(3 Hours) **(Total Marks : 100)**

N.B. : (1) **All** questions are **compulsory**.

(2) **Figures** to the **right** indicate **full** marks.

(3) Draw **neat** diagrams wherever **necessary**.

(5) Symbols have usual meaning unless otherwise stated.

(5) Use of **non-programmable** calculator is allowed.

Q1. Attempt any **two.**

(i) What is Lorentz Fitzgerald contraction hypothesis? How does it explain the negative result of Michelson-Morley experiment? Why was it discarded? **10**

(ii) Write notes on the following: **10**
(a) Relativity of simultaneity
(b) Inertial and non-inertial frame of reference

(iii) State the basic postulates of special theory of relativity. Obtain the Lorentz Transformation equations of space and time stating clearly where and how the postulates are used. **10**

Q2 Attempt any **two.**

(i) Assuming Lorentz transformation equation for velocity, derive Lorentz transformation equation for acceleration (only x component). **10**

(ii) Derive relativistic equations for Doppler effect in light. Show that when the velocity of the moving frame is much less as compared to the velocity of light the relativistic formula reduces to the classical one. **10**

(iii) Using Minkowski's space - time continuum, prove: **10**
a) Lorentz -Fitzgerald length contraction.
b) Two events occurring at different points are simultaneous in one frame of reference but are not simultaneous in another frame of reference which is in different state of motion.

Q3 Attempt any **two.**

(i) Derive Lorentz transformations equations for force components. **10**

(ii) Show that $E^2 = p^2c^2 + m_0^2c^4$ and prove that $\frac{dE}{dp} = u$ where E is the total energy, p is momentum of a body with rest mass m_0. **10**

(iii) Starting with equation of force, derive Einstein's mass energy relation $E= mc^2$. **10**

Q4 Attempt any **two.**

(i) Explain in detail the gravitational red shift, hence obtain the expression for modified frequency of photons when it is emitted from the star and reaches earth. **10**

(ii) Using Lorentz transformation for $\vec{E}$ and $\vec{B}$ and the space time co-ordinates prove the invariance of the following Maxwell's equation Curl $\vec{E} = -\frac{\partial \vec{B}}{\partial t}$ Assume that div $\vec{B} = 0$ is invariant. **10**

(iii) Derive the transformation equation for magnetic field $\vec{B}$ using Lorentz transformation equation for force. **10**

Q5. Attempt any **four.** (5 marks each) **20**

(i) A ball of mass m_1=3kg, moving with a velocity of u_1=+5m/s along the x-axis of frame S approaches a second particle of mass m_2=1kg, moving at velocity of u_2=-3m/s along this axis. After head –on collision, it is found that m_2 has a velocity U_2=+3m/s along the x-axis. Calculate the expected velocity U_1 of m_1, after the collision.

(ii) Calculate the length and the orientation of a rod of length 5m in a frame of reference which is moving with velocity 0.6c in a direction making 30^0 angle with the rod.

(iii) Two electrons approach each other with the same velocity of 0.8c relative to an observer. Calculate their relative velocity.

(iv) Write a note on twin paradox.

(v) Calculate the velocity of an electron having total energy 5 MeV. Rest mass of electron =9.1 X 10^{-31} Kg , c= $3x10^8 m/s$

(vi) Find the momentum of photon having energy 2 eV. c= $3x10^8 m/s$.

(vii) Show that the scalar product of $\vec{E}.\vec{B}$ is invariant under Lorentz transformations for $\vec{E}$ and $\vec{B}$.

(viii) If a small box has electric charge density as 1 C/m^3 when observed at rest, determine its charge density when the box starts moving at a speed of 0.8c with respect to the observer.