How many ion pairs are produced in 10 m of air of STP by one (a) 5 MeV $\alpha$-particle, (b) 1 MeV $\beta$-particle and (c) 1 MeV $\gamma$-quantum ($\mu_m(\text{air}) = \mu_m(\text{water})$)?

First we need to define the electron volt and MeV as:

$$eV := 1.60217733 \times 10^{-19} \text{ joule} \quad \text{MeV} := 10^6 \text{ eV}$$

The ionization energy, eV/ion pair, is taken from Table 7.1: $w := 34 \cdot eV$

(a) The range of a 5 MeV $\alpha$-particle is $<< 10$ m, hence all energy will be used for ionization:

$$E_\alpha := 5 \text{ MeV} \quad \text{Hence} \quad n := \frac{E_\alpha}{w} \quad n = 1.471 \times 10^5 \quad \text{ion pairs}$$

(b) The range of a 1 MeV $\beta$-particle is $< 10$ m, hence all energy will be used for ionization:

$$E_\beta := 1 \text{ MeV} \quad \text{Hence} \quad n := \frac{E_\beta}{w} \quad n = 2.941 \times 10^4 \quad \text{ion pairs}$$

(c) The $\gamma$ passes 10 m of air, hence only part of the energy will be deposited and form ion pairs. The value for $\mu_m(\text{water})$ can be read from Fig. 6.17:

$$E_\gamma := 1 \text{ MeV} \quad \mu_{\text{air}} := 0.026 \cdot \frac{\text{cm}^2}{\text{gm}} \quad \rho_{\text{air}} := 1.293 \times 10^{-3} \cdot \frac{\text{gm}}{\text{cm}^3}$$

$$\mu_{\text{air}} := \mu_{\text{air}} \cdot \rho_{\text{air}} \quad \text{Linear absorption coefficient}$$

$$x := 10 \cdot \text{m} \quad \text{Length of the air path}$$

$$l_0 := 1 \quad \text{Assume one unit of incoming intensity}$$

$$l := l_0 \cdot \exp(-\mu_{\text{air}} \cdot x) \quad \text{Escaping intensity, from eqn.(6.27) with } B=1$$

$$E = E_\gamma (l_0 - l) \quad E = 3.306 \cdot 10^4 \cdot \text{eV} \quad \text{Deposited energy in 10 m of air}$$

Hence

$$n := \frac{E}{w} \quad n = 972 \quad \text{ion pairs}$$