1. Møller Scattering

Compute the differential cross section for Møller scattering ($e^-e^- \rightarrow e^-e^-$) in the centre of mass frame. Express your answer in terms of the energy $E$ of one of the particles, the particle mass $m$, and the centre of mass scattering angle $\theta$.

2. J/ψ decay constant

(i) The $J/\psi$ is a charm-anticharm vector meson whose discovery confirmed the reality of quarks to many physicists. Define the $J/\psi$ decay constant, $f_\psi$, via the relation

$$\langle \psi(p, \lambda) | \bar{c} \gamma_\mu c | 0 \rangle = f_\psi m_\psi \epsilon_\mu^*(p, \lambda)$$

where $p$ and $\lambda$ are the $J/\psi$’s four-momentum and polarisation respectively. Use this definition to compute the decay rate for $J/\psi \rightarrow e^+e^-$. Write your answer in terms of $\alpha$, the charge of the charm quark ($=Q_e$), the decay constant, and the $J/\psi$ and electron’s masses.

(ii) Use $Q = 2/3$, $m_\psi = 3.097$ GeV, and $\Gamma(\psi \rightarrow ee) = 5.39$ keV to obtain the decay constant.