Phys 234H Practice Final Exam *(Note: this practice exam contains more questions than will the final, which will have 25 multiple-choice questions.*

MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question.

1) A 0.025-kg block on a horizontal frictionless surface is attached to an ideal massless spring whose spring constant is $150\ \text{N/m}$. The block is pulled from its equilibrium position at $x = 0.00$ m to a displacement $x = +0.080$ m and is released from rest. The block then executes simple harmonic motion along the horizontal x-axis. When the displacement is $x = 0.024\ \text{m}$, what is the kinetic energy of the block? 1) _____

A) 0.52 J B) 0.41 JC) 0.49 J D) 0.44 J E) 0.46 J

2) A long thin uniform rod of length 1.50 m is to be suspended from a frictionless pivot located at some point along the rod so that its pendulum motion takes 3.00 s. How far from the center of the rod should the pivot be located? 2) _____

A) 8.40 cm B) 8.73 cm C) 23.4 cm D) 7.98 cm E) 7.52 cm

3) Four traveling waves are described by the following equations, where all quantities are measured in SI units and y represents the displacement.

I: $y = 0.12\cos(3x + 2t)$
II: $y = 0.15\sin(6x - 3t)$
III: $y = 0.23\cos(3x + 6t)$
IV: $y = -0.29\sin(1.5x - t)$

Which of these waves have the same speed? 3) _____

A) I and II B) III and IV C) I and III D) I and IV E) II and III

4) A heavy stone of mass m is hung from the ceiling by a thin 8.25-g wire that is 65.0 cm long. When you gently pluck the upper end of the wire, a pulse travels down the wire and returns 7.84 ms later, having reflected off the lower end. The stone is heavy enough to prevent the lower end of the wire from moving. What is the mass m of the stone? 4) _____

A) 8.90 kg B) 349 kg C) 227 kg D) 35.6 kg E) 23.1 kg

5) When light goes from one material into another material having a HIGHER index of refraction 5) _____

A) its speed increases, its wavelength decreases, and its frequency stays the same.
B) its speed decreases but its wavelength and frequency both increase.
C) its speed decreases but its frequency and wavelength stay the same.
D) its speed and wavelength decrease, but its frequency stays the same.
E) its speed, wavelength, and frequency all decrease.

6) The speed of light in a material is $0.50c$. What is the critical angle of a light ray at the interface between the material and a vacuum? 6) _____

A) 24° B) 30° C) 27° D) 21°

7) A convex lens has a focal length f. An object is placed at a distance between f and $2f$ on a line perpendicular to the center of the lens. The image formed is located at what distance from the lens? 7) _____

A) between the lens and f
B) between f and $2f$
C) farther than $2f$
D) $2f$

E) f

8) A goldfish bowl is spherical, 8.0 cm in radius. A goldfish is swimming 3.0 cm from the wall of the bowl. Where does the fish appear to be to an observer outside? The index of refraction of water is 1.33. Neglect the effect of the glass wall of the bowl. 8) _____

A) 3.9 cm inside the bowl
B) 1.7 cm inside the bowl
C) 3.0 cm inside the bowl
D) 3.3 cm inside the bowl
E) 2.5 cm inside the bowl

9) In a double-slit experiment, if the slit separation is increased, which of the following happens to the interference pattern shown on the screen? 9) _____

A) The maxima stay at the same position.
B) The minima and maxima stay at the same position.
C) The maxima get further apart.
D) The minima get closer together.
E) The minima stay at the same position.

10) At most, how many bright fringes can be formed on each side of the central bright fringe (not counting the central bright fringe) when light of 625 nm falls on a double slit whose spacing is 1.97×10^{-6} m? 10) _____

A) 1 B) 2 C) 3 D) 4 E) 5

11) A thin layer of oil (n = 1.25) is on top of a puddle of water (n = 1.33). If normally incident 500-nm light is strongly reflected, what is the minimum nonzero thickness of the oil layer? 11) _____

A) 200 nm B) 100 nm C) 150 nm D) 400 nm E) 250 nm

12) A slit of width 2.0 μm is used in a single slit experiment with light of wavelength 650 nm. If the intensity at the central maximum is I_0, what is the intensity 10° from the center?12) _____

A) $0.43I_0$ B) $0.50I_0$ C) $0.53I_0$ D) $0.35I_0$ E) $0.030I_0$

13) When monochromatic light illuminates a grating with 7000 lines per centimeter, its second order maximum is at 62.4°. What is the wavelength of the light? 13) _____

A) 452 nm B) 363 nm C) 752 nm D) 336 nm E) 633 nm

14) A rocket is moving at 1/4 the speed of light relative to Earth. At the center of this rocket, a light suddenly flashes. To an observer at rest on Earth 14) _____

A) the light will reach the front of the rocket before it reaches the back of the rocket.
B) the light will reach the front of the rocket after it reaches the back of the rocket.
C) the light will reach the front of the rocket at the same instant that it reaches the back of the rocket.

15) A set of twins, Andrea and Courtney, are initially 10 years old. While Courtney remains on Earth, Andrea rides on a spaceship which travels away from Earth at a speed of 0.60c for five years (as measured by Courtney), then immediately turns around and comes back at 0.60c. When Andrea returns, Courtney is 20 years old. How old is Andrea upon her return? 15) _____

A) 12 y B) 10 y C) 20 y D) 18 y E) 15 y

16) In a certain particle accelerator, a proton has a kinetic energy that is equal to its rest energy. What is the speed of the proton relative to the accelerator? 16) _____

A) 0.87c B) 0.50c C) 0.71c D) 0.25c E) 0.75c

17) A proton in a certain particle accelerator has a kinetic energy that is equal to its rest energy. What is the momentum of the proton as measured by a physicist working with the accelerator? ($c = 3.00 \times 10^8$ m/s, $m_{\text{proton}} = 1.67 \times 10^{-27}$ kg) 17) _____

A) 8.68×10^{-19} kg · m/s
B) 2.51×10^{-19} kg · m/s
C) 5.01×10^{-19} kg · m/s
D) 4.34×10^{-19} kg · m/s
E) 2.89×10^{-19} kg · m/s

18) Monochromatic light strikes a metal surface and electrons are ejected from the metal. If the intensity of the light is increased, what will happen to the ejection rate and maximum energy of the electrons? 18) _____

A) greater ejection rate; same maximum energy
B) same ejection rate; same maximum energy
C) same ejection rate; greater maximum energy
D) greater ejection rate; greater maximum energy

19) Light of wavelength 400 nm falls on a metal surface having a work function 1.70 eV. What is the maximum kinetic energy of the photoelectrons emitted from the metal? ($c = 3.00 \times 10^8$ m/s, $h = 6.626 \times 10^{-34}$ J · s = 4.141×10^{-15} ev · s, 1 eV = 1.60×10^{-19} J) 19) _____

A) 1.41 eV B) 3.11 eV C) 4.52 eV D) 2.82 eV E) 1.70 eV

20) An electron inside a hydrogen atom is confined to within a space of 0.110 nm. What is the minimum uncertainty in the electron's velocity? ($\hbar = 1.055 \times 10^{-34}$ J · s, $m_{\text{el}} = 9.11 \times 10^{-31}$ kg) 20) _____

A) 7.50×10^5 m/s
B) 7.50×10^7 m/s
C) 5.26×10^5 m/s
D) 5.26×10^7 m/s
E) 5.26×10^9 m/s

21) At absolute temperature T, a black body radiates its peak intensity at wavelength λ. At absolute temperature $2T$, what would be the wavelength of the peak intensity? 21) _____

A) $\lambda/2$ B) $\lambda/16$ C) λ D) 2λ E) 16λ

22) Light shines through atomic hydrogen gas. It is seen that the gas absorbs light readily at a wavelength of 91.63 nm. What is the value of n of the level to which the hydrogen is being excited by the absorption of light of this wavelength? Assume that the most of the atoms in the gas are in the lowest level. ($h = 6.626 \times 10^{-34}$ J · s, $c = 3.00 \times 10^8$ m/s, 1 eV = 1.60×10^{-19} J, the Rydberg constant is $R = 1.097 \times 10^7$ m^{-1}) 22) _____

A) 14 B) 21 C) 16 D) 11

23) An electric current through a tungsten filament maintains its temperature at 2800 K. Assume the tungsten filament behaves as an ideal radiator at that temperature. If the radiating area of the filament is 2.0×10^{-6} m^2, at what rate does it radiate energy? ($\sigma = 5.670 \times 10^{-8}$ W/m$^2 \cdot$ K^4, Wien displacement law constant is 2.90×10^{-3} m $\cdot$ K) 23) _____

A) 10 W B) 7.0 W C) 11.5 W D) 5.5 W E) 8.5 W

24) A set of five possible wave functions is given below, where L is a positive real number.

$\psi_1(x) = Ae^{-x}$, for all x $\psi_2(x) = A \cos x$, for all x

$\psi_3(x) = \begin{cases} Ae^x, 0 \le x \le L \\ 0, \text{ for all other } x \end{cases}$ $\psi_4(x) = \begin{cases} A, -L \le x \le L \\ 0, \text{ for all other } x \end{cases}$

$\psi_5(x) = \begin{cases} Ax, x \ge L \\ 0, \text{ for all other } x \end{cases}$

Which of the five possible wave functions are normalizable? (There may be more than one correct choice.)24) _____

A) $\psi_2(x)$ B) $\psi_3(x)$ C) $\psi_4(x)$ D) $\psi_1(x)$ E) $\psi_5(x)$

25) Find the value of A to normalize the wave function $\psi(x) = \begin{cases} A, -L \le x \le L \\ 0, \text{ for all other } x \end{cases}$. 25) _____

A) $1/L$ B) $1/\sqrt{2L}$ C) $1/L^2$ D) $1.\sqrt{L}$ E) $\frac{1}{2L}$

26) An electron is trapped in an infinite square well (a box) of width 6.88 nm. Find the wavelength of photons emitted when the electron drops from the $n = 5$ state to the $n = 1$ state in this system. ($c = 3.00 \times 10^8$ m/s, $h = 6.626 \times 10^{-34}$ J $\cdot$ s, $m_{el} = 9.11 \times 10^{-31}$ kg) 26) _____

A) 5.45 μm B) 6.49 μm C) 5.91 μm D) 7.07 μm

27) If two electrons in the same atom have the same four quantum numbers, then they must have the same energy. 27) _____

A) true
B) false
C) They cannot both have the same four quantum numbers.

28) An electron in a hydrogen atom has orbital quantum number $l = 7$. How many possible values of the magnetic quantum number m_l could it have? 28) _____

A) 6 B) 15 C) 33 D) 7 E) 98

29) An atom has completely filled inner shells and a single valence electron in an excited p state. The filled inner shells have an orbital momentum equal to zero. What is the magnitude of the orbital angular momentum L of the atom? 29) _____

A) $1.7\hbar$ B) $1.4\hbar$ C) $2.0\hbar$ D) $1.0\hbar$ E) $1.2\hbar$

SHORT ANSWER. Write the word or phrase that best completes each statement or answers the question.

30) The energy of an electron in the *p*-level of an atom is changed in the presence of a magnetic field of magnitude 4.6 T. What is the difference between the largest and smallest possible energies? (Bohr magneton = $\mu_B = 9.27 \times 10^{-24}$ J/T) 30) _____

31) For a solid in which the occupation of the energy states is given by the Fermi-Dirac distribution, the probability that a certain state is occupied at a temperature T_0 is 0.70. If the temperature is doubled to $2T_0$, what is the probability that the same state is occupied? Assume that the Fermi energy does not change with temperature.31) _____

MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question.

32) A rotating diatomic molecule has rotational quantum number *l*. The energy DIFFERENCE between adjacent energy levels 32) _____

A) is independent of *l*. B) is the same for all changes in *l*.
C) decreases as *l* increases. D) increases as *l* increases.

33) A diatomic molecule has 2.6×10^{-5} eV of rotational energy in the $l = 2$ quantum state. What is its rotational energy in the $l = 1$ quantum state? 33) _____

A) 8.7 μeV B) 3.4 μeV C) 5.3 μeV D) 4.1 μeV E) 7.8 μeV

34) Which of the following statements about the atomic nucleus is correct? (There may be more than one correct choice.) 34) _____

A) All nuclei have nearly the same density.
B) Large nuclei are denser than light nuclei.
C) As the number of nucleons increases the binding energy per nucleon always increases.
D) A nucleus containing 20 nucleons will have approximately twice the radius as a nucleus containing 10 nucleons.
E) The nucleus is held together more by the electrical force than by the gravitational force.

35) A radioactive nuclide of atomic number *Z* emits an electron, then the daughter nuclide emits a gamma ray. What is the atomic number of the resulting nuclide after both processes? 35) _____

A) $Z + 1$ B) $Z + 2$ C) $Z - 3$ D) $Z - 2$ E) $Z - 1$

36) What would be the expected radius of the nucleus of $^{90}_{38}$Sr? (R_0 = 1.2 fm) 36) _____

A) 1.2 fm B) 4.0 fm C) 0.11 pm D) 0.54 pm E) 5.4 fm

37) What is the binding energy per nucleon for $^{27}_{13}$Al? The neutral $^{27}_{13}$Al atom has a mass of 26.981539 u; a neutral hydrogen atom has a mass of 1.007825 u; a neutron has a mass of 1.008665 u; and a proton has a mass of 1.007277 u. (1 u = 931.494 MeV/c^2) 37) _____

A) 2.8 MeV B) 8.3 MeV C) 3.4 MeV D) 5.4 MeV E) 6.7 MeV

38) A certain substance has a half-life of 5.0 hours. How many nuclei of the substance are required to give an initial activity of 6.0 μCi? 1 Ci = 3.7×10^{10} Bq. 38) _____

A) 5.8×10^9 B) 8.5×10^8 C) 2.4×10^9 D) 6.3×10^8 E) 3.2×10^9

39) The stability of $^{47}_{21}Sc$ with respect to alpha, β^+, and β^- decay is to be determined. Do not consider the possibility of decay by electron capture. The following atomic masses are known:

$^{4}_{2}He$: 4.002603 u
$^{43}_{19}K$: 42.960717 u
$^{47}_{20}Ca$: 46.954543 u
$^{47}_{21}Sc$ 46.952409 u
$^{47}_{22}Ti$: 46.951764 u

The $^{47}_{21}Sc$ nuclide is 39) _____

A) subject to alpha decay only.
B) subject to β^- decay only.
C) not subject to alpha, β^+, or β^- decay.
D) subject to β^+ decay only.
E) subject to β^+ or β^- decay, but not to alpha decay.

1) D
2) B
3) D
4) D
5) D
6) B
7) C
8) E
9) D
10) C
11) A
12) D
13) E
14) B
15) D
16) A
17) A
18) A
19) A
20) C
21) A
22) A
23) B
24) B, C
25) B
26) B
27) C
28) B
29) B
30) 8.5×10^{-23} J
31) 0.60
32) D
33) A
34) A
35) A
36) E
37) B
38) A
39) B