Birla Institute of Technology and Science - Pilani, Pilani Campus

Session 2017-18 (Semester - I)

Mid-semester Test

Particle Physics (PHYF413)

Date: 12/10/2017 Weightage: 30 %

Time: 90 Mints. Max. Marks: 60

Note: This question paper has two parts: Part A and Part B. It contains total eight questions including both the parts. Marks are indicated in front of questions. All the symbols not defined here have their usual meaning.

Part A

Q1: For a two body decay process, $a \to 1+2$, decay rate is given by $\Gamma_{fi} = \frac{(2\pi)^{-2}}{2E_a}\int |M_{fi}|^2 \delta(E_a - E_1 - E_2)\delta^3(\vec{p}_a - \vec{p}_1 - \vec{p}_2) d^3p_1/2E_1\, d^3p_2/2E_2$. Here $|M_{fi}|$ is a Lorentz invariant matrix element. Use above expression to obtain a formula for the decay rate of particle a in the centre-of-mass frame of reference in terms of integral of $|M_{fi}|^2$ over solid angle and p^*, where p^* is the momentum of outgoing particles in the center-of-mass frame. [8]

Q2: Assume an electron is moving under the effect of an electromagnetic field described by electromagnetic four potential A^μ. Write Klein-Gordon equation for its motion. Find an expression for the lowest order scattering amplitude T_{fi} (covariant form i.e. $|T_{fi}|^{'}$ in CN notation) in terms of four current J_μ and potential A^μ. [8]

Q3: Obtain covariant form of the Dirac equation for a particle of mass m and moving with a momentum $\vec{p}$ from its corresponding non-covariant form. By using the properties of the Dirac gamma matrices, find Dirac equation for adjoint spinor, $\bar{\psi}$. [8]

Part B

Q4: Draw Feynman's diagram for the lowest order two body scattering process, $e^-\mu^- \to e^-\mu^-$ (do not forget to indicate +ve direction of time!). Write its invariant amplitude, ignoring the spin of the particles involved, using QED Feynman's rules without spin. [8]

Q5: Obtain the commutator of the Dirac Hamiltonian $\hat{H}_D$ with spin angular momentum $\hat{S}$: $[\alpha.\hat{\vec{p}} + \beta m, \hat{S}]$. [8]

Q6: Find an expression for the Dirac four current, J^μ. For a particle moving with a momentum p along z-axis, show that $\hat{S}_z u_1(E,0,0,\pm p = +\frac{1}{2}\, u_1(E,0,0,\pm p)$ and $\hat{S}_z u_2(E,0,0,\pm p) = -\frac{1}{2}\, u_2(E,0,0,\pm p)$. Here $u_1(E,0,0,\pm p)$ and $u_2(E,0,0,\pm p)$ are the Dirac energy momentum dependent particle spinors and $\hat{S}_z$ is the z-component of spin operator. [2+2+4]

Q7: Show that:

(i) $\not{p}\not{p} = p^2$

(ii) $\bar{v}(\gamma^\mu p_\mu + m) = 0$ [6]

for a particle/antiparticle of mass m and moving with three momentum $\vec{p}$.

Q8: Compute the following:

(i) $[\hat{\sigma}.(\vec{p} + e\,\vec{A})]\,[\hat{\sigma}.(\vec{p} + e\vec{A})]$

(ii) $\bar{v}^{(s)} v^{(s)}$ [6]

**** Best of Luck ****