※選擇題請在答案卡內作答，非選擇題請在答案卷內作答

(一)單選題：1~8 題 每題 5 分，答錯倒扣 1.25 分，共 40 分 倒扣至本大題(即單選題) 0 分為止。

1. For a muon with a half lifetime $\tau_{1/2} = 2.7726\times10^{-6}\,s$ and a mass of 250 m_e, (m_e : mass of an electron) moving with a speed of $\upsilon = 0.8\ c$, calculate the mean lifetime τ_0, the traveling distance d measured at rest, during τ_0, the relativistic momentum P by the unit of eV/c, the de-Broglie wavelength λ_d, the phase velocity υ_p, the total energy E and kinetic energy (KE) in the unit of eV.

(A) $\tau_0 = 3.8\times10^{-6}s,\ d = 1519\ m,\ P = 102.2\ MeV/c,\ \lambda_d = 1.2131\times10^{-14}m,\ KE = 35.86\ MeV$

(B) $\tau_0 = 4.5\times10^{-6}s,\ d = 1798\ m,\ P = 102.2\ MeV/c,\ \lambda_d = 1.2131\times10^{-14}m,\ KE = 40.887\ MeV$

(C) $d = 1599\ m,\ P = 113.58\ MeV/c,\ \lambda_d = 1.092\times10^{-14}m,\ KE = 43.18\ MeV$

(D) $d = 1599\ m,\ \lambda_d = 7.2786\times10^{-15}m,\ KE = 85.18\ MeV$

(E) $\tau_0 = 4.5\times10^{-6}s,\ d = 1798\ m,\ \lambda_d = 1.2131\times10^{-14}m,\ \upsilon_p = 3.7475\times10^{8}m/s$

2. For an electron and a neutron with two conditions of kinetic energies : KE=1.0 MeV and 1.0 GeV (M=10^6, G=10^9), calculate the momentum P, de-Broglie wavelength λ_d, the particle velocity υ, and phase velocity υ_p

(A) For an electron with KE= 1.0 MeV, $P = 8.426\ MeV/c,\ \lambda_d = 1.472\times10^{-13}m,\ \upsilon_p = 1.5155\times10^{8}m/s$

(B) For an electron with KE= 1.0 GeV, $P = 266.44\ MeV/c,\ \lambda_d = 4.654\times10^{-15}m,\ \upsilon_p = 4.7925\times10^{6}m/s$

(C) For a neutron with KE= 1.0 GeV, $P = 11.43\ GeV/c,\ \lambda_d = 1.0852\times10^{-16}m,\ \upsilon_p = 2.0553\times10^{8}m/s$

(D) For a neutron with KE= 1.0 MeV, $P = 361.34\ MeV/c,\ \lambda_d = 3.4316\times10^{-15}m,\ \upsilon = 1.3829\times10^{7}\ m/s$

(E) For a neutron with KE=1.0 GeV, $P = 1.697\ GeV/c,\ \lambda_d = 7.3067\times10^{-16}m,\ \upsilon = 2.6226\times10^{8}m/s$

Electron rest mass	$m_e = 9.1095\times10^{-31}kg$
Proton rest mass	$m_p = 1.6726\times10^{-27}kg$
Neutron rest mass	$m_n = 1.6750\times10^{-27}kg$
Hydrogen atomic mass	$M_H = 1.6736\times10^{-27}kg$
lightv elocity	$c = 2.998\times10^{8}\ m/s$
Electron charge	$e = 1.602\times10^{-19}Coul$
Planck's constant	$h = 6.626\times10^{-34}J\cdot s = 4.1361x10^{-15}eV\cdot s$
Permittivity of free space	$\varepsilon_0 = 8.854\times10^{-12}F/m$

注意：背面有試題

3. Which of the following represents the correct kinetic energy that an electron would have in the scenario of nuclear beta decay, where electrons are observed to be ejected from the atomic nucleus? Suppose we assume that electrons are somehow trapped within the nucleus, occasionally escaping and being observed in the laboratory. With a typical nucleus diameter of 10^{-14} m, use the uncertainty principle to estimate the range of kinetic energies.

(A) 11 MeV
(B) 15 MeV
(C) 19 MeV
(D) 23 MeV
(E) 30 MeV

4. In hydrogen electrons in 2s and 2p state have the same……(choose the right answer)

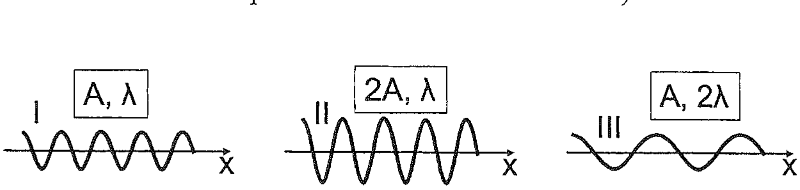
(A) Total energy
(B) Average radius
(C) Angular momentum
(D) More than one of the above is the same
(E) None of the above is the same

5. The Heisenberg Uncertainty Principle is generally applied to very small objects such as electrons and protons. Which of the following statements best explains why don't we use uncertainty principle on larger objects such as cars and tennis balls?

(A) The errors of a measurement can always, in principle, be made smaller by using more sensitive equipment.
(B) Large objects at any instant of time have an exact position and exact momentum and with sufficient care we can measure both precisely.
(C) Large objects obey Newton's laws of motion, to which the uncertainty principle does not apply.
(D) Because it does apply to large objects, but the uncertainties are so small that we don't notice them.
(E) None of above is correct.

6. Rank the velocity of the particles, whose de Broglie waves shown in the figure below ("A" amplitude, and wavelength of the de Broglie waves. All three particles have the same mass.)

(A) II > I > III
(B) II > I = III
(C) III > II = I
(D) III > II > I
(E) II = I > III



注意：背面有試題

7. Consider the states of a negatively charged hydrogen ion $H^{(-)}$. Which of the following states violates the Pauli exclusion principle?

(A) 2 electrons both occupying the 1s orbital and carrying opposite spins
(B) 1 electron occupying 1s and the other 2s and both carrying the same spin
(C) 1 electron occupying 1s and the other 2s and both carrying opposite spins
(D) 2 electrons both occupying $2p_x$ and carrying the same spin
(E) None of the above

8. Consider two spineless, non-interacting particles with identical mass confined in an infinite quantum well. Let E_0 and E_1 denote ground and first excited states, respectively, of a single particle in the well. Which of the following states is not the correct lowest energy state of the two particles?

(A) Both particles being in E_0 in the case of identical classical particles;
(B) One particle being in E_0 and the other in E_1 in the case of distinct Fermi particles;
(C) Both particles being in E_0 in the case of identical Bose particles;
(D) Both particles being in E_0 in the case of one Fermi and one Bose particles;
(E) None of the above.

注意：背面有試題

類組：電機類　科目：近代物理(300F)　

(二)複選題：9~16題 每題5分，答錯倒扣1.0分，共40分 多個答案，全對才給分。倒扣至本大題(即複選題)0分為止。

9. Initially, there are two pairs of electron and positron moving under two conditions : one pair of electron-positron move at the same velocity of 0.6c, side-by-side in the same direction, the other pair of electron and positron move toward each other in an opposite direction with the velocity of -0.6c and 0.8c (c : light velocity). Finally, in the same system, each pair of electron and positron merge together, thus annihilate each other, and totally two photons are generated. Calculate the energies E_{e-}, E_{e+}, momenta P_{e-}, P_{e+} and de-Broglie wavelengths λ_d of the electron and positron, two photons move in the same or opposite directions ? the momenta of two photons, p_1 *and* p_2, the wavelengths λ_1 *and* λ_2, and the energies of two photons E_{p1} *and* E_{p2}

(A) For positron $\upsilon = 0.8c : P_{e+} = 408.87\ KeV/c,\ \lambda_d = 3.033\times10^{-12} m;\ \upsilon = 0.6c : P_{e+} = 306.65\ KeV/c$

(B) For electron $\upsilon = 0.6c : E_{e-} = 638.86\ KeV,\ P_{e-} = 383.32\ KeV/c,\ \lambda_d = 3.235\times10^{-12} m$

(C) Two photons move off in the opposite directions $p_1 = 894.4\ KeV/c,\ p_2 = -596.3\ KeV/c$

(D) Two photons move off $p_1 = 1022\ KeV/c,\ p_2 = -255.5\ KeV/c;\ E_{p1} = 1022\ KeV,\ E_{p2} = 255.5\ KeV$

(E) Two photons move off in the opposite directions $p_1 = 1.9166\ MeV/c,\ p_2 = -851.8\ KeV/c$

$\lambda_1 = 6.4698\times10^{-13} m,\ \lambda_2 = 1.4557\times10^{-12} m$

10. For a neutron with kinetic energy, KE=188 KeV, calculate the velocity υ_n and uncertainty of the position Δx to measure this neutron ? for an electron with the same Δx, calculate the minimum energy E, kinetic energy KE, momentum P_e, velocity υ_e, and the maximum De-Broglie wavelength λ_d.

(A) For a neutron with KE=188 KeV, $\upsilon_n = 5.998\times10^6 m/s,\ \Delta x \ge 4.199\times10^{-14} m$

(B) For an electron with the same Δx, $KE \ge 1.894\ MeV,\ P_e = 2.35 Mev/c,\ \lambda_d = 5.2766\times10^{-13} m$

(C) For an electron with the same Δx, $KE \ge 8.903\ MeV,\ P_e \ge 9.4\ MeV/c,\ \lambda_d \le 1.319\times10^{-13} m$

(D) For an electron with the same Δx, $E \ge 9.414\ MeV,\ \upsilon_e \ge 0.9985\ c$

(E) For an electron with the same Δx, $\Delta x \ge 2.0995\times10^{-14} m,\ P_e \ge 4.7\ MeV/c,\ \lambda_d \le 2.64\times10^{-13} m$

Electron rest mass	$m_e = 9.1095\times10^{-31} kg$
Positron rest mass	$m_{e+} = 9.1095\times10^{-31} kg$
Proton rest mass	$m_p = 1.6726\times10^{-27} kg$
Neutron rest mass	$m_n = 1.67545\times10^{-27} kg$
light velocity	$c = 2.998\times10^8\ m/s$
Electron charge	$e = 1.602\times10^{-19} Coul$
Planck's constant	$h = 6.626\times10^{-34} J\cdot s$
	$h = 4.1361x10^{-15} eV\cdot s$
Permittivity of free space	$\varepsilon_0 = 8.854\times10^{-12} F/m$

注意：背面有試題

台灣聯合大學系統113學年度碩士班招生考試試題

類組：電機類　科目：近代物理(300F)　

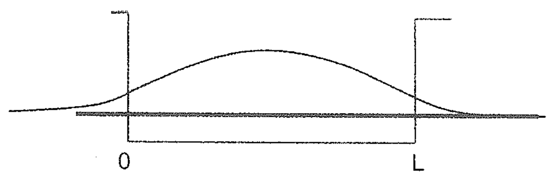
11. Choose the correct statements about photoelectric effect and properties of photons:

(A) The Maxwell equation can perfectly explain the photoelectric effect.
(B) The photoelectric effect shows that light comes in quantized chunks of energy.
(C) The wavelength of a beam of light is increased but the intensity of light remains unchanged. In this situation, there are more incident photons per second but each photon has less energy.
(D) The work function of metal can be measured by using the photoelectric effect.
(E) If a piece of metal has a work function of 2.755 eV, photoelectrons can be emitted when it is illuminated with light with a wavelength of 500 nm.

12. The Davisson-Germer experiment demonstrated the following (choose the correct answers):

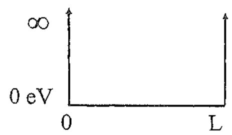
(A) Photons exhibit wave-like characteristics.
(B) Electrons exhibit wave-like characteristics.
(C) Electrons or photons exhibit energy in discrete chunks.
(D) Electrons or photons have well-defined energy.
(E) Verified the de Broglie relation.

13. There is a particle confined within a square well potential, as depicted in the figure. The kinetic energy (KE) of the particle is lower than the potential energy of the well, effectively confining the particle within it. What modifications could be made to enhance the penetration of the particle (de Broglie wave) into the classically forbidden region?



(A) Decrease potential depth
(B) Increase potential depth
(C) Decrease the length of the square well, L
(D) Increase the length of the square well, L
(E) Not possible to enhance the particle penetration

14. You want to calculate electron waves $\psi(x)$ in a thin wire (1-dimensional). What if the potential outside the wire were infinite? Which of the following statements are correct in this scenario?



mathematically
$V(x) = \infty$ for $x<0$ and $x>L$
$V(x) = 0$ eV for $0>x<L$

(A) The allowed kinetic energies of electrons should be quantized.
(B) $\psi(x) \approx 0$ everywhere
(C) $\psi(x) \approx 0$ everywhere, except for $0<x<L$.
(D) $\psi(x) = 0$ everywhere, except for $0<x<L$
(E) Can't tell anything yet. Need to find $\psi(x)$ first.

15. Consider energy bands in a crystal. Which of the following statements are correct?

(A) The conduction band of a metal is partially filled by electrons.
(B) Existence of energy gap is a manifestation of quantum mechanical phenomenon.
(C) Intrinsic semiconductors cannot conduct electricity at all even at high temperatures.
(D) Doped semiconductors can conduct electricity primarily with the carriers in the conduction band or holes in the valence band.
(E) All of the above.

注意：背面有試題

16. Consider a p-n diode. Which of the following statements are correct?

(A) Electrons on the n side and holes on the p side will flow towards each other and recombine until all the carriers are neutralized.
(B) When the diode is forward biased, both electron current and hole current will flow in the diode contributing to the overall current.
(C) When the diode is reverse biased, the current in the diode is essentially negligible if there is any.
(D) A good quality diode can be easily formed by mechanically compressing p- and n- type semiconductors into close contact.
(E) All of the above.

(三)計算題：17~18 題 每題 10 分，共 20 分

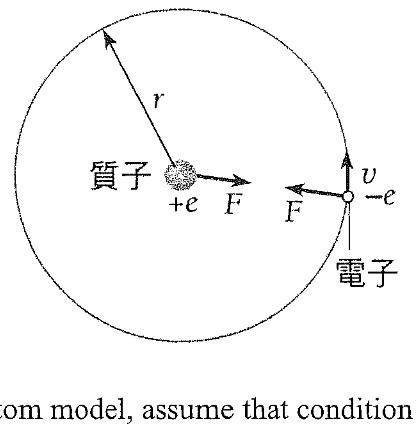
計算題應詳列計算過程，
無計算過程者不予計分

Problem17:

(A) (2%) Write entire one dimensional Schrodinger's equation.
(B) (4%) Derive the **time-dependent part** of one dimensional Schrodinger's equation by variable separation method.
(C) (4%) Derive the **time-independent (space) part** of one dimensional Schrodinger's equation.

Problem 18:

(A) (5%) Consider the Rutherford Hydrogen atom model as following figure , show that the total energy of hydrogen atom is $E = -\frac{e^2}{8\pi\varepsilon_0 r}$



(B) (5%) Consider the Bohr Hydrogen atom model, assume that condition for orbit stability is

$n\lambda = 2\pi \cdot r_n$ where $\lambda = \frac{h}{mv}$. Show that the Bohr Hydrogen atom model's Energy levels is

$$E_n = -\frac{me^4}{8\varepsilon_0^2 h^2}\left(\frac{1}{n^2}\right)$$

注意：背面有試題