**2 A)**

a) Complete the missing entries in the following table that outline the fermions of the standard model. **{4}**

| Generation | ? | Mass | ? | Mass |
|---|---|---|---|---|
| 1 | u | ~ 300 MeV/$c^2$ | e | ? |
| | ? | ~ 300 MeV/$c^2$ | ? | 0 |
| ? | ? | 1.1 GeV/$c^2$ | ? | 100 MeV |
| | s | ? | $\nu_\mu$ | ? |
| 3 | t | ? | $\tau$ | ? |
| | ? | 5 GeV/ $c^2$ | ? | 0 |

b) Draw Feynman diagrams for $e^+e^- \to Z^0 \to f\bar{f}$ where $f$ are all possible fermions to which $Z^0$ can decay.

Take the $e^+e^-$ centre of mass energy to be 90 GeV. **{4}**

c) Sketch the layout of the sensitive parts of the ALEPH detector in an $r-\phi$ (beam's eye) view. **{3}**

d) Choose one possible visible decay mode for the $Z^0$ and describe with a diagram what the particles look like in the detector. **{4}**

e) The quantity $R_z$ is defined as

$$R_z = \frac{\Sigma\Gamma(Z \to \text{hadrons})}{\Gamma(Z \to \mu\mu)}$$

What value of $R_z$ would you expect if it is assumed that the coupling of the $Z$ to all fermions is the same?

Compute the value of $R_z$ assuming that the fermion coupling depends on the electric charge. The true value of $R_z$ is $R_z = 21$. What does this imply about the coupling of the $Z^0$ to fermions? **{5}**

f) Describe how the number of generations was determined at LEP. **{4}**