Non-assessed exercises

Thus follows a set of non-assessed practical exercises to work on in the timetabled lab sessions. These start with an investigation of a basic geometry, and then build up a series of problems from an existing input file. You will gain experience in photon and neutron transport problems by working through the exercises.

There should be enough time in the lab sessions to complete all of the exercises, but do not worry if you struggle to finish. Instead try to get some experience with the different aspects of the code and focus on the problems of personal interest.

Exercise 1 – Investigating geometry:

Run MCNP in geometry plotting mode to examine the geometry described in the file *ex1.ip*. This will show you a 2-D projection of a 3-D geometry, though the origin. Try using some of the graphical plotting commands (generally clicking on the red lettering will give commands to the plot routine. E.g. to change the viewing plane orientation click *xy, yz* or *zx* in the bottom left corner) to see what information they give you on the screen and investigate the use of the display program. Investigate changing the zoom levels and the position of the origin in the display. How many objects are there? And what type of object is each cell? Can you find the Easter egg and its approximate centre?

Open file *ex1.ip* using a text editor and see if you can understand how the surface and cell descriptions in the file relate to each other to define the geometry as described above. Were your answers for the above questions correct?

Exercise 2 – Modifying geometry:

Open *ex2.ip* using a text editor; this file models a large sphere of air with a point photon source at the centre. See if you can understand how the surface and cell descriptions in the file relate to each other and how they define the geometry. Use the geometry plotter to investigate this model.

We will now add some content to the source file to give a more interesting geometry and eventually define a simple physics problem. Modify the file in the following manner: Add a sphere of pure lead, 2cm in radius, to the centre of the geometry. You will need to add surface, cell and materials definitions, and modify the existing cell cards to include the new features. A step-by-step guide is given below:

Add a new surface to define the lead sphere:

```
1       SO      2.0             $ Sphere 2.0cm radius, centred on the origin, id 1
```

Add a materials definition for the lead. Lead has a proton number (Z) of 82 and we will use the natural isotopic composition with the material being 100% lead:

```
M2      82000  1.0      $ Z=82 material, 100% natural composition, id number 2
```

Add a new cell bound by surface 1, filled with lead (M2) with density 11.4 g/cm^3 as mass:

```
1       2       -11.4   -1      $ cell 1, material 2 density 11.4 g/cm3, inside surface 1
```

Modify the existing cell number 98 to exclude the volume of our new cell:

```
98      1       -0.00012        -99     1       $ material 1 inside surface 99, outside 1
```

Modify the importance map to include the new cell, (**in the cell order found in the file**):

```
IMP:P 1 1 0
```

Check your new geometry using the geometry plotting mode. You should see a smaller sphere filled with a different colour (material) to the bounding sphere. If you see any dotted red lines (known as cookie cutter errors) then you have something wrong with your geometry.

Your input file should look similar to ex2.pdf copied into your home directory.

Exercise 3 – Adding some physics

We are now going to add some physics definitions to our problem and run the simulation to calculate some properties of our system; make a copy *ex2.ip* as *ex3.ip*. We will measure the photon flux averaged over the outside surface of the lead sphere as a function of photon energy. To do this we will add a tally to the problem and an input parameter to describe the energy distribution.

The way tallies are defined is a little strange; the letter F tells the code that a tally is required, the following number defines the unique identification number of the tally (1-99) and the final number defines the tally type (1-8). See the Primer page 16 for a list of tally types, quantities and units.

Under the tally cards comment *add*:

```
F12:P           1       $ Tally id number 1 of surface type (2), photons over surface 1
E0      0.01 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0    $ energy bins for all tallies
```

Now run MCNP in simulation mode, this will simulate the creation of 40000 individual photons with energy of 1 MeV and isotopic orientation. The photon behaviour is tracked as they move through the defined geometry; random numbers are used to determine the interaction points and interaction mechanism with reference to the materials cross-section libraries.

Angles of scatter are determined randomly and knowledge of the scattering function determines the final energy of the photon before it continues on its path. Photon tracks are terminated if the photon escapes the system (enters a zero importance region), is absorbed, the energy of the photon or its statistical weight reaches a minimum threshold value.

Locate the output file and open it using Gedit or Wordpad. See if you can understand the information given in the output file and find the problem tallies.

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Interpretation of tally results:

The total energy-integrated photon fluence over the outside surface of this lead sphere is calculated to be 7.55 x 10^{-3} photons / cm^2 / source particle ± 0.75 % (statistical).

The photon fluence within the energy range 0.6 - 0.7 MeV is 4.61 x 10^{-4} photons / cm^2 / source particle ± 3.7 % (statistical).

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The 'ten statistical tests' listed after the tally give indication about the reliability of the results from the simulation. Are these results reliable? Investigate how the number of simulated particles (NPS) affects the relative error of your results; this should scale as the Poisson error, this is shown in a table and can be plotted and confirmed. Consider the figure of merit for the calculation. This represents the computational worth of the simulation and can give you some clues as to the validity of your results.

The figure of merit is defined as: $FoM = (\text{relative error}^2 * \text{computation time})^{-1}$

For any simulation the calculated figure of merit should converge to a constant value over the number of particle histories run. When the figure of merit reaches a constant value running further particle histories does not further reduce the error in the calculation efficiently. What is the optimum number of histories to run in this case?