國立中山大學112學年度
碩士班暨碩士在職專班招生考試試題

科目名稱：近代物理【物理系碩士班】

—作答注意事項—

考試時間：100分鐘

- **考試開始鈴響前不得翻閱試題，並不得書寫、劃記、作答。**請先檢查答案卷（卡）之應考證號碼、桌角號碼、應試科目是否正確，如有不同立即請監試人員處理。
- **答案卷限用藍、黑色筆(含鉛筆)書寫、繪圖或標示**，可攜帶橡皮擦、無色透明無文字墊板、尺規、修正液（帶）、手錶(未附計算器者)。每人每節限使用一份答案卷，請衡酌作答(不得另攜帶紙張，亦不得使用應考證空白處作為計算紙使用)。
- 答案卡請以2B鉛筆劃記，不可使用修正液（帶）塗改，未使用2B鉛筆、劃記太輕或污損致光學閱讀機無法辨識答案者，後果由考生自負。
- 答案卷（卡）應保持清潔完整，不得折疊、破壞或塗改應考證號碼及條碼，亦不得書寫考生姓名、應考證號碼或與答案無關之任何文字或符號。
- 可否使用計算機請依試題資訊內標註為準，如「可以」使用，廠牌、功能不拘，唯不得攜帶具有通訊、記憶或收發等功能或其他有礙試場安寧、考試公平之各類器材、物品（如鬧鈴、行動電話、電子字典等）入場。
- **試題及答案卷（卡）請務必繳回，未繳回者該科成績以零分計算。**
- **試題採雙面列印，考生應注意試題頁數確實作答。**
- **違規者依本校招生考試試場規則及違規處理辦法處理。**

國立中山大學112學年度碩士班暨碩士在職專班招生考試試題

科目名稱：近代物理【物理系碩士班】　　　　　　　　　　　　　　題號：423001
※本科目依簡章規定「可以」使用計算機（廠牌、功能不拘）（選擇題）　　　　共5頁第1頁

單一選擇題，共20題，每題5分，共100分

1. An astronaut traveling with a speed $v = 0.90c$ holds a meterstick in his hand. If he measures its length, he will obtain a value of
   a. 1.0 m.
   b. 2.3 m.
   c. 0.19 m.
   d. 0.43 m.
   e. 0.81 m.

2. The quantity which does not change in magnitude from that observed in system S when observed in system S′ moving away from system S at speed v is
   a. $m\vec{\mathbf{a}}$.
   b. $m\vec{\mathbf{v}}$.
   c. $(\gamma - 1)mc^2$.
   d. $E^2 - p^2c^2$.
   e. $x^2 + y^2 + z^2$.

3. An electron ($m = 9.1 \times 10^{-31}$ kg) has a speed of $0.90c$. What is the difference between its relativistic momentum and its non-relativistic momentum (in kg m/s)?
   a. 4.3×10^{-22}
   b. 3.2×10^{-22}
   c. 5.4×10^{-22}
   d. 6.5×10^{-22}
   e. 2.5×10^{-22}

4. How much energy is in a 63-kHz photon of AM radiation (Hint : the Planck constant $h = 6.626 \times 10^{-34}\ m^2$kg/s) ?
   a. 1.0×10^{-38}J
   b. 6.6×10^{-30}J
   c. 4.2×10^{-29}J
   d. 3.1×10^{-30} J
   e. 13×10^{-29}J

5. What is the maximum velocity (in km/s) of a photoelectron emitted from a surface whose work function is 5.0 eV when illuminated by a light whose wavelength is 200 nm?
   a. 460
   b. 650
   c. 420
   d. 550
   e. 1 480

6. A neutron has a mass of 1.67×10^{-27} kg. The de Broglie wavelength is 1.4×10^{-10}m. How fast is the neutron going (in m/s)?

a. 3.4×10^3

b. 2.8×10^3

c. 3.9×10^3

d. 2.6×10^3

e. 1.7×10^3

7. Assume we can determine the position of a particle within an uncertainty of 0.5 nm. What will be the resulting uncertainty in the particle's momentum (in kg · m/s)?
   a. 1.9×10^{-25}
   b. 4.2×10^{-25}
   c. 1.1×10^{-25}
   d. 1.3×10^{-24}
   e. 6.6×10^{-25}

8. The average position, or expectation value, of a particle whose wave function $\psi(x)$ depends only on the value of x, is given by $< x > =$
   a. $\int_{-\infty}^{+\infty} \sqrt{x}\,\Psi(x)\,dx.$
   b. $\int_{-\infty}^{+\infty} x\Psi(x)\,dx.$
   c. $\int_{-\infty}^{+\infty} \frac{x}{2}\Psi^2(x)\,dx.$
   d. $\int_{-\infty}^{+\infty} \frac{x}{2}\Psi(x)\,dx.$
   e. $\int_{-\infty}^{+\infty} x|\Psi(x)|^2\,dx.$

9. The wave function $\psi(x)$ of a particle confined to $0 \le x \le L$ is given by $\psi(x) = Ax$. $\psi(x) = 0$ for $x < 0$ and $x > L$. When the wave function is normalized, the probability density at coordinate x has the value
   a. $\frac{2}{L^2}x.$
   b. $\frac{2}{L^2}x^2.$
   c. $\frac{2}{L^3}x^2.$
   d. $\frac{3}{L^3}x^2.$
   e. $\frac{3}{L^3}x^3.$

10. Find the kinetic energy (in terms of Planck's constant) of a baseball (m = 1 kg) confined to a one-dimensional box that is 25 cm wide if the baseball can be treated as a wave in the ground state.

a. $3\ h^2$

b. $2\ h^2$

c. h^2

d. $4h^2$

e. $0.5\ h^2$

11. The wave function for a particle confined to a one-dimensional box located between $x = 0$ and $x = L$ is given by $\Psi(x) = A \sin (n\pi x/L) + B \cos (n\pi x/L)$. The constants A and B are determined to be

a. $\sqrt{2/L}$, 0.

b. $\sqrt{1}/L$, $\sqrt{1/L}$.

c. 0, $\sqrt{2/L}$.

d. $\sqrt{2}/L$, $\sqrt{2/L}$.

e. $2/L$, 0.

12. The wave function for a particle in a one-dimensional box is $\Psi = A\sin\left(\frac{n\pi x}{L}\right)$. Which statement is correct?

a. This wavefunction gives the probability of finding the particle at x.

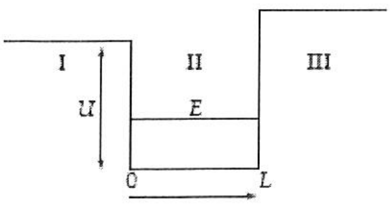
b. $|\Psi(x)|^2$ gives the probability of finding the particle at x.

c. $|\Psi(x)|^2\ \Delta x$ gives the probability of finding the particle between x and $x + \Delta x$.

d. $\int_0^L \Psi(x)dx$ gives the probability of finding the particle at a particular value of x.

e. $\int_0^L |\Psi(x)|^2 dx$ gives the probability of finding the particle between x and $x + \Delta x$.

13. A particle in a finite potential well has energy E, as shown below.



The wave function in region I where $x < 0$ has the form ψ_I =

a. $\alpha e^{-\kappa x}$.

b. $\beta e^{\kappa x}$.

c. $A \sin kx$.

d. $B \cos kx$.

e. $A \sin kx + B \cos kx$.

14. When a particle approaching a potential energy barrier has a total energy that is greater than the potential energy barrier, what is the probability that the particle will be reflected?
   a. $P < 0$.
   b. $P = 0$.
   c. $P = 1$.
   d. $P > 0$.
   e. $P = \infty$.

15. The ground state energy of a harmonic oscillator is
   a. $E = \hbar\omega$.
   b. $E = \hbar\omega/2$.
   c. $E = (2/3)\hbar\omega$.
   d. $E = 0$.
   e. $E = \hbar\omega/4$.

16. An electron in a hydrogen atom makes a transition from the $n = 3$ to the $n = 1$ energy state. Determine the wavelength of the emitted photon (in nm). ($R = 1.097 \times 10^7\ m^{-1}$)
   a. 1006
   b. 209
   c. 306
   d. 103
   e. 821

17. Suppose Bohr had chosen the potential energy of the electron in the hydrogen atom to be $V = 0$ when the electron is in the orbit with $n = 1$. He could do this by
   a. choosing $n = 1$ for the orbit where the kinetic energy of the electron is zero.
   b. adding a constant 13.6 eV to the potential energy for all values of n.
   c. adding a constant 27.2 eV to the potential energy for all values of n.
   d. subtracting a constant 13.6 eV from the potential energy for all values of n.
   e. subtracting a constant 27.2 eV from the potential energy for all values of n.

18. The radial portion of the de Broglie wavefunction for an electron in the ground state of the hydrogen atom is $\Psi_{1s}(r) = \dfrac{1}{\sqrt{\pi r_B^{\,3}}} e^{-r/r_B}$, where r_B is the Bohr radius. The probability of finding the electron is
   a. $\dfrac{1}{\pi r_B^{\,3}} \int \left(e^{-2r/r_B}\right) 4\pi r^2 dr$.
   b. $\dfrac{1}{\sqrt{\pi r_B^{\,3}}} \int \left(e^{-2r/r_B}\right) 4\pi r^2 dr$.
   c. $\dfrac{1}{\sqrt{\pi r_B^{\,3}}} \int \left(e^{-2r/r_B}\right) dr$.

d. $\frac{1}{\pi r_B^3}\int\left(e^{-2r/r_B}\right)dr$.

e. $\frac{d}{dr}\left[\frac{2}{\pi r_B^3}\left(e^{-2r/r_B}\right)\right]\left[\frac{1}{\pi r_B^3}\right]^{1/2}$.

19. Forbidden transitions and selection rules suggest that
 a. a photon has linear momentum.
 b. a photon has energy.
 c. a photon has angular momentum.
 d. a photon has parity.
 e. a photon has mass.

20. Zeke says that the magnitude of the orbital angular momentum in the hydrogen atom has the value $L = \ell\hbar$. Ruth says that the maximum magnitude of the projection of the angular momentum along the direction of a constant magnetic field vector $\vec{\mathbf{B}}$ is $\sqrt{\ell(\ell+1)}\,\hbar$. Which one, if either, is correct, and why?
 a. Ruth, because the maximum value of L is $\sqrt{\ell(\ell+1)}\,\hbar$.
 b. Ruth, because the orbital angular momentum always lines up with a magnetic field so that $\vec{\mathbf{L}}$ has its maximum value along the field.
 c. Zeke, because the maximum magnitude of $\vec{\mathbf{L}}$ is $L = \ell\hbar$.
 d. Zeke, because the orbital angular momentum always lines up with a magnetic field so that $\vec{\mathbf{L}}$ has its maximum value along the field.
 e. Neither, because they have interchanged the maximum magnitude of $\vec{\mathbf{L}}$, $\sqrt{\ell(\ell+1)}\,\hbar$, and $\ell\hbar$, its maximum projection along a magnetic field direction.

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碩士班暨碩士在職專班招生考試試題

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Single-choice questions: (20 questions in total, 5 points each)

1. Which of the following is a correct unit for Newton's gravitational constant?
(A) $\frac{\mathrm{m}^3}{\mathrm{kg}^2\cdot \mathrm{s}^2}$ (B) $\frac{\mathrm{m}^3}{\mathrm{kg}\cdot \mathrm{s}^2}$ (C) $\frac{m}{\mathrm{kg}^2\cdot \mathrm{s}^2}$ (D) $\frac{\mathrm{m}}{\mathrm{kg}\cdot \mathrm{s}^2}$

2. Which physical quantity in a system is conserved if the only force exerted on the system is a conserved force?
(A) momentum (B) angular momentum (C) mechanical energy (D) energy potential

3. If a free electron with charge $-e$ and mass m moving at speed v enters a region with a magnetic field and makes a circular motion of radius r, what is the magnitude of the magnetic field?
(A) $\frac{mv^2}{er}$ (B) $\frac{mv}{er}$ (C) $\frac{m^2v^2}{e^2r^2}$ (D) $\frac{mv}{er^2}$

4. It is known that water is considered incompressible. However, the water stream from the faucet is usually narrower at the bottom than at the top. Which of the following mechanisms best explains this phenomenon?
(A) electric force (B) magnetic force (C) mass conservation (D) momentum conservation

5. An ant of mass m rests on a stationary wheel of radius r with inertia $I = cr^2$ before moving counterclockwise with speed v. If the rotational friction of the wheel is negligible, how much angle does the wheel turn when the ant passes its original spot on the wheel for the first time?
(A) $\frac{2\pi r}{v(c+m)}$ (B) $\frac{2\pi(c-m)}{c+m}$ (C) $\frac{2\pi mr}{vc}$ (D) $\frac{2\pi m}{c+m}$

6. Assuming the exit speed of cannonballs is always the same when fired from the cannon. If the angle of the cannon is φ when aiming at a target 800 m away, what is the condition on angle θ when aiming at 300 m away?
(A) $\sin(2\theta) = \frac{3}{8}\sin(2\varphi)$
(B) $\cos(\theta) = \frac{3}{8}\cos(\varphi)$
(C) $\tan(\theta) = \frac{3}{8}\tan(\varphi)$
(D) $\tan(\theta) = \frac{9}{64}\tan(\varphi)$

7. The heat capacity of object A is three times that of object B, and the initial temperatures of object A and object B are 300 K and 600 K, respectively. What is the final temperature of both objects if they are in thermal contact and isolated from the environment?
(A) 430 K (B) 525 K (C) 400 K (D) 375 K

8. Which of the following descriptions about an inelastic collision is true?
   (A) momentum is not conserved, but kinetic energy is conserved.
   (B) total mass is not conserved, but momentum is conserved.
   (C) neither kinetic energy nor momentum is conserved.
   (D) momentum is conserved, but kinetic energy is not conserved.

9. A stationary source of sound emits a sound wave of frequency f. If a flight flies toward the source at the speed of sound, what frequency does the flight observe?
   (A) $f/2$ (B) f (C) $2f$ (D) cannot hear the sound

10. An 40-N uniform plank leans against a frictionless wall (as shown in Fig. 1). What is the torque (about point P) applied to the plank by the wall?

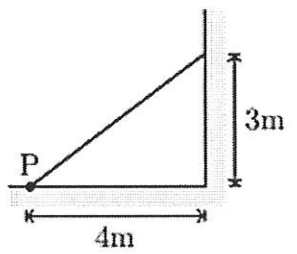

Figure 1. A plank leans on a frictionless wall.

   (A) 60 m·N (B) 30 m·N (C) 120 m·N (D) 80 m·N

11. A wooden ball floats in a fluid of density 13.5 g/mL with 20% of its volume under the fluid. What is the density of the wood?
   (A) 5.0 g/ml (B) 2.7 g/mL (C) 10.8 g/mL (D) 3.4 g/mL

12. Two identical conducting spheres with one carrying charge Q and the other neutral. What is the magnitude of the electrostatic force between the conducting spheres after they touch each other and then separate by distance r?
   (A) $\frac{Q^2}{2\pi\epsilon_0 r^2}$ (B) $\frac{Q^2}{4\pi\epsilon_0 r^2}$ (C) $\frac{Q^2}{8\pi\epsilon_0 r^2}$ (D) $\frac{Q^2}{16\pi\epsilon_0 r^2}$

13. What is the total work to move a point charge of charge q from point **a** to point **b** shown in Fig. 2? (The other two charges in the system both carry charge Q.)

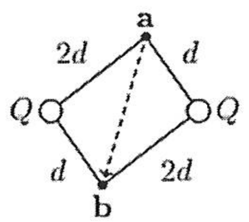

Figure 2. Moving charge from position **a** to **b**.

   (A) $\frac{qQ}{\pi\epsilon_0 d}$ (B) $\frac{5qQ}{16\pi\epsilon_0 d}$ (C) 0 (D) $\frac{5qQ}{8\pi\epsilon_0 d}$

14. A 5.0 kg package is moving at a speed of 20.0 m/s vertically upward when it explodes into three fragments: a 1.00 kg fragment is shot upward with an initial speed of 10.0 m/s and a 2.00 kg fragment is shot horizontally with an initial speed of 10.0 m/s. What is the total kinetic energy provided by the explosion?
(A) 8.0×10^2 J (B) 5.7×10^2 J (C) 2.8×10^3 J (D) 1.3×10^3 J

15. Two parallel wires, 4.0 cm apart, both carry currents of 2.0 A in the same direction. What is the force per unit length of one wire on the other? ($\mu_0 = 1.3 \times 10^{-6}\ \mathrm{N \cdot A^{-2}}$)
(A) 2.0×10^{-5} N/m, attractive
(B) 1.1×10^{-5} N/m, attractive
(C) 2.0×10^{-5} N/m, repulsive
(D) 1.1×10^{-5} N/m, repulsive

16. The magnitude of the magnetic field outside of a long ideal solenoid of n turns per unit length with current I is:
(A) 0 (B) $\mu_0 n I$ (C) $\frac{\mu_0 n}{I}$ (D) $\frac{\mu_0 I}{n}$

17. A particle with charge q is brought from far away to a point near an electric dipole. No total work is done if the final position of the particle is on:
(A) a line that is perpendicular to the dipole moment.
(B) the line through the charges of the dipole.
(C) a line that makes an angle of 45° with the dipole moment.
(D) none of the above.

18. The effective resistance from **a** to **b** in Fig. 3 is 4.0 Ω. What is the resistance of individual resistors in the circuit? (The resistances of all the individual resistors are the same.)

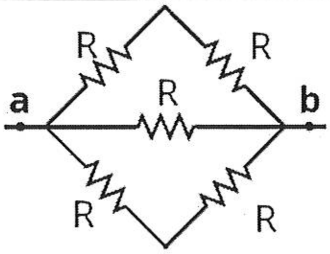

Figure 3. A circuit composed of 5 identical resistors that effectively work as a 4.0-Ω resistor.

(A) 4.0 Ω (B) 2.0 Ω (C) 8.0 Ω (D) 0.8 Ω

19. As shown in Fig. 4, an $m_1 = 1.0$ kg block is placed on top of an $m_2 = 8.0$ kg block, which lies on a frictionless surface. The coefficient of kinetic friction between the two blocks is 0.20; they are connected via a pulley and a string. A hanging block of mass $m_3 = 6.0$ kg is connected to the mass m_2 block via another pulley and string. Both strings are massless and the pulleys are frictionless. What is the acceleration magnitude of the blocks? (Gravitational acceleration $g = 9.8$ m/s^2)

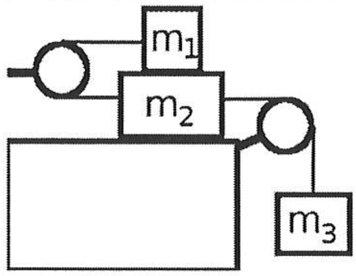

Figure 4. A system composed of three blocks, strings, and pulleys.

(A) 3.7 m/s^2 (B) 2.7 m/s^2 (C) 9.7 m/s^2 (D) 8.0 m/s^2

20. A uniform plate of mass M is placed on two fast-rotating identical wheels of radius r. The coefficients of kinetic friction between the plate and both wheels are μ, the distance between the centers of the two wheels is ℓ, the wheel on the right (left) rotates counterclockwise (clockwise) with angular speed ω (see Fig. 5), and the gravitational acceleration is denoted g. If the mass center of the plate is displaced by d from the center of the two wheels, what is the frequency the plate oscillates with? (Assuming the plate is so heavy that it always stays on the wheels.)

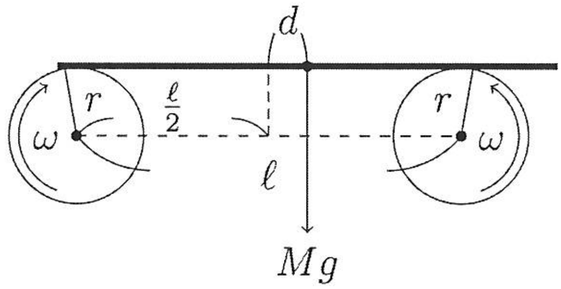

Figure 5. A plate of mass M is placed on two rotating wheels making an oscillating motion.

(A) ω (B) $\frac{\omega d}{r}$ (C) $\sqrt{\frac{2\mu g d}{\ell r}}$ (D) $\sqrt{\frac{2\mu g}{\ell}}$