Roll No. | | | | | | | |

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

Signature of Invigilators

1. _____

2. _____

PAPER – III

1610

Test Booklet No.

PHYSICAL SCIENCES

Time : $2\frac{1}{2}$ Hours

Maximum Marks : 200

Instructions for the Candidates

1. Write your roll number in the space provided on the top of this page.
2. This paper consists of four **Sections – I, II, III & IV.**
3. Answers are to be written in the space provided against the questions.

No additional sheets are to be used.

4. Read instructions given inside carefully.
5. One sheet is attached at the end of the test booklet for rough work.
6. If you write your name or put any special mark on any part of the test booklet which may disclose in any way your identity, you will render yourself liable to disqualification.
7. You should return the test booklet to the invigilator at the end of the examination and should not carry any paper with you outside the examination hall.

FOR OFFICE USE ONLY

Marks Obtained

Question Number	Marks Obtained	Question Number	Marks Obtained	Question Number	Marks Obtained
1		10		19	
2		11		×	
3		12		×	
4		13		×	
5		14		×	
6		15		×	
7		16		×	
8		17		×	
9		18		×	

Total marks obtained .....

Signature of the Co-ordinator .....
(Evaluation)

PHYSICAL SCIENCES

Paper – III

SECTION – I

Note : i) Answer all questions.

ii) Each question carries twenty marks.

iii) Each answer should be given in 500 words. $2 \times 20 = 40$

1. Write an essay on any *one* of the following :

   (a) **Small oscillations and normal modes**

   (b) Bose-Einstein condensation.

   (c) Wave-particle duality.

2. Write an essay on any *one* of the following :

   (a) Band theory of metals.

   (b) **Field effect transistors and their role** in semiconductor technology.

   (c) Nuclear fusion, a possible source of energy of future.

SECTION – II

Note : i) Answer all questions.

ii) Each question carries fifteen marks.

iii) Each answer should be given in 300 words. $3 \times 15 = 45$

3. A certain metal has a body centred cubic space lattice with cubic side a. The electrons are assumed to be free and the metal is monovalent.

(i) Calculate the radius of the fermi surface.

(ii) What should be the minimum value of electron density so that the fermi surface will touch the zone boundary ?

OR

Give the evidences in support of the fact that the nuclear forces are short range, charge independent and exhibit saturation effect.

OR

For each of the following reactions state the fastest interactions through which the conservation laws allow it to proceed. If the reaction is forbidden by all interactions, state why :

(a) $\pi^+ + p \rightarrow p + p + \bar{n}$

(b) $\Omega^- \rightarrow \Xi^0 + \pi^-$

(c) $\pi^- + p \rightarrow \sum^+ + k^-$.

4. One per cent of atomic sites of an insulator of site density N per unit volume are replaced with Mn-ions in the + 2 states. Find the Lande g factor, effective Bohr magnetron number and susceptibility. The electronic configuration of Mn is

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5\ 4s^2$.

OR

(a) If the nuclear potential is assumed to be a rectangular well type of finite depth and width, show how one can determine the lowest energy of a deuteron nucleus.

(b) Hence show that if the strength of the potential becomes infinitely high, the energy levels are quantised. 10 + 5

OR

Design and explain the operation of a modulo-5 counter using JK flip-flops.

5. In a one-dimensional crystal, the electron energy is given by $E = AK^2 + BK^3$ where K is the wave vector, A & B are positive constants.

(a) Obtain the electron velocity at Brillouin zone edge.

(b) What is the electron effective mass at these wave vectors ?

(c) Find the wave number where electron velocity reduces to zero.

(d) Find the phase velocity of electron waves.

OR

What are thermal neutrons ? How is the velocity distribution of thermal neutrons emanating from a reactor moderator ? Express the distribution function as function of wavelength of neutrons and their most probable velocity.

Show that the relation between wavelength of neutron and temperature of the moderator when the neutron flux is maximum is given by

$$\lambda = \frac{h}{\sqrt{5\, m_n\, k_B T}}$$

Draw the curves showing neutron distribution at two different temperatures.

OR

The current voltage characteristic of a diode is given by $I = I_0 [\, exp\, (eV/kT) - 1 \,]$. Two voltages $V_1 \cos \omega_1 t$ and $V_2 \cos \omega_2 t$ are applied to the diode. Prove that the dependence of I on V^2 gives rise to signals of frequency $(\omega_1 \pm \omega_2)$.

SECTION – III

Note : i) Answer all questions.

ii) Each question carries ten marks.

iii) Each answer should be given in 50 words. $9 \times 10 = 90$

6. Find the most general solution for the forced harmonic oscillator

$$m\frac{d^2y}{dt^2} = -m\omega_0^2 x - b\frac{dx}{dt} + F_0 \sin \omega t$$

and explain the solution.

The orbit of a particle moving under central force is given by $r = \alpha (1 + \cos \theta)$ with the centre at the origin. Find the law of force and also show that the kinetic energy of the particle at any point of the orbit is inversely proportional to r^3.

8. Find the amplitude of $\vec{E}$ and $\vec{B}$ fields associated with a laser beam of intensity $\frac{\pi}{3} \times 10^9$ W/m^2 propagating in free space.

9. The ground state of a one-dimensional harmonic oscillator with a potential energy $V(x) = \frac{1}{2} kx^2$ has the normalized wave function $u(x) = \frac{\sqrt{\alpha}}{\pi^{1/4}} e^{-\alpha^2 x^2/2}$ where $\alpha^4 = \frac{mk}{\hbar^2}$.

Find the probability of finding the particle inside the classical limit.

10. In a white dwarf star temperature is of the order of 10^7 K. Show that the content is mostly ionized He and electrons. If the electron gas density is 10^{30} /c.c., could the electron gas be considered as relativistic degenerate Fermi gas ?

11. Determine the number density of donor atoms which have to be added to an intrinsic Ge semiconductor to produce an n type semiconductor of conductivity 5 $\mho$ /cm. Given that the mobility of electrons in the n type semiconductor is 3850 cm^2/volt.sec.

12. Calculate spin and parity of $_7N^{15}$ in ground state.

13. Why are multiplexers called universal building blocks of combinational logic circuits ? Design a single bit full adder using multiplexers.

14. The angular momenta $\vec{J}_1$ and $\vec{J}_2$ combine to from $\vec{J}$ as $\vec{J} = \vec{J}_1 + \vec{J}_2$.

$| j, m >$, $| j_1, m_1 >$ and $| j_2 m_2 >$ are the eigenstates associated with $\vec{J}$, J_z ; $\vec{J}_1$, $\vec{J}_{1z}$ and $\vec{J}_2$, J_{2z} respectively. If $j_1 = 1$ and $j_2 = 1/2$, find the Clebesh-Gordan coefficient matrix.

SECTION – IV

Note : i) Answer all questions.

ii) Each question carries five marks.

iii) Each answer should be given in 30 words. $5 \times 5 = 25$

15. Sketch the graph for the function $f(x) = xe^{-\alpha x^2}$ and locate its maximas and minimas (if any).

16. A neutron of mass m, moving with velocity v collides head on with a nucleus of mass M at rest. The nucleus is driven in a direction at an angle θ with the original direction of the motion of the neutron. Assuming that the collision is perfectly elastic show that the velocity of the nucleus after collision is $2\,mv \cos\theta / (m + M)$.

17. Calculate the minimum X-ray wavelength produced in an X-ray tube which is operating on 50000 volts.

18. Graphically plot the Fermi function

$$f(E) = \frac{1}{exp\left[\left(E - E_F\right) / k_B T\right] + 1}$$

where E_F is the Fermi energy.

Hence, discuss the schematic representation.

19. How can you get FM waves using balanced modulators ?