UCI Department of Physics and Astronomy: Lower Division Exam

INSTRUCTIONS FOR THE STUDENT:

IMPORTANT WARNING: This exam attempts to represent a **<u>MINIMUM</u>** level of knowledge that is necessary to succeed in upper division courses. If material is on this exam, the instructors in upper division courses **will assume that you already know and understand it**. However, this does not mean that you are allowed to forget everything else you learned in lower division. **Other material covered in the courses will be used.**

The exam is divided into three sections. The first section focuses on conceptual knowledge, definitions, and general principles. You should not have to do any detailed calculations. The second section tests you calculation skills. However, you should be able to do most of the problems without computational aids (at most, you will need a calculator). The final problem tests your mathematical skills. For this section, you should definitely NOT use any computational aids. The one thing not covered by this exam is your ability to use Mathematica. This is a test of your pencil (or pen) and paper skills. However, keep in mind that Mathematica, or some other numerical analysis method, will be needed in upper division courses.

Answers are purposely NOT being provided on the web, as this material is considered the minimum requirements. If you are not 100% confident of your answers, you will have the chance to discuss this with a faculty member during a scheduled advising session. This is the time to identify areas of weakness before continuing into upper division courses. We would much rather discuss these questions with you now then see you struggle and have a miserable time in upper division physics.

Finally, keep in mind that the best reason to major in physics is that it is FUN!!! We had fun coming up with these questions; no one will be grading you, so ENJOY thinking about these situations. If it is not fun to try to answer the questions in this exam, please talk to a faculty advisor about you future choices in the physics major. (Frustration is OK. Frustration is a normal experience both as a physics major and as a professional physicist. But, it should be a frustration tempered by the enjoyments of struggling with the problems and eventually reaching an understanding of their solution.)

SECTION I: Conceptual Questions

1) Under what conditions is each of the following conserved:
a) energy b) momentum c) angular momentum d) charge

2) Write down a general expression that relates each of the following to their respective cause (make sure to define all variables): a) change in energy b) change in momentum c) change in angular momentum

3) List sources of electric fields.

4) List sources of magnetic fields.

5) What is the general form of the potential energy for a system undergoing simple harmonic motion? What is the general force law?

6) Describe a circuit that is equivalent to a simple harmonic oscillator. What energy terms for the circuit are equivalent to the potential and kinetic energy of a mass on a spring?

7) For two waves to completely destructively interfere, what condition must be met? For two waves to completely constructively interfere, what condition must be met?

8) Write one of Heisenberg’s uncertainty relations, making sure to define all terms.

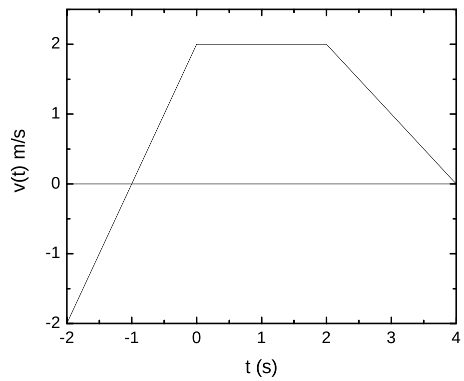
9) What do solutions of the time-independent Schrödinger’s Equation correspond to?

10) Given the wavefunction, $\Psi(x)$, how would you find the most likely position and the average position of a particle?

11) You observe two events in your frame such that A occurs before B. What is a sufficient condition to guarantee that observers in any inertial frame will agree that A occurred before B?

SECTION II: Computations

1) Given the following graph of velocity versus time for a particle moving in one dimension. At t = 0, the particle is located at x = 2 m. Sketch the position and acceleration versus time for a particle.



2) You notice a 36 kg child running up a 37^{o} ramp and leaping to catch a 12 kg tire swing. The child catches the tire swing exactly at the top of the leap. How much higher does the tire swing carry the child before coming to rest if the tire was at a horizontal distance of 1 m from the end of the ramp before the child caught it? (Assume that the child's leap involves an initial velocity with the same angle relative to the horizontal as the ramp, and ignore air resistance. Use the approximation sin(37^{o}) = 3/5.) How much higher would the swing carry the child if the leap and catch were repeated on the moon where the acceleration due to gravity is 1/6 its value on Earth?

3) Consider an infinitely long cylinder of radius R with a charge density that is only a function of the radial distance from the center of the cylinder given by $\rho(r) = Ar^2$. Find **E**(r) and V(r) for r < R an r > R , i.e. find the electric field and electric potential everywhere.

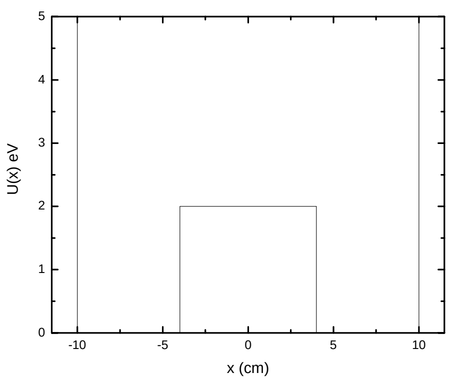
4) An electron in a region of constant magnetic field B moves in a circular orbit with a constant speed v. What is the radius of the orbit in terms of the charge of the electron, the mass of the electron, B, and v? What must be the relation between the direction of B and the orbit of the electron?

5) Consider two speakers that are 3 m apart emitting sound in phase with each other. A person standing a perpendicular distance of 10 m directly in front of one of the speakers hears no sound. What is the lowest possible frequency being emitted from the speakers?

6) An electron is moving in one dimension in an electric field that is described by the following electric potential: $V(x) = -\frac{b}{2}x^2$, where b is a positive quantity. What is the frequency of oscillation of the electron in terms of b, the charge q, and its mass m?

7) Estimate the size of a hydrogen atom using a combination of classical mechanics and the assumption that angular momentum is quantized.

8) Sketch the wavefunction of a particle with energy 4 eV and 1 eV moving in the following potential (where U(x) is infinite for x < -10 cm and x > 10 cm).



9) Using the uncertainty principle, estimate the ratio of kinetic energy of an electron in a diatomic molecule to that in a single atom. Why might this explain the fact that so many gases are diatomic (such as H_2, O_2, N_2, etc.)?

10) A resistor is in series with a battery, a switch, and a capacitor. The switch is initially open and the capacitor is uncharged. When the switch is closed, what is the maximum amount of charge that will accumulate on the capacitor? How long does it take for the charge on the capacitor to reach 90% of this value?

11) Consider a quantum mechanical system consisting of non-interacting particles of mass m in an infinite square well of length a. Assume the system is in thermal equilibrium at temperature T that is so high that the average occupation of each energy state in the well is much smaller than one. Write an expression for the ratio of the number of particles in the first excited state to the number of particles in the ground state.

SECTION III: Mathematical Techniques

1) Sketch the function $f(x) = x^2 e^{-x^2}$.

2) Write the general solution to the following equations:

$$\frac{dx(t)}{dt} = C$$
$$\frac{d^2\Psi(x)}{dx^2} + k\Psi(x) = 0$$
$$\frac{dv(t)}{dt} = bv(t)$$

where C, k, and b are all real constants.

3) Find the eigenvalues and eigenvectors of $\begin{pmatrix} 0 & i \\ -i & 0 \end{pmatrix}$.

4) Find the area under the curve $f(x) = 1 + x^2$ between x = 0 and 1.

5) Find the real and imaginary part of $6e^{i\pi/6}$.

6) Expand to second order in x the function $f(x) = \cos x$.

7) Convert the point (1, -1, 3) in Cartesian coordinates to the appropriate values in cylindrical and spherical coordinates.

8) Write down the volume element, dV, in Cartesian, spherical, and cylindrical coordinates.

9) Let $\vec{F}_1 = x^2\hat{k}$ and $\vec{F}_2 = x\hat{i} + y\hat{j} + z\hat{k}$. One of these vector fields has non-zero divergence but zero curl and the other one has the opposite.

(a) Calculate the divergence and curl of $\vec{F}_1$ and $\vec{F}_2$.

(b) Sketch the field that has non-zero divergence but zero curl in the x-z plane. On your sketch, draw a surface that has non-zero flux and a closed contour that obviously has no circulation.

(c) Which vector field can be written as the gradient of a scalar?

(d) Which vector can be written as the curl of a vector?

10) Which of these Gaussian curves has the largest standard deviation? Which has the largest mean? Write an approximate formula for G(x) represented by curve (a), using approximate numbers read from the graph.