1. a) A new theory postulates a Z' particle with similar properties to the Z boson but a mass of 500 GeV.

Calculate the minimum beam energy required to produce this particle when: (i) an antiproton beam impinges on a liquid hydrogen target, (ii) $\bar{p}p$ beams collide. **{4}**

Why would it be better to use an antiproton-proton collider? **{2}**

Why might it be easier to measure the mass of the new boson at an electron-positron collider than at the antiproton-proton collider ? **{2}**

b) In e^+e^- collisions the definition of the quantity R, is
$R(s) = \sigma [e^- e^+ \rightarrow \text{hadrons}] / \sigma [e^- e^+ \rightarrow \mu^- \mu^+]$.

R takes the value $R=3\ \Sigma q_i^2$, where the sum runs over all quark species that can be produced at the centre of mass energy, $\sqrt{s}$.

i) What is the significance of the factor of 3? **{2}**

ii) Suppose that the measurement of R is performed at an $e^- e^+$ collider having $\sqrt{s}$=500 GeV. Describe our present understanding of quark masses and charges and compute the value of R that is expected. **{3}**

iii) Compute the value of R at this centre of mass energy under the assumption that a new generation of quarks has been found. State clearly your assumptions about the new generation. **{3}**