



## 'Conventional Magnets' lectures 2012.

Neil Marks, STFC, ASTeC.

### TASK SHEET.

#### Using the OPERA 2D non-linear, magneto-static finite element code.

Study of magnets for a possible the 30 Hz, 2 MW, 0.8 to 3.2 GeV RCS ring.

The design exercise will extend over c 1 month, with students working individually to generate satisfactory 2D transverse designs for a **dipole** and a **quadrupole** magnet.

The tutorial will concentrate on the 2D software, demonstrating the input and output methods. It is aimed to cover the input of a simple dipole and quadrupole during the tutorial, leaving students to develop and refine the transverse designs.

### DATA:

A summary of the lattice data, taken from the paper '**Linac, Beam Line and Ring Studies for an Upgrading of ISIS**' by Graham Rees (ASTeC, STFC, RAL), is given below:

Ring circumference (m)	370.0000	Number of protons per cycle	$1.3 \cdot 10^{14}$
Gamma transition value	7.2044	Beam power at 3.2 GeV (MW)	2.0
Betatron tunes ( $Q_x, Q_y$ )	7.21, 7.73	Space for rf cavities (m)	56.4
Long straight lengths (m)	15 x 8.40	Freq. for $h = n = 4$ (MHz)	2.7283-3.1566
F quad lengths (m)	0.77974, 0.8637, 0.693	Bunch area for $h = 4$ (eV sec)	1.8
D quad lengths (m)	0.8657, 0.8580, 1.2834	kVolts & $\Delta p/p$ @ 0.8 GeV	$69 \pm 4.3 \cdot 10^{-3}$
Transv. acceptance (mm mrad)	400 ( $\pi$ )	kVolts & $\Delta p/p$ @ 1.96 GeV	$422 \pm 4.5 \cdot 10^{-3}$
Transv. un-nor. max $\epsilon$ (mm mrad)	135 ( $\pi$ )	kVolts & $\Delta p/p$ @ 3.2 GeV	$218 \pm 4.6 \cdot 10^{-3}$
Quadrupole gradients ( $T m^{-1}$ )	2.166-5.965	Quad inscribed radius (mm)	90.0
No of $8.0^\circ$ rectangular dipoles	5	Number of $16^\circ$ , sector dipoles	20
Length of $8.0^\circ$ dipoles (m)	5.4446	Length of main dipoles (m)	3.8
Radius of $8.0^\circ$ dipoles (m)	38.9941	Bend radius of main dipoles (m)	13.6077
Fields for $8.0^\circ$ dipoles (T)	0.1252-0.3448	Fields of main dipoles (T)	0.3587-0.9880
Dipole v, h good field (mm)	130.0, 165.0	Dipole v, h good field (mm)	132.0, 145.0

Table 6: Main parameters for the 30 Hz, 2 MW, 0.8 to 3.2 GeV RCS ring.

The table provides the following core parameters for the two magnets that are the subject of the study:

1. Main Dipoles:

Field at beam:	minimum 0.359 T; maximum: 0.988 T;
Good field regions (total):	horizontal 145 mm; vertical 132 mm;
Good field tolerance $\Delta B/B_0$ :	$\pm 0.02$ %
Estimated vac vessel thickness:	6 mm;
So magnet gap:	144 mm
Length of each dipole:	3.8 m.

2. Quadrupoles:

Gradients:	minimum 2.17 T/m; maximum: 5.97 T/m;
Quadrupole inscribed radius:	90 mm;
Quadrupole good gradient region:	$\pm 75$ mm;
Quad good grad tolerance $\Delta G/G_0$	$\pm 0.1\%$ .

TASKS:

1. Establish satisfactory transverse 2 D designs for dipole and quadrupole, demonstrating that the design **meets the above defined field tolerances throughout the dynamic range.**
2. i) By examining the vector potential at the centre of the cross sections for the two sides in the coil in the dipole, estimate the total flux cutting the coil over the full length of the coil at minimum and maximum field.  
  
ii) From this, calculate the **inductive** (not resistive) voltage per turn across each dipole when cycling at 30 Hz.