This paper contains total 5 pages.

M.Sc. (IV Sem.) Examination May 2019

Model Answer Key

PHYSICS Paper : PHY-C02

High Energy Physics - II

Time : Three Hours **Maximum Marks : 100**

1. No Supplementary Answer-book will be given to any candidate. Hence the candidate should write their answers precisely in the main answer-book only.
2. All the part of one question should not be answered at different places in the answer book.

Attempt any five questions

The paper consists of two parts.

Part A:- Question No. 1 contains 10 short answer questions. Each question is of two marks.

Part B:- Attempt four question with internal choice. The limit of each answer is five pages. Each question is of 20 marks.

Default conventions are from Halzen-Martin. If you follow any other, you have to explain.

1. Short type questions (2 marks each):

(a) Form factors are factors which explain the distribution of the corresponding physical quantity. For example, if we look at proton structure, it's charge distribution can be explained using Fourier transformation is relevant Form Factor.

(b) $R = 3\,\Sigma e_q^2$ for $q = u, d, s$ (means 3 quarks $R = 2$)

For $q = u, d, s, c$ ratio $R = \frac{10}{3}$ and for $q = u, d, s, c, b$ ratio $R = \frac{11}{3}$

(c) Energy conservation

(d) Color doublet : $R\bar{G}, R\bar{B}, G\bar{R}, G\bar{B}, B\bar{R}, B\bar{G}, \frac{1}{\sqrt{2}}(R\bar{R} - G\bar{G}), \frac{1}{\sqrt{6}}(R\bar{R} + G\bar{G} - 2B\bar{B})$

color singlet : $\frac{1}{\sqrt{3}}(R\bar{R} + G\bar{G} + B\bar{B})$

(e) $P_L = \frac{1}{2}(1 - \gamma^5)$ and $P_R = \frac{1}{2}(1 + \gamma^5)$

$P_L^{\,2} = \frac{1}{4}(1 - \gamma^5)(1 - \gamma^5) = \frac{1}{4}(1 + 1 - 2\gamma^5) = \frac{1}{2}(1 - \gamma^5) = P_L$

$P_L^{\,T} = \frac{1}{2}(1 - \gamma^5)^T = \frac{1}{2}(1 - (\gamma^5)^T) = \frac{1}{2}(1 - \gamma^5) = P_L$

Similarly, $P_R^{\,2} = P_R$ and $P_R^{\,T} = P_R \Rightarrow P_R$ and P_L are projections.

(f) $\sqrt{s} = \sqrt{(p_1 + p_2)^2}$, here $p_1 + p_2 = (E + m, 0, 0, -p)$

So, $(p_1 + p_2)^2 = (E + m)^2 - p^2 = E^2 - p^2 + 2mE + m^2 = 2m^2 + 2mE$

$\Rightarrow \sqrt{s} = \sqrt{2m^2 + 2mE}$ if $E >> m$ then $\sqrt{s} = \sqrt{2mE}$

(g) To understand the decay like $K^+ \to \mu^2\nu_\mu$, which has similarity as $\pi^+ \to \mu^+\nu_\mu$ but at quark level K^+ have $u\bar{s}$ but π^+ have $u\bar{d}$. Since ud can interact via W but $u\bar{s}$ can not do that. To understand that we take a mixing angle of d & s as follows:

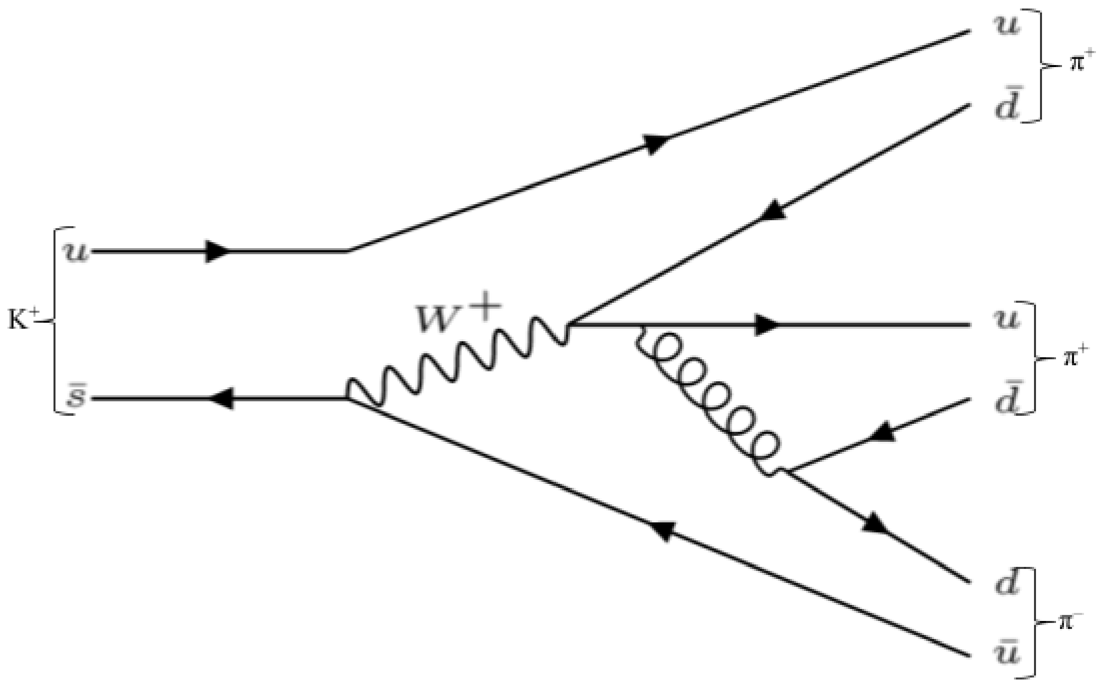
$$d' = d\cos\theta_c + s\sin\theta_c$$

$$s' = -d\sin\theta_c + s\cos\theta_c$$

Here angle θ_c is known as Cabibbo angle.

(h) $\gamma^\mu(1-a\,\gamma^5)$, here $a \in [0, 1]$

(i)



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(j) Using uncertainty principle $\Delta E\,\Delta t \approx \hbar$ and $\Delta E = 80\ GeV$, we can find out Δt

2. In Breit fram $p^\mu = (E, \vec{p})$ and $p'^\mu = (E, -\vec{p})$, therefore $\gamma^\mu(F_1 + \kappa F_2) - \frac{(p^\mu + p'^\mu)}{2M}\kappa F_2$ gives

$\rho = J^0 = e\bar{u}(p')[\gamma^0(F_1 + \kappa F_2) - \frac{E}{M}\kappa F_2)u(p)$

But $\bar{u}\gamma^0 u = 2M$ & $\bar{u}u = 2E$, so

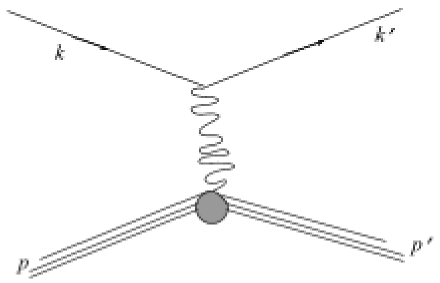
$\rho = 2m_e[F_1 + (1 - \frac{E^2}{M^2})\kappa F_2] = 2m_e G_E$

Using $G_M = F_1 + \kappa F_2$ & $G_E = F_1 + \frac{\kappa q^2}{2M^2} F_2$ and $q^2 = 4\vec{p}^2$

$\vec{J} = e\bar{u}(p')\gamma u(p) G_M$

OR

(a)



Vertex factor [ ] = $F_1(q^2)\gamma^\mu + \frac{\kappa}{2M} F_2(q^2) \iota \sigma^{\mu\nu} q_\nu$

(b) Changing scattering variables in unitless variables x, y is Bjorken scaling. It represents scattering kinematic region in range $0 \le x \le 1$ and $0 \le y \le 1$.

3. Problem 11.5 in Halzen-Martin

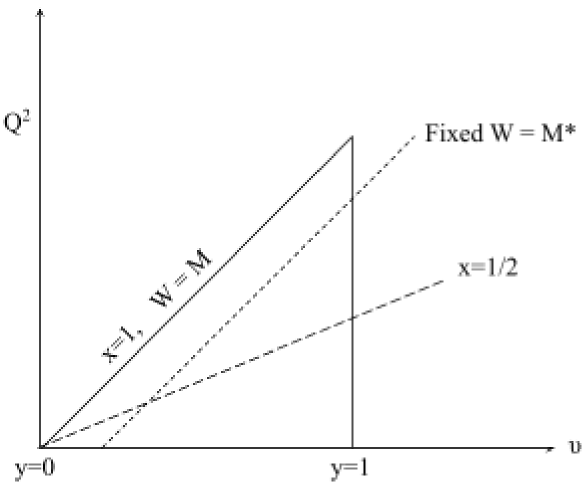
$x_{\bar{q}} \sin\theta = x_T \Rightarrow x_q^2 x_{\bar{q}}^2 \sin^2\theta = 4(1 - x_q)(1 - x_{\bar{q}})(x_q + x_{\bar{q}} - 1) = - 4(1 - x_q - x_{\bar{q}} + \frac{1}{2} x_q x_{\bar{q}})^2 + x_q^2 x_{\bar{q}}$

Using $1 - \sin^2\theta = \cos^2\theta$, we get $1 - x_q - x_{\bar{q}} + \frac{1}{2} x_q x_{\bar{q}} = \frac{1}{2} x_q x_{\bar{q}} \cos\theta$

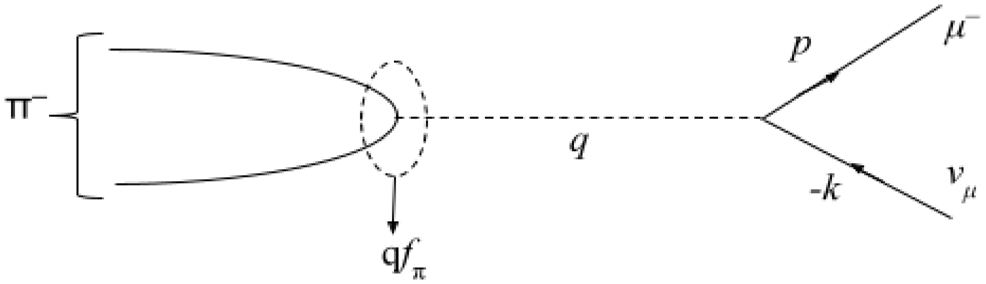
OR

(a) Similar to 2 OR (b), x is fraction of momentum. Or in terms of energy $\hat{s} = xs$, where $\hat{s}$ is real useful energy, $x = -\frac{t}{s+u} = \frac{Q^2}{2M\nu}$ and $y = \frac{p\cdot q}{p\cdot k(lab)} = \frac{\nu}{E} = \frac{E-E'}{E}$

(b) Picture 9.3 in Halzen-Martin



4. $\mathcal{M} = \frac{G}{\sqrt{2}}(p^{\mu} + k^{\mu})f_{\pi}[\bar{u}(p)\gamma_{\mu}(1 - \gamma^{5})\nu(k)] = \frac{G}{\sqrt{2}}f_{\pi}m_{\mu}\bar{u}(p)(1 - \gamma^{5})\nu(k)$



$\pi^{-}(q) \rightarrow \mu^{-}(p) + \bar{\nu}_{\mu}(k)$

OR

Exercise 12.15 in Halzen-Martin

$\sigma(\nu_{e}e^{-}) = \frac{G^{2}s}{\pi}$, Since neutrino mass is zero so, $s \approx 2m_{e}E_{\nu}$

So, $\sigma = \frac{G^{2}}{\pi}(2m_{e}E_{\nu}) = 10^{-3} \times \frac{G^{2}}{\pi}E_{\nu}$

Using strength of weak interaction, we get $\sigma \approx E_{\nu} \times 10^{-41}$ cm^2 if E_{ν} is in GeV.

5. $\mathcal{L} = \frac{1}{2}(\partial_{\mu}\phi_{1})^{2} + \frac{1}{2}(\partial_{\mu}\phi_{2})^{2} + \frac{1}{2}(\partial_{\mu}\phi_{3})^{2} - \sum_{i=1}^{3}[\frac{1}{2}\mu^{2}\phi_{i}^{2} + \frac{1}{4}\lambda(\phi_{i}^{2})^{2}]$

$V = \sum_{i}[\frac{1}{2}\mu^{2}\phi_{i}^{2} + \frac{1}{4}\lambda(\phi_{i}^{2})^{2}]$

If $\mu^2 < 0$ and $\lambda > 0$ then there will be minima in ϕ at

$\phi = \pm\sqrt{\frac{\mu^{2}}{\lambda}} = \nu$(say)

If we use perturbation theory for ϕ such as $\phi = \nu + \eta + \iota\, \xi + j\,\zeta$

Here ι and j used to show orthogonality field η, ξ and ζ. If we will calculate potential V for perturbation then, we get terms of η^2 with some factor $(\sqrt{-2\mu^{2}})^{2}$ but there will not be any term with ξ^2 or ζ^2.

OR

We replace $\phi \rightarrow e^{i\alpha}\phi$, then

$\mathcal{L}$ will be invariant but

$\delta\mathcal{L} = \frac{\partial\mathcal{L}}{\partial\phi}\delta\phi + \frac{\partial\mathcal{L}}{\partial(\partial_{\mu}\phi)}\delta(\partial_{\mu}\phi) + \frac{\partial\mathcal{L}}{\partial\phi^{*}}\delta\phi^{*} + \frac{\partial\mathcal{L}}{\partial(\partial_{\mu}\phi)^{*}}\delta(\partial_{\mu}\phi^{*})$

Using E.L. equation, we will get

$j^{\mu} = ie(\phi^{*}\partial^{\mu}\phi - \phi\partial^{\mu}\phi^{*})$

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