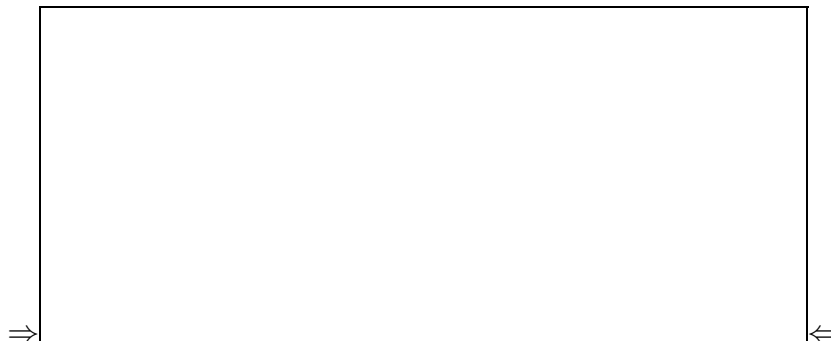


Physics 273– Practice Exam II  
Fall 2011  
Prof. Mohan Kalelkar



Your name sticker with **exam code**

1. The exam will last from 1:45pm to 2:50pm. Use a # 2 pencil to make entries on the answer sheet. Enter the following id information now, before the exam starts.
2. In the section labelled NAME, enter your last name, then fill in the empty circle for a blank, then enter your first name, another blank, and finally your middle initial.
3. Under STUDENT # enter your 9-digit Student ID Number. Under COURSE enter 273. Under CODE enter the exam code given above.
4. During the exam, you may use pencils, a calculator, and **ONE**  $8\frac{1}{2}'' \times 11''$  sheet of paper with formulas and notes.
5. There are 16 multiple-choice questions on the exam. For each question, mark only one answer on the answer sheet. There is no subtraction of points for an incorrect answer, so even if you cannot work out the answer to a question, you should make an educated guess. At the end of the exam, hand in only the answer sheet. Retain this question paper for future reference and study.
6. Useful numerical constants are given on the next page. Before starting the exam, make sure that your copy contains the page of constants and all 16 questions. Bring your exam to the proctor if this is not the case.

Elementary charge  $e = 1.6 \times 10^{-19} \text{ C}$

1 electron volt ( $eV$ ) =  $1.6 \times 10^{-19} \text{ J}$

Speed of light  $c = 3 \times 10^8 \text{ m/s}$

Planck's constant  $h = 6.63 \times 10^{-34} \text{ J} \cdot \text{s} = 1240 \text{ nm} \cdot eV/c$

$\hbar = h/2\pi$

Compton wavelength of electron  $h/mc = 0.0024 \text{ nm}$

Ground-state energy of hydrogen =  $-13.6 \text{ eV}$

Rydberg constant  $R = 0.0109678 \text{ nm}^{-1}$

Avogadro's number =  $6.02 \times 10^{23} \text{ molecules/mole}$

Electron mass =  $9.11 \times 10^{-31} \text{ kg} = 0.511 \text{ MeV}/c^2$

Proton mass =  $1.673 \times 10^{-27} \text{ kg} = 938.3 \text{ MeV}/c^2$

Neutron mass =  $1.675 \times 10^{-27} \text{ kg} = 939.6 \text{ MeV}/c^2$

Atomic mass unit  $1 u = 931.5 \text{ MeV}/c^2$

Fine structure constant  $\alpha = 1/137$

Bohr magneton  $\mu_B = 5.79 \times 10^{-5} \text{ eV/T}$

Energy ordering of subshells:

1s 2s 2p 3s 3p 4s 3d 4p 5s 4d 5p 6s 4f 5d 6p 7s 5f 6d 7p

Values of  $l$  for subshells:

s	p	d	f	g	h
0	1	2	3	4	5

Powers of ten:

femto(f) $10^{-15}$	pico(p) $10^{-12}$	nano(n) $10^{-9}$	micro( $\mu$ ) $10^{-6}$	milli(m) $10^{-3}$
centi(c) $10^{-2}$	kilo(k) $10^{+3}$	Mega(M) $10^{+6}$	Giga(G) $10^{+9}$	Tera(T) $10^{+12}$

1. An electron has a DeBroglie wavelength of  $0.0013 \text{ nm}$ . What is its kinetic energy?
  - a) About  $0.44 \text{ MeV}$
  - b) About  $0.57 \text{ MeV}$
  - c) About  $0.89 \text{ MeV}$
  - d) About  $0.95 \text{ MeV}$
  - e) About  $1.08 \text{ MeV}$
  
2. A particle has a wave function  $\psi(x) = \sqrt{2x}/L$  in the region  $0 < x < L$ . What is the probability that at any instant the particle lies between  $x = 0$  and  $x = L/3$ ?
  - a) About 67%
  - b) About 82%
  - c) About 33%
  - d) About 58%
  - e) About 11%
  
3. A particle has a wave function given by  $\psi(x) = Ae^{-x/L}$  for  $x > 0$ , and  $\psi(x) = 0$  for  $x < 0$ . (The quantity  $L$  is a positive constant). What is the value of  $A$ ?
  - a)  $\sqrt{1/L}$
  - b)  $\sqrt{2/L}$
  - c)  $1/L$
  - d)  $2/L$
  - e) None of the other answers
  
4. Which of the following statements are true?
  - I: The Heisenberg Uncertainty Principle applies to electrons, but not to protons.
  - II: The Heisenberg Uncertainty Principle applies only to electrically charged particles, like electrons.
  - III: A particle of finite lifetime cannot have a precisely defined mass.
  - a) I and III are true; II is false
  - b) II and III are true; I is false
  - c) III is true; I and II are false
  - d) II is true; I and III are false
  - e) All three statements are false

5. A photon, an electron, and a proton all have the same kinetic energy. List them in order of increasing DeBroglie wavelength, i.e. smallest  $\lambda$  first, largest  $\lambda$  last.
- Photon, electron, proton
  - Photon, proton, electron
  - Electron, proton, photon
  - Proton, photon, electron
  - Proton, electron, photon
6. For a particle in a one-dimensional infinite square well, the DIFFERENCE in energy between the first excited state and the ground state is  $12 \text{ eV}$ . What is the ground state energy?
- $1.0 \text{ eV}$
  - $2.0 \text{ eV}$
  - $3.0 \text{ eV}$
  - $4.0 \text{ eV}$
  - None of the other answers
7. An electron in hydrogen has quantum numbers  $l = 3$  and  $m_l = +2$ . According to Schrodinger theory, what are its orbital angular momentum  $L$  (in magnitude) and z-component  $L_z$ ?
- $L = 3\hbar$        $L_z = 2\hbar$
  - $L = 3\hbar$        $L_z = \sqrt{6}\hbar$
  - $L = \sqrt{12}\hbar$        $L_z = 0$
  - $L = \sqrt{12}\hbar$        $L_z = \sqrt{6}\hbar$
  - None of the other answers
8. For an electron in a subshell with quantum numbers  $n = 2$  and  $l = 1$ , what are the possible angles that the orbital angular momentum vector can make with the z-axis (which could be the direction of an external magnetic field)?
- $45^\circ$ ,  $90^\circ$ , and  $135^\circ$
  - $0^\circ$  and  $90^\circ$
  - $0^\circ$  and  $180^\circ$
  - $45^\circ$  and  $135^\circ$
  - $0^\circ$ ,  $90^\circ$ , and  $180^\circ$

9. Consider the hydrogen atom in a state of quantum numbers  $n = 4$  and  $l = 3$ . What is the magnitude of the electron's orbital angular momentum according to the Bohr theory and according to the Schrodinger theory?
- a) Bohr:  $4\hbar$       Schrodinger:  $\sqrt{12}\hbar$
  - b) Bohr:  $4\hbar$       Schrodinger:  $4\hbar$
  - c) Bohr:  $4\hbar$       Schrodinger:  $3\hbar$
  - d) Bohr:  $3\hbar$       Schrodinger:  $3\hbar$
  - e) Bohr:  $3\hbar$       Schrodinger:  $\sqrt{12}\hbar$
10. Consider  ${}_{17}\text{Cl}$  which is the element Chlorine. In which subshell does the outermost electron lie?
- a) 2d
  - b) 3s
  - c) 3p
  - d) 3d
  - e) 4s
11. Consider a hypothetical universe in which the spin quantum number of the electron is  $3/2$  instead of  $1/2$ . For the  $3P$  state of hydrogen in this universe, how many possible values are there for the total angular momentum quantum number  $j$ ?
- a) 1
  - b) 2
  - c) 3
  - d) 4
  - e) None of the other answers
12. Which of the following statements is true? Take into consideration the effects of fine structure, but ignore hyperfine structure and the higher-order effects of Quantum Electrodynamics.
- a) The Heisenberg Uncertainty Principle is the reason why there is an upper limit to the number of electrons that can populate any shell of an atom
  - b) In an atom like Sodium, the energy increases with quantum number  $l$  because of the partial screening of the nuclear charge by inner electrons
  - c) In hydrogen the  $2S_{1/2}$  and  $2P_{3/2}$  states are degenerate
  - d) In hydrogen the  $2P_{1/2}$  and  $2P_{3/2}$  states are degenerate
  - e) In hydrogen the  $2P_{3/2}$  and  $3P_{3/2}$  states are degenerate

13. Consider a hydrogen atom in a state of zero orbital angular momentum. What will be the value of the g-factor?
- a) 0
  - b) 1
  - c) 2
  - d) 1.33
  - e) 1.67
14. Suppose a hydrogen atom in a  $3^2D_{5/2}$  state is placed in an external magnetic field  $B$ . Into how many substates will it split?
- a) 2
  - b) 4
  - c) 5
  - d) 6
  - e) None of the other answers
15. Suppose a complex atom in a  $4^3D_3$  state is placed in an external magnetic field  $B$ . What will be the spacing in energy between adjacent magnetic substates?
- a)  $0.67\mu_B B$
  - b)  $1.33\mu_B B$
  - c)  $2.00\mu_B B$
  - d)  $1.50\mu_B B$
  - e)  $1.67\mu_B B$
16. Consider an atom in a state with quantum numbers  $l = 2$ ,  $s = 1$ ,  $j = 2$ . What is the angle between the spin angular momentum vector and the total angular momentum vector WITHIN the triangle for vector addition  $\vec{J} = \vec{L} + \vec{S}$ ?
- a)  $30^\circ$
  - b)  $45^\circ$
  - c)  $60^\circ$
  - d)  $73^\circ$
  - e)  $90^\circ$
17. Which of the following elements would you consider as a dopant for Silicon (valence structure  $3s^23p^2$ ) if you wanted to make an n-type semiconductor?
- a) Sodium (valence structure  $3s^1$ )
  - b) Arsenic (valence structure  $4s^24p^3$ )
  - c) Helium (valence structure  $1s^2$ )
  - d) Aluminum (valence structure  $3s^23p^1$ )
  - e) Carbon (valence structure  $2s^22p^2$ )

18. The Balmer series corresponds to transitions to the  $n = 2$  state of hydrogen. What is the ratio of the longest wavelength in the Balmer series to the shortest?
- a)  $9/5$
  - b)  $9/4$
  - c)  $3/2$
  - d) 4
  - e) 9