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**Sample Question Paper for Ph.D. (Physics)**

**SPSAT'18**

**INSTRUCTIONS**

The test is 60 minutes long & consists of 40 multiple choice questions (MCQ) adding up to 40 marks.

- The radius of earth is approximately 6400 km. the height  $h$  at which the acceleration due to earth's gravity differ from  $g$  at the Earth's surface by approximately 1% is  
(a) 64 km                      (b) 48 km                      (c) 32 km                      (d) 16 km
- If Lagrangian  $L = q\dot{q}$  then the equation of motion is  
(a)  $\ddot{q} = 0$                       (b)  $\dot{q} = 0$                       (c)  $q = 0$                       (d) There is no equation of motion
- A magnetic field is given by the expression  $B(x, y, z) = Axz\hat{x} + Byz\hat{y} + Gz\hat{z}$ , where  $A, B$  &  $G$  are constants. What is the relationship between  $A$  &  $B$ ?  
(a)  $A = B$                       (b)  $A = -B$                       (c)  $AB = 1$                       (d)  $A$  &  $B$  are uncorrelated
- If  $A^2 = I$ , what is  $\exp(i\alpha A)$  where  $a$  is real,  $A$  is a  $n \times n$  matrix &  $I$  is identity matrix.  
(a)  $I \cos \alpha + iA \sin \alpha$                       (b)  $I \sin \alpha + iA \cos \alpha$   
(c)  $I \cos \alpha - iA \sin \alpha$                       (d)  $I \cos \alpha - iA \sin \alpha$
- For  $f(z) = (z^2 + 5z + 3)/[(z - 1)(z + 2)^2]$ , the sum of residue of all the poles is  
(a) 1                      (b) 2                      (c) 0                      (d) -1
- The ratio of nuclear radii of  ${}_{13}^{27}Al$  &  ${}_4^8Be$  nuclei is  
(a) 1                      (b) 1/2                      (c) 3/2                      (d) 2
- In n-type & p-type semiconductors, the Fermi levels lie  
(a) in the middle of the band gap for both p-type & n-type  
(b) close to the valance band for n-type & close to the conduction band for p-type  
(c) close to the conduction band for n-type & close to the valance band for p-type  
(d) close to the valance band for both p-type & n-type
- The Poisson bracket between the  $z$  component of the angular momentum ( $L_z$ ) &  $x$ , i.e.,  $\{L_z, x\}$  is  
(a)  $+z$                       (b)  $-z$                       (c)  $+y$                       (d)  $-y$
- The dipole moment of a thin charges rod bearing charge density  $\rho(x, y, x) = Az\delta(x)\delta(y)$  for  $z \in (-a, a)$ , where  $A$  is a constant, is  
(a)  $\frac{2}{3}Aa^3\hat{z}$                       (b)  $\frac{1}{12}Aa^3\hat{z}$                       (c)  $\frac{1}{6}Aa^3\hat{z}$                       (d)  $\frac{1}{3}Aa^3\hat{z}$

10. Given that the probability  $P$  of finding a system of canonical ensemble in the energy  $E_r$  at a temperature  $T$  is  $P_r = C \exp(-E_r/kT)$ , then  $C$  is called
- (a) Partition function (b) Inverse of Partition function  
(c) Log of Partition function (d) Free energy
11. The electric field in some region of space is uniform in magnitude & direction. The charge density in this region
- (a) is Zero  
(b) decreases linearly in the direction of electric field  
(c) increases linearly in the direction of electric field  
(d) is uniform throughout the region
12. Propagation of matter or fields in physical processes are sometimes depicted visually in diagrams by lines. Of the following, the lines that can cross are
- (a) streamlines in fluid flow (b) lines of forces in electrostatics  
(c) rays in geometrical optics (d) lines of force in magnetism
13. The following can easily penetrate bone matter:
- (a) violet light (b) ultraviolet light (c) x-rays (d) gamma rays
14. The energy per oscillator of an isolated system of a large number of identical non-interacting fermions in one-dimensional harmonic oscillator potentials is  $5\hbar\omega/4$ , where  $\omega$  is the angular frequency of the harmonic oscillator. The entropy of the system per oscillator is given by
- (a) 0.75 (b) 0.63 (c) 0.56 (d) 0.25
15. In a simple cubic lattice of lattice constant 0.287 nm, the number of atoms per  $\text{mm}^2$  along the 111 plane is
- (a)  $2.11 \times 10^{13}$  (b)  $1.73 \times 10^{13}$  (c)  $1.29 \times 10^{13}$  (d)  $1.21 \times 10^{13}$
16. In an ionization experiment conducted in the laboratory, different singly-charged positive ions are produced & accelerated simultaneously using a uniform electric field along the x-axis. If we need to determine the masses of various ions produced, which of the following methods will NOT work
- (a) Apply a uniform magnetic field along y-axis & measure the deviation  
(b) Apply a uniform electric field along y-axis & measure the deviation  
(c) Detect them at a fixed distance from the interaction point along x-axis & measure their time of arrival  
(d) Apply a uniform electric field along y-axis & a (variable) uniform magnetic field along z-axis simultaneously & note the zero deviation

17. Two homonuclear diatomic molecules produce different rotational spectra, even though the atoms are known to have identical chemical properties. This leads to the conclusion that the atoms must be

- (a) Isomers, i.e. with the same atomic number & weight
- (b) Isotones, i.e. with the same neutron number
- (c) Isobars, i.e. with the same atomic weight
- (d) Isotopes, i.e. with the same atomic number

18. Metallic Copper is known to form cubic crystals & the lattice constant is measured from X-ray diffraction studies to be about 0.36 nm. If the specific gravity of Copper is 8.96 & its atomic weight is 63.5, one can conclude that

- (a) The crystals are of simple cubic type
- (b) The crystals are of b.c.c. type
- (c) The crystals are of f.c.c. type
- (d) The crystals are a mixture of f.c.c. & b.c.c. types

19. The strongest three lines in the emission spectrum of an interstellar gas cloud are found to have wavelengths  $\lambda_0$ ,  $2\lambda_0$  &  $6\lambda_0$  respectively, where  $\lambda_0$  is a known wavelength. From this we can deduce that the radiating particles in the cloud behave like

- (a) Free particles
- (b) Particles in a box
- (c) Harmonic oscillators
- (d) Rigid rotators

20. If we model the electron as a uniform sphere of radius  $r_e$ , spinning uniformly about an axis passing through its centre with angular momentum  $L_e = \hbar/2$ , & demand that the velocity of rotation at the equator cannot exceed the velocity  $c$  of light in vacuum, then the minimum value of  $r_e$  is,

- (a) 19.2 fm
- (b) 0.192 fm
- (c) 4.8 fm
- (d) 480 fm

21. A signal of frequency 10 kHz is being digitized by an A/D converter. A possible sampling time which can be used is:

- (a) 100  $\mu$ s
- (b) 40  $\mu$ s
- (c) 60  $\mu$ s
- (d) 200  $\mu$ s

22. Consider the transition of liquid water to steam as water boils at a temperature of 100°C under a pressure of 1 atmosphere. Which one of the following quantities does not change discontinuously at the transition?

- (a) The Gibbs free energy
- (b) The internal energy
- (c) The entropy
- (d) The specific volume

23. The acceleration due to gravity ( $g$ ) on the surface of Earth is approximately 2.6 times that on the surface of Mars. Given that the radius of Mars is about one half the radius of Earth, the ratio of the escape velocity on Earth to that on Mars is approximately:

- (a) 1.1
- (b) 1.3
- (c) 2.3
- (d) 5.2

24. Four equal point charges are kept fixed at the four vertices of a square. How many neutral points (i.e., points where the electric field vanishes will be found inside the square?)
- (a) 3                      (b) 4                      (c) 5                      (d) 7
25. A laser operating at 500 nm is used to excite a molecule. If the Stokes line is observed at  $770\text{ cm}^{-1}$  the approximate positions of the Stokes & the anti-Stokes lines are
- (a) 481.5 nm & 520 nm                      (b) 481.5 nm & 500 nm  
(c) 500 nm & 520 nm                      (d) 500 nm & 600 nm
26. The minimum energy of an electron (the rest mass of which is 0.5 MeV) that can emit Cherenkov radiation while passing through water (of refractive index 1.5 ) is approximately
- (a) 1.0MeV                      (b) 3.0 MeV                      (c) 0.6 MeV                      (d) 0.5 MeV
27. Two events, separated by a (spatial) distance  $9 \times 10^9\text{m}$  , are simultaneous in one inertial frame. The time interval between these two events in a frame moving with a constant speed  $0.8c$  (where the speed of light  $c=3 \times 10^8\text{m/s}$ ) is:
- (a) 60 s                      (b) 40 s                      (c) 20 s                      (d) 0 s
28. Let  $\Delta W$  be the work done in a quasistatic reversible thermodynamics process. Which of the following statements about  $\Delta W$  is correct?
- (a)  $\Delta W$  is a perfect differential if the process is isothermal  
(b)  $\Delta W$  is a perfect differential if the process is adiabatic  
(c)  $\Delta W$  is always a perfect differential  
(d)  $\Delta W$  cannot be a perfect differential.
29. A live music broadcast consists of a radio-wave of frequency 7 MHz, amplitude-modulated by a microphone output consisting of signals with a maximum frequency of 10 KHz. The spectrum of modulated output will be zero outside the frequency band
- (a) 7.00 MHz to 7.01 MHz                      (b) 6.99 MHz to 7.01 MHz  
(c) 6.99 MHz to 7.00 MHz                      (d) 6.995 MHz to 7.005 MHz
30. The sum of the squares of the eigen values of a  $3 \times 3$  matrix A is 20. The corresponding sum for the matrix  $2A$  is
- (a) 40                      (b) 60                      (c) 120                      (d) 80
- 31.If  $\theta$  is real, the function  $\text{Sin}(\theta^2)$  is
- (a) a periodic function of  $\theta$  with period  $2\pi$                       (b) a periodic function of  $\theta$  with period  $2\pi^2$   
(c) a periodic function of  $\theta$  with period  $\pi^2$                       (d) not a periodic function of  $\theta$
- 32.A hollow metallic waveguide can support

- (a) TE, TM & TEM waves (b) either TE or TM waves  
 (c) both TE & TM waves (d) only TEM waves

33. To use a transistor as an amplifier

- (a) emitter-base junction should be forward-biased & the collector-base junction reverse-biased  
 (b) both junctions should be forward-biased  
 (c) both junctions should be reverse-biased  
 (d) it does not matter how the transistor is biased, it always works as an amplifier

34. Which of the following logic gates can be used as a controlled inverter?

- (a) AND gate (b) OR gate (c) INVERTER gate (d) XOR gate

35. The neutrinos emitted in a  $\beta$  decay process are

- (a) right handed (b) left handed  
 (c) both left & right handed (d) spin-zero & mass less particles

36. Alpha decay is an example of

- (a) nuclear fission (b) barrier penetration  
 (c) coulomb repulsion (d) nuclear ionization

37. An aircraft executes a horizontal loop of radius 1 km with a steady speed of 900 km/h. The ratio of horizontal acceleration of the aircraft to the acceleration due to gravity ( $9.8 \text{ m/sec}^2$ ) is about

- (a) 0 (b) 5 (c) 6 (d) 7

38. Which of the following has non-vanishing Poisson bracket with  $L_z$  the Z-component of the angular momentum  $\vec{L}$  ?

- (a)  $a(x^2 + y^2 + z^2)$  (b)  $a(x^2 + y^2) + bz^2$   
 (c)  $ax^2 + by^2 + az^2$  (d)  $a(x^2 + y^2)^2$

39. For the function  $f(z) = \frac{z}{(z+2)^2}$  the order of the pole at  $z = -2$  & the residue at the pole are respectively given by

- (a) 2, -2 (b) 2, 1 (c) 1, -2 (d) 1, 1

40. If  $\hat{H}$  &  $\hat{p}$  respectively denote the Hamiltonian & the momentum operator for a free particle. then the functions  $\sin kx$  &  $\cos kx$  are eigen functions

- (a) of both  $\hat{H}$  &  $\hat{p}$  (b) only of  $\hat{H}$  but not of  $\hat{p}$   
 (c) only of  $\hat{p}$  but not of  $\hat{H}$  (d) of neither  $\hat{H}$  nor  $\hat{p}$