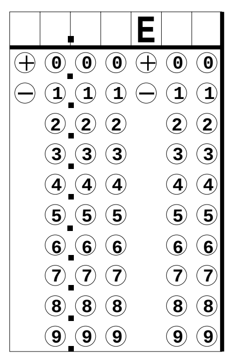
Physics 228 - FINAL EXAM
Tuesday, May 13, 2003
Profs. Shapiro and Devlin

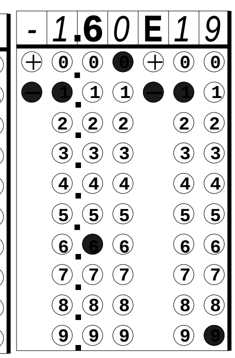
Your name sticker with **exam code**

Turn off and put away cell phones now!

1. **THIS EXAM INCLUDES QUESTIONS WHICH REQUIRE A NUMERICAL ANSWER.**
   The format on the machine-graded answer sheets requires that you express your answer is a very specific format. Several examples are shown below:
   5.30 should be entered as **+5.30+00**
   437 should be entered as **+4.37+02**
   0.62458 should be entered as **+6.25−01**
   $-1.602176 \times 10^{-19}$ should be entered as **−1.60−19**.
   A sample fragment of the mark-sense form is shown.



Form for numerical answers.



The electron's charge entered.

   NOTE THAT MULTIPLE CHOICE QUESTIONS START WITH #16, AND THAT THE POSITIONS ON THE MARK-SENSE FORM INCREASE HORIZONTALLY ACROSS THE PAGE.

2. The exam will last from 4:00 p.m to 7:00 p.m. Use a #2 pencil to make entries on the answer sheet. Enter the following ID information now, before the exam starts.
3. In the section labelled NAME (Last, First, M.I.) 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.
4. Under STUDENT # enter your 9-digit Social Security Number.

5. Enter 228 under COURSE, and your section number (see label above) under SEC.
6. Under CODE enter the exam code given above.
7. During the exam, you may use pencils, a calculator, and two handwritten 8.5 x 11 inch sheets with formulas and notes and without attachments.
8. There are 30 questions on the exam. The first ten questions require you to enter a numerical answers as described above. **Be sure to fill in the circles as well as writing your answer in the boxes.** The remainder are multiple-choice. For each multiple-choice question, mark only one answer on the answer sheet. There is no deduction 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 the answer sheet and the signed cover page.** Retain this question paper for future reference and study.
9. When you are asked to open the exam, make sure that your copy contains all 30 questions. Raise your hand if this is not the case, and a proctor will help you. Also raise your hand during the exam if you have a question.
10. Please SIGN the cover sheet under your name sticker and have your student ID ready to show to the proctor during the exam.

Masses in Atomic Mass Units:

Atom	mass (amu)	Atom	mass (amu)
p	1.007 276	$^{15}_{7}$N	15.000 108
n	1.008 665	$^{16}_{7}$N	16.006 100
$^{1}_{1}$H	1.007 825	$^{20}_{10}$Ne	19.992 435
$^{2}_{1}$H	2.014 102	$^{21}_{10}$Ne	20.993 841
$^{3}_{1}$H	3.016 049	$^{22}_{10}$Ne	21.991 383
$^{3}_{2}$He	3.016 029	$^{28}_{14}$Si	27.976 927
$^{4}_{2}$He	4.002 602	$^{29}_{14}$Si	28.976 495
$^{12}_{6}$C	12.000 000	$^{30}_{14}$Si	29.973 770
$^{13}_{6}$C	13.003 355	$^{238}_{92}$U	238.050 786
$^{14}_{6}$C	14.003 242	$^{234}_{90}$Th	234.043 583
$^{14}_{7}$N	14.003 074		

Some possibly useful information:

c = speed of light = 3.00×10^8 m/s
e = magnitude of electron charge = 1.602×10^{-19} Coulombs
Visible Spectrum of Light is approximately 400 nm to 750 nm wavelength
1 year = 3.156 $\times 10^7$ sec
1 eV = 1 electon-Volt = 1.602×10^{-19} Joules
k_B = Boltzmann's constant = 1.38×10^{-23} J/K = 8.61×10^{-5} eV/K
$\mathrm{R_H}$ = Rydberg constant = $1.097 \times 10^7 \mathrm{m}^{-1}$
N_A = Avagadro's number = 6.022×10^{23} atoms/mole
$\Delta x \Delta p \geq \frac{\hbar}{2} = \frac{h}{4\pi}$ $\qquad \Delta x \Delta (pc) \geq \frac{\hbar c}{2} = \frac{hc}{4\pi}$
$h = 6.626 \times 10^{-34}\,\mathrm{J \cdot s} = 4.14 \times 10^{-15}\,\mathrm{eV \cdot s}$
$\hbar = \frac{h}{2\pi} = 1.055 \times 10^{-34}\,\mathrm{J \cdot s} = 6.59 \times 10^{-16}\,\mathrm{eV \cdot s}$
$hc = 1240\,\mathrm{eV \cdot nm} = 1240\mathrm{eV} \cdot 10^{-9}\,\mathrm{m} = 1240\mathrm{MeV \cdot fm} = 1240\mathrm{MeV} \cdot 10^{-15}\,\mathrm{m}$
The Compton Wavelength = $(h/m_e c)$ = 0.00243 nm
Scale of temperature changes: 1°K = 1°C = 1.8°F
Binding energy of electron in Hydrogen ground state = 13.6 eV
Zeroes of temperature scale: 273°K = 0°C = 32°F
Doppler Shift: $\lambda' = \lambda\sqrt{\frac{1-v/c}{1+v/c}}$ where v = velocity of approach
1 parsec = 1 pc = 3.26 light-years = 3.1×10^{19} km; 1 Megaparsec = 1 Mpc = 10^6 pc
The following prefixes apply to other units as well as meters:
1 Gigameter = 1 Gm = 10^9 m, 1 Megameter = 1 Mm = 10^6 m,
1 kilometer = 1 km = 10^3 m, 1 millimeter = 1 mm = 10^{-3} m,
1 micrometer = 1 μm = 10^{-6} m, 1 nanometer = 1 nm = 10^{-9} m,
1 picometer = 1 pm = 10^{-12} m, 1 femtometer = 1 fm = 10^{-15} m
1 u = atomic mass unit = 1.66 $\times 10^{-27}$ kg, equivalent energy of 931.5 MeV
m_e = electron mass = 9.11×10^{-31} kg; $m_e c^2$ = electron rest energy = 0.511 MeV
m_p = proton mass = 1.67×10^{-27} kg; $m_p c^2$ = 938.27 MeV
m_n = neutron mass = 1.008665 u; $m_n c^2$ = 939.57 MeV

1. A biconvex lens has both faces with radii of curvature 0.204 m. It is made of material with index of refraction 1.510. An object is placed 0.486 m in front of the lens. How far **behind** the lens is the image.
(Note: if the image is actually **in front** of the lens, enter the answer with a minus sign.)
Express your answer in meters = m.

2. If the distance between the 1st and the 4th minima (on the same side of the center) of a single slit pattern is 2.83 mm with the screen 75.0 cm away from the slit and using light having a wavelength of 603 nm, what is the width of the slit?
Express your answer in millimeters = mm.

3. A certain beam of light with a frequency f = 4.62×10^{14} Hz is travelling in a material with index of refraction, n = 1.65. What is its wavelength in this material?
Express your answer in nanometers = nm.

4. A concave mirror forms a real image which is 3.50 times the size of the object. The object is 24.0 cm from the mirror. What is the radius of curvature of the mirror?
Express your answer in centimeters = cm.

5. What is the de Broglie wavelength of an electron whose velocity is 0.800 c?
Express your answer in meters = m.

6. The energy separation between the 2^{nd} and 3^{rd} vibrational levels of the HCl molecule is 0.358 eV. What is the energy of the lowest vibrational level.
Express your answer in electron-Volts = eV.

7. The energy difference between the J = 5 and the J = 4 rotational levels of a given diatomic molecule is 2.80×10^{-3} eV. What is the moment of inertia of this molecule?
Express your answer in $\mathrm{kg \cdot m^2}$**.**

8. The energy needed to ionize an atom of potassium (K) is 4.34 eV. The energy released when a neutral Fluorine (F) atom takes an extra electron (its electron affinity) is 3.45 eV. At their equilibrium separation, the electrostatic potential energy of potassium$^+$ and Fluorine$^-$ is -6.64 eV. What is the energy needed to separate the KFmolecule into neutral potassium and Fluorine atoms? **Express your answer in electron-Volts = eV.**

9. A 3.00 g sample of pure KF from the chemistry stockroom is found to be radioactive and to decay at an absolute rate R = 5940 counts/s. The decay is traced to the element potassium and in particular to the isotope ^{40}K, which constitutes 1.18% of normal potassium. The molecular weight of KF is 58.1 g/mole. What is the disintegration constant, λ.
Express your answer in inverse-seconds = $\mathbf{s^{-1}}$.

10. What is the minimum energy which is required to remove one neutron from $^{29}_{14}$Si in its ground state?
Express your answer in MeV.

16. Light of wavelength λ shines normally on a pair of narrow slits separated by a distance d. On a screen located a distance L away ($L \gg d$), the interference pattern shows that adjacent bright fringes are separated by a distance Δy. Which of the following changes will <u>increase</u> the value of Δy?

a) Increasing the wavelength λ
b) Increasing the slit separation
c) None of the other answers
d) Decreasing the distance L to the screen
e) Increasing the intensity of the light

17. Two electrons move in opposite directions at 0.7c as measured in the laboratory. The speed of one electron as measured from the other is:

a) 1.40c
b) 0.94c
c) 0.35c
d) 1.00c
e) 0.70c

18. A certain metal has a work function ϕ. If light of wavelength λ shines on this metal, the photoelectrons have a maximum kinetic energy K. What will be their maximum kinetic energy if light of wavelength 2λ shines on the metal?

a) $(K+\phi)/2$
b) $(K-\phi)/2$
c) 2K
d) K/2
e) $2(K+\phi)$

19. A hydrogen atom at rest is in a state of quantum number n=6. The electron jumps to a lower state, emitting a photon of energy 1.13 eV. What is the quantum number of the state to which the electron jumped?

a) 5
b) 4
c) 2
d) 1
e) 3

20. Two electrons in lithium (Z = 3) have as their quantum numbers n, ℓ, m_ℓ, m_s the values (1, 0, 0, $\pm\frac{1}{2}$). What are the possible quantum numbers of the third electron if the atom is to be in its first excited state? (There is no magnetic field present).

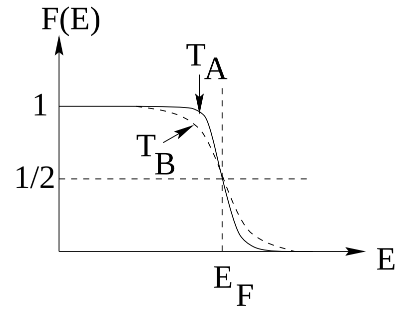
a) 3, 0, 0, $\pm\frac{1}{2}$
b) 2, 2, 1, $\pm\frac{1}{2}$
c) 2, 1, 1, $\pm\frac{1}{2}$
d) 2, 0, 0, $\pm\frac{1}{2}$
e) 1, 1, 1, $\pm\frac{1}{2}$

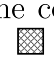
21. The correct ordering of energy scales (from smallest to largest) for a simple diatomic molecule is:

a) Rotational, vibrational, electronic
b) Vibrational, rotational, electronic
c) none of these
d) Electronic, rotational, vibrational
e) Vibrational, electronic, rotational

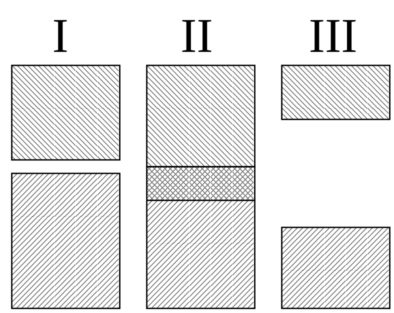
22. The figure shows the Fermi function for a solid at two different temperatures T_A and T_B. From the shape of these curves we can tell that:

a) the solid is an insulator.
b) $T_A < T_B$
c) $T_B = 0$ K
d) states above the Fermi energy are more likely to be occupied at T_A than at T_B.
e) $T_A > T_B$



23. In the energy level diagrams shown, the  region represents the conduction band, the  region represents the valence band, and the  region represents overlap of the two bands, of three different solids. Which best describes solids (I), (II), and (III)?

a) (I) insulator, (II) metal, (III) metal
b) (I) metal, (II) metal, (III) semiconductor
c) (I) metal, (II) insulator, (III) semiconductor
d) (I) semiconductor, (II) metal, (III) insulator
e) (I) insulator, (II) metal, (III) semiconductor



24. The total binding energy of the ${}^{12}_{6}\mathrm{C}$ nucleus is about:

a) 6 GeV
b) 0 MeV
c) 12 MeV
d) 12 GeV
e) 100 MeV

25. For heavy nuclei ($Z > 50$) that are stable or long-lived, which of the following statements is true? (Note: N = number of neutrons in the nucleus, and Z = number of protons in the nucleus.)

a) N>Z because the orbital electrons cannot penetrate the nucleus.
b) N<Z because the number of protons determines the element's chemical properties.
c) N=Z because the net electrical charge on the atom must be zero.
d) N>Z because extra neutrons are needed to overcome the effect of Coulomb repulsion between protons.
e) N=Z exactly because of the Pauli Principle.

26. Starting with a sample of pure ${}^{66}\mathrm{Cu}$, $\frac{7}{8}$ of it decays into Zn in 15 minutes. The corresponding half-life is:

a) 3.75 minutes
b) 5 minutes
c) 7 minutes
d) 15 minutes
e) 10 minutes

27. The following nuclear decay occurs spontaneously: ${}^{211}_{83}\mathrm{Bi} \rightarrow {}^{A}_{Z}\mathrm{X} + \alpha$. Which of the following statements is false?

a) $Q > 0$
b) $M({}^{211}_{83}\mathrm{Bi}) < M({}^{A}_{Z}\mathrm{X}) + M(\alpha)$
c) $A = 207$
d) The kinetic energy of the α-particle is not zero.
e) $Z = 81$

28. A nucleus is characterized by the total number of nucleons, A, and by the charge (or number of protons), Z. When a nucleus undergoes radioactive decay and emits an α, β or γ ray, the new value of A is

a) none of the other answers.
b) never less than its original value of A.
c) never more than its original value of A.
d) always less than its original value of A.
e) always more than its original value of A.

29. A nucleus with an excess of neutrons may decay radioactively with the emission of just

a) a proton
b) a neutron
c) a deuteron
d) an electron and an antineutino
e) a positron and a neutino

30. Consider the nuclear reaction: $^{9}_{4}\mathrm{Be} + \alpha \rightarrow n + {}^{12}_{6}\mathrm{C}$

(Note: M($^{9}_{4}$Be) = 9.012 183u; M(α) = 4.002 603u; M(n) = 1.008 665u; M($^{12}_{6}$C) = 12.000 000u)

This reaction:

a) cannot proceed because it violates conservation of baryon number.
b) is used in carbon dating.
c) will not proceed unless the reactants have a total kinetic energy of 6.3 MeV.
d) will release energy.
e) cannot occur because it violates charge conservation.

31. There are several series of radioactive decays which start from very heavy elements. These series progress by emitting:

a) α and β^+ rays.
b) β^+ and β^- rays.
c) α and β^- rays.
d) α rays and protons.
e) β^+ rays and neutrons.

32. Lithium is expected to play two important roles if we ever manage to develop an efficient power source from controlled fusion. One of these is

a) The reaction ${}^2_1\mathrm{H} + {}^6_3\mathrm{Li} \rightarrow 2\,({}^4_2\mathrm{He})$ has a very high Q value, and will produce lots of energy.
b) The lithium is a good moderator and will slow down the neutrons so they can interact better.
c) The lithium reacts with radioactive byproducts and makes them non-radioactive.
d) The reaction ${}^2_1\mathrm{H} + {}^4_2\mathrm{He} \rightarrow {}^6_3\mathrm{Li}$ has a very high Q value, and will produce lots of energy.
e) The reaction ${}^1_0\mathrm{n} + {}^6_3\mathrm{Li} \rightarrow {}^3_1\mathrm{H} + {}^4_2\mathrm{He}$ absorbs the energy from the neutrons.

33. By analysis of the forces between protons and neutrons in the 1930's, Yukawa predicted the existence of a particle. After some confusion, we now know that the particle he predicted is

a) the pion.
b) the gluon.
c) the Ω^-.
d) the Higgs boson.
e) the muon.

34. If a beam of K^- particles collides with protons in a target, a possible outcome of the collision, due to the strong interactions, is $\mathrm{K}^- + \mathrm{p} \rightarrow ?$

a) $\Lambda^0 + \mathrm{p}$
b) $\Lambda^0 + \mathrm{K}^0$
c) $\Lambda^0 + \pi^0$
d) $\mathrm{p} + \pi^0$
e) $\mathrm{p} + \pi^-$

35. The Δ^{++} particle is a baryon with electric charge +2e and strangeness, charm, bottomness and topness all equal to zero. Which of the following is a possible quark combination for this baryon?

a) $\bar{\mathrm{c}}\bar{\mathrm{c}}\mathrm{u}$
b) ddd
c) $\mathrm{c}\bar{\mathrm{c}}\mathrm{d}$
d) uuu
e) $\mathrm{s}\bar{\mathrm{s}}\mathrm{u}$