

PHYS-448 Introduction to Particle Accelerators

Tutorial 2

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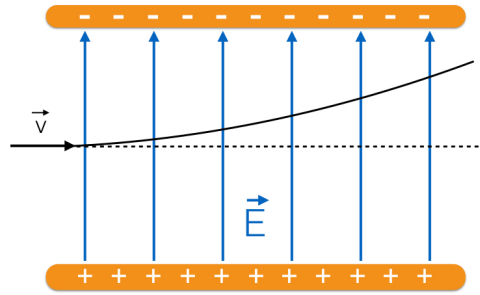
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Exercise 1. ALBA is a Synchrotron Light facility near Barcelona, Spain. The stored electron beam ($m_e = 511 \text{ keV}/c^2$) has a Lorentz factor of $\gamma = 5870.841$. Knowing that the bending radius of the dipole magnets is $\rho = 7.05 \text{ m}$, calculate their magnetic field strength B .

Exercise 2. The Proton Synchrotron Booster (PSB) at CERN accelerates protons up to a kinetic energy of $E_{\text{kin}} = 1.4 \text{ GeV}$. Are the protons *ultra-relativistic* at this stage? Calculate the momentum p of the protons and the bending radius ρ of the dipole magnets given that their maximum magnetic field strength is $B = 1.064 \text{ T}$.

Exercise 3. A characteristic example of length contraction and time dilation is represented by the muon, which has an average life time of $\tau \simeq 2.2 \mu\text{s}$. Cosmic muons are produced in the upper layers of the Earth's atmosphere by the interaction of primary cosmic rays with atmospheric nuclei. Despite their short life time, the muons travelling at a speed close to the speed of light can reach the Earth's surface. The height of the atmosphere is $L \approx 15 \text{ km}$. Assuming that the velocity of a muon is $v = 0.9992c$, calculate the muon life time measured by an observer on the Earth. What is the distance seen by the muon to reach the ground?

Exercise 4. Consider a uniform electric field generated by two electrodes in the vacuum. A charged particle located at the edge of one electrode has initial velocity equal to zero. Undergoing the acceleration of the electric field, it arrives at the opposite electrode with a relativistic $\gamma = 5$. Calculate the required electrostatic potential difference (neglecting the gravitational force) for electrons ($m_e = 0.511 \text{ MeV}/c^2$), for protons ($m_p = 0.938 \text{ GeV}/c^2$), and lead ions ($m_{Pb} = 193.7 \text{ GeV}/c^2$, singly ionized).



Exercise 5. Imagine you bend a proton by using an electric field as illustrated in the figure above. What is the electric field strength you would need to achieve a bending radius equivalent to that of a 8.3 T dipole magnet for a proton energy of $E = 3.3 \text{ TeV}$. We approximate that the electric field is always perpendicular to the direction of motion.

Exercise 6. Will an electron have the same kinetic energy as a proton when accelerated through the same voltage drop of $\Delta V = 1 \text{ MV}$? (Don't forget to reverse the polarity of the voltage source.) What about the momentum and velocity?

(Old CRT-type) color TV sets have an accelerating potential of 26 kV. Is the electron beam that hits the screen relativistic?