Physics 228– Final
MAY 13, 2008
Profs. Coleman and Andrei

Your name sticker ⇒ with exam code

SIGNATURE: _____

TURN OFF CELLPHONES NOW!!!

1. The exam will last from 4:00p.m. to 7:00p.m. 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 (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.

3. Under STUDENT # enter your 9-digit Identification Number.

4. Enter 228 under COURSE, and your section number (see label above) under SEC.

5. Under CODE enter the exam code given above.

6. During the exam, you may use pencils, a calculator, and two **handwritten** 8.5 x 11 inch sheet with formulas and notes, without attachments.

7. There are 32 multiple-choice questions on the exam. For each 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.

8. 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.

9. Please **SIGN the cover sheet under your name sticker.** A proctor will check your name sticker and your student ID sometime during the exam. Please have them ready.

Good luck!

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
Boltzmann's constant	1.380×10^{-23} J/K
Wien's constant	2.90×10^{-3} m·K
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
atomic mass unit u	1.66×10^{-27} kg
	931.49 MeV/c^2
proton mass	1.007276 u
neutron mass	1.008665 u
$M(^1_1H)$	1.007825u
r_0 (nuclear radii $\sim r_0A^{1/3}$)	1.2×10^{-15} m
Bohr magneton	5.788×10^{-5} eV/T
visible light wavelengths	approx. 400-700 nm
1 eV	1.602×10^{-19} J

Boltzmann's constant	k	$1.381 \times 10^{-23}\,\mathrm{J/K}$
Permeability of free space	μ_0	$4\pi \times 10^{-7}\,\mathrm{Wb/A \cdot m}$
Permittivity of free space	ϵ_0	$8.854 \times 10^{-12}\,\mathrm{C^2/N \cdot m^2}$
Coulomb's constant	$k_e = 1/4\pi\epsilon_0$	$8.988 \times 10^{9}\,\mathrm{N \cdot m^2/C^2}$
Avagadro's number	N_A	6.022×10^{23}

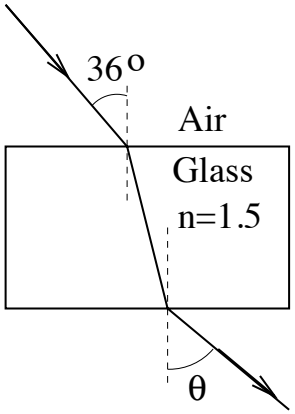
Some quantum numbers:

	Q/e	B	S
u	2/3	1/3	0
d	$-1/3$	1/3	0
s	$-1/3$	1/3	-1

	L_e	L_μ	L_τ
e^-, ν_e	1	0	0
μ^-, ν_μ	0	1	0
τ^-, ν_τ	0	0	1

	$Mass(u)$	Q/e	B	S
π^0	0.1449290	0	0	0
π^+	0.1498674	+1	0	0
π^-	0.1498674	-1	0	0
K^+	0.530011	+1	0	+1
K^-	0.530011	-1	0	-1
Λ^0	1.19808	0	1	-1

1. A ray of light goes from air into a flat block of glass (index of refraction = 1.5) at an angle of 36° with the normal to the interface. After passing through the glass, at what angle to the normal will the ray emerge into air?



   a) 62°
   b) 23°
   c) 67°
   d) 36°
   e) The ray won't emerge into air, because it will be totally internally reflected in the glass.

2. A concave mirror forms a real image which is twice the size of the object. If the object is 20 cm from the mirror, the radius of curvature of the mirror must be about:

   a) 13 cm
   b) 20 cm
   c) 27 cm
   d) 40 cm
   e) 80 cm

3. Diverging lenses have focal length $f < 0$. Which of the following statements is <u>false</u>?

   a) A diverging lens always forms a virtual image of a real object
   b) Diverging lenses are thicker at the ends than in the middle
   c) A diverging lens always forms an enlarged image of a real object
   d) A diverging lens always forms an upright image of a real object
   e) Nearsighted people (who cannot see objects clearly beyond a certain distance) can use diverging lenses to correct this defect

4. Film behind a double-slit is exposed to a parallel beam of light in the following way: First one slit is opened and light is allowed to go through that slit for time Δt. Then the first slit is closed and the other slit is opened and light is allowed to go through it for the same Δt. When the film is developed the pattern will be

   a) one single slit pattern.
   b) two superimposed single slit patterns, their centers displaced from each other by the distance between the two slits.
   c) one double slit pattern.
   d) two double slit patterns, their centers displaced from each other by the distance between the two slits.
   e) random darkening of the film. (no pattern at all)

5. A beam of x-rays of wavelength 0.130 nm is incident on a crystal with a spacing between atomic planes of 0.314 nm. The beam has an angle to the crystal planes of 24.5°. If a diffraction maximum is seen at this angle, what is its diffraction order?

   a) first order
   b) second order
   c) third order
   d) (none of the other answers)
   e) (need more information)

6. A diffraction grating has 750,000 slits per meter. What is the highest order the grating can display, for light with a wavelength of $\lambda = 550$ nm?

   a) 0 b) 1 c) 2 d) 3 e) ∞

7. Which of the following statements about relativity is *false*?

   a) Kinetic energy at relativistic speeds is greater than the classical value
   b) $E = mc^2$ describes the rest energy of a massive particle
   c) Blueshifting of light occurs when the emitter is moving towards the receiver
   d) Events occuring simultaneously in one frame will always appear to be simultaneous in any frame
   e) The quantity γ can never be less than 1.

8. A 30-year-old woman takes a trip on a rocket, leaving her 20-year-old brother behind at rest on the Earth. She travels at a speed of 0.8 c, and is gone for 20 years according to her younger brother's clock. When she returns, how many years older or younger is she than her brother? [Hint. Be careful. Both of them age.]

   a) 2 years younger
   b) 2 years older
   c) 4 years older
   d) 10 years older
   e) 8 years older

9. Find the speed of a particle whose total energy is twice its rest energy.

   a) 0.925 c
   b) 0.866 c
   c) 0.500 c
   d) 0.250 c
   e) 0.792 c

10. An electron has a speed of 0.95c. Its kinetic energy is closest to:

    a) 0.511 MeV
    b) 1.64 MeV
    c) 1.12 MeV
    d) 232 keV
    e) 2.15 MeV

11. In Compton scattering from stationary electrons, the largest change in wavelength occurs when the photon is scattered through an angle of:

    a) 0°
    b) 45°
    c) 90°
    d) 180°
    e) 270°

12. Which of the following statements about the photoelectric effect is <u>FALSE</u>:

    a) The photocurrent increases with increasing light intensity above the cut off frequency.
    b) The cut-off frequency is independent of photon intensity.
    c) The maximum photoelectron kinetic energy increases with decreasing photon wavelength.
    d) The maximum photoelectron kinetic energy increases with increasing light intensity.
    e) The stopping potential increases with increasing photon frequency.

13. The metals lithium, beryllium and mercury have work functions of 2.3 eV, 3.9 eV and 4.5 eV respectively. If light of wavelength 400 nm is incident on each of these metals, which of them exhibit the photoelectric effect?

    a) lithium only
    b) lithium and beryllium only
    c) lithium, beryllium and mercury
    d) mercury only
    e) beryllium and mercury

14. If the kinetic energy of a free non-relativistic electron doubles, its de Broglie wavelength changes by the factor:

    a) $1/\sqrt{2}$ b) $1/2$ c) $1/4$ d) $\sqrt{2}$ e) 2

15. A sub-atomic particle when at rest decays 2 μs after it is created. If moving in the laboratory at 0.99c, its lifetime according to laboratory clocks would be:

a) the same
b) 0.28 μs
c) 14 μs
d) 4.6 μs
e) none of the other answers

16. 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 uncertainty in the linear momentum of the neutron.

a) 2.5×10^{-21} kg·m/s
b) 2.1×10^{-43} kg·m/s
c) 5.2×10^{-35} kg·m/s
d) 2.5×10^{13} kg·m/s
e) 7.7×10^{-23} kg·m/s

17. An electron is in a one-dimensional infinite potential well, with zero potential energy in the interior and infinite potential energy at the walls. The ratio E_3/E_1 of the energy for $n = 3$ to that for $n = 1$ is:

a) 1/3
b) 1/9
c) 3/1
d) 9/1
e) 1/1

18. The statements below all agree with the Bohr model for the hydrogen atom. One of them disagrees with the Schrödinger model for the hydrogen atom. Which is it?

a) In the hydrogen atom, the relationship between total energy, E, potential energy, U, and kinetic energy, K, is given by $E = K + U$.
b) The frequency, f, of a photon emitted when an electron makes a transition from the i^{th} orbit to the j^{th} orbit is given by $hf = E_i - E_j$.
c) The orbital angular momentum of the lowest possible energy level, i.e. the ground state, is $L = 1\hbar$.
d) The potential energy function for the atom is given by $v(r) = -k_e e^2/r$
e) The energy for the ground state of hydrogen is –13.6 eV.

19. The Pauli exclusion principle states:

a) No two electrons in an atom can have the same principal quantum number.
b) No two electrons can have all the same quantum numbers.
c) Identical particles are indistinguishable.
d) Electrons are Fermions.
e) The wavelength associated with a particle is inversely proportional to its momentum.

20. Which of the following (n, ℓ, m_ℓ, m_s) combinations is impossible for an electron in an atom?

a) 3, 1, 1, $-\frac{1}{2}$
b) 3, 1, -2, $\frac{1}{2}$
c) 3, 2, -2, $-\frac{1}{2}$
d) 6, 2, 0, $\frac{1}{2}$
e) 1, 0, 0, $-\frac{1}{2}$

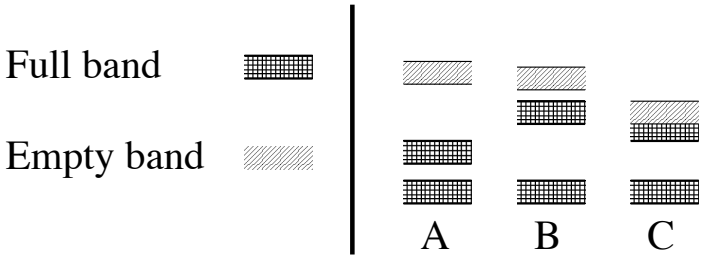
21. Electrons orbiting a nucleus in a particular orbital state with $\ell = 0$ experience an effective magnetic field $B_{\text{eff}} = 0.4$ T. What is the energy splitting between electrons in this orbital with spins parallel and antiparallel to $\vec{B}$?

a) 4.6×10^{-5} eV
b) 2.3×10^{-5} eV
c) 9×10^{-5} eV
d) 0.16 eV
e) 1.5×10^{8} eV

22. Deuterium (atomic mass = 2) is an isotope of hydrogen (atomic mass = 1). Molecular hydrogen (H_2) and deuterium (D_2) have the same bond length and similar chemical properties. How do the rotational energy levels of D_2 molecules compare with those of H_2? One of the following is correct:

a) Rotational energy levels of H_2 and D_2 are the same.
b) The rotational levels are more closely spaced for D_2 than H_2.
c) There is not enough information to answer.
d) The rotational energy levels are more closely spaced for H_2 than D_2.
e) Rotational levels are more closely spaced in H_2 for vibrational levels $v = 0$, 1 and more closely spaced in D_2 for $v \geq 2$.

23. The band structure of three solids are shown



Solids A, B, C are respectively

a) insulator, insulator, insulator
b) insulator, semiconductor, metal
c) insulator, insulator, metal
d) metal, metal, insulator
e) semiconductor, metal, insulator

24. At room temperature kT is about 0.0259 eV. The probability that an electronic state in a metal 0.50 eV above the Fermi level is occupied at room temperature is closest to:

a) 1
b) 0.05
c) 0.25
d) 5.0×10^{-6}
e) 4.1×10^{-9}

25. If $^{204}_{81}$Tl emits a β^- particle from its nucleus:

a) stable Tl is formed
b) $^{202}_{80}$Hg is formed
c) radioactive Tl is formed
d) $^{197}_{79}$Au is formed
e) $^{204}_{82}$Pb is formed

26. Radioactive polonium, $^{214}_{84}$Po, decays by α-emission to:

a) $^{214}_{83}$Bi b) $^{210}_{82}$Pb c) $^{214}_{85}$At d) $^{218}_{84}$Po
e) $^{210}_{83}$Bi

27. What is the binding energy of the boron nucleus ($M(^{10}_{5}B) = 10.012939u$)?

a) 4.66 GeV
b) 0.13 MeV
c) 64.75 MeV
d) 9.33 GeV
e) 1.20 MeV

28. The weak interaction is mediated by the exchange of the Z^o particle which has a mass of about 91 GeV. Approximately what is the spatial range of this force?

a) 10^{-12} m b) 10^{-9} m c) 10^{7} m d) 10^{-18} m
e) 10^{-6} m

29. One of the most important nuclear reactions in the proton-proton cycle that powers stars is:

$$^{2}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{3}_{2}\mathrm{He} + \gamma + Q\ .$$

Where:
$M(^{1}_{1}H) = 1.007825u$
$M(^{2}_{1}H) = 2.014102u$
$M(^{3}_{2}He) = 3.016029u$

The Q-value of this reaction is:

a) 1.44 MeV b) 12.86 MeV c) 5.49 MeV
d) 8.65 MeV e) 0.511 MeV

30. Consider the following decay (through the strong interaction) of the Δ^- particle:

$$\Delta^- \rightarrow \mathrm{n} + \pi^-$$

where n = (udd) and $\pi^- = (\bar{\mathrm{u}}\mathrm{d})$. Based on this information what is the quark composition of the Δ^- ?

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

31. Which of the following statements is false?
(I) To avoid Coulomb repulsion heavy nucleii tend to have more protons than neutrons.
(II) Nuclear Fusion is possible, because the binding energy of the lightest nucleii is reduced by their large surface energy.
(III) The density of nuclear matter is approximately constant.
(IV) Isotopes produced by nuclear fission tend to decay via alpha decay, because they have an excess of protons.

a) I and IV.
b) II only
c) None of the above
d) IV only.
e) I, II and IV.

32. A proton is accelerated in a field of 1 Tesla inside a synchrotron up to a *total* energy of 2GeV. Treating the motion as cyclotron motion, approximately how many times a second will the proton orbit the synchrotron? (Hint - bear in mind that the relativistic mass of the proton increases as its speed approaches the speed of light.)

a) 7.16×10^6
b) 1.53×10^7
c) 2.80×10^{10}
d) 4.56×10^7
e) 2.13×10^5