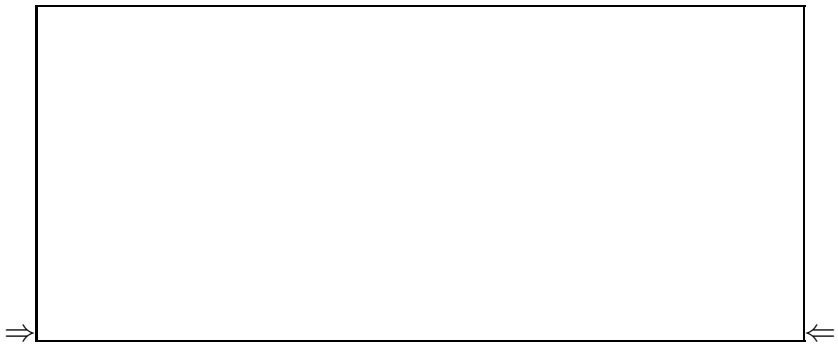
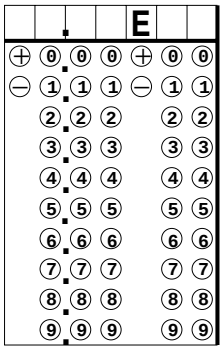
Physics 228 - SECOND COMMON HOUR EXAM
Thursday, April 10, 2003
Profs. Shapiro and Devlin



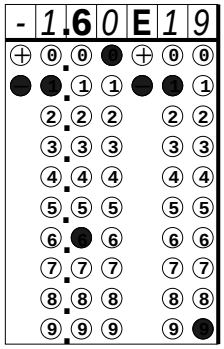
Your name sticker with **exam code**

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 8:00 p.m. to 9:20 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 one handwritten 8.5 x 11 inch sheet with formulas and notes and without attachments.
8. There are 17 questions on the exam. Several 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 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 17 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.

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 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
Wein's Constant = $2.898 \times 10^{-3}\,\mathrm{m \cdot K}$
σ = Stefan's Constant = $5.670 \times 10^{-8}\,\mathrm{W/(m^2 \cdot K^4)}$
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; $m_p c^2$ = proton rest energy = 938.27 MeV
$m_n c^2$ = neutron rest energy = 939.57 MeV
$\Delta x \Delta p \geq \frac{\hbar}{2} = \frac{h}{4\pi}$ $\Delta x \Delta (pc) \geq \frac{\hbar c}{2} = \frac{hc}{4\pi}$
$h = 6.626 \times 10^{-34}\,\mathrm{J \cdot s} = 4.14 \times 10^{-15}\,\mathrm{eV \cdot s}$
$\hbar = \frac{h}{2\pi} = 1.055 \times 10^{-34}\,\mathrm{J \cdot s} = 6.59 \times 10^{-16}\,\mathrm{eV \cdot s}$
$hc = 1240\,\mathrm{eV \cdot nm} = 1240\mathrm{eV} \cdot 10^{-9}\,\mathrm{m} = 1240\mathrm{MeV \cdot fm} = 1240\mathrm{MeV} \cdot 10^{-15}\,\mathrm{m}$
The Compton Wavelength = $(h/m_e c) = 0.00243$ nm
Scale of temperature changes: 1°K = 1°C = 1.8°F
Zeroes of temperature scale: 273°K = 0°C = 32°F
1 u = 1 atomic mass unit = 931.5 MeV/c^2
Doppler Shift: $\lambda' = \lambda\sqrt{\frac{1-v/c}{1+v/c}}$ where v = velocity of approach
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. The emission spectrum of Mercury contains a line at 435.8 nm. What is the difference in energy levels in the atom that gives rise to this spectral line? **Express your answer in electron-Volts (eV).**

2. A meter stick comes flying past you at 2.50×10^8 m/s, pointing in the direction it is travelling. How long does it take between the time the front of the meter stick passes you and the time the back passes you. **Express your answer in seconds.**

3. From the earth an astronaunt travels to a star at a speed of 0.600 c relative to Earth and turns around and returns at the same speed. The star is 6.90 light years from Earth as measured by an observer at rest on Earth. When the astronaut returns to Earth, how many years will she have aged?

4. A photoelectric effect experiment is done using light of some wavelength λ_1. The photoelectrons are observed to have a maximum kinetic energy of 7.00 eV. If the experiment is repeated using light of twice that wavelength, i.e. $\lambda_2 = 2.00\lambda_1$, on the same metal, it is found that the maximum electron kinetic energy is 2.00 eV. What is the work function of the metal? **Express your answer in electron-Volts (eV).**

16. A photon moving at a speed c makes a Compton collision with a free electron at rest. After the collision, the scattered photon travels at an angle θ relative to the direction of the incident photon. The speed of the scattered photon is

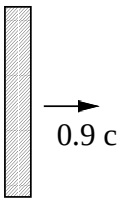
    a) c $\cos\theta$
    b) c$(1 - \cos\theta)$
    c) c
    d) c $\sin\theta$
    e) c $(1 - \sin\theta)$

17. A hydrogen atom is in the 4d state (n = 4, $\ell = 2$). How many values of the z-component of the electron's orbital angular momentum are possible?

    a) 2
    b) 4
    c) 5
    d) 8
    e) 9

18. A stick has proper length 100 cm. Relative to an observer, it moves at a speed of 0.9c in a direction perpendicular to its length. What is the stick's length as measured by the observer?

a) 526 cm
b) 43.6 cm
c) 19 cm
d) 100 cm
e) 229 cm



19. A particle in a one-dimensional box (with $V = 0$ between infinitely high side walls) has a ground-state energy of 2 eV. In the first two excited states, the particle's energy would be respectively

a) 8 eV and 18 eV
b) None of the other answers
c) 4 eV and 8 eV
d) 3 eV and 4 eV
e) 4 eV and 6 eV

20. Two lumps of clay, each having a mass of 100 grams and a speed of 0.6c, collide head-on and stick together. Assuming that no radiation is emitted in the collision, what is the mass of the composite?

a) 250 grams
b) 125 grams
c) None of the other answers
d) 160 grams
e) 200 grams

21. The Beryllium nucleus contains 4 protons. If a Beryllium atom is triply ionized with the one remaining electron in the ground state, the energy required to remove that electron is:

a) 217.6 eV
b) 10.2 eV
c) 13.6 eV
d) 40.8 eV
e) 54.4 eV

22. An electron will remain in the $3p$ level of hydrogen for about 10^{-12} s before it makes a transition to the $2s$ level, emitting a photon. The the uncertainty in the energy of the corresponding spectral line is at least:

a) 13.6 eV
b) 1.9 eV
c) 2.3 eV
d) (1.3×10^{-11}) eV
e) (3.3×10^{-4}) eV

23. How many hydrogen atom states are there with n=4?

a) 48
b) 18
c) 32
d) 16
e) 14

24. A beam of electrons passes through a hole in a screen and generates an intensity pattern beyond the hole. How will the pattern change if the velocity of the electrons is decreased?

a) The pattern will spread out.
b) The pattern will squeeze together.
c) When the electron wavelength becomes bigger than the size of the hole, the electrons will no longer be able to get through.
d) The pattern will stay the same but will get brighter.
e) The pattern will stay the same but will get dimmer.

25. The Lyman series corresponds to transitions to the hydrogen ground state (n = 1). What is the ratio of the longest wavelength in the Lyman series to the shortest?

a) 2
b) 3
c) 4
d) 3/2
e) None of the other answers

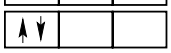
26. A photon undergoes Compton scattering off a free electron at rest. The scattered photon has an energy of 0.160 MeV, and the recoiling electron has a kinetic energy of 0.240 MeV. In which of the following ranges does the photon's scattering angle θ lie?

a) $\theta < 30^\circ$
b) $30^\circ \leq \theta < 60^\circ$
c) $60^\circ \leq \theta < 90^\circ$
d) $90^\circ \leq \theta < 140^\circ$
e) $\theta \geq 140^\circ$

27. A particle with wave function $\psi(x) = A \sin kx$ where $k = 10^{14}$ m^{-1} has momentum:

a) 10^{12} MeV/c
b) 10^{14} MeV/c
c) 0.07 MeV/c
d) 19.7 MeV/c
e) 19.7 keV/c

28. In the ground state, the four valence electrons in atomic $^{28}_{14}$Si are best represented by:

a) 3s:  3p: 
b) 3s:  3p: 
c) 3s:  3p: 
d) 3s:  3p: 
e) 3s:  3p: