

# Wave operator and propagator

Quadratic (free) action

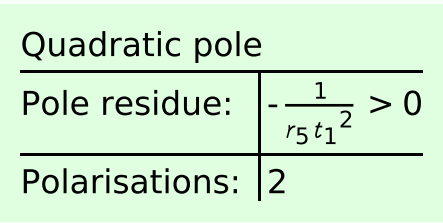
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$$\begin{aligned}
S = & \iiint \left( \frac{1}{6} (2 t_1 \omega_{\alpha}^{\alpha i} \omega_{\prime \theta}^{\theta} + 6 f^{\alpha \beta} \tau_{\alpha \beta} + 6 \omega^{\alpha \beta \chi} \sigma_{\alpha \beta \chi} - 4 t_1 \omega_{\alpha}^{\theta} \omega_{\theta}^{\alpha} \partial_{\prime} f^{\alpha i} + \right. \\
& 4 t_1 \omega_{\prime \theta}^{\theta} \partial_{\prime} f_{\alpha}^{\alpha} - 2 t_1 \partial_{\prime} f_{\theta}^{\theta} \partial_{\prime} f_{\alpha}^{\alpha} - 2 t_1 \partial_{\prime} f^{\alpha i} \partial_{\theta} f_{\alpha}^{\theta} + \\
& 4 t_1 \partial_{\prime} f_{\alpha}^{\alpha} \partial_{\theta} f_{\prime}^{\theta} - 6 t_1 \partial_{\alpha} f_{\prime \theta}^{\theta} \partial^{\theta} f^{\alpha i} - 3 t_1 \partial_{\alpha} f_{\theta \prime}^{\theta} \partial^{\theta} f^{\alpha i} + \\
& 3 t_1 \partial_{\prime} f_{\alpha \theta}^{\theta} \partial^{\theta} f^{\alpha i} + 3 t_1 \partial_{\theta} f_{\alpha \prime}^{\theta} \partial^{\theta} f^{\alpha i} + 3 t_1 \partial_{\theta} f_{\prime \alpha}^{\theta} \partial^{\theta} f^{\alpha i} + \\
& 6 t_1 \omega_{\alpha \theta \prime} (\omega^{\alpha i \theta} + 2 \partial^{\theta} f^{\alpha i})) + 8 r_2 \partial_{\beta} \omega_{\alpha \theta} \partial^{\theta} \omega^{\alpha \beta \prime} - \\
& 4 r_2 \partial_{\beta} \omega_{\alpha \theta \prime} \partial^{\theta} \omega^{\alpha \beta \prime} + 4 r_2 \partial_{\beta} \omega_{\prime \theta \alpha} \partial^{\theta} \omega^{\alpha \beta \prime} - \\
& 2 r_2 \partial_{\prime} \omega_{\alpha \beta \theta} \partial^{\theta} \omega^{\alpha \beta \prime} + 2 r_2 \partial_{\theta} \omega_{\alpha \beta \prime} \partial^{\theta} \omega^{\alpha \beta \prime} - \\
& 4 r_2 \partial_{\theta} \omega_{\alpha \beta} \partial^{\theta} \omega_{\prime}^{\alpha \beta \prime} + 6 r_5 \partial_{\prime} \omega_{\theta}^{\kappa} \partial^{\theta} \omega_{\alpha}^{\alpha i} - \\
& 6 r_5 \partial_{\theta} \omega_{\prime \kappa}^{\kappa} \partial^{\theta} \omega_{\alpha}^{\alpha i} - 6 r_5 \partial_{\alpha} \omega^{\alpha i \theta} \partial_{\kappa} \omega_{\prime \theta}^{\kappa} + \\
& 12 r_5 \partial^{\theta} \omega_{\alpha}^{\alpha i} \partial_{\kappa} \omega_{\prime \theta}^{\kappa} + 6 r_5 \partial_{\alpha} \omega^{\alpha i \theta} \partial_{\kappa} \omega_{\theta \prime}^{\kappa} - \\
& \left. 12 r_5 \partial^{\theta} \omega_{\alpha}^{\alpha i} \partial_{\kappa} \omega_{\theta \prime}^{\kappa} \right) [t, x, y, z] dz dy dx dt
\end{aligned}$$

$$\begin{array}{c} \sigma_2^{\#1} + \alpha\beta \\ \tau_2^{\#1} + \alpha\beta \\ \omega_2^{\#1} + \alpha\beta \end{array} \begin{array}{|c|c|c|} \hline 0 & 0 & \frac{2}{t_1} \\ \hline -\frac{2i\sqrt{2}k}{(1+2k^2)^2 t_1} & \frac{4k^2}{(1+2k^2)^2 t_1} & 0 \\ \hline \frac{2}{(1+2k^2)^2 t_1} & \frac{2i\sqrt{2}k}{(1+2k^2)^2 t_1} & 0 \\ \hline \end{array} \begin{array}{c} \omega_0^{\#1} \\ f_0^{\#1} \\ \sigma_0^{\#1} \end{array} \begin{array}{|c|c|c|c|} \hline 0 & 0 & 0 & k^2 r_2 - t_1 \\ \hline 0 & 0 & 0 & 0 \\ \hline 0 & 0 & 0 & 0 \\ \hline 0 & 0 & 0 & 0 \\ \hline \end{array} \begin{array}{c} \omega_{2^+}^{\#1} + \alpha\beta \\ f_{2^+}^{\#1} + \alpha\beta \\ \omega_{2^-}^{\#1} + \alpha\beta \end{array} \begin{array}{|c|c|c|} \hline \frac{t_1}{2} & -\frac{i k t_1}{\sqrt{2}} & 0 \\ \hline \frac{i k t_1}{\sqrt{2}} & k^2 t_1 & 0 \\ \hline 0 & 0 & \frac{t_1}{2} \\ \hline \end{array} \begin{array}{c} \omega_{1^+}^{\#1} + \alpha\beta \\ \omega_{1^+}^{\#2} + \alpha\beta \\ f_{1^+}^{\#1} + \alpha\beta \\ \omega_{1^+}^{\#1} + \alpha \\ \omega_{1^+}^{\#2} + \alpha \\ f_{1^+}^{\#1} + \alpha \\ f_{1^+}^{\#2} + \alpha \end{array} \begin{array}{|c|c|c|c|c|c|c|} \hline k^2 r_5 - \frac{t_1}{2} & -\frac{t_1}{\sqrt{2}} & -\frac{i k t_1}{\sqrt{2}} & 0 & 0 & 0 & 0 \\ \hline -\frac{t_1}{\sqrt{2}} & 0 & 0 & 0 & 0 & 0 & 0 \\ \hline \frac{i k t_1}{\sqrt{2}} & 0 & 0 & 0 & 0 & 0 & 0 \\ \hline 0 & 0 & 0 & k^2 r_5 + \frac{t_1}{6} & \frac{t_1}{3\sqrt{2}} & 0 & \frac{i k t_1}{3} \\ \hline 0 & 0 & 0 & \frac{t_1}{3\sqrt{2}} & \frac{t_1}{3} & 0 & \frac{1}{3} i \sqrt{2} k t_1 \\ \hline 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \hline 0 & 0 & 0 & -\frac{1}{3} i k t_1 & -\frac{1}{3} i \sqrt{2} k t_1 & 0 & \frac{2k^2 t_1}{3} \\ \hline \end{array} \begin{array}{c} \sigma_0^{\#1} + \\ \tau_0^{\#1} + \\ \tau_0^{\#2} + \\ \sigma_0^{\#1} + \end{array} \begin{array}{|c|c|c|c|} \hline 0 & 0 & 0 & 0 \\ \hline 0 & 0 & 0 & 0 \\ \hline 0 & 0 & 0 & 0 \\ \hline 0 & 0 & 0 & \frac{1}{k^2 r_2 - t_1} \\ \hline \end{array}$$

Diagram illustrating a t-channel exchange process between two pairs of fermions (solid lines) and a meson (dashed line). The meson is labeled with  $J^P = 0^-$  and the momentum vector  $k^\mu$ . The diagram shows the exchange of a meson between two vertices, each connected to two external fermion lines.

| Massive particle |                       |
|------------------|-----------------------|
| Pole residue:    | $-\frac{1}{r_2} > 0$  |
| Polarisations:   | 1                     |
| Square mass:     | $\frac{t_1}{r_2} > 0$ |
| Spin:            | 0                     |
| Parity:          | Odd                   |


$$r_2 < 0 \ \&\& \ r_5 < 0 \ \&\& \ t_1 < 0$$