$$* \quad \int_{-1}^{1} P_m P_n \, dx = \frac{2}{2n+1} \, \delta_{mn}$$

$$\hookrightarrow \begin{cases} 0 & m \neq n \\ 1 & m = n \end{cases}$$

$$\Rightarrow \int_{-1}^{1} P_n^2 \, dx = \frac{2}{2n+1}$$

$$\Rightarrow c_n = \frac{\int_{-1}^{1} f P_n \, dx}{\int_{-1}^{1} P_n^2 \, dx} = \boxed{\frac{2n+1}{2} \int_{-1}^{1} f P_n \, dx}$$

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