Physics 228 - Second Common Hour Exam
30 March 2004
Profs. Shapiro and Conway

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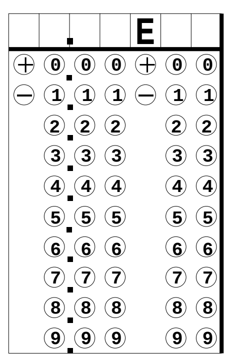
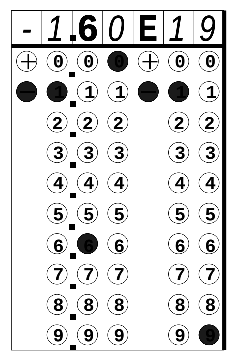
Your name sticker with **exam code**

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**



Form for numerical answers.



The electron's charge entered.

$-1.602176 \times 10^{-19}$ should be entered as **−1.60−19**.
Note that all answers should be accurate to three **significant** digits. A sample fragment of the mark-sense form is shown. Make sure you darken the circles!

NOTE THAT MULTIPLE CHOICE QUESTIONS START WITH THE FIFTH QUESTION, BUT ITS NUMBER IS 16; ENTER THE ANSWERS ON THE MARK SENSE FORM ACCORDING TO THEIR PROBLEM NUMBERS, WHICH INCREASE HORIZONTALLY ACROSS THE FORM.

2. The exam will last from 8:00 pm to 9:20 pm 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 student ID.
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, without attachments.
8. There are 16 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 the rest for future reference and study.
9. When you are asked to open the exam, make sure that your copy contains all 16 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.

Possibly Useful Information

speed of light, c	3.00×10^{8} m/s
Planck's constant, h	6.626×10^{-34} J·s
hc	1240 eV-nm
Rydberg constant R_H	1.097×10^{7} m^{-1}
Bohr radius a_0	0.0529 nm
hydrogen ground state energy	-13.6 eV
elementary charge e	1.602×10^{-19} C
electron mass	9.11×10^{-31} kg
proton mass	1.673×10^{-27} kg
neutron mass	1.675×10^{-27} kg
visible light wavelengths	approx. 400-700 nm
1 meter	$= 100$ cm $= 1000$ mm $= 10^{6}\mu$m
	$= 10^{9}$ nm $= 10^{12}$ pm
1 eV	1.602×10^{-19} J

1. The Fermilab Tevatron accelerates protons to a total energy of 400.0 GeV. What is the relativistic factor γ for these particles?

2. The work function of silver is 4.73 eV. If light with wavelength 250.0 nm shines on the surface, what is the maximum energy of the ejected photoelectrons, in eV?

3. An electron is trapped in a one-dimensional potential well with infinitely steep walls, and length 0.500 nm. Find the difference between the lowest two energy levels, in eV.

4. A helium ion in its unexcited state He^{+} has only one electron in the $1s$ state. The wavelength of a photon which could excite it into the $3p$ state is (in nm)

16. Two twins decide to conduct an experiment. Twin A remains on the earth while twin B travels with constant speed $v = 0.6$c to a star which is 4 light years away. How far does B think he has traveled to reach his destination?

    a) 2.4 light-years
    b) 3.2 light-years
    c) 5 light-years
    d) 5.3 light-years
    e) 6.7 light-years

17. The 'proper time' between two events is measured by clocks at rest in a reference frame in which the two events:

    a) occur at the same time.
    b) occur at the same spatial coordinates.
    c) are separated by the distance a light signal can travel during the time interval.
    d) occur with the maximum possible time interval.
    e) occur with the maximum possible spatial separation.

18. A particle of mass M is at rest. It spontaneously breaks in two particles of equal mass, each moving at speed $0.6c$ in opposite directions. What is the mass m of either decay particle?

    a) $0.65M \leq m < 0.85M$
    b) $0.35M \leq m < 0.45M$
    c) $0.45M \leq m < 0.65M$
    d) $m \geq 0.85M$
    e) $m < 0.35M$

19. An electron in a hydrogen atom is in a state with the wave function given by

$$\psi(x,y,z) = \frac{2}{81\sqrt{2\pi a_0^7}}\,(6a_0 - r)\; z\, e^{-r/3a_0},$$

where $r = \sqrt{x^2+y^2+z^2}$. This state has quantum numbers

a) $n = 1, \ell = 0, m_\ell = 0$
b) $n = 2, \ell = 0, m_\ell = 0$
c) $n = 2, \ell = 1, m_\ell = 0$
d) $n = 2, \ell = 2, m_\ell = 0$
e) $n = 3, \ell = 1, m_\ell = 0$

20. In the Bohr model of the hydrogen atom, let the electron's orbital angular momentum be L, its orbital radius be r, and its speed be v. Pick the correct statement. ("Quantized" here means a quantity can only take on certain discrete values.)

a) L and r are quantized; v is not
b) L and v are quantized; r is not
c) r and v are quantized; L is not
d) L, r, and v are all quantized
e) L is quantized; r and v are not

21. A helium-neon laser is emitting 10^{17} photons every second, all at a wavelength of 633 nm. What is the laser's power output?

a) About 0.75 W
b) About 0.03 W
c) About 12 W
d) About 0.20 W
e) About 4.1 W

22. Planck's blackbody radiation formula

$$I(\lambda, T) = \frac{2\pi h c^2}{\lambda^5 \left(e^{hc/\lambda k_B T} - 1\right)}$$

differs radically from the Rayleigh-Jeans law, which preceeded it,

a) for all wavelengths.
b) for short wavelengths, giving less radiation there and avoiding the ultraviolet catastrophe.
c) for short wavelengths, giving more radiation there and producing the ultraviolet catastrophe.
d) for long wavelengths, giving less radiation there and avoiding the infrared catastrophe.
e) for intermediate wavelengths, giving less visible light from black bodies.

23. A neutron is confined within a nucleus of diameter 4×10^{-14} m. Assuming that the nuclear potential is a one-dimensional infinite potential well of width 4×10^{-14} m, estimate the ground state energy of the neutron.

a) 130 MeV
b) 2.1×10^{-14} eV
c) 3.7×10^{-44} eV
d) 130 keV
e) 7.7×10^{23} eV

24. A photon and an electron have the same wavelength.

a) either may have the greater momentum, depending on the wavelength.
b) the photon has the greater momentum.
c) the electron has the greater momentum.
d) they have the same momentum.
e) only electrons carry momentum.

25. In a hydrogen atom, the ground state wave function is given by

$$\psi = (\pi a_0^3)^{-1/2} e^{-r/a_0}.$$

What, approximately, is the ratio of the probability that the electron will be found beyond the Bohr radius, $r > a_0$, to the probability that it is inside that distance ($r < a_0$)?

a) 1.0
b) 0.5
c) 2.1
d) 1.5
e) 2.5

Hint: $4\int_0^r x^2 e^{-2x} dx = 1 - (2r^2 + 2r + 1)e^{-2r}$

26. What is the correct ground state electron configuration for Magnesium ($Z = 12$)?

a) $1s^2 2s^2 2p^2 3s^2 3p^2 3d^2$
b) $1s^2 2s^2 2p^6 3s^2$
c) $1s^2 2s^4 2p^6$
d) $1s^2 1p^6 2s^2 2p^2$
e) $1s^2 2s^6 2p^2 3s^2$

27. Which of the following atomic configurations cannot exist?

a) $2p^6$
b) $3s^1$
c) $4d^{12}$
d) $5f^2$
e) $3p^4$