1 a) Use quark flow diagrams to describe the following weak decays:

i) $D^{+} \rightarrow \overline{K^{0}}\pi^{+}$

ii) $D^{0} \rightarrow \overline{K^{0}}\pi^{0}$

iii) $\overline{B^{0}} \rightarrow J/\psi\ \overline{K^{0}}$ **{4}**

b) For an $e^{+}e^{-}$ collider operating at a centre of mass energy of 30 GeV, what is the value of the ratio

$$R = \frac{\sigma(e^{+}e^{-} \rightarrow \gamma \rightarrow q\overline{q})}{\sigma(e^{+}e^{-} \rightarrow \mu^{+}\mu^{-})} \ ,$$

where $q\overline{q}$ is the sum over all produced quark-antiquark pairs?

Justify your answer. **{4}**

c) By considering the form of plane wave solutions to the Klein Gordon relativistic wave equation,

$$-\hbar^{2}\frac{\partial^{2}\Psi(\mathbf{x},t)}{\partial t^{2}} = -\hbar^{2}c^{2}\nabla^{2}\Psi(\mathbf{x},t) + m^{2}c^{4}\Psi(\mathbf{x},t)$$

show that both negative and positive energy solutions are possible. What conclusions can be reached from the negative energy states in the analogous case of electrons? **{4}**

d) In a recent experiment (CPLEAR at CERN), the production and decay of K^0 and $\overline{K}^0$ mesons were studied. The rates at which $K^0 \to \overline{K}^0$ i.e. $\left[R\left(K^0 \to \overline{K}^0\right)\right]$ and $\overline{K}^0 \to K^0$ i.e. $\left[R\left(\overline{K}^0 \to K^0\right)\right]$, were measured by identifying, for each event, the nature of the neutral K meson at production and decay. The following result was obtained:

$$\frac{R(\overline{K}^0 \to K^0) - R(K^0 \to \overline{K}^0)}{R(\overline{K}^0 \to K^0) + R(K^0 \to \overline{K}^0)} = (6.6 \pm 1.3_{statistical} \pm 1.0_{systematic}).10^{-3}$$

Without giving any experimental details, discuss the significance of this result with respect to the laws of physics. Why is the above ratio measured and not, for example, the quantity

$$R(\overline{K}^0 \to K^0) - R(K^0 \to \overline{K}^0)?$$ **{4}**