Physics 5C Fall 2022

PRACTICE FINAL EXAM

You will be given 180 minutes for this exam. Derive all answers symbolically, then plug in the numbers, if appropriate. Your description of the physics involved and symbolic answers are worth much more than the numerical answers. Show all work, and take particular care to explain what you are doing. Cross out rather than erase parts of the problem you wish the grader to ignore. Box or circle final answers.

Some problems will take significantly longer than others, so judge time appropriately. At the beginning of the exam, please look through all problems and plan how you'll spend your time.

(1) When a third polarizer is inserted at 45° between two orthogonal polarizers, some light is transmitted. If, instead of a single polarizer at 45°, we insert a large number N of polarizers, each time rotating the axis of polarization over an angle 90° / N,

a. no light
b. less light
c. the same amount of light
d. more light gets through.

(2) A xenon arc lamp is covered with an interference filter that only transmits light of 400-nm wavelength. When the transmitted light strikes a metal surface, a stream of electrons emerges from the metal. If the intensity of the light striking the surface is doubled,

a. more electrons are emitted in a given time interval.
b. the electrons that are emitted are more energetic.
c. both of the above.
d. neither of the above.

(3) Single electrons are directed, one by one, toward a double slit. The distribution pattern of impacts that make it through to a detector behind the slits is identical to an interference pattern. We now repeat this experiment, but block slit 1 for the first half of the experiment and slit 2 for the second half. The distribution of impacts in the second experiment is
a. the same as in the first experiment.
b. the sum of the distributions one gets for each slit separately.
c. neither of the above.

(4) An emission spectrum for hydrogen can be obtained by analyzing the light from hydrogen gas that has been heated to very high temperatures (the heating populates many of the excited states of hydrogen). An absorption spectrum can be obtained by passing light from a broadband incandescent source through hydrogen gas. If the absorption spectrum is obtained at room temperature, when all atoms are in the ground state, the absorption spectrum will
a. be identical to the emission spectrum.
b. contain some, but not all, of the lines appearing in the emission spectrum.
c. contain all the lines seen in the emission spectrum, plus additional lines.
d. look nothing like the emission spectrum.

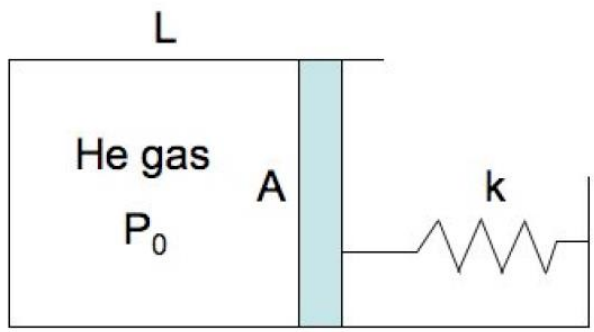
(5) In the photoelectric effect, the threshold wavelength for a particular metal is 275.6 nm. If light of wavelength 170.0 nm is incident on a surface of this metal, determine the kinetic energy of the photoelectrons.
(a) 4.50 eV
(b) 2.25 eV
(c) 3.60 eV
(d) 2.79 eV

(e) 7.29 eV

(6) Which of the following is *NOT* a true statement about quantum physics?

(a) The wavefunction is always a real quantity
(b) The wavefunction represents the complete physical state
(c) All wavefunctions are finite, single-valued, and continuous
(d) For every observable, there is a Quantum Mechanical operator

2. Consider a system described in the figure. The vessel is filled with Helium gas, has a length of L and a cross-section area of A. The piston can move in the vessel without friction. It has a mass of M and is connected to a spring with spring constant of k. At equilibrium the gas pressure is P_0, outside pressure is 0 (vacuum), and the spring is compressed by x_0. If one tap on the piston, it will start to oscillate. We assume that the gas will expand and compress isothermally in all processes.
(a) Find out the pressure of the gas when the piston is displaced by Δx to the left.
(b) What is the total force acting on the piston with the displacement of Δx?
(c) What is the oscillation frequency of the piston in this system?
(Useful relation: $1/(1+x)=1-x$ when $x<<1$.)



3. (30 points) Suppose that the number of states of an isolated system of N particles in a volume V at a given total energy E is given by

$$g(E) = c(V - bN)^N (E + \frac{N^2 a}{V})^{3N/2}$$

where a, b, and c are constants.
(a) What is the entropy of the system?
(b) Determine the temperature T as a function of E.
(c) What is the average energy of a single particle in terms of T , the density $\rho = N/V$, and the parameters a and b?
(d) What is the pressure as a function of T and ρ?
(e) What are the units of the parameters a and b?

(Reminder: The first and second law for reversible processes: TdS=dE+pdV.)

4. Neutron diffraction is one of the methods used to determine crystal structure of a material. Imagine that a beam on mono-energetic neutrons (of mass m and kinetic energy K) impinging on a crystal lattice with atomic spacing d at the inclination angle (it is customary in crystallography to measure the angle from the plane of the crystal, as opposed to the normal to the surface). If neutron energy is relatively small (thermal or cold neutrons), they would typically reflect off the nuclei of the crystal lattice elastically.

(a) At what angles would the intensity of the reflected neutrons be maximal ?
(b) What is the smallest possible spacing d that this imaging using thermal neutrons (K = 0.026 eV, m = 939 MeV) could resolve ? How do you think it compares to the typical crystal lattice spacing ?

5. Consider an infinite square well where U(x) = 0 at L/2<x<L/2. The wave function of a particle of mass m trapped in the well has the form of

$$\psi(x,t=0) = C(\sin\frac{\pi x}{2L}\cos\frac{3\pi x}{2L} - 2\sin\frac{\pi x}{L}).$$

(a) Determine the value of C to normalize the wavefunction.
(b) How will the wavefunction evolve as a function of time.
(c) Calculate the average position <x> as a function of time.
(d) Calculate the average momentum <p> as a function of time.
(e) Calculate the force acting on the particle as a function of time using force-momentum relation.

6. Consider a particle of mass m with energy E incident on a barrier of energy height of V and width L. Under what condition will the particle transmit through the barrier with 100% probability?