1) Can pair production

   $\gamma \rightarrow e^+ + e^-$

   occur in vacuum?

2) Momentum selection by dipole magnet.

   Charged pions with momentum 50 GeV/c are deflected through a collimator slit 3 mm wide by a bending magnet 2 m long which produces a uniform field of 1.5 T. Calculate how far from the magnet the slit should be placed so that it accepts particles with momentum within about 1% of the central value.

3) Greisen-Zatsepin-Kuz'min cutoff

   The electromagnetic radiation from the big bang has cooled down during the expansion of the universe. Today we observe it as the cosmic microwave background (CMB) radiation. The COBE satellite measured the spectrum with high precision. It corresponds to a blackbody radiation spectrum with T = 2.74°K. The wavelength peaks around 1 mm, corresponding to an energy of 2×10^{-4} eV. This radiation is isotropic and of high density with $\approx 4 \times 10^8$ photons/m³. High energy cosmic protons could lose energy by head-on collisions with the photons of this cosmic back ground radiation producing π°'s:

   $$p + \gamma \rightarrow p + \pi^\circ$$

   What is the threshold energy for this process? We would not expect to observe cosmic ray protons above this energy provided their mean free path is appropriate (GZK cutoff).

4) A K^+ meson with momentum of 55o MeV/c traverses a water Čerenkov counter (n = 1.33). Is Čerenkov radiation emitted?