國立中山大學 113 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。
- 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，唯不得攜帶書籍、紙張（應考證不得做計算紙書寫）、具有通訊、記憶、傳輸或收發等功能之相關電子產品或其他有礙試場安寧、考試公平之各類器材入場。
- 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 113 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

一、選擇題 (共 20 題，每題 5 分，滿分 100 分)

1. What is the maximum kinetic energy (in eV) of a photoelectron when a surface, whose work function is 5.0 eV, is illuminated by photons whose wavelength is 400 nm?

   A. 3.1
   B. −1.9
   C. 1.9
   D. 0
   E. 1.2

2. How much energy is in an 89.7-MHz photon of FM radiation?
   (*Hint* : The Planck constant is $h = 6.626 \times 10^{-34}\ \text{J} \cdot \text{Hz}^{-1} = 4.135 \times 10^{-15}\ \text{eV} \cdot \text{Hz}^{-1}$)

   A. 2.2×10^{-33} J
   B. 5.9×10^{-27} J
   C. 7.4×10^{-42} J
   D. 9.5×10^{-26} J
   E. 3.7×10^{-25} J

3. The experimental observation(s) below that require(s) a quantum explanation for the photoelectric effect

   A. is that more photoelectrons are emitted when the light frequency increases.
   B. is that the maximum kinetic energy of the photoelectrons is related linearly to the frequency of the light.
   C. is that every metal surface has a work function, a minimum amount of energy needed to free electrons.
   D. is that the stopping potential measures the kinetic energy of the photoelectrons.
   E. are all of the above.

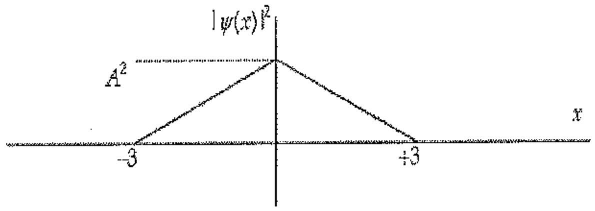
4. An electron is accelerated through a potential difference of 25 000 V. What is the de Broglie wavelength of the electron (in m)? (Hint : the electron mass is $m_e = 9.11 \times 10^{-31}$ kg and 1 eV = 1.602×10^{-19} J)

   A. 7.8×10^{-12}
   B. 6.8×10^{-12}
   C. 6.5×10^{-12}
   D. 5.9×10^{-12}
   E. 5.5×10^{-12}

5. Because the factor h on the right side of Heisenberg's uncertainty principle has units of joule-seconds, it suggests that the energy of a system also has uncertainty. The uncertainty in energy depends on the length of the time interval during which a system exists. $\Delta E \Delta t \geq h/4\pi$. Suppose an unstable mass is produced during a high-energy collision such that the uncertainty in its mass is $m_e/100$ ($m_e = 9.11 \times 10^{-31}$ kg). How long will this particle exist?
   A. 8.1×10^{-19} s
   B. 2.3×10^{-23} s
   C. 1.0×10^{15} s
   D. 1.2×10^{13} s
   E. 6.4×10^{-20} s

6. The expectations value of a function $f(x)$ of x when the wave function depends only on x is given by $\langle f(x) \rangle =$
   A. $\int_{-\infty}^{+\infty} \sqrt{f(x)}\, \psi(x) dx$.
   B. $\int_{-\infty}^{+\infty} f(x)\psi(x) dx$.
   C. $\int_{-\infty}^{+\infty} \psi^*(x) f(x) \psi(x) dx$.
   D. $\int_{-\infty}^{+\infty} f(x)\psi^*(x) dx$.
   E. $\int_{-\infty}^{+\infty} \psi^*(x) \frac{f^2(x)}{2} \psi(x) dx$.

7. The graph below shows the value of the probability density $|\psi(x)|^2$ in the region $-3.00\text{ m} \leq x \leq +3.00\text{ m}$. The value of the normalization constant A is

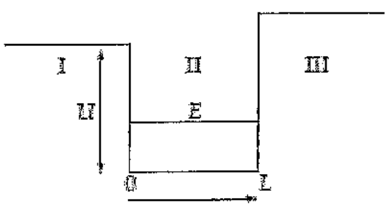


   A. $-\frac{1}{3}$.
   B. $-\frac{1}{\sqrt{3}}$.
   C. $+\frac{1}{\sqrt{3}}$.
   D. $+\frac{1}{3}$.
   E. either $-\frac{1}{\sqrt{3}}$ or $+\frac{1}{\sqrt{3}}$.

8. What is the quantum number n of a particle of mass m confined to a one-dimensional box of length L when its energy is $2\,h^2/mL^2$?
   A. 2
   B. 4
   C. 8
   D. 1
   E. 16

9. The wave function for a particle in a box of length L is given by $\psi(x) = A\sin(\frac{n\pi x}{L})$. If the box extends from $x = 0$ to $x = L$, What is the probability of finding the particle between $x = 0.60\,L$ and $x = 0.70\,L$?
   A. 0.05
   B. 0.20
   C. 0.25
   D. 0.10
   E. The probability is not given.

10. 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 $\psi_I =$
   A. $\beta e^{\kappa x}$.
   B. $\alpha e^{-\kappa x}$.
   C. $A \sin(kx)$.
   D. $B \cos(kx)$.
   E. $A \sin(kx) + B \cos(kx)$.

11. Classically, the concept of "tunneling" is impossible. Why?
   A. The total energy of a particle is equal to the kinetic and potential energies.
   B. The velocity of the particle would be negative.
   C. The kinetic energy of the particle would be negative.
   D. The kinetic energy must be equal to the potential energy.
   E. The total energy for the particle would be negative.

12. The ground state energy of a harmonic oscillator is
   A. $E = \hbar\omega$.
   B. $E = \hbar\omega/4$
   C. $E = (2/3)\hbar\omega$.
   D. $E = 0$.
   E. $E = \hbar\omega/2$.

13. Rutherford's experiment, in which he fired alpha particles of 7.7-MeV kinetic energy at a thin gold foil, showed that nuclei were very much smaller than the size of an atom because
   A. some alpha particles passed through the foil undeflected.
   B. some alpha particles were deflected backwards.
   C. some alpha particles were captured by the gold nuclei.
   D. the alpha particles could not get closer than 10^{-10} m to the gold nuclei.
   E. the alpha particles split into deuterium nuclei when they encountered the gold nuclei.

14. An electron in a hydrogen atom makes a transition from the $n = 4$ to the $n = 3$ energy state. Determine the energy (in eV) of the emitted photon.
   A. 0.54
   B. 1.51
   C. 0.85
   D. 0.66
   E. 10.2

15. How fast is the electron moving in the first Bohr orbit?
   A. 3.3×10^6 m/s
   B. 5.5×10^{15} m/s
   C. 4.4×10^6 m/s
   D. 5.5×10^6 m/s
   E. 2.2×10^6 m/s

16. 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.

17. The Pauli exclusion principle states
   A. when an atom has orbitals of equal energy, the maximum number of electrons will have unpaired spins.
   B. there is an inherent uncertainty in the position and momentum of a particle.
   C. no two electrons in the same atom can have the same set of quantum numbers.
   D. when an atom has orbitals of equal energy, the maximum number of electrons will be paired spins.
   E. no two atoms can have the same set of quantum numbers.

18. As a spaceship heads directly to Earth at a velocity of $0.8c$, it sends a radio signal to Earth. When those radio waves arrive on Earth, their velocity relative to Earth is
   A. c.
   B. $0.8c$.
   C. $1.8c$.
   D. $\sqrt{c^2 + v_E^2}$, where v_E is the velocity of the Earth.
   E. $\sqrt{(0.8c)^2 + v_E^2}$, where v_E is the velocity of the Earth.

19. The speed of FM waves will be observed to be $c = 2.9979 \times 10^8$ m/s when the antenna emitting the waves is
   A. at rest relative to the receiving antenna.
   B. moving to the right of the detecting antenna at $0.5c$.
   C. moving to the left of the detecting antenna at $0.5c$.
   D. moving at 2.9979×10^8 m/s.
   E. moving as described in (a), (b) or (c) above.

20. The half-life of a muon is 2.20 μs as measured in a stationary reference frame. What is the half-life of the muon (in μs) when it is moving with a speed of $v = 0.800c$?
   A. 8.13
   B. 3.67
   C. 2.75
   D. 15.8
   E. 1.32

國立中山大學 113 學年度
碩士班暨碩士在職專班招生考試試題

科目名稱：普通物理【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。
- 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，唯不得攜帶書籍、紙張（應考證不得做計算紙書寫）、具有通訊、記憶、傳輸或收發等功能之相關電子產品或其他有礙試場安寧、考試公平之各類器材入場。
- 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 113 學年度碩士班暨碩士在職專班招生考試試題

科目名稱：普通物理【物理系碩士班】　題號：423002

※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

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

1. Given a circuit in Fig. 1, which is composed of a battery of voltage V, six resistors of resistance R, and a voltmeter, what is the readout from the voltmeter?

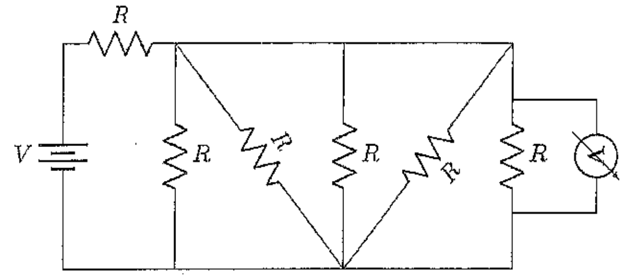


Figure 1: A circuit composed of a battery, six identical resistors, and a voltmeter.

(A) $\frac{5V}{6}$
(B) $\frac{2V}{3}$
(C) $\frac{V}{2}$
(D) $\frac{V}{3}$
(E) $\frac{V}{6}$

2. It is known that all mechanical quantities, including the universal constants G, c and $\hbar$, can be expressed in terms of length, time, and mass. In SI units, where the base of unit of length is meter (m), time is second (s), and mass is kilogram (kg), the three universal constants are $G = 6.67 \times 10^{-11}\ \mathrm{m}^3 \cdot \mathrm{s}^2 \cdot \mathrm{kg}^{-1}$, $c = 3.00 \times 10^8\ \mathrm{m} \cdot \mathrm{s}^{-1}$, and $\hbar = 1.05 \times 10^{-34}\ \mathrm{m}^2 \cdot \mathrm{s}^{-1} \cdot \mathrm{kg}$. In another unit system, the base units of length, time, and, mass are denoted as ℓ_p, t_p, and m_p, respectively, so that $G = 1\ \ell^3 \cdot t_\mathrm{p}^{-2} \cdot m_\mathrm{p}^{-1}$, $c = 1\ \ell_\mathrm{p} \cdot t_\mathrm{p}^{-1}$, and $\hbar = 1\ \ell_\mathrm{p}^2 \cdot t_\mathrm{p}^{-1} \cdot m_\mathrm{p}$. What is ℓ_p in SI units?
(A) 1.61×10^{-35} m
(B) 2.18×10^{-8} m
(C) 5.39×10^{-44} m
(D) 1.42×10^{32} m
(E) 7.30×10^{-3} m

3. A sound source emits a sound wave of frequency f. If the source is moving toward a stationary observer at one third (i.e., 1/3) of the speed of sound, what frequency does the observer observe?
(A) $3f$
(B) $\frac{3f}{2}$
(C) f
(D) $\frac{2f}{3}$
(E) $\frac{f}{3}$

4. A string with two ends fixed has 12 Hz, 30 Hz, 33 Hz, and 45 Hz as harmonic frequencies. Which of the following is a possible fundamental frequency (first harmonic) of the string?
(A) 2 Hz
(B) 3 Hz
(C) 5 Hz
(D) 12 Hz
(E) 18 Hz

5. Two blocks with masses m_A and m_B are attached to two identical springs. The block with mass m_A oscillates with amplitude A_A and frequency f_A, while the block with mass m_B oscillates with amplitude A_B and frequency f_B. What is the ratio between m_A and m_B, i.e., $\frac{m_A}{m_B}$?
(A) $\frac{A_A f_A}{A_B f_B}$
(B) $\frac{f_A}{f_B}$
(C) $\frac{A_B f_A}{A_A f_B}$
(D) $\frac{f_B^2}{f_A^2}$
(E) $\frac{A_A f_B}{A_B f_A}$

6. Two 5-kg objects with velocities $\vec{v}_1 = 2\hat{e}_x + 3\hat{e}_y$ and $\vec{v}_2 = 2\hat{e}_x + 5\hat{e}_y$ in the unit of m/s collide and stick together. How much energy is lost in the process?
(A) 5 J
(B) 24 J
(C) 78 J
(D) 132 J
(E) 247 J

7. On July 16, 1945, in the Manhattan Project led by Robert Oppenheimer, a physicist named Richard Feynman was observing the nuclear test. After the bomb was detonated (引爆), Feynman saw the flash of the bomb explosion roughly 40 seconds before he heard the sound of the explosion. Given the speed of light is 3.0×10^8 m/s and the speed of sound is 3.4×10^2 m/s, estimate the distance between Feynman and the place of detonation.
(A) 1.6 km
(B) 1.4×10 km
(C) 3.1×10^2 km
(D) 7.0×10^2 km
(E) 1.2×10^7 km

8. According to the second law of thermodynamics, which of the statements below is **correct**?
(A) Heat can never pass from a colder to a warmer body.
(B) Heat cannot be converted into work.
(C) Heat can flow spontaneously from hotter to colder regions.
(D) It is derived from the first law of thermodynamics.
(E) The entropy of a closed system always remains unchanged.

9. Two identical satellites, A and B, are circling around Earth in circular orbits. Given the orbital radius of A is twice that of B, what is the ratio of the speed of A to the speed of B?
(A) 1
(B) $\sqrt{2}$
(C) $1/\sqrt{2}$
(D) 2
(E) 1/2

10. If the period of a simple pendulum on Earth is T what would be the period of the same pendulum on the Moon, where the gravitational acceleration is 1/6 of that on Earth?
(A) $\sqrt{6}T$
(B) $\sqrt{3}T$
(C) T
(D) $T/\sqrt{3}$
(E) $T/\sqrt{6}$

11. Two spherical shells, A and B, surround an isolated charged point particle. Given that the radius of shell A is twice that of the radius of shell B, what is the ratio between the electric flux through shell A and the electric flux through shell B?
(A) 4
(B) 2
(C) 1
(D) 1/2
(E) 1/4

12. A thin hoop rolls without sliding on a level surface (see Fig. 2). What is the ratio between the rotational energy and the translational energy?

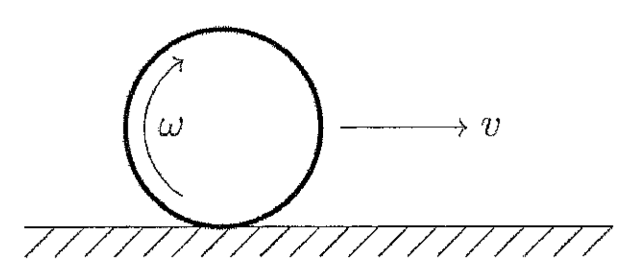


Figure 2: A hoop rolls on a level surface.

(A) 2
(B) $\sqrt{2}$
(C) 1
(D) $1/\sqrt{2}$
(E) 1/2

13. A combination of pulleys is shown in Fig. 3, where a weight of mass m_1 is hung on the leftmost pulley, and a weight of mass m_2 is attached to the right end of the string. What is m_2 in terms of m_1 so that the system is in equilibrium?

(A) m_1
(B) $m_1/2$
(C) $m_1/3$
(D) $m_1/8$
(E) $m_1/16$

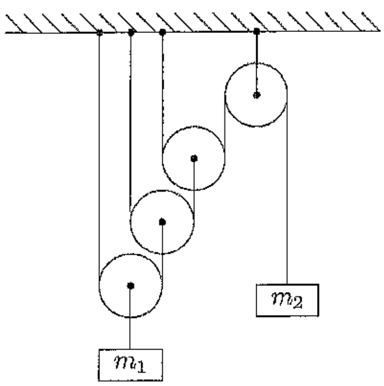


Figure 3: A combination of pulleys.

14. The heat capacities of objects A, B, and C are C_A , $C_B = 2C_A$, and $C_C = 3C_A$, respectively. If the temperatures of objects A, B, and C are 60°C, 30°C, and 20°C, what is the equilibrium temperature after objects A, B, and C are in touch?
(A) 30°C
(B) 35°C
(C) 40°C
(D) 45°C
(E) 50°C

15. About two-thirds of a solid wooden ball of density 0.53 g/ml is floating in an unknown liquid. Which of the following liquids could be the unknown liquid?
(A) Ethyl alcohol (density 7.89×10^2 kg/m^3)
(B) Water (density 1.00×10^3 kg/m^3)
(C) Mercury (density 1.36×10^4 kg/m^3)
(D) Hexane (density 6.54×10^2 kg/m^3)
(E) Olive oil (density 9.11×10^2 kg/m^3)

16. A rocket weighs 1.7×10^6 kg, where 80% of it is the fuel, and exhausts fuel with a relative speed of 2000 m/s. If the rocket is initially at rest in space, what is its speed after consuming all the fuel?
(A) 1.0×10^4 m/s
(B) 2.5×10^3 m/s
(C) 3.2×10^3 m/s
(D) 1.6×10^3 m/s
(E) 4.0×10^2 m/s

17. A coil with a constant cross-section $\vec{A}$ is moving with velocity $\vec{v}$ in a constant and uniform magnetic field $\vec{B}$. What is the voltage in the coil generated by the magnet?
(A) $\vec{B} \cdot \vec{A}|\vec{v}|$
(B) $\vec{B} \cdot \vec{v}|\vec{A}|$
(C) 0
(D) $|\vec{B} \cdot \vec{v}|/|\vec{A}|$
(E) $|\vec{A}||\vec{B}||\vec{v}|$

18. How much work is done by an ideal gas in an isothermal expansion from volume V_i to V_f? (Let n be the amount of the gas, R be the gas constant, and T be the absolute temperature.)
(A) $nRT(V_f - V_i)$
(B) $nRT\frac{V_f+V_i}{V_i}$
(C) $nRT\ln\frac{V_f+V_i}{V_f}$
(D) $nRT\ln\frac{V_f+V_i}{V_f-V_i}$
(E) $nRT\ln\frac{V_f}{V_i}$

19. A block of mass m_1 is stacked on top of another block of mass m_2 and attached via a massless string (see Fig. 4). The coefficient of static friction between the blocks is μ_B, and the coefficient of static friction between the block and the surface is μ_S. The pullies are massless and frictionless. What is the maximal mass W of a weight attached to the bottom block that still makes the system stationary?

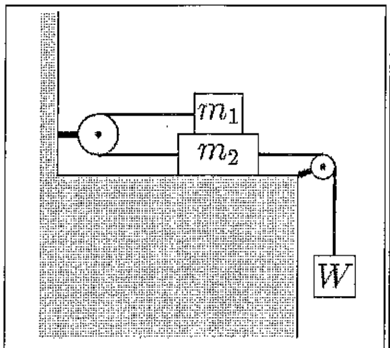


Figure 4: A stack of blocks.

(A) $m_1\mu_B + (m_1 + m_2)\mu_S$
(B) $2m_1\mu_B + (m_1 + m_2)\mu_S$
(C) $(m_1 + m_2)\mu_S$
(D) $-2m_1\mu_B + (m_1 + m_2)\mu_S$
(E) $m_1\mu_B + m_2\mu_S$

20. After heating a metal annular disc with inner radius r_i and outer radius r_o (see Fig. 5), which of the following statements is **not** true?

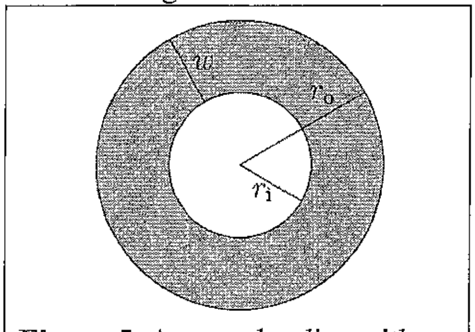


Figure 5: An annular disc with inner radius r_i and outer radius r_o.

(A) The outer radius r_o increases.
(B) The inner radius r_i increases.
(C) The total area of the annular disc increases.
(D) The width w, where $w = r_o - r_i$, of the annular disc remains the same.
(E) The sum of the areas of the annular disc and the hole increases.