# HAWAI'I PACIFIC UNIVERSITY

# PHYS 2054: SECOND PRACTICE EXAM

| Campus/Centre: | ( x ) Downtown campus ( ) Loa Campus |
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| Examination Day: | TBD | Examination Date: | TBD |
|---|---|---|---|
| Examination Time: | TBD | Duration: | 80 min |

| Course Abbreviation & Number: | PHYS 2054 |
|---|---|
| Course Title: | General Physics III |

Name of Student: ______________________________

Student Number: ______________________________

**INSTRUCTIONS TO CANDIDATES**

1. This examination consists of 5 pages.
2. There are 8 conceptual and 9 quantitative questions in this examination. Answer ALL questions.
3. **All working must be shown.**
4. **Units must be shown.**
5. A list of selected formulae is provided below.

**LIST OF SELECTED FORMULAE**

Bohr model

$$L_n = mv_n r_n = n\hbar$$
$$r_n = \frac{4\pi\epsilon_0\hbar^2 n^2}{me^2} = n^2 a_0$$
$$v_n = \frac{e^2}{4\pi\epsilon_0 \hbar n}$$
$$E_n = -\frac{13.60\text{ eV}}{n^2}$$

Constants / conversions

$\epsilon_0 \approx 8.854\times10^{-12}$ F/m
$h \approx 6.626\times10^{-34}$ kg m$^2$/s
$\hbar \approx 1.055\times10^{-34}$ kg m$^2$/s
$\sigma \approx 5.67\times10^{-8}$ W K$^{-4}$ m
$k \approx 1.381\times10^{-23}$ J/K
Electron mass $\approx 9.109\times10^{-31}$ kg
Proton mass $\approx 1.673\times10^{-27}$ kg
$c \approx 2.998\times10^{8}$ m/s
1 eV $\approx 1.602\times10^{-19}$ J
$R \approx 1.097\times10^{7}$ m$^{-1}$

Black body

$$I = \sigma T^4$$
$$\lambda_m T \approx 2.90\times10^{-3}\text{ K m}$$
$$I(\lambda) = \frac{2\pi hc^2}{\lambda^5\left(e^{hc/\lambda kT}-1\right)}$$

De Broglie

$$\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{h}{\sqrt{2meV}}$$
$$E = hf$$

Schrodinger

$$\left[-\frac{\hbar^2}{2m}\nabla^2 + U(r)\right]\Psi(\vec{r},t) = i\hbar\frac{\partial}{\partial t}\Psi(\vec{r},t)$$
$$\left[-\frac{\hbar^2}{2m}\nabla^2 + U(r)\right]\psi(\vec{r}) = E\psi(\vec{r})$$

wavefunctions

$$\Psi(\vec{r},t) = \psi(\vec{r})e^{-iEt/\hbar}$$
$$1 = \int \psi^*(\vec{r})\psi(\vec{r})\,dV$$
$$P(a\le x\le b) = \int_a^b \psi^*(x)\psi(x)\,dx$$

Photons

$$E = hf = \frac{hc}{\lambda}$$
$$p = \frac{hf}{c} = \frac{h}{\lambda}$$

Particle-in-a-box

$$E_n = \frac{n^2\pi^2\hbar^2}{2mL^2}$$
$$\psi(x) = \sqrt{\frac{2}{L}}\sin\left(\frac{n\pi x}{L}\right)$$

Uncertainty

$$\Delta x\Delta p \le \hbar/2$$
$$\Delta E\Delta t \le \hbar/2$$

Zeeman effect

$$U = -\mu_z B = m_l\frac{e\hbar}{2m}B = m_l\mu_B B$$

QHO

$$E_n = \left(n+\frac{1}{2}\right)\hbar\omega$$

H atom

$$E_n = -\frac{me^4}{32\pi^2\epsilon_0^2\hbar^2 n^2}$$
$$L = \sqrt{l(l+1)}\hbar$$
$$L_z = m_l\hbar$$

Rigid rotator

$$E_l = l(l+1)\frac{\hbar^2}{2I}$$
$$I = m_r r_0^2$$
$$m_r = \frac{m_1 m_2}{m_1+m_2}$$

Free electron

$$g(E) = \frac{(2m)^{\frac{3}{2}}V}{2\pi^2\hbar^3}$$
$$f(E) = \left[e^{(E-E_F)/kT}+1\right]^{-1}$$
$$E_{F0} = \frac{3^{\frac{2}{3}}\pi^{\frac{4}{3}}\hbar^2}{2m}\left(\frac{N}{V}\right)^{\frac{2}{3}}$$

Screening

$$E_n = -\frac{Z_{\text{eff}}^2}{n^2}(13.60\text{ eV})$$

pn junction

$$I = I_S\left(e^{eV/kT}-1\right)$$

Spin

$$S = \sqrt{s(s+1)}\hbar$$
$$S_z = \pm\frac{1}{2}\hbar$$

Atomic line spectra

$$E_i - E_f = hf = \frac{hc}{\lambda}$$

x ray

$$f = (2.48\times10^{15}\text{ Hz})(Z-1)^2$$

**<u>Conceptual Section</u>** (Circle the correct answer)

1. When comparing a typical visible light microscope to a typical electron microscope, [2]
   A. the electron microscope has a lesser resolution.
   B. the electron microscope has a lesser maximum magnification.
   C. the electron microscope has a greater maximum resolution.
   D. The electron microscope is only theoretical and has not been created.

2. A nonrelativistic electron and a nonrelativistic proton have the same kinetic energy. Which of the following statements about these particles is accurate? [2]
   A. The electron has a longer de Broglie wavelength.
   B. The proton has a longer de Broglie wavelength.
   C. Both particles have the same de Broglie wavelength.
   D. Both particles have the same speed.

3. Which of the following is an accurate statement concerning the simple harmonic oscillator? [2]
   A. The spacing between energy levels increases with increasing energy.
   B. The number of nodes of the wave function decreases with increasing energy.
   C. The spacing between energy levels decreases with increasing energy.
   D. The number of nodes of the wave function increases with increasing energy.

4. Suppose that a particle is trapped in a box. What effect does the size of the box have on the ground-state energy of the particle? [2]
   A. The size of the box has no influence on the energy.
   B. If the box is larger, the energy is greater.
   C. Additional information is needed to answer the question.
   D. If the box is smaller, the energy is greater.

5. Suppose that a particle is trapped in a box. How does the spacing between adjacent energy levels change as the quantum numbers increase? [2]
   A. The spacing between adjacent energy levels alternately increases and decreases.
   B. The spacing between adjacent energy levels remains constant.
   C. The spacing between adjacent energy levels increases.
   D. The spacing between adjacent energy levels decreases.

6. Suppose a hydrogen atom is in the $n = 4$ excited state. What is the largest number of photons that can be emitted as the atom returns to the ground state? [2]
   A. 1
   B. 2
   C. 3
   D. 4

7. How is an *n*-type semiconductor produced? [2]
   A. By doping the host crystal with acceptor impurities.
   B. By doping the host crystal with donor impurities.
   C. It is produced from a pure crystal of germanium.
   D. It is produced from a pure crystal of arsenic.

8. How is a van der Waals bond formed? [2]
   A. As a result of the transfer of electrons between atoms.
   B. As a result of the sharing of electrons between atoms.
   C. As a result of the bonding of atoms to hydrogen molecules.
   D. As a result of the unequal charge distributions around neutral molecules.

## Quantitative Section

1. (a) In an electron microscope, what accelerating voltage is needed to produce electrons with wavelength 0.0600 nm? [3]

   (b) If protons are used instead of electrons, what accelerating voltage is needed to produce protons with wavelength 0.0600 nm? [2]

2. A 100 W incandescent light bulb has a cylindrical tungsten filament 30.0 cm long, 0.45 mm in diameter, and with an emissivity of 0.28.

   (a) What is the temperature of the filament? [3]

   (b) For what wavelength does the spectral emittance of the bulb peak? [3]

   (c) Explain why incandescent light bulbs are not a very efficient source of visible light. [2]

3. Answer the following questions for a one-dimensional particle-in-a-box (infinite square-well).

   (a) What is the excitation energy from the ground level ($n$ = 1) to the second excited level ($n$ = 3) for an electron confined to a box that has a width of 1.20 nm. [3]

   (b) What is the wavelength of this photon that excites the electron from the ground level ($n$ = 1) to the second excited level ($n$ = 3)? [3]

4. The potential-energy function $U(x)$ is zero in the interval $0 \leq x \leq L$ and has the constant value $U_0$ everywhere outside this interval. An electron is moving past this square well. The electron has energy $E = 8U_0$. What is the ratio of the de Broglie wavelength of the electron in the region $x > L$ to the wavelength for $0 < x < L$? [4]

5. Answer the following for the wavefunction $\psi(x) = A\cos\frac{\sqrt{2mE}}{\hbar}x + B\sin\frac{\sqrt{2mE}}{\hbar}x$.

   (a) Calculate $\frac{d^2\psi}{dx^2}$. [3]

   (b) Show that the wavefunction is a solution of the equation $-\frac{\hbar^2}{2m}\frac{d^2}{dx^2}\psi(x) = E\psi(x)$. [3]

6. A hydrogen atom in a 3p state is placed in a uniform external magnetic field $\vec{B}$. Consider the interaction of the magnetic field with the atom's orbital magnetic dipole moment.

   (a) What field magnitude $B$ is required to split the 3$p$ state into multiple levels with an energy difference of $2.48\times10^{-5}$ eV between adjacent levels? [3]

   (b) How many levels will there be? [2]

7. The doubly charged ion $N^{++}$ is formed by removing two electrons from a nitrogen atom.
   (a) What is the ground-state electron configuration for the $N^{++}$ ion? [3]

   (b) Estimate the energy of the least strongly bound level in the L shell of $N^{++}$. [3]

8. Determine the Fermi energy of potassium by making the simple approximation that each atom contributes one free electron. The density of potassium is 851 kg/m$^3$, and the mass of a single potassium atom is $6.49\times10^{-26}$ kg. [3]

9. For a certain p-n junction diode, the saturation current at room temperature (20° C) is 0.950 mA.
   (a) What is the resistance of this diode when the voltage across it is 86.0 mV? [3]

   (b) What is the resistance of this diode when the voltage across it is -50.0 mV? [3]

**END OF EXAMINATION**