Standard Model and Beyond Quiz

The following questions are meant to give you an indication of how well you understand the material of this course on a conceptual level. This means there are no questions that require calculations. More mathematical questions can however be expected to be part of the exam (!).

The questions in this quiz are randomly ordered. The answers to the questions will be published in a correction model, which also contains a reference to the relevant lecture(s) for each question.

Question 1 - The Klein-Gordon theory applies to:

(a) All bosons

(b) Particles with spin 0

(c) Particles with spin 1

(d) Only bosons with spin 0 and spin 1

Question 2 - The Dirac equation applies to

(a) All fermions

(b) Particles with spin 1/2

(c) Only leptons

(d) Only electron-like particles

Question 3 - Which of the following is true? Multiple answers possible.

(a) A global gauge transformation is automatically also a local gauge transformation.

(b) The derivative of $\partial_\mu F^{\mu\nu}(x)$ with respect to index ν, where $F^{\mu\nu}(x)$ is the EM field-strength tensor, can be nonzero.

(c) The gauge principle states that particles are the result of introducing new symmetries

(d) The field-strength tensor is proportional to the commutator of two covariant derivatives.

Question 4 - When constructing a new term in a Lagrangian, which of the following is restricted in some way, if you want your theory to be THE absolute theory?

(a) The presence of derivatives in interaction terms

(b) The number of unique fields

(c) The mass dimensionality of each term

(d) The number of symmetries

Question 5 - True or false: we could add a mass term for the photon manually to the Lagrangian, its just that we don't observe a photon mass that we don't do this.

(a) True

(b) False

Question 6 - The Klein-Gordon equation is obeyed by

(a) All quantum fields and their components

(b) All boson fields and their components

(c) All quantum fields, but not fermion fields

(d) Only boson fields, but not their components

Question 7 - True or false: the number of degrees of freedom for a gauge boson depend on the boson's mass

(a) True

(b) False

Question 8 - Which of the following are part of the procedure of converting a Feynman diagram to its mathematical equation? Multiple answers possible.

(a) A relative minus sign is placed when two fermions are interchanged between two diagrams

(b) The expression is constructed by going in the opposite direction of particle flow in the diagram

(c) A closed loop contributes a minus sign to the expression

(d) Energy and momentum conservation may temporarily be violated in a vertex

Question 9 - What is the relation between luminosity and the cross section?

Question 10 - The Standard Model is described in terms of multiplets. These multiplets and their field content is fully determined by

(a) The symmetry groups

(b) Experiments

(c) The quantum numbers of the particles in the theory

(d) The higgs mechanism

Question 11 - Which of the following is true? Multiple answers possible.

(a) The kinetic term $\partial_\mu A \partial^\mu A$ for a field originating from an Abelian group differs from the kinetic term for a field originating from a non-Abelian group.

(b) Fields originating from a non-Abelian group have an extra term in their associated field-strength tensor.

(c) The commutator of two generators of a group is always zero.

(d) A characteristic of non-Abelian gauge fields is that they can have interaction with themselves.

Question 12 - How many generators does the group SU(5) have?

(a) 10

(b) 12

(c) 24

(d) 25

Question 13 - A synchrotron is a particle accelerator which has a defining feature that

(a) Its circular

(b) Multiple bunches of particles can be accelerated at the same time

(c) The strength of the magnet field in the accelerator adapts to the energy of the particles being accelerated

(d) The RF cavities contain standing waves that oscillate synchronous with the particles that travel through them

Question 14 - Which of the following are disadvantages of a hadron collider compared to a lepton collider? Multiple answers possible.

(a) Collisions are non-pointlike

(b) Collisions are complex due to initial state QCD effects

(c) The total energy in the interaction between the colliding partons is unknown

(d) Collisions can result in jets which are hard to distangle

Question 15 - What is the formula for luminosity in terms of the number of particles in beam 1 and 2, the crossing frequency and the collision area between the two beams?

Question 16 - True or false: The direction of the magnetic field in the beam channels of the LHC is different than the direction of this field in the LEP collider.

(a) True

(b) False

Question 17 - True or false: When colliding protons, most of the time the initial interaction takes place between u quarks.

(a) True

(b) False

Question 18 - Which of the following is true? Multiple answers possible.

(a) Individual quarks in a proton can not carry more than 1/3 of the momentum of the proton

(b) At the LHC you are more likely to produce μ^+ than μ^- particles.

(c) Gluons are very likely to carry a large momentum fraction of the hadron they are part of

(d) When colliding protons, the interaction taking place can be between any two coloured elementary particles present in the Standard Model.

Question 19 - Place the quarks in order of increasing mass.

Question 20 - Which of the following are true about the gauge structure of the Standard Model? Multiple answers are possible.

(a) The charge of SU(3) is colour

(b) The charge of SU(2) is helicity

(c) The charge of U(1) is electric charge

(d) The force associated with SU(2) is always the weakest force in the standard model.

Question 21 - How are the leptons represented in the standard model? For each generation there are:

(a) two doublets, one for the left-handed particles and one for the right-handed particles

(b) two doublets, one for the electron-like particles and one for the neutrinos

(c) one doublet for the left-handed particles and one singlet for the right-handed electron

(d) one doublet for the electron-like particles and two singlets for the neutrinos

Question 22 - True or false: the μ in the Higgs potential is part of a mass-like term $\mu^2\phi^\dagger\phi$ and is therefore not allowed to be complex.

(a) True

(b) False

Question 23 - Which of the following is true about the Higgs doublet? Multiple answers are possible.

(a) The doublet has two degrees of freedom

(b) The upper component has an isospin of 1/2

(c) The upper component of the doublet has a positive electric charge

(d) The lower component has an isospin of 1/2

Question 24 - True or false: the Higgs mechanism is manually added to the standard model and is not a result of any underlying symmetry.

(a) True

(b) False

Question 25 - Which of the following experiments at the LHC aim at *general signals beyond the standard model*? Multiple answers possible.

(a) ALICE

(b) ATLAS

(c) CMS

(d) LHCb

Question 26 - Which three bounds could be set on the Higgs mass before the start of the LHC?

Question 27 - True or false: the Higgs particle was identified via a decay to two photons because that channel has a high branching ratio.

(a) True

(b) False

Question 28 - In order to exclude new physics or to accept it, which statistical significances do you need respectively in the field of high energy physics?

(a) 2σ and 2σ

(b) 2σ and 5σ

(c) 3σ and 5σ

(d) 5σ and 5σ

Question 29 - A statistical significance of 5σ means that there is a chance of 1 in ... that the measured signal is a not a statistical fluctuation of the background.

(a) ± 20

(b) ± 1 milion

(c) ± 3 milion

(d) ± 6 milion

Question 30 - True or false: Fermion masses are a mathematical result of introducing the Higgs mechanism.

(a) True

(b) False

Question 31 - In weak interactions with a quark ...

(a) mass eigenstates of the quarks are equal to the gauge eigenstates

(b) quarks can only change type when having interaction via a W boson

(c) an element of the PMNS matrix has to be included in the interaction term

(d) a bottom quark can never change into a down quark

Question 32 - True or false: The Standard Model allows for diagrams in which quarks change flavour and a photon is emitted in the final state.

(a) True

(b) False

Question 33 - What does a fermionic Dirac mass term look like?

(a) $-m(\bar{\psi}_L\psi_R + h.c.)$

(b) $-m(\bar{\psi}_L\psi_L + \bar{\psi}_R\psi_R)$

(c) $-m(\bar{\psi}^C_L\psi_L + \bar{\psi}^C_R\psi_R + h.c.)$

(d) $-m(\bar{\psi}^C_L\psi_R + \bar{\psi}^C_R\psi_L + h.c.)$

Question 34 - True or false: Under charge conjugation a left-handed fermion field is changed into a right-handed one.

(a) True

(b) False

Question 35 - Which of the following are true about neutrinos and majorana masses? Multiple answers are possible.

(a) All neutrinos must have a mass

(b) The masses of the neutrinos originate (partly) from a majorana mass term

(c) Majorana neutrinos are their own anti-particle

(d) If the seesaw mechanism is realised in nature, a right-handed neutrino exists with a very high majorana mass

Question 36 - Draw the Feynman diagram for neutrinoless double-β decay

Question 37 - The Standard Model describes approximately ... of the energy content of the universe

(a) 4%

(b) 14%

(c) 26%

(d) 27%

Question 38 - True or false: The coupling constants of the gauge groups in the Standard Model unify at high energy

(a) True

(b) False

Question 39 - Which of the following are true about neutrinos? Multiple answers are possible.

(a) The gauge eigenstates of the neutrinos are equal to the mass eigenstates

(b) The electron neutrino is the lightest neutrino

(c) For the oscillation of neutrino types, both the mass differences and the PMNS matrix are relevant

(d) Double-β decay would be impossible if neutrinos would be massless

Question 40 - Which of the following is not addressed and explained by the standard model?

(a) The difference between the presence of matter and anti-matter in the universe

(b) The fact that the muon, electron and tau have the same charge

(c) The nature of dark matter

(d) The difference between the electroweak scale and the Planck scale

Question 41 - True or false: Theories that introduce extra dimensions to explain the weakness of gravity can be tested by looking at gravity at small distance scales

(a) True

(b) False

Question 42 - Which of the following statements are true about supersymmetry (SUSY)? Multiple answers possible.

(a) SUSY doubles the particle content of the Standard Model

(b) In SUSY there are 5 Higgs bosons

(c) Neutralinos are bosons

(d) If R-parity is conserved supersymmetric particles can only be produced in pairs