Deeltjesfysica

(30/08/2012 (9u-13u))

Answers may be in English or in Dutch.

Part I: Severijns

1 *Oral with written preparation.*

(a) Describe what "strange" particles are.

(a) Explain why particle decays in which the strangeness S changes by one unit (e.g. $\Lambda^0 \to p + e + \overline{\nu_e}$) can occur. Include the Cabibbo-Kobayashi-Maskawa matrix in your answer.

2 *Written.*
Compare the operating principles of a cloud (Wilson) chamber to that of a bubble chamber.

2 *Written.*
Are the following reactions possible?
If yes, explain via which interaction the reaction proceeds and why.
If not, explain why it is not possible.

(a)	$D_s^+ \to K^0 + \overline{K}^0 + \pi^+$	($D_s^+ = c\overline{s}$, $K^0 = d\overline{s}$, $\overline{K}^0 = \overline{d}s$, $\pi^+ = u\overline{d}$)
(b)	$p + \overline{p} \to \Lambda^0 + \overline{\Lambda}^0$	($p = uud$, $\Lambda^0 = uds$)
(c)	$p + p \to \Sigma^+ + K^+$	($\Sigma^+ = uus$, $K^+ = u\overline{s}$)
(d)	$e^- + e^+ \to \gamma$	
(e)	$\nu_\mu + p \to \mu^+ + n$	($n = uud$)

4 *Written.*
Show that for the decay $\pi^+ \to \mu^+ + \nu_\mu$ the combined CP symmetry is conserved. Do this by making drawings that show the spins and momenta (impulse) of the particles and explain these drawings in view of the C and P operations. The spin of the positive pion is zero.

5 *Written.*
Draw Feynman-diagrams for the following weak interaction processes. Indicate also whether the reaction or decay is of the purely leptonic, semi-leptonic or hadronic type and whether it procees via a charged-current or a neutral current weak interaction.

(a)	$\Lambda_c^+ \to p + K^- + \pi^+$	($\Lambda_c^+ = udc$, $p = uud$, $K^- = \overline{u}s$, $\pi^+ = u\overline{d}$)
(b)	$\mu^+ + \overline{\nu_e} \to e^+ + \overline{\nu_\mu}$	
(c)	$K^+ \to \pi^0 + e^+ + \nu_e$	($K^+ = u\overline{s}$, $\pi^0 = \overline{u}u$)
(d)	$D^+ \to K^- + \pi^+ + e^+ + \nu_e$	($D^+ = c\overline{d}$, $K^- = \overline{u}s$, $\pi^+ = u\overline{d}$)
(e)	$K^+ \to \mu^+ + \nu_\mu + \gamma$	($K^+ = u\overline{s}$)

Part II: Van Proeyen

1 *Oral with written preparation.*
Consider the theory with a particle of spin 0, whose associated field we will indicate as $\phi(x)$, and electrons, with associated field $\psi(x)$. We consider this theory to be determined by a Lagrangian of the form

$$\mathcal{L} = \text{kinetic term for the spin 0} + \text{kinetic term for the spin 1/2} + g\phi\overline{\psi}\gamma^5\psi. \quad (1)$$

(a) Fill in an expression for the kinetic terms.

(b) In order that $\mathcal{L}$ is real, should g be a real or imaginary number?

(c) Write down the propagators and vertices for this theory.

(d) Draw Feynman diagrams for the scattering of an electron with a positron in this model in which (1) is the complete Lagrangian.

(e) Calculate the matrix element for the diagram in chich the incoming particles annihilate to a spin 0, which ten decays in a new electron - positron pair. First give names to relevant momenta, helicities, ...

(f) What is the differential cross section in the center of mass frame, net yet inserting the result for the matrix element of part (e)? A simplified expression is

$$\frac{\mathrm{d}\sigma}{\mathrm{d}\Omega} = |\mathcal{M}|^2 \frac{1}{(16\pi E)^2}.$$

How did I obtain this? What is E?

(g) Suppose that we do not measure the spins of the electrons in such a scattering experiment. Continue now the calculation of the differential cross section using the result of part (e). However, you do not have to wrok out the traces.

(h) If you would continue the calculation correctly, you would get

$$\frac{\mathrm{d}\sigma}{\mathrm{d}\Omega} = \frac{g^4}{(8\pi E)^2} \frac{\left(2E^2 - m_e^2\right)^2}{\left(4E^2 - m_\phi^2\right)^2}.$$

What is the total cross section σ?

2 *Written.*
Here are some short questions.

(a) A fermion ψ appears in the Lagrangian as

$$\mathcal{L} = \mathrm{i}\overline{\psi}\partial\!\!\!/\psi + 6A_\mu\overline{\psi}\gamma^\mu\psi,$$

where A_μ is the field corresponding to the photon. What is the charge of that fermion?

(b) Suppose that we measure the coupling constant of the electron to the photon in an experiment where the electron has energy E. We increase the energy to $E' > E$.
How will this influence the result for the coupling constant? Explain in an intuitive way.

(c) Suppose that the standard model would not correspond to $\mathrm{U}(1)\times\mathrm{SU}(2)\times\mathrm{SU}(3)$, spontaneously broken to $\mathrm{U}(1)\times\mathrm{SU}(3)$, but to $\mathrm{SU}(2)\times\mathrm{SU}(3)$ with spontaneous symmetry breaking to $\mathrm{U}(1)\times\mathrm{SU}(3)$. Which particle of the standard model would not exist?

◇ ◇ ◇