Roll No. | | | | | | | |

(Write Roll Number from left side exactly as in the Admit Card)

Signature of Invigilators

1. ______________________

2. ______________________

Question Booklet Series **X**

1618

PAPER–II **Question Booklet No.**

(Identical with OMR Answer Sheet Number)

Subject Code : 16

PHYSICAL SCIENCES

Time : 2 *Hours* *Maximum Marks:* 200

Instructions for the Candidates

1. Write your Roll Number in the space provided on the top of this page as well as on the OMR Sheet provided.
2. At the commencement of the examination, the question booklet will be given to you. In the first 5 minutes, you are requested to open the booklet and verify it:
   (i) To have access to the Question Booklet, tear off the paper seal on the edge of this cover page.
   (ii) Faulty booklet, if detected, should be got replaced immediately by a correct booklet from the invigilator within the period of 5 minutes. Afterwards, neither the Question Booklet will be replaced nor any extra time will be given.
   (iii) Verify whether the Question Booklet No. is identical with OMR Answer Sheet No.; if not, the full set is to be replaced.
   (iv) After this verification is over, the Question Booklet Series and Question Booklet Number should be entered on the OMR Sheet.
3. This paper consists of One hundred (100) multiple-choice type questions. All the questions are compulsory. Each question carries *two* marks.
4. Each Question has four alternative responses marked: (A) (B) (C) (D). You have to darken the circle as indicated below on the correct response against each question.

   Example: (A) (B) ● (D), where (C) is the correct response.
5. Your responses to the questions are to be indicated correctly in the OMR Sheet. If you mark your response at any place other than in the circle in the OMR Sheet, it will not be evaluated.
6. Rough work is to be done at the end of this booklet.
7. If you write your Name, Roll Number, Phone Number or put any mark on any part of the OMR Sheet, except in 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.
8. Do not tamper or fold the OMR Sheet in any way. If you do so, your OMR Sheet will not be evaluated.
9. You have to return the Original OMR 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 question booklet and duplicate copy of OMR Sheet after completion of examination.
10. **Use only Black Ball point pen.**
11. **Use of any calculator or mobile phone etc. is strictly prohibited.**
12. **There are no negative marks for incorrect answers.**

[Please Turn Over]

PHYSICAL SCIENCES

Paper II

1. Consider the matrix $\begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix}$. Its eigenvalues and normalized eigenvectors are

(A) $\left[0, \frac{1}{\sqrt{2}}\begin{pmatrix} 0 \\ 1 \\ 1 \end{pmatrix}\right], \left[1, \frac{1}{\sqrt{3}}\begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix}\right], \left[2, \frac{1}{2}\begin{pmatrix} 2 \\ 1 \\ -1 \end{pmatrix}\right]$

(B) $\left[0, \frac{1}{2}\begin{pmatrix} 2 \\ -1 \\ -1 \end{pmatrix}\right], \left[0, \frac{1}{\sqrt{2}}\begin{pmatrix} 0 \\ 1 \\ -1 \end{pmatrix}\right], \left[3, \frac{1}{\sqrt{3}}\begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix}\right]$

(C) $\left[1, \frac{1}{\sqrt{3}}\begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix}\right], \left[1, \frac{1}{\sqrt{2}}\begin{pmatrix} 0 \\ 1 \\ 1 \end{pmatrix}\right], \left[1, \frac{1}{\sqrt{2}}\begin{pmatrix} 1 \\ 1 \\ 0 \end{pmatrix}\right]$

(D) $\left[1, \frac{1}{\sqrt{2}}\begin{pmatrix} 1 \\ 1 \\ 0 \end{pmatrix}\right], \left[1, \frac{1}{\sqrt{2}}\begin{pmatrix} 1 \\ 0 \\ 1 \end{pmatrix}\right], \left[1, \frac{1}{\sqrt{2}}\begin{pmatrix} 0 \\ 1 \\ 1 \end{pmatrix}\right]$

2. A (3×3) matrix M has $\mathrm{Tr}[M] = 6$ and $\mathrm{Tr}[M^2] = 26$. Which one of the following can be a possible set of eigenvalues of M?

(A) $\{1, 1, 4\}$

(B) $\{-1, 0, 7\}$

(C) $\{-1, 3, 4\}$

(D) $\{2, 2, 2\}$

3. The unit vector normal to the surface $3x^2 + 4y = z$ at the point (1, 1, 7) is

(A) $\frac{1}{\sqrt{24}}\left(3\hat{i} + 4\hat{j} - \hat{k}\right)$

(B) $\frac{1}{\sqrt{51}}\left(6\hat{i} + 4\hat{j} - \hat{k}\right)$

(C) $\frac{1}{\sqrt{53}}\left(6\hat{i} + 4\hat{j} - \hat{k}\right)$

(D) $\frac{1}{\sqrt{51}}\left(\hat{i} + \hat{j} + 7\hat{k}\right)$

4. Let $\vec{a}$ and $\vec{b}$ be two distinct three dimensional vectors. Then the component of $\vec{b}$ that is perpendicular to $\vec{a}$ is given by

(A) $\frac{\vec{a} \times \left(\vec{b} \times \vec{a}\right)}{a^2}$

(B) $\frac{\left(\vec{a} \cdot \vec{b}\right)\vec{b}}{b^2}$

(C) $\frac{\vec{b} \times \left(\vec{a} \times \vec{b}\right)}{b^2}$

(D) $\frac{\left(\vec{b} \cdot \vec{a}\right)\vec{a}}{a^2}$

5. If the force on some particle is given by $\vec{F} = -\hat{i}\,y + \hat{j}\,x$, then the work done by this force in moving the particle one complete turn along the closed curve $9x^2 + 4y^2 = 1$ is given by

(A) $\frac{\pi}{6}$

(B) $\frac{\pi}{3}$

(C) $\frac{\pi}{48}$

(D) $\frac{\pi}{2}$

6. Identify the correct statement about the following infinite series:

$$1-\frac{1}{2}+\frac{1}{3}-\frac{1}{4}+\frac{1}{5}-\frac{1}{6}+\frac{1}{7}-\cdots$$

(A) The series is not convergent.

(B) The series is absolutely convergent.

(C) The series is convergent but not absolutely convergent.

(D) None of the above statement is true.

7. Consider the differential equation

$$\frac{d^2x}{dt^2}+2\frac{dx}{dt}+x=0$$

with boundary conditions at $t=0, x=1, \frac{dx}{dt}=0$. The value of x at $t = 1$ is

(A) $\frac{1}{e}$

(B) $\frac{2}{e}$

(C) e

(D) 1

8. The Fourier transform of the derivative of the Dirac δ-function, namely $\delta'(x)$, is proportional to

(A) 0

(B) 1

(C) $\sin k$

(D) ik

9. The locus represented by the equation $|z-3|+|z+3|=10$ is

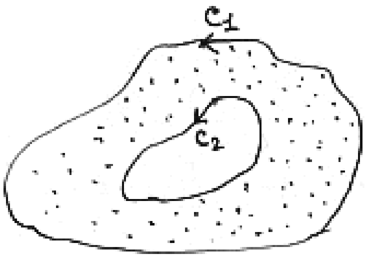
(A) Circle

(B) Ellipse

(C) Parabola

(D) Hyperbola

10. If $f(z)$ is analytic within and on the boundary of a region bounded by two closed curves C_1 and C_2 then



(A) $\oint_{C_1} f(z)dz$ is greater than $\oint_{C_2} f(z)dz$

(B) $\oint_{C_1} f(z)dz$ is less than $\oint_{C_2} f(z)dz$

(C) $\oint_{C_1} f(z)dz$ is equal to $\oint_{C_2} f(z)dz$

(D) None of the above

11. Which one of the following is an analytic function of the complex variable $z = x + iy$ in the domain $|z|<2$?

(A) $(3+2x-iy)^7$

(B) $(1+x+iy)^4(7-x-iy)^3$

(C) $(1-x-iy)^4(7-x+iy)^3$

(D) $(x+iy-1)^{1/2}$

12. If $f(x)=x$ for $-\frac{\pi}{2}\le x\le\frac{\pi}{2}$

$=\pi-x$ for $\frac{\pi}{2}\le x\le\frac{3\pi}{2}$

then the first Fourier coefficient a_0 is

(A) 2π

(B) -2π

(C) 1

(D) 0

13. A block sits on a plane that is inclined at an angle. Assume that the friction force is large enough to keep the block at rest. For what value of the angle is the horizontal component of the friction force maximum?

(A) π

(B) $\frac{\pi}{2}$

(C) $\frac{\pi}{3}$

(D) $\frac{\pi}{4}$

14. A particle is moving in one dimension under the potential $V(x) = \lambda\left(x^2 - \alpha x^4\right)$. At $t = 0$ the particle is released from a distance 'a' from the origin. The motion will be bounded if

(A) $|a| \geq \frac{4}{\sqrt{\alpha}}$

(B) $|a| < \frac{1}{\sqrt{2\alpha}}$

(C) $|a| \geq \frac{1}{\sqrt{3\alpha}}$

(D) $|a| \leq \frac{4}{\sqrt{\alpha}}$

15. Galileo dropped two unequal masses simultaneously from the top of the leaning tower of Pisa and found that they hit the ground simultaneously. This proved that

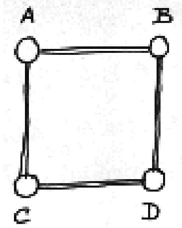
(A) acceleration is inversely proportional to mass.

(B) gravitational force is independent of mass.

(C) falling bodies eventually reach the same terminal velocity.

(D) gravitational mass is equal to inertial mass.

16. Four massive balls A, B, C and D are connected by massless rigid rods, pivoted at the points A, B, C, D to rotate freely in all three dimensions. The number of degrees of freedom of this system is



(A) 4

(B) 8

(C) 10

(D) 12

17. Consider circular orbits in a central force potential $V(r) = -\frac{k}{r^n}$, when $k > 0$ and $0 < n < 2$. If the time period of a circular orbit of radius R is T_1 and that of radius 2R is T_2, then $\left(\frac{T_2}{T_1}\right)$

(A) $2^{\frac{n}{2}}$

(B) $2^{\frac{2}{3}n}$

(C) $2^{\frac{n}{2}+1}$

(D) 2^n

18. The Lagrangian of a free particle in spherical polar co-ordinate is $L = \frac{1}{2}\left[m\dot{r}^2 + mr^2\dot{\theta}^2 + mr^2\dot{\varphi}^2 \sin^2\theta\right]$. The entity that is conserved is

(A) $\frac{\partial L}{\partial \dot{r}}$

(B) $\frac{\partial L}{\partial \dot{\theta}}$

(C) $\frac{\partial L}{\partial \dot{\varphi}}$

(D) $\frac{\partial L}{\partial \dot{\varphi}} + \dot{r}\dot{\theta}$

19. A particle moving in one dimension is subjected to a Lagrangian of the form $L = \frac{1}{2}\dot{x}\ln\dot{x} - \frac{1}{2}\omega^2 x^2$. The Hamiltonian H of this system will be

(A) $H = \frac{1}{2}\exp(2p-1) + \frac{1}{2}\omega^2 x^2$

(B) $H = \frac{1}{2}p\exp(2p) - \frac{1}{2}\omega^2 x^2$

(C) $H = \frac{1}{2}\dot{x}\ln\dot{x} + \frac{1}{2}\omega^2 x^2$

(D) $H = 2p\exp(2p-1) + \frac{1}{2}\omega^2 x^2$

20. A Hamiltonian is described by the canonical coordinate q and canonical momentum p. A new coordinate Q is defined as $Q(t) = q(t+\tau) + p(t+\tau)$, where t is the time and τ is a constant. The new canonical momentum P(t) can be expressed as

(A) $p(t+\tau) - q(t+\tau)$

(B) $p(t+\tau) - q(t-\tau)$

(C) $\frac{1}{2}[p(t-\tau) - q(t+\tau)]$

(D) $\frac{1}{2}[p(t+\tau) - q(t+\tau)]$

21. The position (x, y, z) and momentum (p_x, p_y, p_z) coordinates satisfy the standard Poisson bracket relations. What is the value of the Poisson bracket $\{x y^2, p_z p_x\}$

(A) $x p_z$

(B) y^2

(C) $y^2 p_x$

(D) $y^2 p_z$

22. What is the proper time interval between the occurrence of two events if in one inertial frame events are separated by $7{\cdot}5 \times 10^8$ m and occur 6·5 sec. apart?

(A) 6·5 sec

(B) 6·00 sec

(C) 5·75 sec

(D) 5·00 sec

23. What is the speed of a particle having momentum $p = 5\frac{\text{MeV}}{C}$ and total relativistic energy E = 10 MeV?

(A) 0·75 c

(B) $\frac{c}{\sqrt{3}}$

(C) $\frac{c}{2}$

(D) $\frac{c}{4}$

24. The Hamiltonian of a relativistic particle of rest mass m and momentum p is given by $H = \sqrt{p^2 + m^2} + V(x)$ in units in which the speed of light c = 1. The corresponding Lagrangian is

(A) $L = m\sqrt{1+\dot{x}^2} - V(x)$

(B) $L = -m\sqrt{1-\dot{x}^2} - V(x)$

(C) $L = \sqrt{1+m\dot{x}^2} - V(x)$

(D) $L = \frac{1}{2}m\dot{x}^2 - V(x)$

25. If ψ_1, ψ_2, ψ_3 are three normalized energy eigenstates of a system corresponding to the energy $\in_1, \in_2$ and $\in_3$ respectively and a state ϕ is represented as $\phi = 3\psi_1 + 2\psi_2 + \psi_3$, then

(A) a single measurement of energy will yield a value $3\in_1 + 2\in_2 + \in_3$

(B) the average value of energy measured on a large number of replica of this system in the state ϕ will yield a value $3\in_1 + 2\in_2 + \in_3$

(C) a single measurement will yield a value $\in_3$ with a probability $\frac{1}{6}$

(D) a single measurement will yield a value $\in_2$ with a probability $\frac{2}{7}$

26. Which one of the following wavefunction can be a bound state solution of Schrödinger equation for all values of x?

(A) $\sec x$

(B) x^2

(C) $e^{-|x|}$

(D) $\log x$

27. $\hat{A}$ and $\hat{B}$ are two operators defined by $\hat{A}\psi(x) = \psi(x) + x$ and $\hat{B}\,\psi(x) = \frac{d\psi(x)}{dx} + 2\psi(x)$. Which one of the following statements is correct?

(A) Both $\hat{A}$ and $\hat{B}$ are linear operators.

(B) Both $\hat{A}$ and $\hat{B}$ are non-linear operators.

(C) $\hat{B}$ is a linear operator, but $\hat{A}$ is not.

(D) $\hat{A}$ is a linear operator, but $\hat{B}$ is not.

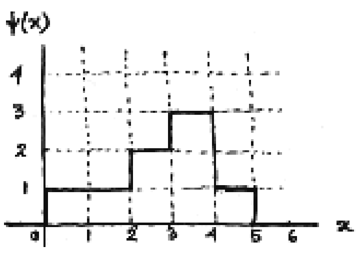
28. The profile of a wavefunction is given below $(\psi(x) = 0$ for $x < 0$ and also, for $x > 5)$. What is the probability of finding the particle between $x = 2$ and $x = 4$?

(A) $\frac{17}{64}$

(B) $\frac{25}{64}$

(C) $\frac{5}{8}$

(D) $\frac{13}{16}$



29. The eigenfunctions of the position operator (in one dimension) are of the form of a

(A) Step function

(B) Dirac delta function

(C) Sine function

(D) Exponentially decaying function

30. $|\psi\rangle$ is an eigenvector of an operator $\hat{A}$. The operator $\hat{B} = \hat{U}\hat{A}\hat{U}^{+}$ where $\hat{U}$ is a unitary operator. Which one of the following is an eigenvector of the operator e^{B}?

(A) $|\psi\rangle$

(B) $\hat{U}\,|\psi\rangle$

(C) $\hat{U}^{+}\,|\psi\rangle$

(D) $e^{\hat{U}}\,|\psi\rangle$

31. For a one-dimensional harmonic oscillator, the raising (a^{+}) and lowering (a) operators satisfy $[a, a^{+}] = 1$. Which one of the results below is correct?

(A) $[a^n, (a^{+})^n] = 1$

(B) $[a^n, a^{+}] = 0$

(C) $[a^{+}, a^n] = na^{n-1}$

(D) $[a^n, a^{+}] = na^{n-1}$

32. A one dimensional harmonic oscillator of frequency ω with mass m and charge q is placed in a uniform electric field E. The energy levels are given by

(A) $\left(n+\frac{1}{2}\right)\hbar\omega$

(B) $\left(n+\frac{1}{2}\right)\hbar\omega - \frac{q^2E^2}{2m\omega^2}$

(C) $\left(n+\frac{1}{2}\right)\hbar\omega + \frac{q^2E^2}{2m\omega^2}$

(D) $\left(n+\frac{1}{2}\right)\hbar\omega + n\frac{q^2E^2}{m\omega^2}$

33. A particle starts out in a linear combination 'Ψ' of two stationary states ψ_1 and ψ_2 corresponding to energy eigenvalues E_1 and E_2 respectively, namely, $\Psi(x,0) = \psi_1(x) + \psi_2(x)$. If $E_1 \neq E_2$, at any latter time 't', the probability density will

(A) be independent of time

(B) vary inversely with time

(C) be sinusoidally oscillating with time

(D) be a linear function of time

34. The Hamiltonian operator in certain orthonormalized basis in a three dimensional vector space is written as $H = \begin{pmatrix} \in & \eta & 0 \\ \eta & \in & \eta \\ 0 & \eta & \in \end{pmatrix}$ where both $\in$ and η have the dimension of energy. The results of measurement of energy of the system will be

(A) $\in$, 0 and $-\in$

(B) $\dfrac{\in\eta}{\in \pm \eta}$ and 0

(C) $\in$ and $\in \pm \sqrt{2}\,\eta$

(D) zero

35. An operator $\hat{A}$ is represented in certain orthonormal basis $\{|\psi_i\rangle, i = 1, 2\}$ by the matrix $\hat{A} = \begin{pmatrix} 1 & \lambda \\ \lambda & 1 \end{pmatrix}$. If one constructs a 'new basis' by the kets $|\varphi_1\rangle = \frac{1}{\sqrt{2}}(|\psi_1\rangle + |\psi_2\rangle)$ and $|\varphi_2\rangle = \frac{1}{\sqrt{2}}(|\psi_1\rangle - |\psi_2\rangle)$, then the same operator is represented in the new basis by

(A) $\begin{pmatrix} \lambda & 1 \\ 1 & \lambda \end{pmatrix}$

(B) $\begin{pmatrix} 1+\lambda & 0 \\ 0 & 1-\lambda \end{pmatrix}$

(C) $\begin{pmatrix} 0 & \lambda \\ \lambda & 0 \end{pmatrix}$

(D) $\begin{pmatrix} \lambda & \lambda \\ 1 & -1 \end{pmatrix}$

36. If 's' and 'p' represent hydrogen-like orbitals, then which one of the following statements is true?

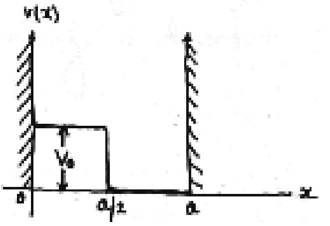
(A) Both $\langle 2s\,|x|\,2p_y\rangle$ and $\langle 2p_x\,|x|\,2p_y\rangle$ are non-zero.

(B) $\langle 2p_x\,|x|\,2p_y\rangle$ is non-zero, and $\langle 2s\,|x|\,2p_y\rangle$ is zero.

(C) $\langle 2s\,|x|\,2p_y\rangle$ is non-zero and $\langle 2p_x\,|x|\,2p_y\rangle$ is zero.

(D) Both $\langle 2s\,|x|\,2p_y\rangle$ and $\langle 2p_x\,|x|\,2p_y\rangle$ are zero.

37. A constant perturbation is given to the floor of an infinite square well, in the form of lifting the floor from $x = 0$ to $x = \frac{a}{2}$, as shown below. The first order correction to the nth energy level is given by



(A) $\dfrac{V_0}{2}$

(B) V_0

(C) $2V_0$

(D) $\dfrac{3}{2}V_0$

38. The power of the radiation emitted from an oscillating dipole, $\vec{p}(t) = \vec{p}_o \cos \omega t$ is

(A) isotropic

(B) maximum along $\vec{p}$

(C) maximum along a perpendicular direction of $\vec{p}$

(D) maximum along a direction 45° to $\vec{p}$

39. Electric field in a region R, is given by $\vec{E} = y^2\,\hat{i} + x^2\,\hat{j}$, then

(A) the region does not have any magnetic field.

(B) x and y components of the magnetic field are time independent.

(C) charge density is increasing function of time.

(D) charge density is decreasing function of time.

40. A charge q is located at the centre of a cube of side a. Electric flux through any face of the cube is

(A) $\dfrac{q}{\in_0}$

(B) $\dfrac{q}{4\pi \in_0}$

(C) $\dfrac{q}{2 \in_0}$

(D) $\dfrac{q}{6 \in_0}$

41. The state of polarization of an electromagnetic wave given by

$\vec{E}(z,t) = \hat{i}\; E_0 \cos(kz - \omega t) - \hat{j}\, E_0 \cos(kz - \omega t)$ is

(A) linearly polarized

(B) plane polarized

(C) circularly polarized

(D) unpolarized

42. A parallel plate capacitor C with plates separated by d is connected to a resistance R. The displacement current on charging the capacitor with source V is

(A) $\frac{V}{CRd} e^{-t/CR}$

(B) $\frac{\epsilon_o Vd}{CR} e^{-t/CR}$

(C) $\frac{CRV}{\epsilon_o d} e^{-t/CR}$

(D) $\frac{\epsilon_o V}{CRd}$

43. For a linear dielectric material which is isotropic and homogeneous, the relation between free charge density and bound charge density can be expressed as

(A) $\rho_f = \frac{\epsilon_r \rho_b}{1-\epsilon_r}$

(B) $\rho_f = -\frac{\epsilon_o \rho_b}{1-\epsilon_o \epsilon_r}$

(C) $\rho_b = \frac{\rho_f}{1-\epsilon_r}$

(D) $\rho_b = -\frac{(1-\epsilon_r)\rho_f}{\epsilon_o \epsilon_r}$

44. An infinite conducting plane (say, $x-y$ plane) is maintained at zero potential everywhere except within a circular region of radius r where the potential is V_o. The electric field along the z-axis is

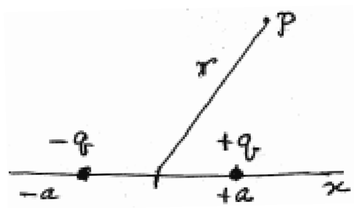
(A) $\frac{V_o z}{r+z}$

(B) $\frac{V_o r^2}{z^3}$

(C) $\frac{V_o r^2}{(r^2+z^2)^{3/2}}$

(D) $\frac{V_o}{z}$

45. Two charges $+q$ and $-q$ are placed on the x-axis at $x = +a$ and $x = -a$ respectively. The electrostatic potential at a distance r from the origin will have terms proportional to



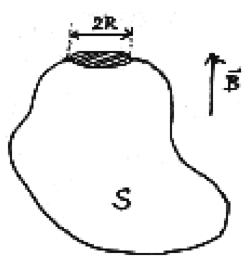
(A) $\frac{1}{r}$ and $\frac{1}{r^2}$

(B) $\frac{1}{r^2}$ only

(C) $\frac{1}{r^2}, \frac{1}{r^3}$, and all higher powers

(D) $\frac{1}{r^2}, \frac{1}{r^4}$, and all higher even powers

46. Consider a surface S, as shown in the figure, which has a circular hole of radius R at one end. If this is placed in a uniform magnetic field $\vec{B}$, as shown in the figure, the flux of $\vec{B}$ through the surface S is



(A) $-4\pi R^2 |\vec{B}|$

(B) $-\pi R^2 |\vec{B}|$

(C) $\pi R^2 |\vec{B}|$

(D) $4\pi R^2 |\vec{B}|$

47. In a cathode ray oscilloscope an electron with velocity v_{0x} along x-axis enters in y-deflection plates across which a uniform electric field E_y is acting. The displacement of the electron in y-direction at time t after entering the field is

(A) $-\frac{eE_y\, x^2}{2m\, v_{0x}^2}$

(B) $\frac{-eE_y\, x^2}{2m\, v_{0x}}$

(C) $\frac{-eE_y\, x}{2m\, v_{0x}}$

(D) $\frac{-eE_y\, x}{2m\, v_{0x}^2}$

48. A polarized dielectric sphere of radius R with polarization $\vec{p}(\vec{r}) = k\vec{r}$ is placed at the origin. The electric field inside and outside the sphere are

(A) $-\frac{k\vec{r}}{\in_0}, 0$

(B) $-\frac{R^3 k\vec{r}}{4\pi \in_0 r^3}, 0$

(C) $0, \frac{R^3 k\vec{r}}{4\pi \in_0 r^3}$

(D) $-\frac{k\vec{r}}{\in_0}, \frac{k\vec{r}}{\in_0}$

49. Results of superposition of two sets of electric field

Set I: $E_x = E_1 \cos(\omega t - kz);\ E_y = 0$

Set II: $E_x = E_3 \cos(\omega t - kz);\ E_y = E_4 \cos(\omega t - kz - \pi/2)$ will result

(A) Plane polarized wave

(B) Circularly polarized wave

(C) Elliptically polarized wave

(D) Unpolarized polarized wave

50. The temperature of a cavity of fixed volume is doubled. Which one of the following is true for black body radiation?

(A) Its energy and number of photons both increases by 8 times.

(B) Its energy increases by 8 times and the number of photons increases by 16 times.

(C) Its energy increases 16 times and the number of photons increases by 8 times.

(D) Its energy and number of photons both increase by 16 times.

51. In a microcanonical ensemble, a system A of fixed volume is in contact with a large reservoir B. Then

(A) A can exchange only entropy 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.

52. An ensemble of N three level systems with energies $\in = -\in_0, 0, \in_0$ is in thermal equilibrium at temperature T. If $\frac{\in_0}{K_B T} = 2$, the probability of finding the system in the level $\in = 0$ is

(A) cosh(2)

(B) $(\cosh(2))^{-1}$

(C) $(2\cosh(2))^{-1}$

(D) $(1 + 2\cosh(2))^{-1}$

53. The work done W during an isothermal process in which a gas expands from volume V_i to volume V_f is given by

(A) $R(V_f - V_i)\log_e \frac{T_1}{T_2}$

(B) $R(T_2 - T_1)\log_e \frac{V_f}{V_i}$

(C) $RT \log_e \frac{V_f}{V_i}$

(D) $RT \log_e \frac{V_i}{V_f}$

54. Planck's formula for black body radiation reduces to Rayleigh-Jeans and Wien's formula for

(A) small and large wavelength
(B) large and small wavelength
(C) large and complex wavelength
(D) complex and large wavelength, respectively

55. The black body temperature of 6000 K emits a radiation whose intensity spectrum peaks at 600 nm. If the temperature is reduced to 300 K, the spectrum will peak at

(A) 120 μm
(B) 12 μm
(C) 12 mm
(D) 120 mm

56. Which one of the following relations is *true* for chemical potential μ for the physical system (N, V, E)?

(A) $\mu = H/N$
(B) $\mu = G/N$
(C) $\mu = A/N$
(D) $\mu = E/N$

57. The Fermi energy of a free electron gas is 4·5 eV. The probability of finding an electron with "up-spin" ($S_z = +1$) and energy 4·5 eV at T = 0 is

(A) 1
(B) 0·5
(C) 0·25
(D) nearly zero

58. According to Debye theory, the heat capacity of a solid at low temperature is proportional to

(A) T^6
(B) T^3
(C) 1/T
(D) T^3

59. How does the specific heat of a Bose gas vary at very low temperature?

(A) $C_v \propto T$
(B) $C_v \propto T^{2/3}$
(C) $C_v \propto T^{3/2}$
(D) $C_v \propto T^{1/2}$

60. One kilogram of ice melts at 0°C into water at the same temperature. The change in entropy (cal/K) is

(A) $\propto$
(B) 0
(C) 273
(D) 293

61. An ensemble for which the density function $\rho(p, q, T) \propto \exp(-H(q, p)|kT)$, where H(p, q) is the Hamiltonian for that ensemble is

(A) micro canonical
(B) canonical
(C) grand canonical
(D) macro canonical

62. Given the mass of muon is 207 times that of an electron, the ionization potential of a muonic atom ($p^+ \mu^-$) is of the order of

(A) 2·5 eV
(B) 2·5 keV
(C) 2·5 MeV
(D) 0·025 eV

63. Due to fine structure each of the line in Balmer series is split into

(A) 2 lines
(B) 3 lines
(C) 5 lines
(D) 7 lines

64. The number of lines observed in the Zeeman splitting of D–line of sodium is

(A) Four
(B) Six
(C) Eight
(D) Ten

65. Relative intensities of successive lines in the obtained Raman spectra of nitrogen molecule is

(A) 3 : 4
(B) 1 : 2
(C) 2 : 3
(D) 1 : 3

66. Spectral line width of the He–Ne LASER is 0·01 nm and the cross-sectional area of the beam is 0·01 cm^2. If the output power is 1 mW, the radiation intensity per unit wavelength is

(A) 10^{10} W/cm^3
(B) 10^{8} W/cm^3
(C) 10^{-8} W/cm^3
(D) 10^{-10} W/cm^3

67. Consider a homonuclear diatomic molecule containing N(N ≥ 1) electrons, where the internuclear line of the molecule is lying along the z-axis of the coordinate system. If the position vectors of electrons are $\vec{r}_i (i = 1,...N)$, which one of the following is correct?

(A) Rotation about the z-axis is not a symmetry of the molecule.
(B) Reflection of electrons in the *xz* plane and the transformations $\vec{r}_i \to -\vec{r}_i$ are the symmetries of the molecule.
(C) Reflection of electrons in the *xz* plane is a symmetry but the transformations $\vec{r}_i \to -\vec{r}_i$ is not a symmetry of the molecule.
(D) Neither reflection of electrons in *xz* plane nor the transformations $\vec{r}_i \to -\vec{r}_i$ is a symmetry of the molecule.

68. Suppose ΔE_e, ΔE_v and ΔE_r are the energy separations between two neighbouring states in the electronic, vibrational and rotational spectra of a molecule respectively. Then which one of the following is correct?

(A) $\Delta E_e >> \Delta E_v >> \Delta E_r$
(B) $\Delta E_e = \Delta E_v >> \Delta E_r$
(C) $\Delta E_e = \Delta E_r >> \Delta E_v$
(D) $\Delta E_e << \Delta E_v << \Delta E_r$

69. The energy of an electron which is bound inside a nucleus of size around 1 fm is around

(A) 1·2 eV
(B) 1·2 keV
(C) 1·2 MeV
(D) 1·2 GeV

70. The meson K°, with strangeness quantum number – 1, decays through the modes $K^\circ \to \pi^+ \pi^-$, $K^\circ \to \pi^\circ \pi^\circ$. These decays are due to

(A) gravitational interactions
(B) strong interactions
(C) weak interactions
(D) electromagnetic interactions

71. Consider a nucleus with spin ½. If this has an intrinsic magnetic moment P_n and an electron has intrinsic magnetic moment P_e, the ratio P_n/P_e will have magnitude

(A) zero, because the nucleus behaves like a point.
(B) >> 1, because the nucleus is much smaller than the electron.
(C) << 1, because the nucleus is much heavier than the electron.
(D) << 1, because the strong interaction is much stronger than the electromagnetic interaction.

72. A proton is accelerated to an energy E and shot directly at a nucleus of nitrogen ($^{14}_{7}N$). In order for the proton to overcome the Coulomb repulsion and reach the nucleus, its energy must be at least

(A) 250 keV

(B) 45 MeV

(C) 105 MeV

(D) 1·8 GeV

73. According to the quark model

(A) nucleons are made up of a pair of quarks.

(B) mesons are made up of a pair of quarks.

(C) mesons are made of two quarks and an antiquark.

(D) mesons are made of a quark and an antiquark.

74. Any $0 \rightarrow 0$ gamma transition is forbidden due to

(A) parity conservation

(B) isospin asymmetry

(C) angular momentum conservation

(D) strong interactions

75. Semiconductor particle detectors consist of an array of

(A) silicon crystals cooled in liquid nitrogen.

(B) p-n junctions in reverse bias.

(C) nano-sized MOSFETs sandwiched between gold foil.

(D) Josephson junctions cooled in liquid helium.

76. In the powder diffraction pattern of an fcc sample, the first peak arises at 30°. The second peak will appear at

(A) $\sin^{-1}\frac{1}{\sqrt{3}}$

(B) $\sin^{-1}\frac{2}{\sqrt{3}}$

(C) $\sin^{-1}\frac{1}{2\sqrt{3}}$

(D) $\sin^{-1}\frac{1}{\sqrt{2}}$

77. Density of atoms in the plane (110) of a sc lattice will be

(A) $\frac{1}{\sqrt{3}a^2}$

(B) $\frac{1}{\sqrt{2}a^2}$

(C) $\frac{\sqrt{2}}{a^2}$

(D) $\frac{\sqrt{3}}{a^2}$

78. A diatomic linear structure with masses M_1 and M_2 ($M_1 > M_2$) connected by the force constant C has lattice constant *a*. The angular frequency of the optical branch at the zone boundary:

(A) $\left(\frac{2C}{M_2}\right)^{1/2}$

(B) $\left(\frac{2C}{M_1}\right)^{1/2}$

(C) $\left(\frac{C}{M_2}\right)^{1/2}$

(D) $\left(\frac{C}{M_1}\right)^{1/2}$

79. An electron, with a wavevector $\vec{k}$ is incident on a square lattice of lattice constant '*a*'. If $k_x = k_y = \pm\frac{\pi}{a}$, the electron will be "Bragg reflected" by

(A) lattice planes parallel to the *x*-axis only.

(B) lattice planes parallel to the *y*-axis only.

(C) lattice planes parallel to both *x* and *y*-axes.

(D) an infinite number of lattice planes aligned in any direction.

80. The dispersion relation for a simple cubic crystal is given by $E(\vec{k}) = E_0 - 2\beta(\cos k_x a + \cos k_y a + \cos k_z a)$, where β is a constant having the dimension of energy. The width of the energy band is

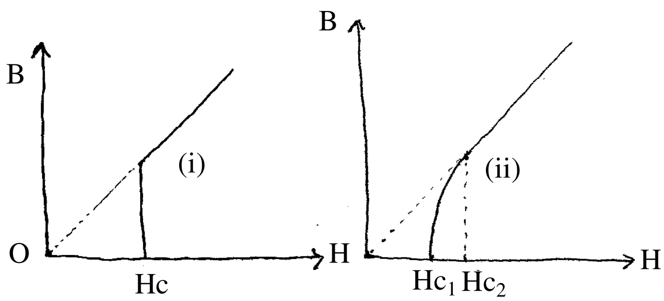
(A) 2β
(B) 4β
(C) 8β
(D) 12β

81. The energy eigenvalue $E_n(\vec{k})$ in the nth band of an infinite periodic crystal is related to that for a wavevector $-\vec{k}$ by the relation

(A) $E_n(\vec{k}) = -E_n(-\vec{k})$
(B) $E_n(\vec{k}) = E_n(-\vec{k})$
(C) $E_n(\vec{k}) = \sqrt{E_n(-\vec{k})}$
(D) $E_n(\vec{k}) + E_n(-\vec{k}) = 2$

82. The figures (i) and (ii) below show the flux penetration as a function of an external magnetic field for

(A) a normal metal (i) and a superconductor (ii)
(B) a normal metal (ii) and a superconductor (i)
(C) a type-I superconductor (i) and a type-II superconductor (ii)
(D) a normal metal, both in fig. (i) and in fig. (ii)



83. The intrinsic carrier concentration of Ge at room temperature (300 K) is $2{\cdot}4 \times 10^{13}$/c.c. It is doped by acceptor impurity with a concentration of 10^{17}/c.c. The electron concentration in the doped Ge sample will be

(A) $2{\cdot}4 \times 10^{13}$/c.c.
(B) 10^{17}/c.c.
(C) $4{\cdot}16 \times 10^{3}$/c.c.
(D) $5{\cdot}76 \times 10^{9}$/c.c.

84. For designing a laser diode it is necessary to have a

(A) direct band gap semiconductor.
(B) indirect band gap semiconductor.
(C) any kind of semiconductor direct or indirect.
(D) Si or Ge as the semiconductor material.

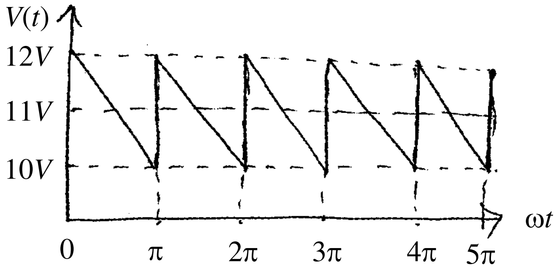
85. For switching operation, the BJT should be operated in the

(A) Active region only
(B) Saturation region only
(C) Cut-off region only
(D) Cut-off and saturation region

86. A junction field effect transistor (JFET) is a

(A) Bipolar device
(B) Unipolar device
(C) Low input impedance device
(D) High recombination noise device

87. The following saw-tooth ac voltage, $v(t)$, has a *rms* value of the ac components equal to



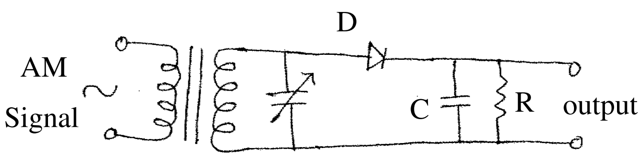
(A) $\sqrt{2}V$

(B) $\frac{1}{\sqrt{2}}V$

(C) $\sqrt{3}V$

(D) $\frac{1}{\sqrt{3}}V$

88. The following circuit is that of a



(A) Amplitude modulator
(B) Balanced modulator
(C) AM signal amplifier
(D) Envelope detector

89. For a 100% amplitude modulated (AM) signal the ratio of carrier power to total AM signal power at the output is

(A) 2 : 1
(B) 5 : 2
(C) 2 : 3
(D) 1 : 2

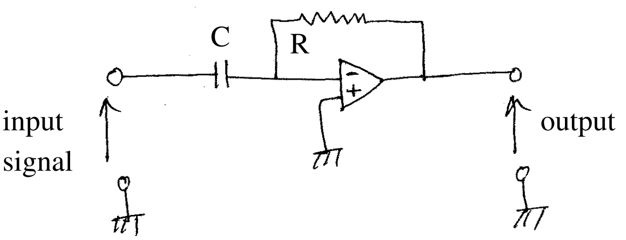
90. To design a transistorized phase shift oscillator with 3 identical R-C sections in its feedback network, the transistor h_{fe} parameter

(A) can have any value.
(B) can have a value in the range 20–35·8.
(C) should have a value exceeding 44·6.
(D) must have a value exceeding 100.

91. A tuned collector transistorized oscillator with a capacitor of 500 pF in the tank circuit oscillates at a frequency of 1 MHz. In order that the circuit can oscillate at 2 MHz, the inductor in the tank circuit should be

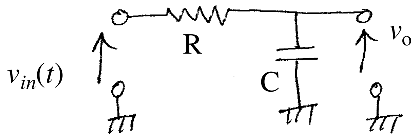
(A) increased by a factor of 2
(B) reduced by a factor of 2
(C) reduced by a factor of 8
(D) reduced by a factor of 4

92. The following circuit is that of



(A) A differentiator
(B) An integrator
(C) Low pass filter
(D) A low frequency oscillator

93. A sinusoidal signal voltage, $v_{in}(t) = V\sin\omega t$ is applied to the input of the following circuit with RC = 0·1 sec. The output voltage, v_o, will



(A) lead the input voltage by an angle $\varphi = \tan^{-1}\left(\omega/10\right)$

(B) lead the input voltage by an angle $\varphi = \tan^{-1}(10\,\omega)$

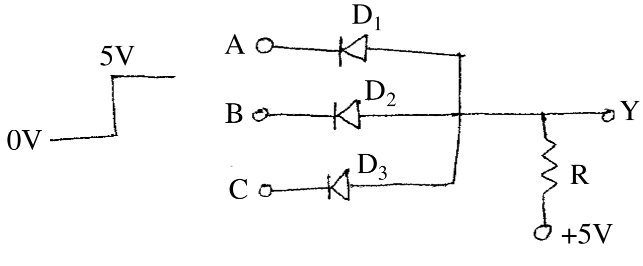
(C) lag behind the input voltage by an angle $\varphi = \tan^{-1}\left(\frac{\omega}{10}\right)$

(D) lag behind the input voltage by an angle $\varphi = \pi/2$ radian

94. The hexadecimal equivalent of the octal number 225_8 is

(A) 83
(B) 95
(C) 53
(D) 59

95. The following circuit with D_1, D_2, D_3 as identical diodes in positive diode logic is that of



(A) an OR gate
(B) an AND gate
(C) an EX-OR gate
(D) a NAND gate

96. The minimum number of two input NAND gates required to realize an EX-OR operation is

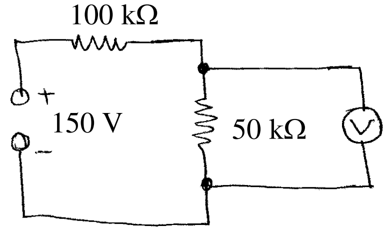
(A) 2
(B) 5
(C) 3
(D) 4

97. The truth table below represents which of the following boolean expression?

Inputs			Output
A	B	C	X
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	0
1	1	0	1
1	1	1	1

(A) A + BC
(B) $\bar{A}C + B$
(C) $\bar{A}C + AB$
(D) $\bar{A}BC$

98. The voltage across the 50-kΩ resistor in the circuit is measured using a voltmeter with sensitivity of 1000 Ω/V and range of 0–50 V. The error of measurement expressed as a percentage of the true value will be



(A) 4%
(B) 5%
(C) 40%
(D) 50%

99. The current passing through a resistor of 100 ± 0·2 Ω is 2·00 ± 0·01 A. Maximum error in computing power dissipation will be

(A) 1·2%

(B) 0·8%

(C) 0·5%

(D) 0·2%

100. A large member of 100 Ω resistors is measured with mean value of 100·00 Ω and standard deviation of 0·20 Ω. If the data is dispersed normally what percentage of all the resistors on the average will have values that lie between the limits ± 0·20 Ω?

(A) 50%

(B) 68%

(C) 80%

(D) 95%

ROUGH WORK

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