===== Problems 1

1) Write down general expression for the decay rate a -> 1+2.
   Outline steps taken how from the starting formula of Fermi's golden rule
   one arrives to the final expression.

2) Write down expression for the differential cross-section
   for the process a+b -> c+d in the centre-of-mass frame.
   Outline steps taken how from the starting formula of Fermi's golden rule
   and general expression for the decay rates one arrives to the
   final expression.

===== Problems 2

~~1) Write down expression for Klein-Gordon equation.~~
   ~~Outline steps how to arrive to the expression starting~~
   ~~from Einstein energy-momentum relationship.~~
   ~~Explain why it is not providing consistent description~~
   ~~of a single particle states for a relativistic system.~~

~~2) Write down expression for Dirac equation.~~
   ~~Explain what are the solutions (the properties),~~
   ~~introduce gamma matrices and use them to express~~
   ~~Dirac equation in a different form.~~

3) Explain the problem with particle antiparticle representation
   using Dirac formalism.
   Why the Feynman-Stuckelberg interpretation was essential to
   complete theoretical description.

~~4) Explain the concept of helicity eigenstates.~~

~~5) In the formalism as above write down two discrete~~
   ~~symmetry transformations, which correspond to charge~~
   ~~conjugation and parity.~~

===== Problems 3

1) Draw diagram in time-ordered quantum mechanics
   and Feynman diagram for a+b -> c+d process in t-channel
   explain differences

~~2) What is the simplest form for Lorentz Invariant Matrix Element.~~
   ~~Could you explain it?~~

~~3) Explain the concept of chirality and helicity. When they are equal?~~
   ~~Could you write down the definitions?~~
   ~~What does it mean that "helicity is conserved in the vertex~~
   ~~of QED interactions"?~~

4) In the QED, cross-section for e+e- -> mu+mu- is calculated
   averaging over initial spin states and summing over the final
   spin states.
   What is the form for the differential cross-section dsigma/dOmega
   could you draw it and explain contributions.
   What is the form for total (integrated) cross-section, how it
   behaves with increasing energy in the centre-of-mass frame of

annihilating electrons

===== Problems 4

1) Write down Rutherford, Mott and
Rosenbluth formulas describing electron-proton scattering.
Explain the differences and how they relate to the cases
each of them is applicable to?

2) In case of electron-proton elastic scattering, with finite
size proton described by Rosenbluth formula: could you explain
what are the components of the formula.
Explain what are the form-factors.

3) How is described differential cross-section for inelastics
scattering e p->e X. What are the characteristic kinematical
variables.

4) What you can say about parton distribution functions
and quark parton model.

===== Problems 5

1) Symmetries in Particle Physics: Isospin, SU(3) flavour.
   Could you explain what they are, if they are exact, and how they lead to
   predicting observed multiplet structure for mesons/baryons.

===== Problems 6

1) Quantum Chromodynamics
Strong interactions are described by Quantum Chromodinamics.
Can you shortly characterise their structure, comparing/contrasting
with QED.

2) What were experimental evidence from e+e- colliders, eg. CELLO
confirming prodictions of QCD for the differencial cross-sections,
ratios of cross-sections, etc.

3) QCD predictions provide an excellent description of the dijet
data at Tevatron p pbar collider and of running alpha_s.
Could you expand those statements.

===== Problems 7

1) Parity operator:
What is the form of this operator and what are the intrinsic parities
of fundamental particles? Which interactions conserve parity.

2) The parity is violated in beta decay.
Explain how it was observed experimentally.

3) Weak interactions:
Explain the V-A structure of this interaction.
What is the evidence for it. What is the strength of weak interactions.
Write down few master formulas and illustrate with Feynman diagrams.

4)Leptonic weak interactions:

Could you explain meaning of "charged current lepton universality"?
Draw illustrative Fenman diagrams and write down formulas.
What is the experimental evidence for it?

===== Problems 9

1) Weak interactions of quarks:
What were two experimental evidences that weak interactions are not
universal for quarks (depends on the quark flavour).
They led to idea of CKM matrix. Could your write down its form
and explain components. Do you know their approximate values?

2) Neutral kaon system and decay to fermions.
What you can say about:
  --> KL, KS transition
  --> strageness oscillation
  --> CP violation

===== Problems 10

1) W-boson decays to fermion via weak interaction.
Write down formulas for longitudinal and transverse matrix elements.
Show that for unpolarised W decay is isotropic.
What are relations between decay width to different fermionic flavors.
Does the measured and predicted values agree?

2) Could you explain concept of EW unification?
What is the group structure of the Standard Model and interactions.
Write down few master relations between couplings, explain the role
of weak mixing angle.

3) Z-boson decays to fermion via electromagnetic and weak interaction.
Write down formula for the total decay width, explain role of
cV, cA, cR, cL couplings.

===== Problems 11

1) Breit-Wigner resonance propagator:
Write down and explain the formula that models it.

2) Draw the distribution of ee->Z->ff cross-section as a function of
invariant
mass of fermion pairs. Explain characteristic shapes in different regions,
which
processes dominate there, draw corresponding Feynman diagrams.

3) Measurements of Z resonance line shape of LEP.
What are the characteristic quantities which were measured.
Write down few master formulas, explain the strategy of the measurement,
explain the impact of QED radiation, draw illustrative plot comparing
uncorrected and correct measurement.

4) Measurement of number of neutrino generations at LEP
Explain strategy of the measurement, write down few master formulas,
draw illustrative plot comparing predicted line-shape for different N_nu.

5) Measurement of forward-backward asymmetry and weak mixing angle at LEP
Explain strategy of the measurement, write down few master formulas,

~~draw illustrative plot comparing on-peak and off-peak A_FB, explain where from this difference. How one infer weak mixing angle from this measurement.~~

===== Problems 12

1) What are the production processes and dominant decay channels
   of the Standard Model Higgs boson discovered at LHC

2) How the mass, spin and parity of the Higgs boson was measured at LHC

3) What do we know about Higgs couplings based on LHC data.
   How well they agree with Standard Model predictions.