

# Dirac equation 1

From Fitzpatrick problem 11.11.

Let

$$\psi^r = \exp\left(-\frac{i}{\hbar}\epsilon_r p_\mu x^\mu\right) w^r(\mathbf{p})$$

where  $\epsilon = (1, 1, -1, -1)$  and

$$\begin{aligned} w^1(\mathbf{p}) &= \sqrt{\frac{E + mc^2}{2mc^2}} \begin{pmatrix} 1 \\ 0 \\ \frac{p_z c}{E + mc^2} \\ \frac{(p_x + ip_y)c}{E + mc^2} \end{pmatrix} & w^2(\mathbf{p}) &= \sqrt{\frac{E + mc^2}{2mc^2}} \begin{pmatrix} 0 \\ 1 \\ \frac{(p_x - ip_y)c}{E + mc^2} \\ \frac{-p_z c}{E + mc^2} \end{pmatrix} \\ w^3(\mathbf{p}) &= \sqrt{\frac{E + mc^2}{2mc^2}} \begin{pmatrix} \frac{p_z c}{E + mc^2} \\ \frac{(p_x + ip_y)c}{E + mc^2} \\ 1 \\ 0 \end{pmatrix} & w^4(\mathbf{p}) &= \sqrt{\frac{E + mc^2}{2mc^2}} \begin{pmatrix} \frac{(p_x - ip_y)c}{E + mc^2} \\ \frac{-p_z c}{E + mc^2} \\ 0 \\ 1 \end{pmatrix} \end{aligned}$$

Verify that  $\psi^r$  are solutions to the Dirac equation

$$i\hbar\gamma^\mu\partial_\mu\psi = mc\psi$$

and that the solutions are normalized as

$$|\psi|^2 = \frac{E}{mc^2}$$

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