1. a) In a colliding beam experiment, define *luminosity* and explain how it is related to the *interaction rate*. Obtain an expression for luminosity in terms of the design features of an accelerator and discuss how the features can be optimised to improve overall performance. **{4}**

b) The LEP electron-positron accelerator at CERN was designed so that it could initially study the production of the Z^0 boson of mass ~ 91 GeV/c^2. Thereafter it was modified to study the production of W^+ and W^- bosons (mass ~ 80 GeV/c^2). Briefly describe the reason for these studies being carried out in this order. Explain why the same reason accounts for the fact that the variation in total cross section near the $W^{\pm}$ threshold differs substantially from that observed near the Z^0 production threshold. **{4}**

c) At LEP the cross section for the hadronic process

$$e^- e^+ \rightarrow Z^0 \rightarrow q^+ q^-$$

is described by the Breit-Wigner formula. The peak cross section is given by

$$\sigma^0{}_{qq} = [\,(12\pi)/M^2{}_z\,]\;[(\Gamma_{ee}\Gamma_{qq})/\Gamma^2{}_z\,].$$

i) What is the lifetime of the Z^0? **{2}**

ii) What is the peak cross section one expects for the measurement of

$$e^- e^+ \rightarrow Z^0 \rightarrow \mu^- \mu^+$$ **{3}**

iii) Use the Z^0 partial width for decay into neutrinos to compute the number of light neutrinos. **{3}**

$\hbar = 6.582 \times 10^{-22}$ MeV s

$\hbar c = 197$ MeV fm

Total width of the Z^0	$\Gamma_z = 2484\ \mathrm{MeV}/c^2$
Mass of the Z^0	$M_z = 91.182\ \mathrm{GeV}/c^2$
Lepton partial width	$\Gamma_{ll} = 83\ \mathrm{MeV}/c^2$
Neutrino partial width	$\Gamma_{vv} = 164\ \mathrm{MeV}/c^2$
Hadronic partial width	$\Gamma_{qq} = 1736\ \mathrm{MeV}/c^2$
The peak hadronic cross section	$\sigma^0_{had} = 41.44\ \mathrm{nb}$