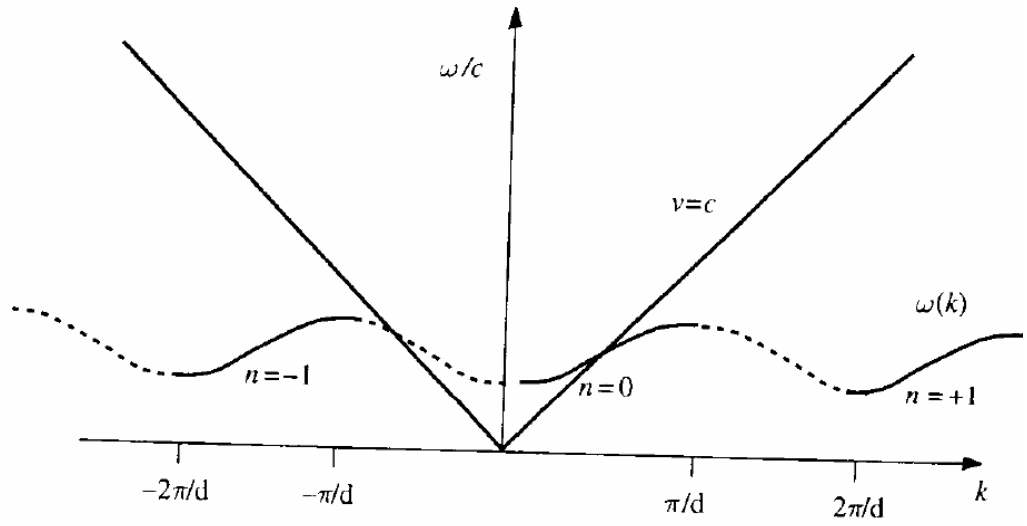
Accelerator Physics Exercises 3

Answers to be handed in on 23 November 2017

1. Using the dispersion diagramme below and assuming a four-cell cavity:

a) Plot the points on the first, $n = 0$, arm of the diagramme which correspond to the appropriate k-value.

b) Estimate the phase and group velocities for these points by inspection.



2. A new 50 GeV (kinetic energy) proton synchrotron, the PS2 accelerator, is being designed to replace the CERN PS. The new accelerator will sit in a new ring tunnel which has a mean radius of 215 m. and will receive an injected beam at 4 GeV (kinetic energy) from a new linear accelerator - the Superconducting Proton Linac (SPL). The 1.8 T magnetic field of the bending magnets is excited by a sine wave which oscillates between injection and top energy at a frequency of 0.3 Hz. Given that the mass of the proton is 0.9383 GeV:

a) What is the revolution frequency at 4 GeV, 20 GeV and at 50 GeV?

b) Assuming the revolution frequency at 20 GeV, calculate the voltage per turn necessary to match the maximum rate of the rise of the field.

c) If $\sin \varphi_s = \sin 60^o$, what is the peak voltage necessary in the cavity? Note that $\varphi_s=0$ corresponds to the zero crossing of the accelerating voltage and the particle is not accelerated.

d) If the harmonic number is 32, what are the RF frequencies at 4 GeV and at 50 GeV for $\varphi_s=0$?

3. Because it is commonly available, relatively inexpensive and an excellent conductor, copper is used extensively in 'warm' waveguides and cavities. The conductivity of copper is $\sigma_c = 5.96 \times 10^7\ \Omega^{-1}\ m^{-1}$.

For a common S-band frequency, $f_{RF} = 2.856$ GHz, what is the skin depth and surface resistivity of copper at this frequency?

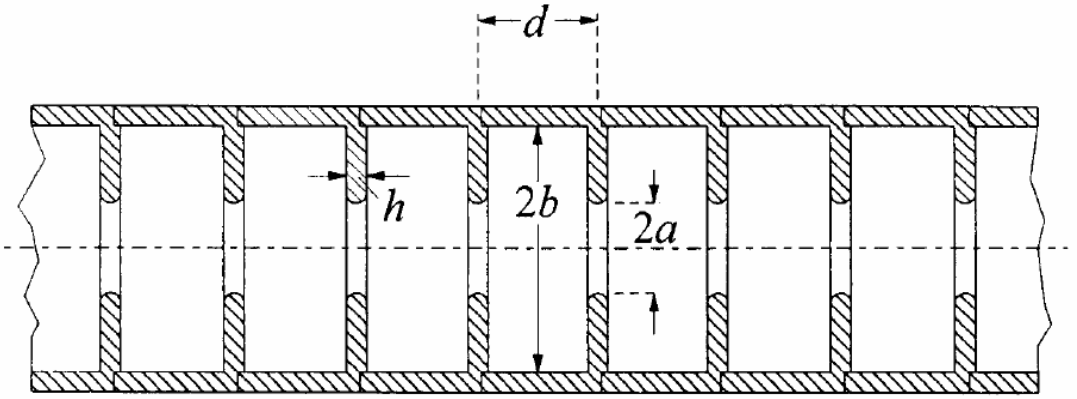
4. Design a pill-box cavity 50 cm. long for a representative 10 MHz frequency for the PS2 accelerator. What is the resonant frequency for the next highest mode (TM_{011}) in the cavity?

5. What is the transit-time factor for protons of 4 GeV (kinetic energy)?

6. Find out how to represent RF cavities in MAD-X. How would a PS2 RF cavity be described in MAD-X?

7. The SLAC accelerating linac structure has the design shown in the figure below with the following dimensions:

$2b = 82.474$ mm.
$2a = 22.606$ mm.
$h = 5.842$ mm.
$d = 35.001$ mm.



Assuming that the cavities are operated in the $2\pi/3$ mode with a phase velocity $\beta_z = 1$ and a supplied power of 35 MW, what is the total accelerating voltage and energy gain per metre for a SLAC structure of length $l = 3$ m.?