P1 A photon strikes an electron at rest and produces an electron-positron pair. After
the interaction all three particles (two electrons and one positron) have the same
momentum $p$. What is the energy of the incident photon? (This is the threshold
energy of the pair production in the vicinity of an electron).

P2 The Geant4 package offers two different formulas for the width of the angular distri-
bution of multiple scattering:

$$\theta_0 = \frac{13.6 \text{ MeV}}{\beta c \rho} z \sqrt{\frac{x}{X_0}} \left[ 1 + 0.038 \ln \left( \frac{x}{X_0} \right) \right]$$

and

$$\theta_0 = \frac{13.6 \text{ MeV}}{\beta c \rho} z \left( \frac{x}{X_0} \right)^{0.555}.$$

(a) What is the maximum difference between the two formulas in the $10^{-3} < x/X_0 < 100$ range?

(b) The Geant4 physics reference manual claims that the latter formula gives a much
smaller step dependence in the angular distribution, can you substantiate this
claim? E.g. compare the average angular distribution width for a single $x/X_0 = 1$
step vs two successive $x/X_0 = 0.5$ steps.

P3 Find the total transition radiation energy emitted by (a) an electron, and (b) a pion
of momentum $p = 10 \text{ GeV}$ passing a transition radiation detector consisting of a stack
of 100 kapton foils ($\hbar \omega p = 24.5 \text{ keV}$).

P4 Cherenkov threshold detectors discriminate between different particles based on whether
or not a particle produces the Cherenkov radiation. What is the range of momenta
$p_{\text{min}} < p < p_{\text{max}}$ for which the Cherenkov threshold detector filled with CO$_2$ (the
index of refraction $n = 1.00043$) can discriminate between pions and kaons?