※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：共10題，每題4分，答錯倒扣1分，倒扣至該大題0分為止。

1. Select the correct formula of Doppler effect with observed and source frequencies defined as ν_{obs} and ν_s, and correct solutions under specified conditions

(A) Observer approaching the source with the velocity of υ: $\nu_{obs}=\frac{\sqrt{1+(\upsilon/c)^2}}{\sqrt{1-(\upsilon/c)^2}}\nu_s$, c: *light velocity*

(B) Observer receding the source with the velocity of υ: $\nu_{obs}=\frac{\sqrt{1-(\upsilon/c)^2}}{\sqrt{1+(\upsilon/c)^2}}\nu_s$, c: *light velocity*

(C) Observer approaching the source with the velocity of υ: $\nu_s=4.0\times10^{14}Hz$, $\nu_{obs}=5.0\times10^{14}Hz$, can be achieved at $\upsilon=0.2c$ and $\gamma=1.025$

(D) Observer receding the source with the velocity of υ: $\nu_s=5.0\times10^{14}Hz$, $\nu_{obs}=4.0\times10^{14}Hz$, can be achieved at $\upsilon=0.2c$ and $\gamma=1.025$

(E) Observer approaching the source with the velocity of υ: $\nu_s=3.0\times10^{14}Hz$, $\nu_{obs}=4.0\times10^{14}Hz$, can be achieved at $\upsilon=0.28c$

2. A spacecraft is moving relative to the earth. An observer on the earth finds that, between 1 P.M. and 2 P.M. according to her clock, 3601 seconds elapse on the spacecraft's clock. What is the spacecraft's speed relative to the earth?

(A) 5.6×10^6 m/s

(B) 7.1×10^6 m/s

(C) 1.2×10^7 m/s

(D) 1.7×10^7 m/s

(E) 1.2×10^8 m/s

3. An electron collides with a hydrogen atom in its ground state and excites it to a state of n = 3. How much energy was given to the hydrogen atom in this inelastic collision?

(A) 13.6eV

(B) 12.1eV

(C) 11.3eV

(D) 10.2eV

(E) 9.6eV

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4. For metals with specified work function Φ_0, subject to exposure of light with different wavelengths or frequencies

(A) For metal with Φ_0 =3.72eV, the maximum wavelength required to stimulate the photoelectron emission is λ_{max} =350 nm, which is the kind of ultra-violate (UV)

(B) For metal with Φ_0 =2.48eV, the maximum wavelength required to stimulate the photoelectron emission is λ_{max} =480 nm, which is blue light

(C) For metal with Φ_0 =3.875eV, UV light with $\lambda \leqq 320$ nm is necessary to stimulate the photoelectron emission. Under the exposure of light with λ =155 nm, the photoelectrons emitted from this metal can have the maximum kinetic energy of 4.125eV

(D) For metal with Φ_0 =2.48eV, visible light with $\lambda \leqq 500$ nm is necessary to stimulate the photoelectron emission. Under the exposure of light with λ =248 nm, the photoelectrons emitted from this metal can have the maximum kinetic energy of 2.72eV

(E) The increase of exposure light intensity can increase the photoelectrons numbers and energy

5. A photon with energy E_0 = 1 MeV collides with a free electron and scatters through an angle of 90°. What is the energy of the scattered photon?

(A) 1/3 MeV

(B) 1/2 MeV

(C) 1 MeV

(D) 2 MeV

(E) 3 MeV.

6. The following wave-function $\psi(x)$ candidates are all zero for $|x| > 1$ and only non-zero for the interval $-1 < x < 1$. Without knowing anything about the system and its potential, which of the following $\psi(x)$ is a possible solution to the time-independent Schrödinger equation?

(A) All wave functions $\psi(x)$ below are possible solutions

(B) $\psi(x) = 1 - |x|$

(C) $\psi(x) = 3x^2 - 1$

(D) $\psi(x) = \sin(\pi x)$

(E) $\psi(x) = 3.75(x^2 - x^4)$

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7. Choose the correct combination of the answers in the parentheses below.

Suppose a particle of mass m is in a one-dimensional box of length L. We assume that the particle can move freely in the box and the collision of the particle with the wall is an elastic collision. The average momentum of the particle is ((a)). Using the uncertainty principle $\Delta x \Delta p_x \geq \hbar$, we can estimate the ground state energy of this system $E =$((b)). The probability that the particle can be found between 0.45L and 0.55L for the ground state is ((c))%.

(A) (a) $\frac{\pi\hbar}{L}$, (b) $\frac{\hbar}{2mL^2}$, (c) 9.8

(B) (a) $\frac{\pi\hbar}{L}$, (b) $\frac{\hbar^2}{2mL}$, (c) 10.0

(C) (a) 0, (b) $\frac{\hbar}{8mL}$, (c) 10.0

(D) (a) 0, (b) $\frac{\hbar^2}{2mL^2}$, (c) 19.8

(E) (a) 0, (b) $\frac{\hbar^2}{8mL^2}$, (c) 19.8

8. If the wavefunction of a particle is given by $\psi(x) = \sqrt{a}\exp(-a|x|)$ (a: the real and positive constant) is given, calculate the probability of finding the particle in the region of $|x| < L$.

(A) 0

(B) 1

(C) $\exp(2aL)$

(D) $\frac{1}{2}[\exp(2aL) - \exp(-2aL)]$

(E) $1 - \exp(-2aL)$

9. Consider electron transmission in the step potential given by $V(x < 0) = V_0 > 0$, $V(x > 0) = 0$. Let the region with $x < 0$ be the source electrode and that with $x > 0$ be the drain electrode, and the electron wave function

$\psi(x<0) = e^{ikx} + re^{-ikx}$,

$\psi(x>0) = te^{ik'x}$,

where k and k' are the corresponding electron wave vectors. Moreover, let E(electron energy) > 0, T = transmission coefficient, and R = reflection coefficient. Which of the following is true?

(A) $T = 1$

(B) $R > 0$

(C) $T = |t|^2$

(D) $R = |r|^2\, k / k'$

(E) None of the above

10. Consider the Fermi-Dirac distribution $f(E;\mu,T)=1/[e^{(E-\mu)/k_BT}+1]$ for a metal, where E = electron energy, T = temperature, and $\mu=O(eV)$. Which of the following is wrong?
(A) At T = 300 K, f approaches 1 for E substantially below k_BT.
(B) For $E-\mu<<k_BT$, f approaches 1.
(C) For T << 300 K, f approaches 1.
(D) For $E-\mu>>k_BT$, f approaches 0.
(E) $\mu(T=0\text{ K})$ is identical to the Fermi energy.

(二)複選題：共 10 題，每題 4 分，答錯倒扣 0.8 分，倒扣至該大題 0 分為止。

11. A muon has a lifetime of $5.00\times10^{-8}s$ and a mass of $200\ m_e$. This muon is moving with a speed of $\upsilon=0.94\ c$. Please calculate the traveling distance d, the relativistic momentum P, the de-Broglie wavelength λ_d, the total energy and kinetic energy (KE) by the unit of eV, and the wavelengths of a photon with the same kinetic energy KE λ_{KE} or the same momentum P, λ_p
(A) The traveling distance measured at rest is $d=40.5m$
(B) The relativistic momentum is $P=281.63\ Mev/c$
(C) The de-Broglie wavelength is $\lambda_d=5.75\times10^{-15}m$
(D) The total energy and kinetic energies are $E=325.6\ Mev,\ KE=199.4\ Mev$
(E) The wavelengths of photon with the same P or the same KE: $\lambda_{KE}=6.28\times10^{-15}m, \lambda_p=4.4\times10^{-15}m$

12. Choose the correct description below.
(A) Electromagnetic waves are coupled electric and magnetic oscillations that move with the speed of light and exhibit typical wave behavior.
(B) A moving body behaves in certain ways as though it has a wave nature
(C) Photons can behave as they have gravitational mass.
(D) The probability of experimentally find the body described by the wave function $\psi(x,y,z)$ at the time t is proportional to the value of $|\psi|$.
(E) The greater the quantum number, the closer quantum physics approaches classical physics

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13. A mixture of ordinary hydrogen and tritium, a hydrogen isotope whose nucleus is 3 times more massive than the ordinary hydrogen, is excited and its spectrum observed. The wavelengths of the H lines ($n_i=6,\ n_f=2$ in Balmer series) of the ordinary hydrogen and tritium, λ_H and λ_T, and the difference $\Delta\lambda=\lambda_H-\lambda_T$

(A) $\lambda_H=387.4475\ nm, \lambda_T=387.2866\ nm,\ \Delta\lambda=\lambda_H-\lambda_T=0.1609 nm$

(B) $\lambda_H=410.5164\ nm,\ \lambda_T=410.3675\ nm$

(C) $\lambda_H=422.3264\ nm,\ \lambda_T=422.1775\ nm$

(D) $\Delta\lambda=\lambda_H-\lambda_T=0.1489\ nm$

(E) *For* $n_i=6,\ n_f=1$ in Lyman series $\lambda_H,\ \lambda_T,\ \Delta\lambda$ are reduced by a factor of 4 compared to those of the Balmer series

14. An electron is in a box of 0.1 nm across, which is the order of magnitude of atomic dimensions. What are the permitted energies?

(A) 38 eV

(B) 108 eV

(C) 152 eV

(D) 342 eV

(E) 508 eV

15. Assume that a laser beam with 2 mW of power and a wavelength of 311 nm is incident on a metal photo-cathode. If the electrons emitted from the photo-cathode have a maximum velocity of 0.002 c, which of the following statements are correct?

(A) The number of photons incident is $2\text{x}10^{15}$ per second.

(B) If the quantum efficiency of the photo-cathode is 75%, the number of electrons leaving the metal per second is $2.35\text{x}10^{15}$.

(C) The maximum kinetic energy of the ejected electrons is 1.02 eV.

(D) The work function of the metal is 2.98 eV.

(E) If the power of the laser were double, the number of electrons leaving will double; and, the maximum kinetic energy of the outgoing electrons will also double.

※選擇題請在答案卡內作答，非選擇題請在答案卷內作答

16. Which of the following statements are correct?

(A) The Millikan oil-drop experiment yielded independent measurements of the mass and charge of the electron.

(B) The photoelectric-effect experiment is credited with establishing that light carries momentum.

(C) The Blackbody radiation experiment provided the first evidence for the quantization of energy.

(D) It had been known that electron orbits were unstable was a fundamental problem for the Rutherford model of the atom.

(E) All statements are correct.

17. Choose the correct statements below.

(A) Consider a particle is confined in a box of the length L along the x-axis. The potential V is $V = 0$ $(0 < x < L)$ and $V = \infty$ $(x \leq 0, x \geq L)$. The wavefunction of the particle can penetrate slightly in the region of $x \leq 0$ and $x \geq L$ due to the tunnel effect.

(B) In the harmonic oscillator model, the spacing between the neighboring energy levels is hv, where h is the Planck's constant and v is the frequency.

(C) Consider a particle described by the wavefunction: $\psi = \exp(ix) + 2i\exp(i3x)$, $(-\pi \leq x \leq \pi)$. If we precisely measure the momentum of the state expressed by the wavefunction ψ, the values of the momentum are $\hbar$ and $3\hbar$. The probability for the momentum $\hbar$ is 1/5, and the probability for $3\hbar$ is 4/5.

(D) The term symbol of the ground state of sodium is $3^2S_{1/2}$ and that of its first excited state is $3^2P_{1/2}$

(E) Consider the normal Zeeman effect applied to the 3d to 2p transition of the hydrogen atom. In a magnetic field, we can expect five lines appear in the spectrum.

18. Consider metals, semiconductors, and insulators. Which of the following statements are true?

(A) An undoped semiconductor is an insulator.

(B) A light doping can turn a semiconductor into a metal with high electrical conductivity.

(C) The existence of energy gap in semiconductors is a manifestation of quantum phenomena.

(D) An undoped semiconductor can never absorb any EM waves.

(E) All of the above are true.

19. Which of the following statements are true?

(A) Electron energy in a system is always discrete due to the quantum nature of electrons.

(B) A particle of mass "*m*" moving in a parabolic potential $V(x) = -1/2\ m\ w^2\ x^2$ ($k > 0$) has energy levels given by "$(n+1/2)\ \hbar w$" (n = 0, 1, 2,.....).

(C) In an infinite square well potential of size L, a particle with wave length $\ll L$ exhibits nearly classical behavior.

(D) Electrons are Fermi particles with spin 1/2, which means they always have a spin either up or down in the *z*-direction when measured.

(E) None of the above.

20. Choose the correct statements below.

For (A) and (B): In the Stern-Gerlach experiment, a beam of neutral silver (Ag) atoms from an oven is directed into a magnetic field and a photographic plate records the spot of the beam after it passes through the field.

(A) To observe two distinct spots on the photographic plate, a homogeneous magnetic field is required instead of an inhomogeneous magnetic field.

(B) The entire magnetic moment of an Ag atom is due to the spin of only one of its electrons, because the configuration of the electrons in an Ag atom is as follows:

Ag: $(1s)^2(2s)^2(2p)^6(3s)^2(3p)^6(3d)^{10}(4s)^1$ and the orbital angular quantum number $\ell = 0$.

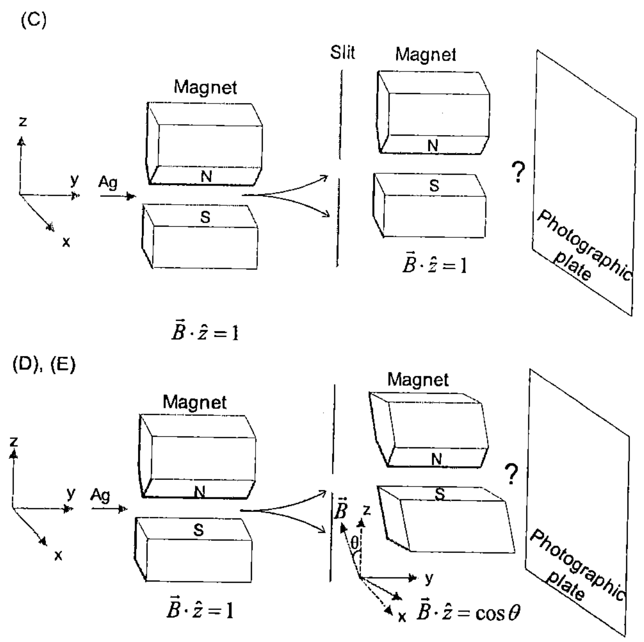
For (C)–(E): Suppose the Stern-Gerlach experiment is carried out sequentially, that is, so called Double Stern-Gerlach experiments. One of the two distinct beams is selected after they pass through the first magnetic field and let the selected beam pass the second magnetic field.

(C) If the second magnetic field is the same direction as the first field, we can still expect two spots on a photographic plate when the selected beam passes through the second field.

(D) If the second magnetic field is tilted from the first field around the y-axis, we can still expect two spots on a photographic plate when the selected beam passes through the second field.

(E) Suppose an Ag atom has the magnetic moment μ_B, the expectation value of the magnetic moment for the direction of the second magnetic field is $\mu_B \cos\theta$

※選擇題請在答案卡內作答，非選擇題請在答案卷內作答



(三)非選擇題：共 2 題，每題 10 分

21. (10%) There are **three statistical distribution function** of statistical mechanics

(a). (4%) Give each distribution function formula.

(b). (3%) Give the category of particles for each statistical distribution.

(c). (3%) Give an example for each statistical distribution application, respectively.

22. (10%) The electrons move in a metal under an electrical field.

(a). (2%) Draw a proper figure to describe the electron drift velocity.

(b). (4%) Determine the electron drift velocity (v_d) formula of metal.

(c). (4%) Determine the resistivity (ρ) of metal.

Parameters

Electron mass	$m_e = 9.1095\times10^{-31}\ kg$
Hydrogen atomic mass	$M_H = 1.6736\times10^{-27}\ kg$
Electron charge	$e = 1.602\times10^{-19}\ Coul$
Planck's constant	$h = 6.626\times10^{-34}\ J\cdot s$
Light velocity	$c = 2.998\times10^{8}\ m/s$
Permittivity of free space	$\varepsilon_0 = 8.854\times10^{-12}\ Coul/V\cdot m$