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並不得書寫、畫記、作答。

國立清華大學 112學年度學士後醫學系單招試題

系所班組別：學士後醫學系
自然科學組

科目代碼：0103

考試科目：化學與物理

—作答注意事項—

1. 請核對答案卡上之准考證號、科目名稱是否正確。
2. 作答中如有發現試題印刷不清，得舉手請監試人員處理，但不得要求解釋題意。
3. 答案卡限用 2B 鉛筆畫記；如畫記不清（含未依範例畫記）致光學閱讀機無法辨識答案者，其後果一律由考生自行負責。
4. 其他應考規則、違規處理及扣分方式，請自行詳閱簡章附錄上「國立清華大學試場規則及違規處理辦法」，無法因本試題封面作答注意事項中未列明而稱未知悉。

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Choose one best answer for the following questions

【單選題】每題 2.5 分, 共計 150 分。答錯一題倒扣 0.625 分, 未作答, 不給分亦不扣分。1~30 題為化學, 31~60 題為物理。

1. If a certain volume of potassium hydroxide solution with a solute mass percentage of 14% is evaporated to remove 50 g of water, the solute mass fraction becomes 28% and the volume of the solution becomes 62.5 mL. What is the concentration of the substance in the concentrated solution?

- (A) 2.20 M (B) 3.00 M (C) 4.00 M (D) 5.00 M (E) 6.25 M

2. Which of the following statements is (are) correct?

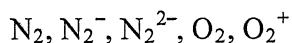
- I. Molecules SO_3 , SeS_2 , PCl_5 , TeCl_4 , ICl_3 , and OCl_2 all exhibit at least one bond angle of approximately 120° .
II. The order of the nitrogen-oxygen bond length from the shortest to the longest is: $\text{NO}^+ < \text{NO}_2^- < \text{NO}_3^-$.
III. In the compound O_2F_2 , the oxidation state of oxygen is +1 and the formal charge of oxygen is 0.
IV. The bond angle in XeCl_2 should be similar to that of CS_2 or KrF_2 .
V. Among compounds SF_4 , KrF_4 , and IF_5 , only SF_4 is polar.

- (A) III (B) II, IV, and V (C) I, V (D) I, II, and III (E) II, III, and IV

3. After the reaction $\text{Cl}_2 \rightarrow \text{Cl}^- + \text{ClO}_3^-$ (in a basic solution) is balanced with the smallest whole-number coefficients, which of the following statements is correct?

- (A) The coefficient of OH^- is 12.
(B) Water is on the reactant side with a coefficient of 3.
(C) Cl^- and ClO_3^- are produced in a 1:1 mole ratio.
(D) 1 mole of Cl_2 will produce 2 moles of Cl^- .
(E) The sum of all coefficients is equal to 18.

4. To remove an electron from each of the following species, which requires the least energy?



- (A) N_2^{2-} (B) N_2^- (C) O_2 (D) N_2 (E) O_2^+

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5. The rate of H_2 gas production from a reaction of magnesium turnings and hydrochloric acid in a beaker is plotted against time as shown in the figure below.

Which of the following statements is *incorrect*?

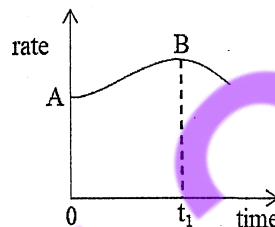
(A) The reaction rate is dependent on the concentration of hydrochloric acid.

(B) The reaction rate is dependent on the pressure of H_2 .

(C) The reaction rate is dependent on the surface area of magnesium turnings.

(D) In the figure, the reaction rate decreases after t_1 , because the concentration of hydrochloric acid decreases.

(E) The formation of the AB section in the figure is because the reaction is exothermic, the temperature of the solution increases, and thus the reaction rate increases.



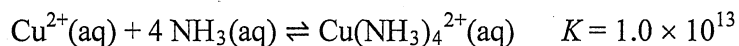
6. The complete combustion of n moles of benzene produces a certain amount of water and CO_2 . Which of the following n moles of compounds will produce the same amount of respective water and CO_2 upon complete combustion as the previous reaction?

(A) glucose (B) acetylene (C) phenol (D) cyclohexane (E) n -hexane

7. A and B are two elements in the first three periods of the periodic table. In their ground states, the L shell of the atom A has 3 less electrons than the L shell of the atom B. The total number of electrons in the atom B is 5 more than the total number of electrons in the atom A. Which of the following is the chemical formula of the compound formed by A and B?

(A) A_2B_3 (B) A_2B (C) A_3B_2 (D) AB_4 (E) AB_2

8. An electrochemical cell consists of an iron metal electrode immersed in a 1.0 M FeSO_4 solution, separated by a porous disk from a copper metal electrode. If the copper electrode is placed in a solution of 2.0 M $\text{NH}_3(\text{aq})$, which contains 0.010 M $[\text{Cu}(\text{NH}_3)_4]^{2+}$, what is the cell potential at 25 °C? (The standard reduction potentials are 0.34 V for Cu^{2+}/Cu and -0.44 V for Fe^{2+}/Fe , respectively. $\log 2 = 0.301$)



(A) -0.18 V (B) 0.30 V (C) 0.44 V (D) 0.68 V (E) 1.26 V

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9. Which of the following statements about the structures of metals and ionic solids is (are) correct?

- I. Atoms in a solid consisting of only one element would have six nearest neighbors, if the crystal structure is a simple cubic array.
- II. There are four tetrahedral holes in a cubic closest packed unit cell.
- III. If the metal with an atomic radius of r has a body-centered cubic structure, the edge length of the unit cell will be $\frac{4}{3}\sqrt{3}r$.
- IV. For a simple cubic array, the radius of an interior sphere (cubic hole) in terms of the radius (r) of a sphere in the array is $(\sqrt{3} - 1)r$.
- V. Cobalt fluoride crystallizes in a cubic closest packed array of fluoride ions with the cobalt ions filling one-half of the octahedral holes, and thus the charge of cobalt ions is +3 in this compound.

(A) III (B) II and V (C) III and IV (D) I, III, and IV (E) I, IV, and V

10. You are diluting an aqueous sucrose solution. You first add 0.98 mL of distilled water twice into a vial and then add 90.0 μL of sucrose solution. If the weight of the final solution is 2.0934 g, what is the correct expression for the density (g/mL) of the final solution?

(A) 1.021170 (B) 1.02117 (C) 1.0211 (D) 1.021 (E) 1.02

11. White phosphorus (P_4) has two different crystalline forms, $\alpha\text{-P}_4(\text{s})$ and $\beta\text{-P}_4(\text{s})$, where the P_4 molecules are packed in different ways. The α -form is always obtained when the liquid freezes. However, it spontaneously converts to the β -form when the temperature is below -76.9°C ($\alpha\text{-P}_4(\text{s}) \rightarrow \beta\text{-P}_4(\text{s})$). Assume that the ΔH and ΔS for this process are temperature independent, which of the following statements are correct?

- I. This is an endothermic process.
- II. The sign of ΔS is positive for this process.
- III. The ΔG at -76.9°C is zero for this process.
- IV. The α -form is less ordered than the β -form.

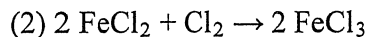
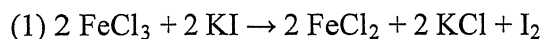
(A) I and II
(B) III and IV
(C) II and III
(D) I and IV
(E) I, III, and IV

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12. Three redox reactions are shown as follows:

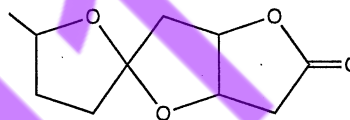


If a solution contains Fe^{2+} , Cl^- , and I^- , which of the following is the reagent to be added to remove I^- without oxidizing Fe^{2+} and Cl^- ?

- (A) Cl_2 (B) KMnO_4 (C) FeCl_3 (D) HCl (E) I_2

13. Natural product synthesis is one of the great intellectual tasks in organic synthesis.

One small molecule containing reactive functional groups and chiral centers used in natural product synthesis is shown below. Which of the following statements about this molecule is correct?



- (A) It has four chiral carbons.
 (B) It has a carboxyl group.
 (C) It has three ether functional groups.
 (D) Two sp^2 -hybridized carbons are in the molecule.
 (E) All the oxygen atoms in the molecule are sp^3 -hybridized.

14. A certain reaction has the form:



At 298 K, the concentration of A ($[A]$) versus time was measured. A plot of $1/[A]$ versus time (minutes) gave a straight line with a slope of 2.00×10^{-2} . $[A]_0$ represents the initial concentration at $t = 0$, and k is the rate constant. Which of the following statements about this reaction is (are) correct?

- I. The differential rate law is $\text{rate} = k[A]^2$.
 II. The integrated rate law is $1/[A] = 1/[A]_0 - kt$.
 III. The rate constant is $2.00 \times 10^{-2} \text{ min}^{-1}$.
 IV. If $[A]_0$ for this reaction is 0.100 M, the first half-life is 34.7 min.
 V. If $[A]_0$ for this reaction is 0.100 M, it will take 1.50×10^3 min to consume 0.0750 M of A.

- (A) I (B) II and III (C) II and V (D) III and IV (E) I and V

15. It is known that the reaction of FeS_2 with a certain concentration of HNO_3

solution produces $\text{Fe}(\text{NO}_3)_3$, H_2SO_4 and a reduced N-containing byproduct. To consume 1 mole of FeS_2 , 8 moles of HNO_3 are required. Which of the following is a byproduct of the reaction?

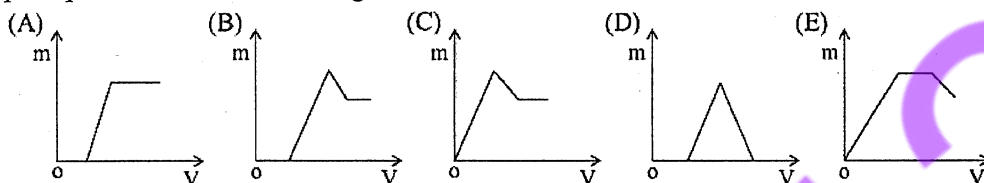
- (A) NO (B) N_2O_3 (C) N_2O (D) NH_4NO_3 (E) NO_2

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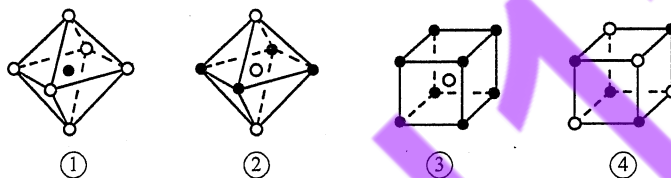
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16. A colorless solution contains cationic species H^+ , Mg^{2+} , and Al^{3+} . The relationship between the added volume (V) of NaOH solution and the mass (m) of the resulting precipitate is shown in the figure below. Which one is correct?



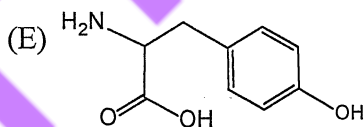
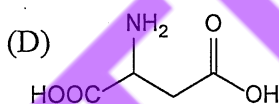
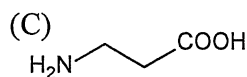
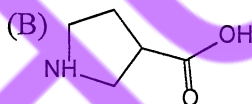
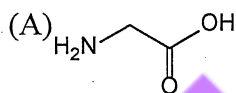
17. The following figures (①-④) are part of the NaCl or CsCl crystal structure.

Which of these are structures of the split from the NaCl crystal?



- (A) ① and ② (B) ③ and ④ (C) ① and ③
(D) ② and ④ (E) ① and ④

18. Which of the following compounds is not among the 20 common amino acids?



19. Consider a container with a piston containing 2.0 moles of a monatomic ideal gas with initial conditions of $V = 6.0 \text{ L}$ and $P = 2.0 \text{ atm}$ at 300 K . If the external pressure suddenly increases to 4.0 atm and the gas is compressed isothermally, which of the following statements about this process is true? (gas constant $R = 8.314 \text{ J} \cdot \text{K}^{-1} \cdot \text{mol}^{-1}$; $\ln 2 = 0.693$)

- (A) This is a reversible process.
(B) This process is spontaneous.
(C) The change of enthalpy (ΔH) is positive.
(D) The entropy change (ΔS) is -11.5 J/K .
(E) The entropy change of the surrounding (ΔS_{surr}) is -4.1 J/K .

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20. As the lead chemist in the Superior Analytical Laboratory (SAL), you want to design an experiment to determine the density of an unknown liquid to three significant figures. The density is of the order of 1 g/cm^3 . You have about 5 mL of the liquid and only graduated cylinders and balances to use. Which of the following combinations of equipment will allow you to achieve your goal?

	A graduated cylinder	A balance
(A)	with an uncertainty of $\pm 0.1 \text{ mL}$	with an uncertainty of $\pm 0.1 \text{ g}$
(B)	with an uncertainty of $\pm 0.01 \text{ mL}$	with an uncertainty of $\pm 0.1 \text{ g}$
(C)	with an uncertainty of $\pm 0.1 \text{ mL}$	with an uncertainty of $\pm 0.01 \text{ g}$
(D)	with an uncertainty of $\pm 0.01 \text{ mL}$	with an uncertainty of $\pm 0.001 \text{ g}$
(E)	with an uncertainty of $\pm 0.1 \text{ mL}$	with an uncertainty of $\pm 0.001 \text{ g}$

21. In the periodic table, five elements A, B, C, D, and E with their atomic numbers in an increasing order of $A < B < C < D < E < 20$. B and C are adjacent to each other. B and E exist in the form of diatomic molecules under normal conditions. A reacts with B, C and E to give Q, X, and Z, respectively, and both Q and X are 10-electron compounds, while Z is an 18-electron compound. The number of outermost electrons in the atom of D equals the number of electron shells. Given that $Q + Z \rightarrow M$, which of the following statements is correct?

- (A) ionic radius: $D > C > B$
 (B) Z is an ionic compound.
 (C) M is composed of non-metallic elements and contains only covalent bonds.
 (D) D can be in the second period of group IIA in the periodic table.
 (E) Three types of 10-electron species can be formed by reacting A and C.

22. The Martian atmosphere contains a large amount of CO_2 . A new all-solid-state battery that involves CO_2 in the reaction is expected to power the Mars rover. The battery uses sodium metal as the negative electrode and carbon nanotubes as the positive electrode. Which of the following statements during the discharge of the battery is correct?

- (A) Reduction reaction occurs at the negative electrode.
 (B) CO_2 is reduced to C and CO at the positive electrode.
 (C) Cations move from the positive electrode to the negative electrode.
 (D) Electrical energy is converted into chemical energy.
 (E) The byproduct is Na_2O_2 .

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23. To a solution containing 1 mole of HNO_3 and 1 mole of H_2SO_4 gradually add iron powder to excess. The relationship between the amount of metal cations **a** and **b** in the solution and the amount of iron powder added is shown in the following figure (given that NO is the sole product upon reduction of dilute nitric acid).

Which of the following statements is incorrect?

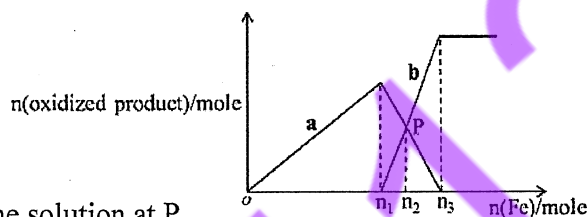
(A) **a** represents Fe^{3+}

(B) $n_1 = 0.75$

(C) at P, $n(\text{Fe}^{2+}) = 0.5625 \text{ mol}$

(D) $n_3 = 1.125$

(E) If copper powder is added to the solution at P, up to 14.4 g of copper powder can be dissolved.



24. A colloid is a mixture in which one substance consisting of microscopically dispersed insoluble particles is suspended throughout another substance. Which of the following statements about colloids is correct?

(A) A visible light beam is used to distinguish the solution from the colloid.

(B) H^+ , K^+ , S^{2-} , and Br^- can coexist in large amounts in iron hydroxide colloids.

(C) $\text{Fe}(\text{OH})_3$ colloid can be produced upon the dropwise addition of saturated $\text{FeCl}_3(\text{aq})$ to the concentrated ammonia.

(D) The hydrolysis of alum produces colloidal particles with adsorption, which can be used as bleaching agent.

(E) The specific surface area of soil colloidal particles is huge and generally positively charged, which can adsorb NH_4^+ and other ions and make the soil have fertilizer retention capacity.

25. Complete combustion of a benzene sample under limited oxygen yielded 135 g of total product. In contrast, when the same amount of benzene was completely burned in excess oxygen, 159 g of total product was collected. In the first experiment, what was the final molar ratio of CO to CO_2 ?

(A) $\text{CO}:\text{CO}_2 = 3:4$

(B) $\text{CO}:\text{CO}_2 = 2:1$

(C) $\text{CO}:\text{CO}_2 = 3:2$

(D) $\text{CO}:\text{CO}_2 = 1:1$

(E) $\text{CO}:\text{CO}_2 = 3:1$

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26. A mixture of Cu, Cu₂O and CuO is dissolved upon the addition of 100 mL of 0.6 mol/L HNO₃ solution, from which 224 mL of NO gas (under standard condition) is collected. Which of the following statements is *incorrect*?
- (A) The amount of copper nitrate in the product is 0.025 mol.
 - (B) The amount of Cu in the mixture is greater than 0.005 mol.
 - (C) The amount of Cu in the mixture is smaller than 0.015 mol.
 - (D) If the mixture contains 0.01 mol Cu, there are 0.005 mol Cu₂O and 0.005 mol CuO in the mixture.
 - (E) If the amount of Cu in the mixture is 0.005 mol, the total amount of Cu₂O and CuO in the mixture is 0.020 mol.
27. A sample containing 3.00 moles of a monatomic ideal gas is taken from **state X** ($P_X = 1.00$ atm, $V_X = 5.0$ L) to **state Y** ($P_Y = 1.00$ atm, $V_Y = 35.0$ L). For this process, assuming that the external pressure is constant and equals the final pressure of the gas. Which of the following statements is correct? (gas constant $R = 8.314 \text{ J} \cdot \text{mol}^{-1} \cdot \text{K}^{-1}$).
- (A) This is an adiabatic process.
 - (B) The process is isothermal.
 - (C) ΔE (the change of internal energy) = -4.56 kJ
 - (D) ΔH (the change of enthalpy) = 7.60 kJ
 - (E) The work of 3.04 kJ flows into the system.
28. Water treatment includes water purification, disinfection, distillation, etc. Common water treatment agents include chlorine, ozone, bleach, activated carbon, etc. Swimming pools commonly use ozone and activated carbon to disinfect and purify the pools. Which of the following statements is correct?
- (A) The principles of ozone and activated carbon treatment are the same.
 - (B) Chlorine is a common disinfectant and the water disinfected with chlorine can be directly used to prepare chemical reagents.
 - (C) Both chlorine and sulfur dioxide have bleaching properties, and mixing the two in equal volumes will increase the efficiency of bleaching.
 - (D) Bleaching powder will be ineffective when left in the air for a long time.
 - (E) The most important ingredient of bleaching powder is CaCl₂.

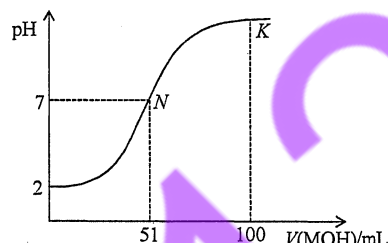
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29. At room temperature, a 0.02 mol/L MOH solution was added dropwisely to a 100 mL of 0.01 mol/L HA solution, and the curve shown in the figure below indicates the pH change of the mixed solution. Which of the following statements is correct?

- (A) N is the equivalence point.
 (B) At N, $[A^-] = [M^+] + [MOH]$.
 (C) At K, $[M^+] > [A^-] > [OH^-] > [H^+]$.
 (D) HA is a weak acid and MOH is a strong base.
 (E) At pH = 7, both HA and MOH are completely consumed.



30. The following data was recorded for the decomposition of ethanol on alumina

(Al_2O_3) surface at 600 K. Which of the following statements is correct?



- (A) At $t = 80$ s, P_{total} is 370 torr.
 (B) The rate constant is 15 torr/s.
 (C) This a first order reaction.
 (D) At $t = 200$ s, P_{total} is 500 torr.
 (E) At $t = 100$ s, the partial pressure of ethanol is 50 torr.

t (s)	P_{total} (torr)
0	200
10	215
20	230
30	245
40	260
50	275

31. A rectangular buoy with cross section A and thickness h floats on the water surface.

Jane waits for the buoy to reach static equilibrium and pushes the buoy 1 cm into the water, then releases it. Jane measured that the frequency of oscillation of the buoy was f_1 . John did the same experiment, but he pushed the buoy 2 cm into the water. The frequency of oscillation is said to be f_2 . It is assumed that the damping is negligible, so only buoyancy and gravity need to be considered. In addition, the density of the buoy is uniform and the buoy is never completely submerged by water. Which of the following statements is correct?

- (A) $f_1 > f_2$, because the magnitude of the buoyancy force is greater in Jane's case.
 (B) $f_2 > f_1$, because the magnitude of the buoyancy force is greater in John's case.
 (C) $f_1 > f_2$, because the magnitude of the buoyancy force is greater in John's case.
 (D) $f_2 > f_1$, because the magnitude of the buoyancy force is greater in Jane's case.
 (E) $f_1 = f_2$.

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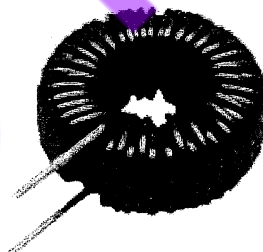
32. For an ideal diatomic gas (let us treat them as non-rigid rotators), there are N molecules confined to a two-dimensional space of area A , as shown in the figure below. These diatomic molecules can only rotate in the plane (i.e., with angular velocity perpendicular to the plane), but are allowed to translate and vibrate in the two-dimensional plane. In thermal equilibrium at a temperature T (assuming that T is high enough so that the gas can be handled classically), which of the following statements is true?

- (A) The internal energy of the ideal diatomic gas is $2Nk_B T$.
(B) The internal energy of the ideal diatomic gas is $5Nk_B T/2$.
(C) The total rotational kinetic energy is greater than the total translational energy.
(D) The total rotational kinetic energy is greater than the total vibrational energy.
(E) The speed distribution is the same Maxwell-Boltzmann distribution for the ideal monatomic gas in three dimensions.



33. A toroidal inductor with an inductance of 20 mH has a volume of 0.02 m^3 . If the average energy density of the toroidal coil is 50.0 J/m^3 , which of the following values is closest to the current (in amperes) through the inductor?

- (A) 0.2 (B) 1.0 (C) 2.0 (D) 10.0 (E) 20.0



34. A rigid rod of length L rotates about an axis perpendicular to the rod, with one end of the rod fixed to the axis. Which of the followings are equal at all points on the rod?

- I. the angular position
II. the angular velocity
III. the angular acceleration
IV. the centripetal acceleration
V. the linear velocity

- (A) I and II
(B) I, II, and III
(C) I, II, and IV
(D) I, II, III, and IV
(E) I, II, III, IV, and V

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35. An air raid siren on top of a tall pole radiated sound waves uniformly in all directions. At a distance of 15.0 m, the intensity of the sound is 0.25 W/m^2 . At how many meters from the siren is the intensity 0.01 W/m^2 ?
(A) 1.5 (B) 30 (C) 70 (D) 150 (E) 250
36. A nonconducting sphere of radius 10 cm is uniformly charged with a density of 100 nC/m^3 . What is the potential difference between the center and a point 4.0 cm away?
(A) 1.0 V (B) 3.0 V (C) 12.0 V (D) 24.0 V (E) 36.0 V
37. An electron is trapped in a square well potential of infinite depth with width L . If the electron is in the ground state, which of the following values is closest to the probability of finding the electron between $x = 0$ and $x = L/3$?
(A) 35% (B) 25% (C) 20% (D) 15% (E) 10%
38. A particle of mass m is attached to a spring with a force constant k . The motion of the particle is described by $x(t) = 10\sin(\pi t)$. At what point does the potential energy of the particle equal its kinetic energy?
(A) $\pi \text{ s}$ (B) 0.5 s (C) 1.0 s (D) 1.5 s (E) 2.0 s
39. Consider the following 4 objects rolling down the same slope from the same height without slipping: a solid copper ball of radius R , a hollow copper ball of radius R , a solid silver ball of radius R , and a hollow silver ball of radius R . Note that the mass density of silver is greater than that of copper. Assume that all the objects have the same initial center-of-mass velocity and travel down the slope. The moment of inertia for a solid sphere and a hollow sphere is $I_s = \frac{2}{5}m_s R^2$ and $I_h = \frac{2}{3}m_h R^2$, respectively. Which of the following statements is true?
(A) The silver solid sphere, when reach bottom of the slope, is the fastest.
(B) The silver hollow sphere, when reach bottom of the slope, is the fastest.
(C) The copper hollow sphere, when reach bottom of the slope, is the fastest.
(D) All solid spheres, when reach bottom of the slope, are the fastest and have the same speed.
(E) All hollow spheres, when reach bottom of the slope, are the fastest and have the same speed.
40. Light from a helium-neon laser ($\lambda = 632.8 \text{ nm}$) is incident upon a 0.20-mm-wide slit. What is the total width of the central maximum 2.00 m from the slit?
(A) 0.63 mm (B) 3.16 mm (C) 0.63 cm (D) 1.27 cm (E) 6.32 cm

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41. In a one-dimensional problem, an object of mass $m = 2.0$ kg is subjected to the resultant force F_x as shown below. If the object passes the origin ($x = 0.0$ m) at $t = 0$ with an initial velocity $v_0 = -2.0$ m/s, then at which of the following times does the object have a velocity of 0.0 m/s?

I. 0 ~ 1.0 s

II. 1.0 s

III. 2.0 s

IV. 3.0 s

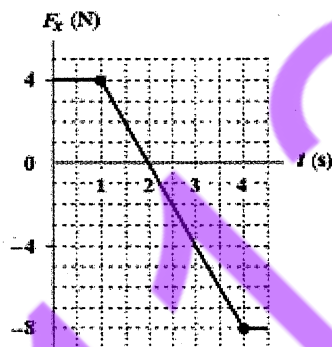
V. 8.0 s

(A) III (B) I, II, and V

(C) II, III, and V

(D) II and IV

(E) III and IV



42. A block of mass $m = 2.0$ kg is connected by two springs with force constants $k_1 = 800$ N/m and $k_2 = 500$ N/m, as shown in the figure below. The block is displaced from its equilibrium position and oscillates on the frictionless surface. Which of the following is closest to the frequency of this oscillation?

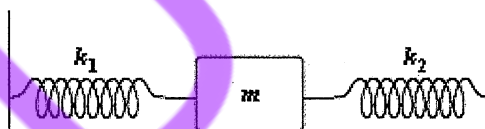
(A) 2 Hz

(B) 4 Hz

(C) 6 Hz

(D) 8 Hz

(E) 10 Hz



43. In an engine, 0.25 mol of an ideal diatomic gas in the cylinder expands rapidly adiabatically by the action of a piston. During the expansion, the temperature of the gas drops from 1000 K to 400 K. Which of the following values (in J) is closest to the work that the gas does?

(A) 3000

(B) 2000

(C) 1500

(D) 1000

(E) 60

44. As shown in the figure below, a long straight wire carries a current $i_1 = 30$ A and a rectangular loop carries current $i_2 = 20$ A. Take $a = 1.0$ cm, $b = 8.0$ cm, and $L = 30.0$ cm. Which of the following values is closest to the magnitude of the net force generated by i_1 in the loop? ($\mu_0 = 4\pi \times 10^{-7}$ T·m/A)

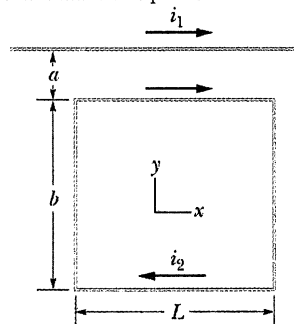
(A) 3.0×10^{-3} N

(B) 2.0×10^{-1} N

(C) 8.0 N

(D) 0.3 N

(E) 0.05 N



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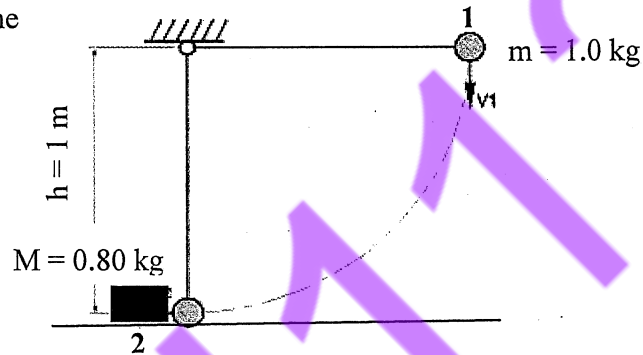
45. For double-slit experiments for particles, which of the following statements is true?
- (A) The interference pattern would disappear if we send particles through the double-slit apparatus one by one.
 - (B) The spacing of the interference fringes increases as the speed of particles increases.
 - (C) The spacing of the interference fringes increases as the separation of slits increases.
 - (D) The spacing of the interference fringes decreases as the speed of particles decreases.
 - (E) The interference pattern is more significant for lighter particles with lower speed.
46. Inside a planet, the mass density is usually not homogeneous across the planet. However, if a spherical planet is decomposed into concentric spherical shells, the mass density is approximately the same for each concentric shell. As a result, for a spherical planet X of radius R , the mass density can be treated as a function of its distance to the center of the planet, $\rho(r) = \rho_0 \left[1 - \frac{r}{2R} \right]$. Assuming the gravitational field strength at the surface of the planet is g_0 , which of the following statements is true?
- (A) At $r = R/2$, the gravitational field strength is still g_0 .
 - (B) At $r = R/2$, the gravitational field strength is equal to 0.
 - (C) At $r = R/2$, the gravitational field strength is equal to $g_0/2$.
 - (D) At $r = R/2$, the gravitational field strength is smaller than $g_0/2$ but not equal to 0.
 - (E) At $r = R/2$, the gravitational field strength is greater than $g_0/2$ but not equal to g_0 .
47. Which of the following values is closest to the number of photons per second emitted by a 3.2 mW helium-neon laser with a wavelength of 632 nm?
($h = 6.63 \times 10^{-34} \text{ J}\cdot\text{s}$; $c = 3.0 \times 10^8 \text{ m/s}$)
- (A) 1.0×10^{16} (B) 6.0×10^{15} (C) 2.0×10^{15} (D) 5.0×10^{14} (E) 3.0×10^{13}
48. A 5000-kg truck is turning on a flat road with a radius of 50 m. The road surface is wet and the coefficient of static friction $\mu_s = 0.4$. Above what speed the truck will skid on the road? ($g = 10 \text{ m/s}^2$).
- (A) 40 km/h (B) 50 km/h (C) 60 km/h (D) 70 km/h (E) 80 km/h

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49. A 1.0-kg ball is attached to the end of an incompressible massless rod of length 1.0 m to form a pendulum as shown in the figure below. The pendulum is released at position 1 with velocity $v_1 = 0$ m/s. At the lowest point of its swing, while it is moving horizontally, the ball collides head-on with a 0.80-kg block initially resting on a frictionless surface at position 2. After the collision, the speed of the block is found to be 3.0 m/s. What is the speed of the ball after the collision?



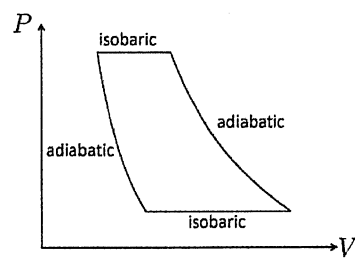
- (A) 0.0 m/s
(B) 2.0 m/s to the left
(C) 3.0 m/s to the right
(D) 3.0 m/s to the left
(E) 6.0 m/s to the right

50. A disk (radius = 8.0 cm) rotates about a fixed axis passing through its center and, starting from rest, accelerates at a constant rate to an angular velocity of 4.0 rad/s in 2.0 s. What is the magnitude of the total linear acceleration at a point on the edge of the disk when the angular velocity of the disk is 1.5 rad/s?

- (A) 16.0 cm/s² (B) 18.0 cm/s² (C) 24.0 cm/s²
(D) 34.0 cm/s² (E) 44.0 cm/s²

51. A gas undergoes a reversible thermodynamic cycle composed of two adiabatic processes and two isobaric processes as shown in the figure below. Which of the following statements is true?

- (A) The entropy change of the gas in a cycle is zero.
(B) The cyclic process is operated between two heat reservoirs of fixed temperatures.
(C) The work done by the gas in a cycle depends on whether it is monatomic or diatomic gas.
(D) The internal energy of the gas is a constant throughout the process.
(E) The total work done by the system equals the total heat absorbed by the system.



52. The armature of a 60-Hz AC generator rotates in a magnetic field of 0.15 T. If the area of the coil is $2.0 \times 10^{-2} \text{ m}^2$, how many rings must the coil contain if the peak output is to be close to 150 V?

- (A) 6 (B) 15 (C) 60 (D) 90 (E) 130

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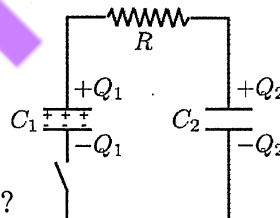
53. A non-conducting sphere of radius 10 cm is uniformly charged with a density of 100 nC/m^3 . What is the magnitude of the electric field at 4.0 cm from the center of the sphere? ($\epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/\text{N}\cdot\text{m}^2$)

- (A) 50 N/C
- (B) 100 N/C
- (C) 150 N/C
- (D) 300 N/C
- (E) 600 N/C

54. Which of the following statements about an ideal gas confined in a box is true?

- (A) For an adiabatic free expansion process, the temperature remains constant.
- (B) For an isobaric process, the temperature can only increase.
- (C) For an adiabatic process, the temperature remains constant, regardless of the gas expansion or not.
- (D) For an isochoric (fixed volume but not adiabatic) process, the temperature remains constant.
- (E) For an isochoric (fixed volume) process, the internal energy can decrease as the temperature increases.

55. As shown in the figure below, an RC circuit consists of a resistor R , and two capacitors C_1 and C_2 (with different capacitance). At $t = 0$, the charges stored on C_1 and C_2 are Q_0 and 0, respectively. And the switch is also closed at $t = 0$.



Initially,
 $Q_1(0) = Q_0$
 $Q_2(0) = 0$

Which of the following statements is true?

- (A) The charges would go back and forth between C_1 and C_2 repeatedly.
- (B) The charge would flow back and forth between C_1 and C_2 , but the amount of charge is getting less and less.
- (C) When one waits long enough, both capacitors share the same amount of energy.
- (D) When one waits long enough, the voltage across the resistor becomes zero.
- (E) When one waits long enough, the charges are neutralized and both the positive and negative charges of the two capacitors are zero.

56. A small helium-neon laser emits red visible light with a power of 3.0 mW in a beam with a radius of 2.0 mm. Which of the following values is closest to the electric field amplitude of this light in V/m? ($\epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/\text{N}\cdot\text{m}^2$)

- (A) 0.8
- (B) 5.0
- (C) 30
- (D) 400
- (E) 1000

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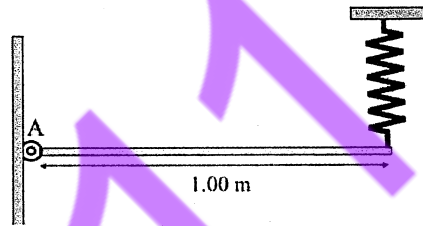
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57. A charger for a cell phone contains a transformer that steps down 120-V AC to 5.0-V AC. Suppose the secondary coil contains 30 turns and the charger delivers 700 mA to the phone. Which of the following values is closest to the converted power (W)?

(A)0.2 (B)1 (C)3 (D)10 (E)20

58. A uniform stick is 1.0-m long and weighs 1.0 kg. It is attached to a hinge at one end and to a spring with spring constant $k = 3.0 \text{ N/m}$ at the other end, and is placed horizontally as shown in the figure. The stick oscillates slightly up and down. Which of the following values is closest to its period in s?



(A)4 (B)2 (C)1 (D)0.6 (E)0.2

59. A man wants to know the magnitude of the magnetic field generated by an overhead power line. He estimates that a transmission line is about 10 meters above the ground. The local power company tells him that the line operates at 15 kV and provides a maximum of 65 MW to the area. Which of the following values is closest to the peak current (A)?

(A)500 (B)400 (C)200 (D)50 (E)15

60. A 100-W light bulb is made from a glass sphere with a radius of 3.0 cm and a thickness of 0.5 mm. It consumes 100 W of electricity and produces 95 W of heat, which is dissipated through the glass bulb. The thermal emissivity of uncoated smooth glass is about 0.9. The value of the Stefan-Boltzmann constant is $\sigma = 5.67 \times 10^{-8} \text{ W/m}^2 \cdot \text{K}^4$. The thermal conductivity of glass is $0.84 \text{ J/s} \cdot \text{m} \cdot ^\circ\text{C}$. Which of the following values is closest to the temperature difference (K) between the inner and outer surfaces of the glass?

(A)20.0 (B)10.0 (C)5.0 (D)2.0 (E)0.4