LONGITUDINAL BEAM DYNAMICS - TUTORIAL
CAS 2014 - Prague

For the Large Hadron Collider (LHC), the beam gets accelerated in the PS Booster (PSB) and transferred to the Proton Synchrotron (PS). The PS receives proton bunches ($\Delta t_b \approx 150$ ns) during a first magnetic flat-top (i.e. no acceleration) with a kinetic energy of 1.4 GeV. When the PS machine is filled, the proton beam is accelerated up to a final momentum of 26 GeV/c and extracted to the Super Proton Synchrotron (SPS).

1) What are the relativistic β and γ for the protons at injection into the PS?
2) Calculate the magnetic field in the PS at injection and ejection.
3) At injection into the PS, calculate and compare the RF frequencies in the PS and in the PSB. The harmonic numbers are $h_{PSB} = 1$ and $h_{PS} = 8$.
4) What is the synchronous phase in the PS at injection?
5) Assuming that the orbit remains the same during the acceleration, how does the RF frequency change between injection and ejection in the PS?
6) Should a phase jump system be implemented in the PS?
7) With the peak RF voltage in the PS at injection of $V_{rf} = 25.6$ kV calculate the PS synchrotron frequency f_s and the synchrotron tune Q_s at injection. Does it verify $Q_s << 1$?

Numerical values:

$R_{PS} = 100\,\text{m}$	PS radius
$R_{PSB} = R_{PS}/4 = 25$ m	PSB radius
$\alpha_p^{PS} = \gamma_{tr,PS}^{-2} = 0.027$	PS momentum compaction factor
$\rho_{PS} = 70\,\text{m}$	PS curvature radius