Answer all the questions. Notations used have their usual meaning.

1(a) Differentiate between ‘conventional sensors’ and ‘nanotechnology enabled sensors’. [04]

1(b) What do you understand by static characteristics of sensors? Describe ten static characteristics. [05]

1(c) Describe zero order, first order, and second order sensing systems. [06]

2(a) What are DNA biosensors? Write its applications. [06]

2(b) What are the main components of a biosensor? What is the role of immobilization in designing a biosensor? [06]

2(c) Describe the mechanism of glucose biosensor. [03]

3(a) Discuss the salient features of DNA biosensor. [07]

3(b) Write the operating principle of Biochips and explain its use in medical diagnostic. [08]

4(a) Write brief notes on ten physical effects employed for making sensors. [07]

4(b) Discuss applications of the physical effects in developing sensors for defence, pressure and load sensors and night vision sensors. [08]
1(a) Describe extrusion and tip growth mechanism of carbon nanotubes. Also explain the special properties of carbon nanotubes in brief. [5]

(b) Explain vapour phase growth and laser-assisted thermal chemical vapour deposition methods to synthesize MWCNTs. [4]

(c) With the help of suitable illustrations, explain the continuous wave laser-powder method and aero-gel supported chemical vapour deposition process for synthesis of SWCNTs. Mention the drawback of laser ablation method. [6]

OR

(c') Describe the potential applications of CNTs in field emission & micoelectromechanical devices. How CNTs could be used in fuel cell applications? [6]

2(a) Give an account on the allotropes of carbon with special reference to graphene and carbon nanotubes? Discuss in detail the geometry of the carbon nanotubes. [4]

OR

(a') What is a mesoscopic system? Define different characteristics lengths in mesoscopic system. How can we control them? [4]

(b) Give the detailed account on the optical properties of CNTs with special reference to absorption, photoluminescence and Raman spectroscopy. [6]

(c) Explain in detail the transport of charge carriers in Ballistic conductor. [5]

3(a) What is the need of functionalization of CNTs? Which functionalizations has great interest and why? [6]

(b) Describe addition of nitrenes and solution-phase ozonolysis methods of sidewalls functionalization of CNTs. [4]

(c) Explain two approaches to the non-covalent functionalization of CNTs in brief. [5]

4(a) Describe any two synthesis techniques used for the fullerene preparation. What are the different methods used to extract them? Discuss any two techniques used to determine the composition and purity of fullerenes. [8]

(b) Prove that irrespective of the number of hexagons all fullerene molecules contain 12 pentagons. Find the number of hexagons in C_{96} & C_{220}. [3]

(c) Write short notes on diamond like carbon (DLC) and nanodiamonds. [4]
Answer ALL the questions. Notations used have their usual meaning.

1(a) Differentiate between graphene and graphene oxide. Explain in detail one method of synthesis of each. [8]

(b) Mention the methods used for the characterization of graphene. Discuss a method in detail which is used for the determination of number of layers in a graphene sample. [7]

OR

(b') Compare the electronic properties of graphene with common bulk semiconductors. Explain the technique used to measure the band structure of graphene? [7]

2(a) Define \( sp^2 \) and \( sp^3 \) hybridizations with two examples of each? Evaluate primitive unit vectors and reciprocal lattice vectors of graphene. [8]

(b) Define density of states (DOS) and obtain its value for graphene. With the help of Fermi-Dirac distribution and DOS prove that intrinsic carrier density in graphene is given by
\[
n_i = \frac{\pi}{6} \left( \frac{k_B T}{h v_F} \right)^2.
\]

3(a) Using Dirac equation, obtain eigenstates of the graphene in ultra-relativistic limit. Show that \( E(k) = 0 \) at the Dirac points. [4]

(b) Discuss Chirality and Klein paradox in graphene. Plot the transmission probability versus incident angle for the single and bi-layer graphene. [6½]

(c) Describe Quantum Hall effect in graphene. [4½]

4(a) ‘Graphene has exceptional transport properties’. Discuss in detail and explain the method used for the measurement of ambipolar field effect. [8]

(b) Discuss the potential applications of graphene in any two of the following: [7]

(i) Transistors  (ii) Light emitting diode
(iii) Photovoltaic (iv) Sensors