General Physics II Exam 4 - Chs. 26, 27, 28 - Relativity & Quantum Physics April 29, 2013

Name Rec. Instr. Rec. Time

For full credit, make your work clear. Show formulas used, essential steps, and results with correct units and significant figures. Points shown in parenthesis. For TF and MC, choose the *best* answer.

1. (3) An inertial reference frame is one in which

a. Newton's First Law is valid. b. objects always remain at rest.
b. objects move at constant velocity. c. objects move at constant acceleration.

2. (3) The statement: *The laws of physics are the same in all inertial reference frames*, is known as

a. The correspondence principle. b. The relativity principle.
c. The principle of complementarity. c. The duality principle.

3. (3) Alice is running towards the east at 1.0×10^8 m/s while pointing a flashlight east towards Mr. Tompkins standing still. At what speed does Mr. Tompkins see the light coming at him?

a. 1.0×10^8 m/s b. 2.0×10^8 m/s c. 3.0×10^8 m/s d. 4.0×10^8 m/s

4. (12) A certain star is 18.0 light-years away. A spacecraft leaves Earth and after a short acceleration, travels at a constant speed of $v = 0.980c$ to the star. How long does it take to reach the star,

a) (6) as measured by observers on Earth?

b) (6) as measured by astronauts in the spacecraft?

5. (8) A house uses an average power of 2.0 kW for 24 hours a day for an entire year. How many grams of matter would have to be completely destroyed to produce this energy?

6. (14) The rest energy of an electron is $E_0 = 0.511$ MeV. Suppose an electron has been accelerated through a potential difference of magnitude 4.80 MV.

a) (4) How large is the kinetic energy of the electron, in MeV?

b) (4) How large is its total energy, in MeV?

c) (6) How fast is the electron moving, in units of c?

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7. (3) Which of these phenomena is evidence of the particle-like properties of light?

a. diffraction. b. thin film interference. c. photoelectric effect. d. length contraction.

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8. (8) Two laser pointers emit monochromatic light each with a power of 1.5 mW. Pointer A emits at wavelength 680 nm and pointer B emits at wavelength 450 nm.

a) (2) Which pointer's photons have the higher energy? a. A b. B. c. it's a tie.

b) (2) Which pointer's photons travel faster? a. A b. B. c. it's a tie.

c) (2) Which pointer emits more photons per second? a. A b. B. c. it's a tie.

d) (2) Which pointer emits more radiant energy in a minute? a. A b. B. c. it's a tie.

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9. (8) A metal used in a photoelectric effect experiment has a work function of 2.62 eV.

(a) (4) How many photoelectrons will be produced by a photon of wavelength 656 nm on this metal?

a. none. b. between 0 and 1. c. 1. d. between 1 and 2. e. 2. f. more than 2.

(a) (4) How many photoelectrons will be produced by a photon of wavelength 350 nm on this metal?

a. none. b. between 0 and 1. c. 1. d. between 1 and 2. e. 2. f. more than 2.

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10. (8) A metal has a work function of 3.48 eV. Light of an unknown wavelength produces photoelectrons of maximum kinetic energy of 0.55 eV. What is the wavelength of the light?

11. (8) What kinetic energy in eV should electrons have, so that their de Broglie wavelength is 1.25 nm?

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12. (3) For the indicated particles and kinetic energies, which has the largest de Broglie wavelength for its matter waves?

a. electron, KE=25 eV. b. electron, KE=2.5 keV. c. proton, KE=25 eV. d. proton, KE=2.5 keV.

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13. (3) Which would not show significant diffraction effects when passing through a double slit with spacing of 100 nm? (λ is wavelength or de Broglie wavelength.) Check all that apply.

a. photon, $\lambda = 400$ nm. b. proton, $\lambda = 400$ nm. c. photon, $\lambda = 4.0$ nm. d. proton, $\lambda = 4.0$ nm.

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14. (3) According to Bohr's model, which classical physics effect **does not** take place in a hydrogen atom?

a. The nucleus and electron attract each other according to Coulomb's Law.
b. The angular momentum is the product of electron linear momentum and radius.
c. An accelerated electric charge continuously emits electromagnetic radiation.
d. The electron's acceleration in circular motion is towards the center of the circle.

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15. (3) When the emission spectrum of hydrogen gas in an electrified tube was viewed as we did in lecture, what we saw was

a. only one emission line in the red.
b. an emission line in the red and one that looks turquoise.
c. three emission lines: one red, one turquoise, and one blue/violet.
d. four emission lines: one red, one yellow, one turquoise, and one violet.

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16. (12) Use the Bohr model for a hydrogen atom here. Suppose the atom is initially in the $n = 3$ stationary state, and then suddenly makes a transition to the ground state.

a) (4) Calculate the initial energy of the atom, in eV.

b) (4) Calculate the energy of the photon associated with this transition, in eV.

c) (4) Is the photon absorbed or emitted by the atom? Explain why.

These are questions about the Bohr model for a hydrogenic atom (or ion) with nuclear charge $+Ze$.

17. (2) **T F** The Bohr model applies only to atoms (or ions) with one electron.

18. (2) **T F** When the atom is in the ground state, it cannot emit a photon.

19. (2) **T F** When the atom is in an excited state, it cannot absorb a photon.

20. (2) **T F** The n^{th} circular electron orbit satisfies a standing wave with $2\pi r = n\lambda$.

21. (2) **T F** An emitted photon's energy equals the difference in energy of two allowed electron orbits.

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22. (8) A proton is traveling with a speed measured as 7.50×10^6 m/s $\pm 1.5 \times 10^3$ m/s. Estimate the uncertainty Δx with which its position can be measured along its direction of motion.

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23. (2) **T F** The Pauli exclusion principle says that only two electrons can occupy a given quantum state.

24. (2) **T F** The energy of hydrogen atomic states depends mostly on principle quantum number n.

25. (2) **T F** The angular momentum of hydrogen atoms is described by orbital quantum number l.

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26. (4) For a hydrogen atom with principle quantum number $n = 5$, write down the possible values of the orbital quantum number l.

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27. (8) For a hydrogen atom where the orbital quantum number is $l = 4$,

a) (4) write down the possible values of magnetic quantum number m_l.

b) (4) what is the maximum number of electrons that can occupy the $l = 4$ subshell?

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28. (2) Which of the following subshells does not exist in any atom?

a. 1s. b. 2p. c. 3d. d. 3f. e. 4d.

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29. (2) Which one of the following electron configurations is not allowed?

a. $1s^2 2s^2 2p^1$ b. $1s^2 2s^2 2p^5$ c. $1s^2 2s^1 2p^5$ d. $1s^2 2s^2 2p^7$ e. $1s^1 2s^1 2p^6$

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30. (2) Which one of these outer shell electronic configurations corresponds to a halogen?

a. $2s^2$ b. $3s^1$ c. $3p^5$ d. $4d^6$ e. $4s^1$

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31. (2) Which one of these outer shell electronic configurations corresponds to a noble gas?

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

Score = ____________/146.

Prefixes

a=10^{-18}, f=10^{-15}, p=10^{-12}, n=10^{-9}, $\mu = 10^{-6}$, m=10^{-3}, c=10^{-2}, k=10^{3}, M=10^{6}, G=10^{9}, T=10^{12}, P=10^{15}

Physical Constants

$k = 1/4\pi\epsilon_0 = 8.988$ GN·m^2/C^2 (Coulomb's Law)
$\epsilon_0 = 1/4\pi k = 8.854$ pF/m (permittivity of space)
$e = 1.602 \times 10^{-19}$ C (proton charge)
$\mu_0 = 4\pi \times 10^{-7}$ T·m/A (permeability of space)
$m_e = 9.11 \times 10^{-31}$ kg (electron mass)
$m_p = 1.67 \times 10^{-27}$ kg (proton mass)
$c = 3.00 \times 10^{8}$ m/s (speed of light)
$c = 2.99792458 \times 10^{8}$ m/s (exact value in vacuum)
$h = 6.62607 \times 10^{-34}$ J·s (Planck's constant)
$\hbar = 1.05457 \times 10^{-34}$ J·s (Planck's constant/2π)
$\sigma = 5.67 \times 10^{-8}$ W/(m^2·K^4) (Stefan-Boltzmann const.)
hc =1239.84 eV·nm (photon energy constant)

Units

$N_A = 6.02 \times 10^{23}$/mole (Avogadro's #)
1 u = 1 g/N_A = 1.6605×10^{-27} kg (mass unit)
1.0 eV = 1.602×10^{-19} J (electron-volt)
1 V = 1 J/C = 1 volt = 1 joule/coulomb
1 F = 1 C/V = 1 farad = 1 C^2/J
1 H = 1 V·s/A = 1 henry = 1 J/A^2
1 A = 1 C/s = 1 ampere = 1 coulomb/second
1 Ω = 1 V/A = 1 ohm = 1 J·s/C^2
1 T = 1 N/A·m = 1 tesla = 1 newton/ampere·meter
1 G = 10^{-4} T = 1 gauss = 10^{-4} tesla

Chapter 22 Equations

Electromagnetic waves:

$|\vec{E}|/|\vec{B}| = c = 1/\sqrt{\epsilon_0\mu_0}$, (fields)
$f\lambda = c$ (wave equation)

Approximate wavelengths λ for types of EM waves:

0 (γ-rays) 30 pm (x-rays) 3 nm (uv) 400 nm (visible) 700 nm (ir) 300 μm (μ-waves) 3 cm (radio) ∞

$\longrightarrow$ $\longrightarrow$ $\longrightarrow$ increasing wavelength $\longrightarrow$ $\longrightarrow$ $\longrightarrow$

Chapter 26 Equations

Time dilation and length contraction:

$\Delta t = \gamma \Delta t_0 = \Delta t_0/\sqrt{1 - v^2/c^2}$
$L = L_0/\gamma = L_0\sqrt{1 - v^2/c^2}$
$\gamma = 1/\sqrt{1 - v^2/c^2}$ (relativistic factor)
$v/c = \sqrt{1 - 1/\gamma^2}$ (velocity)

Dyanmics, mass, energy:

$p = \gamma m_0 v$ (relativistic momentum)
$m_{\text{rel}} = \gamma m_0$ (relativistic mass)
$E_0 = m_0 c^2$ (rest energy)
$E = \gamma m_0 c^2 = m_{\text{rel}} c^2$ (relativistic energy)
$\text{KE} = E - E_0 = (\gamma - 1) m_0 c^2$ (kinetic energy)
$E = E_0 + \text{KE}$ (total energy)

Chapter 27 Equations

Blackbody radiation, photons, photo-electric effect:

$\lambda_p T = 2.90$ mm·K (Wien's Law) | $I = \sigma T^4$ (intensity or power/area)

$E = nhf,\ n = 1, 2, 3...$ (quantized radiation energy) | $E = hc/\lambda = (1240 \text{ eV} \cdot \text{nm})/\lambda$ (photons)

$E = hf = W_0 + \text{KE}_{\text{max}}$ (photo-electrons) | $hc/\lambda_{\text{max}} = W_0$ (work function)

$\text{KE}_{\text{max}} = eV_0$ (stopping potential) | $v_{\text{max}} = \sqrt{2\text{KE}_{\text{max}}/m}$ (max. speed)

Momentum, matter waves:

$p = h/\lambda$ (photon momentum) | $\lambda' = \lambda + \frac{h}{mc}(1 - \cos\phi)$ (Compton effect)

$\lambda = h/p = h/(mv)$ (de Broglie wavelength) | $v = \sqrt{2q\Delta V/m}$ (acceleration thru potential)

Bohr Model:

$hf = E_n - E_{n'}$ (quantum jump) | $L = mvr = n\frac{h}{2\pi}$ (Bohr's quantization)

$r_n = \frac{n^2}{Z} r_1$ (Bohr radii) | $r_1 = \frac{h^2}{4\pi^2 mke^2} = 52.9$ pm (1^{st} Bohr radius)

$E_n = -(13.6 \text{ eV})\frac{Z^2}{n^2}$ (Bohr energies) | $E_n = \frac{1}{2}mv^2 - \frac{kZe^2}{r_n}$ (total energy)

$n = 1, 2, 3, ...$ (Bohr's quantum number)

Chapter 28 Equations

Wave functions:

$N \propto I \propto |\vec{E}|^2$ (photon detection) | $N \propto |\Psi|^2$ (particle detection)

Heisenberg Uncertainty Principle:

$\Delta x\ \Delta p_x \geq \hbar$ (uncertainty principle) | $\hbar = \frac{h}{2\pi} = 1.05459 \times 10^{-34}$ J·s

$\Delta E\ \Delta t \geq \hbar$ (energy-time form) | (← These are approximate relations.)

$\Delta E = \Delta m \cdot c^2$ (Einstein's mass-energy equivalence) | (← This one is exact.)

Quantum numbers for atoms:

principle quantum number $n = 0, 1, 2, 3...$ | $E_n = -(13.6 \text{ eV})/n^2$ (energy of hydrogen states)

orbital quantum number $l = 0, 1, 2...(n-1)$ | $L = \sqrt{l(l+1)}\ \hbar$ (angular momentum mag.)

magnetic quantum number $m_l = -l$ to $+l$ | $L_z = m_l \hbar$ (z-component of $\vec{L}$)

spin quantum number $m_s = -\frac{1}{2},\ +\frac{1}{2}$ | $S_z = m_s \hbar$ (z-comp., spin angular momentum)

shell means a particular value of (n) is given. | *sub-shell* means values of (n, l) are given.

orbital means particular (n, l, m_l) are given. | *state* means particular (n, l, m_l, m_s) are given.

$l = 0, 1, 2, 3, 4, 5, 6...$ are indicated with respective letters: s, p, d, f, g, h,...

Pauli exclusion principle: *No two electrons in an atom can occupy the same quantum state.*

Subshells in order of increasing energy: 1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p, 5s, 4d, 5p, 6s, 4f, 5d, 6p, 7s, 5f, 6d, 7p

(They fill in order of increasing $n + l$, or increasing n if there is a tie.)