THE MAHARAJA SAYAJIRAO UNIVERSITY OF BARODA, VADODARA

Ph. D. ENTRANCE TEST (PET) 2023

Signature of Invigilator

Roll. No. | | | | | | |

Paper - II
Physical Sciences

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Maximum Marks: 50 **No. Of Printed Pages: 8**

Instruction for the Candidate:

1. This paper consists of **FIFTY (50)** multiple choice type questions. Each Question carries **ONE (1)** mark.
2. There is no Negative Marking for Wrong Answer.
3. A separate OMR Answer Sheet has been provided to answer questions. Your answers will be evaluated based on your response in the OMR Sheet only. No credit will be given for any answering made in question booklet.
4. Defective question booklet or OMR if noticed may immediately replace by the concerned invigilator.
5. Write roll number, subject code, booklet type, category and other information correctly in the OMR Sheet else your OMR Sheet will not be evaluated by machine.
6. Select most appropriate answer to the question and darken appropriate oval on the OMR answer sheet, with black / blue ball pen only. DO NOT USE PENCIL for darkening. In case of over writing on any answer, the same will be treated as invalid. Each question has exactly one correct answer and has four alternative responses (A), (B), (C) and (D). You have to darken the circle as indicated below on the correct response against each item.
   Example: Ⓐ ● Ⓒ Ⓓ where (B) is correct response.
7. Rough Work is to be done in the end of this booklet.
8. If you write your Name, Roll Number, Phone Number or put any mark on any part of the OMR Answer Sheet, except for the space allotted for the relevant entries, which may disclose your identity, or use abusive language or employ any other unfair means, such as change of response by scratching or using white fluid, you will render yourself liable to disqualification.
9. Calculators, Log tables any other calculating devices, mobiles, slide rule, text manuals etc are NOT allowed in the examination hall. If any of above is seized from the candidates during examination time; he/ she will be immediately debarred from the examination and corresponding disciplinary action will be initiated by the Center Supervisor as deemed fit.
10. DO NOT FOLD or TEAR OMR Answer sheet as machine will not be able to recognize torn or folded OMR Answer sheet.
11. **You have to return the OMR Answer Sheet to the invigilator at the end of the examination compulsorily** and must not carry it with you outside the Examination Hall. You are however, allowed to carry original question booklet on conclusion of examination.

Paper - II
Physical Sciences

Note: This paper contains **FIFTY (50)** multiple-choice questions. Each Question carries **ONE (1)** mark.

01) The solution for differential equation for *y(t)*: $\frac{d^2y}{dt^2} - y = 2\cosh(t)$, subject to the initial conditions $y(0) = 0, \frac{dy}{dt} = 0 \ at \ t = 0$, is

A) $tsinh(t)$
B) $-sinh(t) + tcosh(t)$
C) $cosh(t) + tsinh(t)$
D) $tcosh(t)$

02) The function $f(x) = x^2 - \pi < x < \pi$, has a Fourier series representation

$$x^2 = \frac{\pi^2}{3} + 4\sum_{n=1}^{\infty} \frac{(-1)^n}{n^2} cosnx$$

Using this, the value of $\sum_{n=1}^{\infty} \frac{1}{n^2}$ is,

A) $2\pi^2$
B) π^2
C) $\frac{\pi^2}{3}$
D) $\frac{\pi^2}{6}$

03) Four forces are given below in cartesian and spherical polar coordinates, here K is constant.

$\vec{F}_1 = Kexp\left(\frac{-r^2}{R^2}\right)\hat{r}$, $\vec{F}_2 = K(x^3\hat{y} - y^3\hat{z})$, $\vec{F}_3 = K(x^3\hat{x} - y^3\hat{y})$, $\vec{F}_4 = K\left(\frac{\hat{\varphi}}{r}\right)$

Choose correct option.

A) $\vec{F}_3$ and $\vec{F}_4$ are conservative but $\vec{F}_1$ and $\vec{F}_2$ are not.
B) $\vec{F}_1$ and $\vec{F}_2$ are conservative but $\vec{F}_3$ and $\vec{F}_4$ are not.
C) $\vec{F}_2$ and $\vec{F}_3$ are conservative but $\vec{F}_1$ and $\vec{F}_4$ are not.
D) $\vec{F}_1$ and $\vec{F}_3$ are conservative but $\vec{F}_2$ and $\vec{F}_4$ are not.

04) The maximum value of the solution y(t) of the differential equation for $y(t) + \ddot{y}(t) = 0$, subject to the initial condition $\dot{y}(0) = 1 \ and \ y(0) = 1 \ for \ t \geq 0$, is

A) π
B) $\sqrt{2}$
C) 2
D) 2π

05) A vector function $\vec{A} = 4y\hat{x} + 2x\hat{y}$ then $\oint \vec{A}.\overrightarrow{dl}$ over a circular path of radius R, centred at origin in the xy-plane is

A) πR^2
B) $2\pi R^2$
C) $-\pi R^2$
D) $-2\pi R^2$

06) If $\vec{A} \ and \ \vec{B}$ are constant vectors and $\vec{r}$ is a position vector of a point P(x,y,z), then $\vec{\nabla}\left(\vec{A}(\vec{B} \times \vec{r})\right)$ is

A) Zero
B) $\vec{A}.\vec{B}$
C) $\vec{A} \times \vec{B}$
D) $\vec{r}$

07) A particle is in ground state of an infinite square well potential given by

$$V(x) = \begin{cases} 0 & for \quad -a \leq x \leq a \\ \infty & otherwise \end{cases}$$

The probability of finding a particle between $-\frac{a}{4}$ and $\frac{a}{4}$ is?

A) $\frac{1}{2} + \frac{\sqrt{2}}{\pi}$
B) $\frac{1}{4} + \frac{1}{\sqrt{2}\pi}$
C) $\frac{1}{4} - \frac{1}{\sqrt{2}\pi}$
D) $\frac{1}{2} - \frac{\sqrt{2}}{\pi}$

08) A particle of mass m, confined in two-dimensional harmonic oscillator. If non-normalized wave function is given by $\psi(x,y) = yexp\left[-\frac{m\omega}{2\hbar}(2x^2 + y^2)\right]$, what will be the corresponding energy eigen value?

A) $E = \hbar\omega$
B) $E = \frac{3}{2}\hbar\omega$
C) $E = \frac{5}{2}\hbar\omega$
D) $E = \frac{7}{2}\hbar\omega$

09) In a basis, in which the z-component S_Z of spin is diagonal, an electron is in a spin-state

$\psi = \begin{pmatrix} (1+i)/\sqrt{6} \\ a \end{pmatrix}$

Where, a is constant. The probabilities that the measurement of S_Z, will yield the values $\frac{\hbar}{2}$ and $-\frac{\hbar}{2}$ are, respectively,

A) 1/2 and 1/2
B) 1/4 and 3/4
C) 2/3 and 1/3
D) 1/3 and 2/3

10) A hydrogen atom is found in a state having wave function

$$\psi(r,t) = \frac{1}{\sqrt{14}} exp\left(\frac{iE_1 t}{\hbar}\right)\psi_1(r) + \sqrt{\frac{2}{7}} exp\left(\frac{iE_2 t}{\hbar}\right)\psi_2(r) + \frac{3}{\sqrt{14}} exp\left(\frac{iE_3 t}{\hbar}\right)\psi_3(r)$$

Where E_1, E_2, E_3 and $\Psi_1(r)$, $\Psi_2(r)$, $\Psi_3(r)$ are ground state, first excited state and third excited state, respectively. If E_0 is the ionization energy of hydrogen atom then average energy is given by,

A) $-\frac{54}{7}E_0$
B) $-\frac{3}{14}E_0$
C) $-\frac{1}{7}E_0$
D) $-\frac{1}{14}E_0$

11) A particle of mass m in a cubic box of size a. The potential inside the box $(0 \le x \le a, 0 \le y \le a, 0 \le z \le a)$is zero and outside is infinite. If the particle is in an eigenstate of energy $\frac{7\pi^2\hbar^2}{ma^2}$, its wave function is.

A) $\psi = \left(\frac{2}{a}\right)^{3/2} sin\frac{\pi x}{a} sin\frac{\pi y}{a} sin\frac{2\pi z}{a}$
B) $\psi = \left(\frac{2}{a}\right)^{1/2} sin\frac{\pi x}{a} sin\frac{\pi y}{a} sin\frac{2\pi z}{a}$
C) $\psi = \left(\frac{2}{a}\right)^{1/2} sin\frac{\pi x}{a} sin\frac{2\pi y}{a} sin\frac{3\pi z}{a}$
D) $\psi = \left(\frac{2}{a}\right)^{3/2} sin\frac{\pi x}{a} sin\frac{2\pi y}{a} sin\frac{3\pi z}{a}$

12) Consider a potential $V(x) = -\frac{\hbar^2 a^2}{m} sech^2(ax)$, if the ground state wave function is $\psi(x) = Asech(ax)$, then corresponding energy is given by,

A) $-\frac{\hbar^2 a^2}{2m}$
B) $-\frac{\hbar^2 a^2}{m}$
C) $-\frac{2\hbar^2 a^2}{m}$
D) $-\frac{3\hbar^2 a^2}{2m}$

13) Which of the following CANNOT be explained by considering a harmonic approximation of lattice vibrations in solids?

A) Debye's T^3 law
B) Thermal expansion
C) Optical branches in lattices
D) Dulong Petit Law

14) The cubic lattice with lattice parameter a_c, undergoes transition into a tetragonal structure with lattice parameters $a_t = b_t = \sqrt{2}a_c$ and $c_t = 2a_c$, below a certain temperature. The ratio of interplanar spacing of (1 0 1) planes for the cubic and tetragonal structure is

A) $\sqrt{\frac{1}{6}}$
B) $\frac{1}{6}$
C) $\sqrt{\frac{3}{8}}$
D) $\frac{3}{8}$

15) From the X-ray diffraction study, the lattice constant of a certain material is found to be 0.36nm. If the specific gravity of the material is 8.96 and its atomic weight is 63.5. Then the crystal structure of the material can say to be

A) FCC
B) SC
C) BCC
D) HCP

16) The dispersion relation for a one-dimensional monoatomic crystal with lattice spacing a is given as $\omega = A\left|sin\frac{ka}{2}\right|$, at the boundary of the first Brillouin Zone, the derivative of the angular frequency with respect to wave vector is

A) $\sqrt{\frac{aA^2}{2}}$
B) $\sqrt{aA^2}$
C) 0
D) 1

17) Consider a one-dimensional lattice with weak periodic potential $U(x) = U_0 cos\frac{2\pi x}{a}$. Find the gap at the edge of the BZ (k=π/a).

A) $\frac{U_0}{2}$
B) U_0
C) $\frac{U_0}{4}$
D) $2U_0$

18) Consider a 3-D cubic lattice, the ratio of kinetic energy of a free electron at the corner of the first Brillouin Zone (E_C) to that of at the face centre of anyone face (E_F) is,

A) 1/3
B) 2
C) 3
D) 2/3

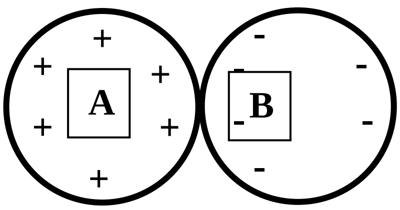
19) An electric charge distribution produces an electric field $\vec{E} = (1 - e^{-\alpha r})\frac{\vec{r}}{r^3}$, where $\alpha$is constant. The net charge within a sphere of radius α^{-1}centres at origin is

A) $4\pi\varepsilon_0(1 - e^{-1})$
B) $4\pi\varepsilon_0(1 + e^{-1})$
C) $-4\pi\varepsilon_0\frac{1}{\alpha e}$
D) $4\pi\varepsilon_0\frac{1}{\alpha e}$

20) A point charge q of mass m is released from the rest at distance d from the infinite grounded conducting plate. How long does it take for the charge to hit the plate (ignore gravity)?

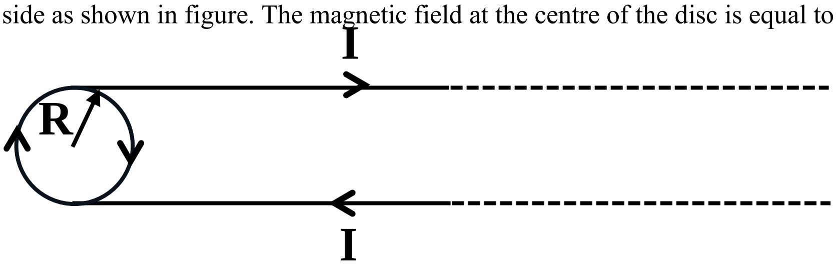
A) $\frac{\sqrt{2\pi^3\varepsilon_0 md}}{q}$
B) $\frac{\sqrt{\pi^3\varepsilon_0 md^3}}{q}$
C) $\frac{\sqrt{\pi^3\varepsilon_0 md}}{q}$
D) $\frac{\sqrt{2\pi^3\varepsilon_0 md^3}}{q}$

21) Two uniformly charges insulating solid spheres A and B both of radius R, carries total charge +Q and -Q respectively. The spheres are placed side by side such that their boundaries are touching each other as shown in figure. If the potential at the centre of sphere A is V_A and at the centre of sphere B is V_B, then the potential difference VA-VB is?



A) $\frac{Q}{2\pi\varepsilon_0 R}$
B) $\frac{Q}{4\pi\varepsilon_0 R}$
C) $\frac{Q}{8\pi\varepsilon_0 R}$
D) 0

22) Consider a thin long wire carrying current I. It is wound once around an insulating thin disc of radius R to bring wire back to same side as shown in figure. The magnetic field at the centre of the disc is equal to:



A) $\frac{\mu_0 I}{2R}$

B) $\frac{\mu_0 I}{4R}\left[3+\frac{2}{\pi}\right]$
C) $\frac{\mu_0 I}{2R}\left[1+\frac{2}{\pi}\right]$
D) $\frac{\mu_0 I}{2R}\left[3+\frac{1}{\pi}\right]$

23) If the electrostatic potential in spherical coordinates is $\varphi(r) = \varphi_0 e^{-r/r_0}$, where φ_0 and r_0 are constants, then the charge density at $r = r_0$ is:
A) $\frac{\varepsilon_0 \varphi_0}{e r_0^2}$
B) $\frac{e \varepsilon_0 \varphi_0}{2 r_0^2}$
C) $-\frac{\varepsilon_0 \varphi_0}{e r_0^2}$
D) 0

24) Consider the superposition of two coherent EM waves whose electric field vectors are given as $\vec{E}_1 = \hat{\imath} E_0 cos\omega t$ and $\vec{E}_2 = \hat{\jmath} E_0 \cos(\omega t + \varphi)$, where φ is phase difference. The intensity of resulting wave is given by $\frac{\varepsilon_0}{2}\langle E^2 \rangle$, where $\langle E^2 \rangle$ is the time-average of E^2. The total intensity is:
A) 0
B) $\varepsilon_0 E_0^2$
C) $\varepsilon_0 E_0^2 sin^2(\varphi/2)$
D) $\varepsilon_0 E_0^2 cos^2(\varphi/2)$

25) A plane EM wave has the magnetic field given by, $\vec{B}(x,,y,z,t) = B_0 sin\left[(x+y)\frac{k}{\sqrt{2}} + \omega t\right]\hat{k}$, where k is the wave number and $\hat{\imath}, \hat{\jmath}, \hat{k}$ are the Cartesian unit vectors in x, y and z direction respectively. The electric field $\vec{E}(x,,y,z,t)$ corresponding to the above wave is given by:
A) $cB_0 sin\left[(x+y)\frac{k}{\sqrt{2}} + \omega t\right]\frac{\hat{\imath}-\hat{\jmath}}{\sqrt{2}}$
B) $cB_0 sin\left[(x+y)\frac{k}{\sqrt{2}} + \omega t\right]\frac{\hat{\imath}+\hat{\jmath}}{\sqrt{2}}$
C) $B_0 sin\left[(x+y)\frac{k}{\sqrt{2}} + \omega t\right]\hat{\imath}$
D) $B_0 sin\left[(x+y)\frac{k}{\sqrt{2}} + \omega t\right]\hat{\jmath}$

26) What is the wavelength of the radiation emitted when the electron in H atom jumps from n=∞ to n=2 ?
A) 356 Å
B) 356 nm
C) 565 Å
D) 565 nm

27) Which element has the highest electronegativity?
A) F
B) Ne
C) Ni
D) Fe

28) The direction of the magnetic moment vector for an atomic orbit is:
A) Normal to the plane of the orbit and parallel to *l*
B) Normal to the plane of the orbit and anti-parallel to *l*
C) Tangent to the orbit
D) In the direction of the motion of the orbiting electron

29) An electron collides with a hydrogen atom in its ground state and excites it to a state of n=3. How much energy was given to the hydrogen atom?
A) 13.6 eV
B) 16.8 eV
C) 12.1 eV
D) 1.51 eV

30) When an electric dipole is placed in a uniform electric field, at what angle will the torque be maximum?
A) 0 degree
B) 45 degree
C) 90 degree
D) 180 degree

31) A rigid body is an example of the following constraint:
A) Holonomic
B) Nonholonomic
C) None of these

D) Both holonomic as well as nonholonomic

32) Moment of force is defined as:
A) $r \times P$
B) $r \times F$
C) $r \cdot P$
D) $r \cdot F$

33) D'Alembert's principle helps in:
A) Adding unknown forces
B) Changing the constraint from one another
C) Removing forces of constraint
D) None of these

34) Kepler's second law of planetary motion states that:
A) The orbits of planets are circular
B) The force is given by inverse square law
C) The orbits of planets are elliptical
D) The radius vector sweeps out equal area in equal time

35) A reduced mass is defined as:
A) $\mu = \frac{m1m2}{m1+m2}$
B) $\mu = \frac{m1m2}{m1-m2}$
C) $\mu = \frac{m1+m2}{m1m2}$
D) $\mu = \frac{m1-m2}{m1m2}$

36) The Gibbs function of a thermodynamic system is given by:
A) G= U-TS-PV
B) G= U+TS+PV
C) G= U+TS-PV
D) G= U-TS+PV

37) Which one of the following is NOT a thermodynamic potential:
A) Internal Energy
B) Enthalpy
C) Entropy
D) Helmholtz Function

38) In a micro canonical ensemble, a system A of fixed volume is in contact with a large reservoir B, Then:
A) A can exchange only energy with B
B) A can exchange only particles with B
C) A can exchange neither energy nor particles with B
D) A can exchange both energy and particles with B

39) According to Debye's theory of specific heat at low temperature specific heat is proportional to:
A) T
B) T^2
C) T^3
D) T^4

40) Which of the following relations between free energy F and the microcanonical partition function Z is correct:
A) F = -N $\frac{d}{dT}$(log Z)
B) F = NkT log Z
C) F = NkT^2 log Z
D) F = Nk $\frac{d}{dV}$(log Z)

41) In case of Bose-Einstein condensation:
A) Number of particles increases in lower energy levels at low temperatures and high pressures
B) Number of particles decreases in lower energy levels at low temperatures and high pressures
C) Number of particles increases in lower energy levels at high temperatures and low pressures
D) Number of particles decreases in lower energy levels at high temperatures and low pressures

42) For an active operation of a transistor, base emitter junction and collector-base junction should biased in which of the following pairs:
A) FORWARD; REVERSE

B) REVERSE; FORWARD
C) REVERSE; REVERSE
D) FORWARD; FORWARD

43) For an ideal operational amplifier (OP-AMP), which of the following is **NOT** true:
A) Infinite voltage gain
B) Infinite input resistance
C) Zero output resistance
D) Zero bandwidth

44) An 8-bit D/A converter has an output of voltage range of 0 to 2.55 V. The resolution of the system will be:
A) 0.1 V
B) 0.01V
C) 0.001 V
D) 0.025V

45) A high pass filter allows:
A) low frequency to pass
B) high frequency to pass
C) mid band frequency to pass
D) upper and lower frequency to pass

46) At elevated temperatures, the extrinsic semiconductor behaves like:
A) Extrinsic Semiconductor
B) Intrinsic Semiconductor
C) An Insulator
D) Conductor

47) Two resistances 100 Ω ± 10 Ω and 250 Ω ± 15 Ω are connected in series. If the deviations are standard deviations, the resultant resistance can be expressed as:
A) 350 Ω ± 250 Ω
B) 350 Ω ± 5 Ω
C) 350 Ω ± 16.4 Ω
D) 350 Ω ± 18.7 Ω

48) The mass density of a nucleus in $kg.m^{-3}$ is of the order of:
A) 10^{-13}
B) 10^{17}
C) 10^{-17}
D) 10^{13}

49) If an electron is assumed to exist in a nucleus, then its energy on the basis of uncertainity principle will be:
A) 20 keV
B) 20 eV
C) 200 eV
D) 20 MeV

50) According to Fermi gas model of the nucleus, which of the following statement is TRUE for an actual nucleus (N > Z):
A) Neutron depth being slightly greater than the proton depth
B) Neutron depth being slightly smaller than the proton depth
C) Neutron Fermi energy being slightly greater than the proton Fermi energy
D) Neutron Fermi energy being slightly smaller than the proton Fermi energy

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Rough Work: