類組：物理類　科目：近代物理(2003)　※請在答案卡內作答

Part A: 單一選擇題，(每題5分，共60分，每題答錯倒扣一分)

1. Which gives the correct form of the relativistic energy and momentum? Here, m, v, c are the rest mass, speed of motion relative to observer, and the speed of light, respectively, and $\gamma^{-1}=\sqrt{1-\frac{v^2}{c^2}}$.

(A) $E=\gamma mc^2, p=rmv$ (B) $E=\frac{\gamma c^2}{2m}, p=\frac{mc^2}{2}$ (C) $E=\frac{m\gamma v^2}{2}, p=\gamma mv$ (D) $E=\frac{1}{2}mv^2, p=mv$ (E) $E=mc^2, p=mc$

2. In 1905 Lennard obtained the following results from his experiment of the photoelectric effect. "The maximum kinetic energy of the photoelectrons depends solely on the (a), not on the (b). The number of the photoelectrons are proportional to the (c). There is no measurable time delay between irradiation and electron ejection." Which of the followings shows the correct combination of words filled in the blanks in the above statements?
(A) (a) phase, (b) wavelength, (c) temperature
(B) (a) wavelength, (b) frequency, (c) intensity
(C) (a) wavelength, (b) intensity, (c) intensity
(D) (a) intensity, (b) temperature , (c) wavelength
(E) (a) intensity, (b) phase, (c) wavelength

3. A photon with a wavelength λ is scattered by an electron, and the wavelength is increased to λ' due to the Compton effect. Let h, c, and m be the Plank constant, the speed of light, and the rest mass of the electron, respectively. The recoil kinetic energy of the scattered electron is equal to

(A) $K=h(\omega-\omega')$ (B) $K=h(\lambda'-\lambda)$ (C) $K=\left(\frac{h}{mc}\right)(1-\cos\theta)$ (D) $K=hc\left(\frac{1}{\lambda}-\frac{1}{\lambda'}\right)$ (E) $K=\frac{1}{2}m\lambda^2$.

4. In quantum mechanics, physical quantities are represented by operators. Which of the followings show the energy and momentum operators?

(A) $\hat{E}=-i\hbar\frac{\partial}{\partial t}, \hat{p}=i\hbar\frac{\partial}{\partial x}$ (B) $\hat{E}=i\hbar\frac{\partial}{\partial t}, \hat{p}=\frac{\hbar^2}{2m}\frac{\partial^2}{\partial x^2}$ (C) $\hat{E}=-i\hbar\frac{\partial^2}{\partial t^2}, \hat{p}=i\hbar\frac{\partial^2}{\partial x^2}$ (D) $\hat{E}=i\hbar\frac{\partial}{\partial x}, \hat{p}=i\hbar\frac{\partial}{\partial t}$
(E) $\hat{E}=i\hbar\frac{\partial}{\partial t}, \hat{p}=-i\hbar\frac{\partial}{\partial x}$

5. Consider a step function

$$V(x)=\begin{cases}0 & (x<0)\\ V_0 & (x\geq 0)\end{cases},$$

and the solution of the time-independent Schrodinger equation ($E>V_0$) satisfying the boundary conditions, $\lim_{x\to-\infty}\psi(x)=A\exp(ikx)+B\exp(-ikx)$, and $\lim_{x\to\infty}\psi(x)=C\exp(ik'x)$. The reflection probability $R=\left|\frac{B}{A}\right|^2$ is

(A) $R=\left|\frac{2k'}{k+k'}\right|^2$ (B) $R=\left|\frac{k-k'}{k+k'}\right|^2$ (C) $R=\left|\frac{k+k'}{k-k'}\right|^2$ (D) $R=\left|\frac{2k}{k+k'}\right|^2$ (E) $R=\left|\frac{k'}{k}\right|^2$.

6. Consider two observers $O(t,x,y,z)$ and $O'(t',x',y',z')$, each using their own Cartesian coordinate system to measure space and time intervals. Assume the y-axis is parallel to the y'-axis, and the z-axis parallel to the z'-axis. The relative velocity between the two observers is v along the common x-axis; O measures O' to move at velocity v along the coincident xx' axes. Also assume that the origins of both coordinate systems are the same, that is, coincident times and positions. Which is the correct transformation of the velocity?

(A) $v_x=\frac{-v+v_x'}{1-\frac{v}{c^2}v_x'}, v_y=\frac{v_y'}{\gamma\left(1-\frac{v}{c^2}v_y'\right)}, v_z=\frac{v_z'}{\gamma\left(1-\frac{v}{c^2}v_z'\right)}$ (B) $v_x=\frac{v_x'}{\gamma\left(1-\frac{v}{c^2}v_x'\right)}, v_y=\frac{v_y'}{\gamma\left(1-\frac{v}{c^2}v_x'\right)}, v_z=\frac{v_z'}{\gamma\left(1-\frac{v}{c^2}v_x'\right)}$

(C) $v_x=\gamma\left(v+v_x'\right), v_y=\gamma v_y', v_z=\gamma v_z'$ (D) $v_x=\frac{-v+v_x'}{1-\frac{v}{c^2}v_x'}, v_y=\frac{v_y'}{\gamma\left(1-\frac{v}{c^2}v_x'\right)}, v_z=\frac{v_z'}{\gamma\left(1-\frac{v}{c^2}v_x'\right)}$

(E) $v_x=\frac{v_x'}{\gamma\left(1-\frac{v}{c^2}v_x'\right)}, v_y=\frac{v_y'}{\gamma\left(1-\frac{v}{c^2}v_y'\right)}, v_z=\frac{v_z'}{\gamma\left(1-\frac{v}{c^2}v_z'\right)}$

7. Which of the following phenomena explain why the sky is blue?
(A) Compton scattering (B) Rayleigh scattering (C) Mie scattering (D) Rutherford scattering (E) Raman scattering

注意:背面有試題

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8. What is the product of the group velocity and the phase velocity for a relativistic particle?
(A) $\sqrt{2}c^2$ (where c is the speed of light) (B) $2c^2$ (C) c^2 (D) $c^2/\sqrt{2}$ (E) $c^2/2$

9. How many allowed transitions of the L_α line in the x-ray spectrum of a heavy atom can be found under the selection rule $\Delta l = \pm 1$, $\Delta j = 0, \pm 1$? (A) 7 (B) 8 (C) 9 (D) 10 (E) 11

10. Assuming that the sun is a perfect blackbody radiator having an effective surface temperature of 5000 K, estimate the thermal radiation intensity that we receive from the sun overhead. The sun has a radius of 7×10^8 m and is 1.4×10^{11} m away from the earth. (Hint: the Stefan-Boltzmann constant $\sigma \sim 6\times10^{-8}$ W/m^{2}K^4).
(A) 938 W/m^2 (B) 1104 W/m^2 (C) 1251 W/m^2 (D) 1382 W/m^2 (E) 1657 W/m^2

11. An UFO is escaping away from earth with a speed $v = 0.5\,c$ (where c is the speed of light). An observer on earth sends a radio message to the object when the object already travels a distance of 3×10^{11} m from earth. How long should the observer wait for the alien in the UFO to receive the message?
(A) 1000 s (B) 1455 s (C) 1850 s (D) 2000 s (E) 2455 s

12. Consider two particles, **A** and **B**, having the same rest mass m_0 and charge e, experiencing accelerating potentials of V_h and V_L, respectively. As a result, **A** moves relativistically, while **B** is still in the non- relativistic regime. Approximate the ratio of the de-Broglie wavelengths of **A** and **B** if $eV_h = m_0c^2$ (where c is the speed of light).
(A) $\sqrt{\frac{V_L}{3V_h}}$ (B) $\sqrt{\frac{2V_L}{3V_h}}$ (C) $\sqrt{\frac{V_L}{2V_h}}$ (D) $\sqrt{\frac{2V_h}{3V_L}}$ (E) $\sqrt{\frac{V_h}{3V_L}}$

Part B: 多重選擇題，(每題 5 分，共 40 分，每題單一選項答錯倒扣一分)

13. Which of the following physical quantities have the same dimension as the Plank constant?
(A) velocity (B) photon energy (C) action (D) momentum (E) angular momentum

14. A carbon atom has six electrons, and its configuration of the ground state is given by $(1s)^2(2s)^2(2p)^2$. Which of the following statements about the ground state of carbon atom are correct?
(A) Total spin is 1. (B) Total angular momentum is 1. (C) z-component of the total angular momentum is 1.
(D) It has a magnetic moment. (E) The term symbol is 2^3P_0.

15. Which of the following correspondences are true?
(A)Millikan's oil drop experiment → electron mass
(B) Rutherford scattering → nuclear fission.
(C) Electron diffraction → the de Broglie wave
(D) Michelson-Morley experiment → Atomic model
(E) Compton scattering → Photon

16. Which following Nobel laureates were awarded because of their contributions to the area of optics/photonics?
(A) Peter W. Higgs (B) Wolfgang Pauli (C) Charles Kuen Kao (D) Shuji Nakamura (E) Charles H. Townes

17. Which of the following methods could be used to generate x-rays?
(A) High-velocity electrons colliding with metal (B) Deceleration of a charged particle (C) Pair production (D) A silver atom beam passing through an inhomogeneous magnetic field (E) Irradiation of a metal with intense UV light

18. Which following sets of (principal, orbital angular momentum, magnetic, spin) quantum numbers (n, l, m_l, m_s) are allowed for a hydrogen atom?
(A) (3,1,-1,1/2) (B) (2,-1,1,-1/2) (C) (2,0,-1,1) (D) (2,0,0,1) (E) (3,2,-1,-1/2)

19. Which of the following statements are true?
(A) A massless particle always travels at the speed of light.
(B) The speed of light depends on the motion of the inertial observer.
(C) An electron can't be observed (with the aid of light) without changing its momentum.
(D) Pair production cannot occur with an isolated photon.
(E) A free electron moving in vacuum cannot emit a photon.

20. Consider the following three scattering processes of a photon: (i) through one Compton scattering of 180° scattering angle (with respect to the incident direction); (ii) through two successive Compton scatterings of 90° scattering angle each; (iii) through three successive Compton scatterings of 60° scattering angle each. In terms of the energy loss of the photon in the three scattering processes, which of the following relationships are true?
(A) (i) > (ii) (B) (i) = (ii) (C) (ii) = (iii) (D) (ii) > (iii) (E) (i) = (iii)

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