text and a diagram or calculation to support your answer.

14. What is a ground state, or a zero-point, energy? Is this a classical or quantum phenomenon? Give an example

15. Derive the expression for the penetration depth in the finite well,

    $$\delta = \frac{\hbar}{\sqrt{2m(U_o - E)}}$$

    Start from the wavefunction within the classically forbidden region, $\psi(x) = e^{-\alpha|x|}$. Include a definition of the penetration depth and text to explain your reasoning.

    Use the above equation correctly in calculations.

16. Determine the photon wavelength (or frequency) associated with transitions between states in the

    (a) infinite well
    (b) simple harmonic oscillator