Question Number	Answer	Mark
13(a)	• Use of eV to J conversion factor **(1)** • Use of $\Delta E = c^2\Delta m$ **(1)** • Determines mass of Z boson = 1.62×10^{-25}(kg) **Or** mass of proton = 9.39×10^{8} (eV/c^2) **(1)** • Mass is 97 times greater **(1)** Example of calculation mass of boson $= \frac{91\ \text{GeV/c}^2\times10^{9}\times1.6\times10^{-19}\text{JeV}^{-1}}{(3\times10^{8})^2\ (\text{m s}^{-1})^2} = 1.62\times10^{-25}\ \text{kg}$ mass $= \frac{1.62\times10^{-25}\text{kg}}{1.67\times10^{-27}\text{kg}}$ mass = 97 times that of a proton Alternative: mass of proton $= \frac{1.67\times10^{-27}\text{kg}\times(3\times10^{8})^2\ (\text{m s}^{-1})^2}{1.6\times10^{-19}\text{JeV}^{-1}} = 0.939\ \text{GeV/c}^2$ 100 ×0.939 GeV/c^2 = 94 GeV/c^2 which is just a bit more than mass of Z boson.	**4**
13(b)	• Mass-energy is conserved **Or** refers to $\Delta E = c^2\Delta m$ **(1)** • Need for large amounts of energy to create a high-mass particle **Or** Need more energy because mass of Z much greater than mass of proton(s) [accept 97 times] **(1)** • (Additional) energy comes from the kinetic energy of colliding particles **(1)**	**3**
13(c)	• At speeds close to the speed of light **(1)** • there is a relativistic increase in lifetime **Or** time dilation occurs [do not accept dilution] **(1)**	**2**
	Total for question 13	**9**