

**(Physics)****Relativity & Cosmology**
 Time Allowed : 3 hrs
 Max. Marks : 50

 Attempt any **FOUR** Questions, selecting at least **ONE** from each section.
 All questions carry equal marks
SECTION I

- 1- a) What is Light Cone? Discuss its different regions in detail. 5
- b) Show that the interval between two events (t_1, x_1, y_1, z_1) and (t_2, x_2, y_2, z_2) and defined by $s^2 = (t_1 - t_2)^2 + (x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2$ is invariant under special Lorentz Transformations. Deduce Minkowski line element for infinitesimally separated events. What does s^2 become if $t_1 = t_2$ and how is it related to Euclidean distance between two events? 7.5
- 2- a) Find components of 4-force and 4-momentum. 4
- b) A π -meson of rest mass m_π comes to rest and disintegrates to μ -meson of rest mass m_μ and neutrino of rest mass zero. Show that kinetic energy of μ -meson is,
$$T_\mu = \frac{(m_\pi - m_\mu)^2 c^2}{2m_\pi}$$
 Also calculate kinetic energy of the neutrino. 8.5
- 3- a) Write down equations of Lorentz Transformations (do not derive)? Show that four dimensional volume element is invariant under Lorentz transformation. 6
- b) Show that the wave equation, $\nabla^2 \phi - \frac{1}{c^2} \frac{\partial^2 \phi}{\partial t^2} = 0$ is invariant under Lorentz transformations. 6.5

SECTION II

- 4- What is Doppler effect? Develop relativistic formulae for apparent change in frequency in following cases:
 a) Source and observer are approaching.
 b) Source and observer are receding.
 c) Source and observer are in perpendicular direction. 12.5
- 5- a) What is Geodesic? Derive equation of geodesic on a manifold. 8
- b) Show that Y_{bc}^a and Z_{bc}^a are tensors of type (1, 2) then so is their sum and difference. 4.5
- 6- a) Find Christoffel symbols of second kind for element $ds^2 = r^2 d\theta^2 + r^2 \sin^2 \theta d\phi^2$ 8
- b) If X^{ab} is Skew-symmetric and Y_{ab} is Symmetric, then show that $X^{ab} Y_{ab} = 0$ 4.5
- 7- a) Discuss concept of Close and Open Universe and describe the Friedmann model about Universe. 8
- b) Define a Manifold. Show that for n-dimensional manifold, $g^{\mu\nu} g_{\mu\nu} = n$ 4.5
- 8- Write brief notes on any Three of the following: 12.5
- Lie Derivative
 - Riemann Tensor
 - Twin Paradox
 - Cosmological Principle.
 - K-factor