

4-101

ENTRANCE EXAMINATIONS 2020  
Ph.D. (Nano Science and Technology)

Marks: 70

Time: 2 h

Hall Ticket No:

- I. Write your Hall Ticket Number on the OMR Answer Sheet given to you. Also write the Hall Ticket Number in the Space provided above.
- II. Read the following instructions carefully before answering the questions.
- III. This Question paper has TWO parts: PART 'A' AND PART 'B'

1. Part 'A': It consists of 20 objective type questions of 1.75 marks each. There is a negative marking of 0.5 marks for every wrong answer.
2. Part 'B': It consists of 35 objective questions of one mark each with no negative marking.
3. All questions are to be answered. Answers for these questions are to be entered on the OMR sheet, filling the appropriate circle against each question. For example, if the answer to a question is D, it should be marked as below:



No additional sheets will be provided. Rough work can be done in the question paper itself.

4. Hand over the OMR answer sheet at the end of the examination to the invigilator.
5. Mobile phones, log tables and calculators of any type are NOT permitted inside the Examination Hall.
6. This book contains 13 pages including this cover sheet.

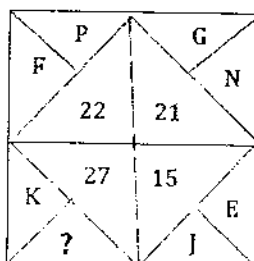
4-101

**THIS PAGE IS INTENTIONALLY LEFT BLANK**

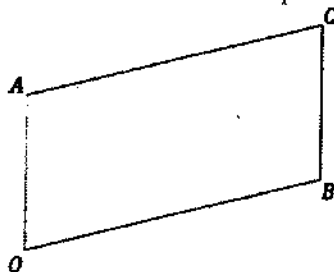
**PART A**

1. How many spheres can be placed adjacent (end-to-end) to each other on a straight line of length 1.65 nm if the diameter of each sphere is 1.5 Å?
  - A. 90
  - B. 1
  - C. 11
  - D. 9
  
2. Which of the following statements is correct w.r.t. the surface area of a solid spherical microparticle ( $S_m$ ) and the surface area of a solid spherical nanoparticle ( $S_n$ ) made of the same material?
  - A.  $S_m$  is equal to  $S_n$  because micro- and nano- particles are made of same material
  - B.  $S_m$  is always greater than  $S_n$  irrespective of the material with which micro- and nano- particles are made
  - C.  $S_m$  is always lesser than  $S_n$  irrespective of the material with which micro- and nano- particles are made
  - D.  $S_m$  is always negligible in comparison to  $S_n$  irrespective of the material with which micro- and nano- particles are made
  
3. If the deflection length of a cantilever beam loaded by its own weight scales as  $L^2$ ,  $L$  being any linear dimension in the cantilever beam, then, how does the cantilever beam bend if  $L$  is made 1000 times linearly smaller?
  - A. The cantilever beam bends  $10^4$  times lesser
  - B. The cantilever beam bends  $10^4$  times more
  - C. The cantilever beam bends  $10^6$  times lesser
  - D. The cantilever beam bends  $10^6$  times more
  
4. Amit and Bob enter into a business partnership in which Amit contributes Rs 2000 per month for 9 months and Bob contributes Rs 5000 per month for 7 months. A profit of Rs 1100 will be divided between Amit and Bob in the ratio of?
  - A. 6:11
  - B. 2:5
  - C. 7:9
  - D. 18:35
  
5. For a nonzero polynomial of degree 'n', which of the following is true?
  - A. It cannot have more than 'n' roots
  - B. It can have more than 'n' roots
  - C. It can have more than 'n+1' roots
  - D. It must have 'n' roots

6. The missing letter/number in place of '?' is



- A. M
  - B. Q
  - C. S
  - D. P
7. The breadth and height of a rectangle are reduced by 10 and 5 m, respectively, to make it as a square having an area  $650 \text{ m}^2$  less than the original area of the rectangle. What is the area of the original rectangle in  $\text{m}^2$ ?
- A. 1120
  - B. 2250
  - C. 2928
  - D. 4538
8. For the parallelogram  $OABC$  shown in the sketch, if  $\overline{OA} = p\hat{i} + q\hat{j}$  and  $\overline{OB} = r\hat{i} + s\hat{j}$  then what is the area of the parallelogram?



- A.  $pq - rs$
  - B.  $pr + qs$
  - C.  $ps + qr$
  - D.  $ps - qr$
9. If  $1 \times 10^{27}$  cubes with side 1 nm are carved out from a cube of side 1 m without any loss of material, then what is the collective surface area of the nanometer-sized cubes?
- A.  $6000 \text{ km}^2$
  - B.  $600 \text{ km}^2$
  - C.  $60000 \text{ km}^2$
  - D.  $600000 \text{ km}^2$

10. Which of the following statements is not true?
- A. Any square matrix can be written as the sum of a Hermitian and skew-Hermitian matrix
  - B. The eigenvalues of a Hermitian matrix are purely imaginary or zero
  - C. The eigenvalues of a Hermitian matrix are real
  - D. The inverse and transpose of an orthogonal matrix are also orthogonal
11. Which of the following functions is not analytic?
- A. Bessel functions
  - B. Gamma functions
  - C. Trigonometric functions
  - D. Complex conjugate functions
12. What is the ratio between the number of atoms on the surface to the number of atoms in the interior of an ideal nanoparticle made up of 50 atoms in total?
- A. 0.52
  - B. 0.62
  - C. 0.72
  - D.  $\geq 1$
13. Consider the following paragraph: Two-dimensional (2D) materials, sometimes referred to as single-layer materials, are crystalline materials consisting of a single layer of atoms. These materials have found use in applications such as photovoltaics, semiconductors, electrodes and water purification. The meaning of this paragraph is
- A. All 2D materials are semiconductors
  - B. The necessary and sufficient condition to qualify as a 2D material is crystallinity
  - C. The necessary and sufficient condition to qualify as a 2D material is to have a single layer of atoms
  - D. 2D materials must be crystalline and also consist of a single layer of atoms
14. If  $a > 1$  then
- A.  $\log_a x < 0$ , if  $0 < x < 1$
  - B.  $\log_a x = 0$ , if  $0 < x < 1$
  - C.  $\log_a x > 0$ , if  $0 < x < 1$
  - D.  $\log_a x < 0$ , for  $x > 1$

15. If the earth shrinks one third in radius with its mass keeping the same, the weight of an object on earth will
- A. Decrease by 33%
  - B. Increase by 33%
  - C. Increase by 800%
  - D. Decrease by 800%
16. Where will it be profitable to purchase 1 kg of gold?
- A. At poles
  - B. At equator
  - C. At  $45^\circ$  latitude
  - D. At  $45^\circ$  longitude
17. If the motion of a moving body is defined by  $a(t) = -2\sin(2t)$  with unit  $m/s^2$ , then the jerk of the body is?
- A.  $2a(t)$  with units  $m/s^3$
  - B.  $4a(t)$  with units  $m/s^3$
  - C.  $-2a(t)$  with units  $m/s^3$
  - D.  $-4a(t)$  with units  $m/s^3$
18. If  $L$  is any linear dimension in a solid body, the area of the body scales as  $L^2$  and volume of the body scales as  $L^3$  irrespective of the shape of the body. How does the mass of the body scale as?
- A.  $L^{1/2}$
  - B.  $L$
  - C. Same as area
  - D. Same as volume
19. A body weighs 500 N on the surface of the earth. What is its weight on the surface of a planet whose mass is  $1/5^{\text{th}}$  of that of earth and radius is  $1/3^{\text{rd}}$  of earth?
- A. 400 N
  - B. 700 N
  - C. 900 N
  - D. 500 N
20. If a person is typing the numbers 1 to 1000 using the keyboard of a computer, then the number of times the person presses the keys on the keyboard is
- A. 2892
  - B. 1892
  - C. 1000
  - D. 999

**PART B**

21. Which of the following statements best describes the characteristics of a covalent bond?
- A. Overlap of charge distributions of parallel electron spins
  - B. Overlap of charge distributions of antiparallel electron spins
  - C. Overlap of charge distributions of 30% parallel electron spins and 70% parallel electron spins
  - D. Overlap of charge distributions of 40% parallel electron spins and 60% parallel electron spins
22. What is the wave-vector selection rule when a crystal lattice with a reciprocal lattice vector  $G$  inelastically scatters a neutron from wave-vector  $k$  to  $k'$  resulting in the absorption of a phonon of wave-vector  $K$ ?
- A.  $k' + K = k + G$
  - B.  $k' = k + K + G$
  - C.  $k' + k = K + G$
  - D.  $k' + G = K + k$
23. In which of the following energy quantization can be clearly observed? (a) an electron confined to move in 1 Å wide box and (b) a 5 g marble confined to move in 100 cm wide box.
- A. Only in the case of (a)
  - B. Only in the case of (b)
  - C. In both (a) and (b) cases
  - D. In neither (a) nor in (b) case
24. What should be the wavelength ( $\lambda$  nm) of light to photo-lithographically fabricate small sized components of dimension  $L$  nm?
- A.  $\lambda^{3/2} = L$
  - B.  $\lambda^{1/2} = L$
  - C.  $\lambda \leq L$
  - D.  $\lambda \geq L^{3/2}$
25. What is the estimated magnetic moment per molecule of  $\gamma$ - $\text{Fe}_2\text{O}_3$ ?
- A. 2.39  $\mu_B$
  - B. 2.93  $\mu_B$
  - C. 2.50  $\mu_B$
  - D. 3.50  $\mu_B$

26. According to second law of thermodynamics, in a natural process
- Gibbs energy of the system always increases
  - Gibbs energy of the system + surrounding always increases
  - Entropy of the system always increases
  - Entropy of the system + surrounding always increases
27. A mild steel component exposed to sea water can be protected from corrosion using 'cathodic protection' using a block of pure
- Mg
  - Fe
  - Ag
  - C
28. The difference in potential between the fixed part of the double layer and bulk solution in the electrical double layer model is called
- Double layer potential
  - Zeta potential
  - Sedimentation potential
  - Chemical potential
29. A vertical pipe contains a stationary incompressible fluid of density  $\rho$ . The pressure at the top surface of liquid at height  $h = h_1$  is  $P_0$ . If a hole is made at a height  $h_2$  below the top surface, then the velocity with which the liquid will leak out is ( $g$  is acceleration due to gravity)
- $[2g(h_2 - h_1)]^{1/2}$
  - $[2g(h_1 - h_2)]^{1/2}$
  - $(2gh_1)^{1/2}$
  - $(2gh_2)^{1/2}$
30. The load line of a transistor circuit is given by  $5V_{CE} + 2I_C = 50$ , where  $V_{CE}$  and  $I_C$  are measured in V and mA, respectively. The values of  $V_{CC}$  and  $R_C$  for this circuit, if  $R_E = 0$  are, respectively,
- 50V and 25 Ohms
  - 5V and 400 Ohms
  - 10V and 400 Ohms
  - 10V and 0.4 Ohms
31. Curie-Weiss law is applicable at the
- Ferroelectric state
  - Anti-ferroelectric state
  - Para-electric state
  - Ferrielectric state



32. What will happen if the size of an electrically conductive component is reduced by 1000 times?
- A. Electrical power dissipated per unit area of the component at a constant voltage will increase greatly
  - B. Electrical power dissipated per unit area of the component at a constant voltage will reduce greatly
  - C. High voltage will be generated at constant current
  - D. Low voltage will be generated at constant current
33. The protectivity of corrosion resistant coatings is significantly affected by
- A. Mechanical strength
  - B. Electrical conductivity
  - C. Porosity
  - D. Capacitance
34. The elastic limit and yield strength of an alloy are determined using uniaxial tensile testing. The difference between the two depends on
- A. Strain rate
  - B. Sensitivity of the strain gauge
  - C. Applied load
  - D. Resilience
35. Consider a spherical charge distribution which has a density  $\rho$  from the center to its radius  $R$ . The electric field at distance  $r < R$  and  $r > R$  is, respectively, proportional to
- A.  $1/r$  and  $1/r^2$
  - B.  $r$  and  $1/r$
  - C.  $r^2$  and  $1/r^2$
  - D.  $r$  and  $1/r^2$
36. Ductility of a metal increases with
- A. Increase in grain size
  - B. Increase in dislocation density
  - C. Increase in number of active slip systems
  - D. Decrease in number of twins
37. What is the relation with regards to the volume ( $V$ ) of unit cells of face centered cubic (FCC), body centered cubic (BCC) and simple cubic (SC) crystal systems?
- A.  $V_{FCC} > V_{BCC} > V_{SC}$
  - B.  $V_{FCC} = V_{BCC} = V_{SC}$
  - C.  $V_{FCC} = V_{BCC} \neq V_{SC}$
  - D.  $V_{FCC} < V_{BCC} < V_{SC}$

38. Which of the following corresponds to the measured trajectory of the tip scanned on the crystal surface in a standard scanning tunneling microscopy experiment?
- Contour of local density of states on the crystal surface taken at the Fermi level
  - Contour of local density of states on the crystal surface taken below the Fermi level
  - Contour of local density of states on the crystal surface taken above the Fermi level
  - Contour of local density of states on the crystal surface independent of the location of the Fermi level.
39. Which of the following is not true about Magnetite?
- Its chemical formula is  $\text{Fe}_3\text{O}_4$  and has an inverse cubic spinel structure at ambient conditions
  - It is a metallic ferrimagnet at ambient temperature and pressure
  - It is metallic below 122K
  - It becomes an insulator below 122K
40. If the distance between two magnetic poles and their strength are doubled, then the force between the magnetic poles
- Increases to two times
  - Increases to four times
  - Remains unchanged
  - Decreases by half
41. Which of the following equations is used for calculation of stress in thin films?
- Stoney equation
  - Hall-Petch equation
  - Taylor equation
  - Orowan equation
42. To form a crystal, every lattice point should be attached with an identical basis composed of  $n$  atoms positioned at  $R_m = x_m a_1 + y_m a_2 + z_m a_3$ , where  $a_1$ ,  $a_2$  and  $a_3$  are translational vectors along X, Y and Z axes and  $m = 1, 2, 3, \dots, n$ . What are the values of  $x_m, y_m$  and  $z_m$ ?
- $x_m, y_m$  and  $z_m \geq 1$
  - $x_m, y_m$  and  $z_m > 0$
  - $0 \leq x_m, y_m$  and  $z_m \leq 1$
  - $0 < x_m, y_m$  and  $z_m < 1$

43. At a given temperature the order of pressure exerted by a gas of fermions is  $P_f$ , a gas of bosons is  $P_b$  and a gas of classical molecules is  $P_c$ , then
- $P_f > P_c > P_b$
  - $P_c > P_b > P_f$
  - $P_b > P_f > P_c$
  - $P_f > P_b > P_c$
44. What will be the crystal structure if the ratio  $c/a$  ('c' being the lattice constant along Z primitive axis and 'a' being the lattice constant along X and Y primitive axes) is far greater than 1.633?
- Face centred cubic
  - Rhombohedral
  - Hexagonal close-packed, but the planes of the close-packed atoms are loosely stacked
  - Hexagonal close-packed with much tighter stacking of the planes of the close-packed atoms
45. With which of the following Morse potential is associated?
- Vibrational energy levels in molecules
  - Rotational energy levels in molecules
  - Electronic energy levels in molecules
  - Nuclear energy levels in molecules
46. The equation relating the current  $I$ , flowing through a diode at a bias  $V$ , is given by  $I = I_0 \exp[(V/nkT)-1]$ . If  $I_0$  is the reverse saturation current,  $n$  the ideality factor,  $k$  the Boltzmann constant and  $T$  the temperature, then knowing the ideality factor, the value of  $k$  can be extracted from
- Slope of the graph between  $I$  vs  $V$
  - Slope of the graph between  $\ln I$  vs  $1/T$
  - y -intercept of the graph between  $\ln I$  vs  $1/T$
  - Slope of the graph between  $I$  vs  $1/T$
47. A cylindrical capacitor consists of two coaxial metal tubes of different radii insulated from each other. This capacitor is suspended in an insulating jar into which different quantities of benzene are poured. The capacitance of this system changes as the volume of benzene changes. Such a coaxial capacitor system can be used to estimate the
- Polarizability of the jar
  - Conductivity of the liquid
  - Polarizability of the liquid
  - Conductivity of the metal tube

48. The defect which occurs due to the solidification of casting is known as
- A. Swell
  - B. Misrun
  - C. Metal penetration
  - D. Shrinkage cavity
49. Which of the following statements is false with regards to heat capacity?
- A. Heat capacity can be measured using calorimetry
  - B. Heat capacity can be used to calculate Gibbs energy
  - C. Heat capacity changes abruptly when a solid transforms to liquid
  - D. Heat capacity at constant pressure is lower than the heat capacity at constant volume
50. Two mild steel rods A and B (having similar dimensions) were subjected to similar forging operations above and below the recrystallization temperature, respectively. If the dislocation density in A and B is given by  $\rho_A$  and  $\rho_B$ , respectively, then
- A.  $\rho_A > \rho_B$
  - B.  $\rho_A = \rho_B$
  - C.  $\rho_A < \rho_B$
  - D.  $\rho_A = \rho_B = 0$
51. A magnetized wire of magnetic moment 'M' is bent at the middle, such that the two parts are perpendicular to each other. The resultant magnetic moment is,
- A.  $M/\sqrt{2}$
  - B. M
  - C.  $M\sqrt{2}$
  - D.  $\sqrt{2}/M$
52. Rolling along which of the following crystallographic directions is easiest in interstitial free steels?
- A.  $\langle 111 \rangle$
  - B.  $\langle 100 \rangle$
  - C.  $\langle 110 \rangle$
  - D.  $\langle 001 \rangle$
53. How many effective carbon atoms are there in unit cell of diamond?
- A. 12
  - B. 10
  - C. 8
  - D. 4

54. Which of the following combinations would give the best microscopic resolution?
- A. Small numerical aperture lens, long wavelength radiation
  - B. Large numerical aperture lens, long wavelength radiation
  - C. Large numerical aperture lens, short wavelength radiation
  - D. Small numerical aperture lens, short wavelength radiation
55. Which of the following spectroscopic techniques is based on the principle of photoelectric effect?
- A. X-ray photoelectron spectroscopy
  - B. Secondary ion mass spectroscopy
  - C. Rutherford backscattering spectroscopy
  - D. Energy dispersive spectroscopy