UNIVERSITY OF LEIPZIG INSTITUTE FOR THEORETICAL PHYSICS Department: Theory of Elementary Particles TP3 2017

Lecturer: PD Dr. A. Schiller

List of problems 13 (Voluntary to get additional points)

- 38. (a) Find the magnitude of the momentum p of a relativistic particle of mass m as function of its kinetic energy T.
 (b) A particle of mass m has the energy E. Determine its velocity v. Consider the non-relativistic and the extreme relativistic limits.
 (c) Under the condition v ≪ c find approximate expressions for the kinetic energy T of a particle of mass m, expressed via its velocity v or momentum p to accuracy of v⁴/c⁴ or p⁴/(m⁴ c⁴), respectively.
- 39. Show that the annihilation of an electron-positron pair under emission of one real photon (mass zero) is forbidden by energy-momentum conservation, the emission of two photons is allowed.
- 40. A 4-vector is called timelike/spacelike if its invariant length squared (scalar product) is larger/smaller than zero in arbitrary inertial frames. Show that the acceleration 4-vector defined as

$$(W^0, \mathbf{W}) = (\frac{dU^0}{d\tau}, \frac{d\mathbf{U}}{d\tau})$$

and expressed via the 3-velocity vector \mathbf{u} and its derivative (3-acceleration vector) $\mathbf{a} = \dot{\mathbf{u}} \equiv \frac{d\mathbf{u}}{dt}$ is spacelike. Here τ is the proper time and $U^{\alpha} = (U^0, \mathbf{U})$ is the contravariant 4-velocity vector.