An Introduction to MCNP

This part introduces basic notions and concepts to model a radiological scene with the MCNP (Monte-Carlo N-Particle) transport code. The block structure of a typical input file is discussed. The elementary surfaces and geometries enabling the construction of cells are described and applied in simple examples. The other features, such as particle characteristics (type, energy, flux, etc.), evaluated quantities, physics parameters and biasing, will be specifically addressed in applications developed throughout this book.

Two case studies will be used to illustrate different points addressed, as explanations to create an MCNP input file will be detailed.

The first case is an isotropic point-like source of ^{60}Co located at positions $x = 51$ cm, $y = 2$ cm and $z = 3$ cm. We aim to assess the fluence in a water cube located in the air, 50 cm away from the source. The cube of 4 cm edge length is centered in the location $x = 1$ cm, $y = 2$ cm and $z = 3$ cm. In the second case, the configuration is inverted: the water cube becomes a ^{60}Co volumetric source and we intend to evaluate the fluence at the location of the source in the first case.

We must point out that this introduction offers only an elementary vision of the MCNP code formalism. It can be supplemented by the MCNP User's Manual (Pelowitz, 2013) completeness as well as the numerous specific documents provided by LANL: https://laws.lanl.gov/vhosts/mcnp.lanl.gov/references.shtml#mcnp6_refs.

(a) MCNP input file structure

The MCNP input file is written in ASCII format (text format, prepared for example with the "notepad" application for a Windows OS). The file is composed of three parts referred to as blocks, separated by a blank line. The first block encompasses the definition of the objects modeled in space, denoted as cells (3D geometry, materials and apparent densities). The second block contains the surfaces enabling to form the cells described in the first block. The third block states all the instructions necessary to generate, transport and track particles: the source, the type of particles, the physics parameters, the spatial and energy biasing, the calculation time, and the quantities to evaluate, so-called "tallies". Note that the length of a line in the input file cannot exceed 80 characters, spaces included. If this

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limitation is exceeded, adding a "&" character at the end of the line enables to link up with the next line.

(b) Units used in MCNP

For basic parameters, the units used are the length in cm, the energy in MeV, the time in shakes (10^{-8} s), the atom density in atoms.b^{-1}.cm^{-1} (10^{24} atoms.cm^{-3}), the mass density in g.cm^{-3}, and the cross sections in barns.

(c) Block 2: Geometry specification

The volume of cells described in the 1st block is characterized by the intersection of elementary geometric objects. The latter are defined by elementary surfaces listed in table 1.

In the example illustrated in figure 1, the plan normal to x-axis, located at $x = 5$ cm, is a surface described by the instruction "px 5". This surface is identified by a number at the beginning of the line, "10" in the case described below.

```
10 PX 5
```

A cylinder of radius 5 cm, of axis meeting $x = 2$ cm and $y = -1$ cm, parallel to the z-axis, indicated by the number 15, is also represented in figure 1. It is described by the following instruction:

```
15 C/Z 2 -1 5
```

Note that the cylinder is infinite along z-axis.

Since the release of MCNPX and MCNP5, closed surfaces, referred to as "macrobodies", are available. These pre-defined surfaces are, for instance, rectangular parallelepiped, spheres and finite cylinders. The macrobodies implemented in MCNP are described in table 2. It is possible to combine macrobodies with elementary surfaces presented in table 1.

Therefore, the cube used in both presented cases (cube centered at the position $x = 1$, $y = 2$ and $z = 3$ of 4 cm edge length) is defined by "rpp −1 3 0 4 1 5", but it can also be described with the instruction "box −1 0 1 4 0 0 0 4 0 0 0 4". This cube is displayed in figure 1 (in the xy plane). Generally, we will find out throughout this book that it is more convenient to use macrobodies instead of elementary surface. In most cases, macrobodies help avoid the description of a great number of surfaces necessary for cell definition.

A 45° inclined cylinder (in the xy plane) of 5 cm height and 1 cm radius whose lower base center is located at (−2 2 0) is defined by the instruction "rcc −2 2 0 3.5355 3.5355 0 1". The coordinates of the steering vector in the xy-plane stem from the hypotenuse projection, *i.e.*, $5/\sqrt{2} = 3.5355$.

(d) Block 1: Cell definition

The cells are described in the 1st block. To each of them are attached a cell number "n", a material number "m" (defined in the 3rd block), a density "ρ" and a geometry "s_i" composed of surfaces listed in the 2nd block. A comment preceded by the character "$" can be added at the end of each line.

```
n m ρ s1 s2 ... sn $ cell N
```

TAB. 1 – Elementary surfaces, available in the MCNP User's Manual (Pelowitz, 2013).

Mnemonic	Type	Description	Equation	Card entries
P	Plane	General	$ax + by + cz - d = 0$	$a\ b\ c\ d$
PX		Normal to x-axis	$x - d = 0$	d
PY		Normal to y-axis	$y - d = 0$	d
PZ		Normal to z-axis	$z - d = 0$	d
SO	Sphere	Centered at the origin	$(x)^2 + (y)^2 + (z)^2 - R^2 = 0$	R
S		General	$(x-a)^2 + (y-b)^2 + (z-c)^2 - R^2 = 0$	$a\ b\ c\ R$
SX		Centered to x-axis	$(x-a)^2 + (y)^2 + (z)^2 - R^2 = 0$	$a\ R$
SY		Centered to y-axis	$(x)^2 + (y-b)^2 + (z)^2 - R^2 = 0$	$b\ R$
SZ		Centered to z-axis	$(x)^2 + (y)^2 + (z-c)^2 - R^2 = 0$	$c\ R$
C/X	Cylinder	Parallel to x-axis	$(y-b)^2 + (z-c)^2 - R^2 = 0$	$b\ c\ R$
C/Y		Parallel to y-axis	$(x-a)^2 + (z-c)^2 - R^2 = 0$	$a\ c\ R$
C/Z		Parallel to z-axis	$(x-a)^2 + (y-b)^2 - R^2 = 0$	$a\ b\ R$
CX		On x-axis	$(y)^2 + (z)^2 - R^2 = 0$	R
CY		On y-axis	$(x)^2 + (z)^2 - R^2 = 0$	R
CZ		On z-axis	$(x)^2 + (y)^2 - R^2 = 0$	R
K/X	Cone	Centered to x-axis	$\sqrt{(y-b)^2 + (z-c)^2} - t(x-a) = 0$	$a\ b\ c\ t^2 \pm 1$
K/Y		Centered to y-axis	$\sqrt{(x-a)^2 + (z-c)^2} - t(y-b) = 0$	$a\ b\ c\ t^2 \pm 1$
K/Z		Centered to z-axis	$\sqrt{(x-a)^2 + (y-b)^2} - t(z-c) = 0$	$a\ b\ c\ t^2 \pm 1$
KX		On x-axis	$\sqrt{(y)^2 + (z)^2} - t(x-a) = 0$	$a\ t^2 \pm 1$
KY		On y-axis	$\sqrt{(x)^2 + (z)^2} - t(y-b) = 0$	$b\ t^2 \pm 1$
KZ		On z-axis	$\sqrt{(x)^2 + (y)^2} - t(z-c) = 0$	$c\ t^2 \pm 1$
				± 1 used only for 1-sheet cone

Tab. 1 – (continued).

Mnemonic	Type	Description	Equation	Card entries
SQ	Ellipsoid Hyperboloid paraboloid	Axis parallel to x-, y- Or z-axis	$E(x-a)^2+F(y-b)^2+G(z-c)^2+2H(x-a)$ $+2I(y-b)+2J(z-c)+K=0$	$E\ F\ G\ H\ I\ J$ $K\ a\ b\ c$
GQ	Cylinder, cone ellipsoid paraboloid hyperboloid	Axis are not parallel to x-, y- Or z-axis	$E(x)^2+F(y)^2+G(z)^2+Hxy$ $+Iyz+Jzx+Kx+Ly+Mz+N=0$	$E\ F\ G\ H\ I\ J\ K$ $L\ M\ N$
TX	Ellipsoid or circular torus. Axis is parallel to x-, y-, z axis	$(x-a)^2/E^2+\left(\sqrt{(y-b)^2+(z-c)^2}-D\right)^2\Big/F^2-1=0$		$a\ b\ c\ D\ E\ F$
TY		$(y-b)^2/E^2+\left(\sqrt{(x-a)^2+(z-c)^2}-D\right)^2\Big/F^2-1=0$		$a\ b\ c\ D\ E\ F$
TZ		$(z-c)^2/E^2+\left(\sqrt{(y-b)^2+(x-a)^2}-D\right)^2\Big/F^2-1=0$		$a\ b\ c\ D\ E\ F$

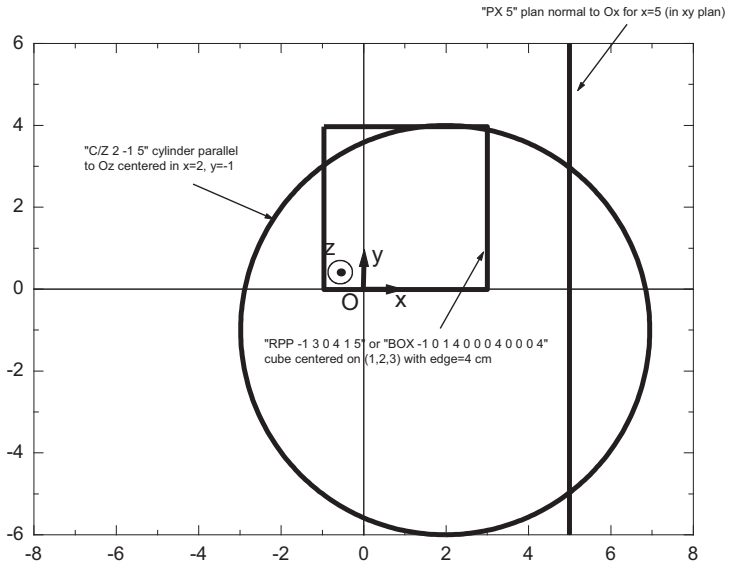


FIG. 1 – Examples of elementary surfaces (xy view).

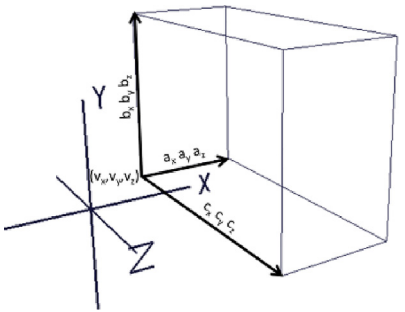
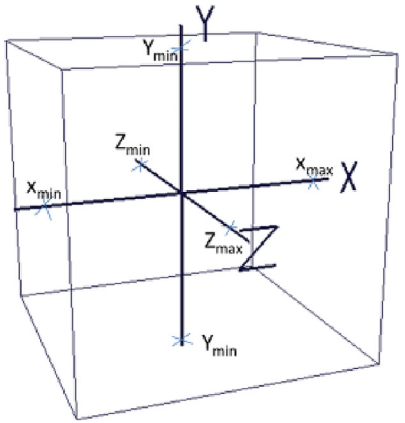
Special care has to be taken with the density: if ρ is negative, the density is expressed in g.cm^{-3}. Else, if ρ is positive, the unit is (atoms).b^{-1}.cm^{-1}.

A 3D geometry is designed with a mix of intersection and union of surfaces. To define spatial regions bounded by these surfaces, it is necessary to couple them with a sign. A "+" sign for a closed surface points the "region outside the surface" and a "–" sign indicates the "region inside the surface". As to unclosed surfaces, every point where $f(x, y, z) > 0$ is located positively (+) with regard to the surface, and every point where $f(x, y, z) < 0$ is positioned negatively (−). Let us take the example of the flat surface "15", normal to the x-axis and located at $x = 10$, *i.e.*, the plane defined by "15 px 10". The region where $x > 10$ is denoted as "+", and that where $x < 10$ corresponds to the "−" region. The shaded areas of figure 2 illustrate the spatial regions defined by the instructions "−15" or "+15". By default, the absence of sign before a surface is interpreted as a "+" sign. The intersection and/or union operators are applied to several surfaces to define a volume.

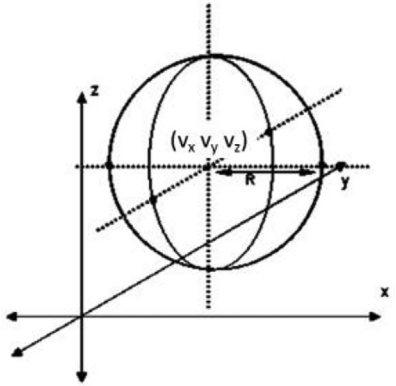
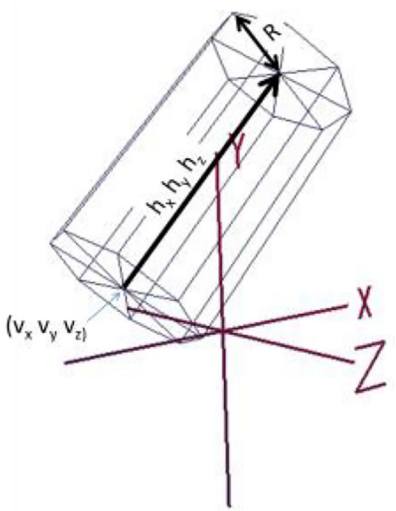
Surface intersections are stated with the logical 'AND' operator and unions with the 'OR' operator. In the code, these operators are, respectively, written as a blank space and a colon. For instance, the instruction "5 15" defines the region which is at the same time in the region "5" AND in the region "15". On the other hand, "5:15" is used to point the region which is in the region "5" OR in the region "15". To illustrate this concept, we consider two planes "15 px 10" and "5 py − 10". The shaded area of figure 3a represents the region defined by the instruction "5 −15" and that of figure 3b that provided with "5:−15".

Let us summarize this approach with the example of the 4 cm edge length cube centered at (1 2 3) used in both case studies. We intend to define the regions,

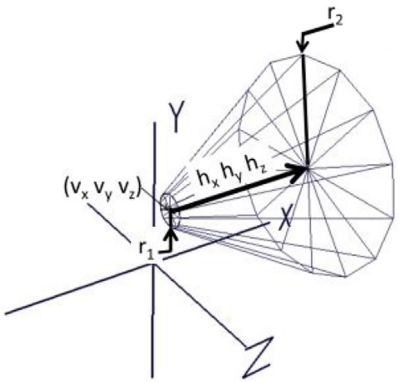
TAB. 2 – Definitions and input parameters for macrobodies.

Description	Mnemonic and sketch		Definition of entry
Arbitrarily oriented orthogonal box	 BOX $v_x\ v_y\ v_z\ a_x\ a_y\ a_z\ b_x\ b_y\ b_z\ c_x\ c_y\ c_z$	$(v_x\ v_y\ v_z)$	The x, y, z coordinates of a corner of a box
		$a_x\ a_y\ a_z$	Vector of 1st side from the specified corner coordinates
		$b_x\ b_y\ b_z$	Vector of 2nd side from the specified corner coordinates
		$c_x\ c_y\ c_z$	Vector of 3rd side from the specified corner coordinates
Rectangular parallelepiped	 RPP $x_{\min}\ x_{\max}\ y_{\min}\ y_{\max}\ z_{\min}\ z_{\max}$	$x_{\min}\ x_{\max}$	Termini of box sides normal to the x-axis
		$y_{\min}\ y_{\max}$	Termini of box sides normal to the y-axis
		$z_{\min}\ z_{\max}$	Termini of box sides normal to the z-axis

Tab. 2 – (continued).

Sphere	 SPH $v_x\ v_y\ v_z\ R$	$(v_x\ v_y\ v_z)$ R	The x, y, z coordinates of the center of the sphere Radius of the sphere
Right circular cylinder	 RCC $v_x\ v_y\ v_z\ h_x\ h_y\ h_z\ R$	$(v_x\ v_y\ v_z)$ $h_x\ h_y\ h_z$ R	The x, y, z coordinates at the center of the base for the RCC Right circular cylinder axis vector, which provides both the orientation and the height of the cylinder Radius of the RCC

Tab. 2 – (continued).

Description	Mnemonic and sketch		Definition of entry
Truncated right-angle cone		v_x v_y v_z	The x, y, z coordinates of the cone bottom
		h_x h_y h_z	Axis height vector
		r_1	Radius of the lower cone base
		r_2	Radius of the upper cone base, where $r_1 < r_2$
	TRC v_x v_y v_z h_x h_y h_z r_1 r_2		

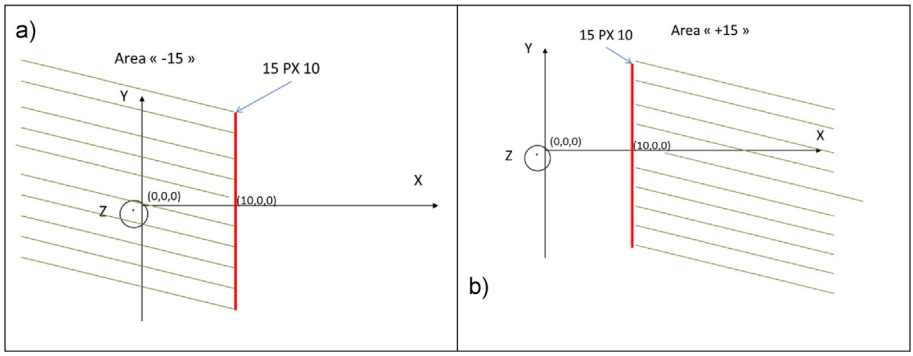


FIG. 2 – Illustration of the spatial region (shaded area) depending on the sign of the sign used with the flat surface. (a) " − " sign and (b) " + " sign.

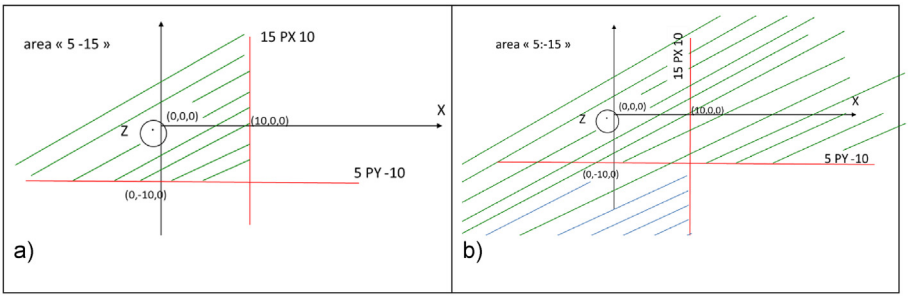


FIG. 3 – Regions from (a) the intersection of surfaces "5 −15", (b) the union of surfaces "5:−15".

respectively, inside and outside this cube. Basically, the cube is defined by its six faces. Inside block 2, these faces correspond to the following planes:

```
5 PX -1
10 PX 3
15 PY 0
20 PY 4
25 PZ 1
30 PZ 5
```

The inner region of the cube can be written as "5 −10 15 −20 25 −30" and the outer region as "−5:10:−15:20:−25:30".

A more straightforward way to define the cube is from a RPP rectangular parallelepiped macrobody:

```
10 RPP -1 3 0 4 1 5
```

In this case, the inner region of the cube is written as "−10" and the outer region as "10". Finally, a third way to define the same cube is to use the BOX macrobody:

```
10 BOX -1 0 1 4 0 0 0 4 0 0 0 4
```

The inside is described by the instruction "−10" and the outside by "10".

(e) Block 3: Materials' definition

The aim now is to assign a material and a density to the cell. The material has to be defined in the 3rd block beforehand. Each element composing the material is written as "ZZAAA.lib", where Z is the atomic number and A is the mass number. The ".lib" extension refers to a particular cross section library (one can refer to J.L. Conlin (2017) for further explanation on the different libraries and their features). The part ".lib" can be omitted and by default, the code will work with the first library listed in the "xsdir" file of MCNP. For instance, the term "8016" defines oxygen-16 with its default library. When adding the extension "8016.80c", the oxygen-16 is treated with the neutron cross sections available in the ENDF/B-VII.1 library, taken at $T = 293.6$ K. The extension "60c" in the term "8016.60c" would refer to neutron cross sections from a former library, ENDF/B-VI.0, at $T = 293.6$ K. If the simulation only carries out photon or electron transport, stable oxygen can be defined as "8000", without adding an extension. It is important to note that for neutron transport, this format is not accepted and it is necessary to mention the atomic masses (AAA) to refer to a cross section library dedicated to neutrons.

A material is described by a succession of chemical elements, each associated with a weighting factor k: "$Z_1Z_1A_1A_1A_1\ k_1\ Z_2Z_2A_2A_2A_2\ k_2\ \ldots\ Z_nZ_nA_nA_nA_n\ k_n$" where Z_nZ_n is the atomic number of the element n, $A_nA_nA_n$ is its mass number and k_n is its mass fraction (if k_n is negative) or its atom fraction (if k_n is positive). In the case studies, if we consider material 8 to be water, it is defined through the instruction m8 and can be described by both of the following forms:

```
c ------------------------------------------------------------
c WATER for gamma-ray or electron transport (by atom fraction)
c ------------------------------------------------------------
M8 1000 2 8000 1 $ water

c ------------------------------------------------------------
c WATER for gamma-ray or electron transport (by mass fraction)
c ------------------------------------------------------------
M8 1000 -0.11190 8000 -0.88810 $ water
```

The text following the "c" characters is considered as a comment and is therefore not interpreted by the code. Note that lots of MCNP material definitions are provided in the reference McConn *et al.* (2011).

(f) Block 3: Particle transport definition

The types of particles transported in the simulation have to be specified in the 3rd block, within the "mode" card. The list of particles used in this book is provided in table 3.

Tab. 3 – Particle types and associated symbols in MCNP.

IPT	Type of particles	Symbol
1	Neutron	N
2	Photon	P
3	Electron	E
8	Positron	F
9	Proton	H
31	Deuteron	D
32	Triton	T
33	Helion (He-3)	S
34	Alpha (He-4)	A
37	Heavy ion*	#

*The "#" represents all possible heavy-ion types – in other words, any ion that is not one of the four light ions available in MCNP6.

For instance, setting the instruction "mode p" allows the transport of photons only, whereas the instruction "mode p n" enables the mixed transport of photons and neutrons.

(g) Block 3: Source definition

The particle source (type, energy, flux, emission geometry,…) is defined in the third block. The source is defined by entering the "sdef" card whose parameters are listed in table 4. The "default" column provides the default value or characteristics of parameters when the latter are not specified. For instance, when setting the "mode n", the "sdef" card used alone would indicate a point-like source, located at the origin, isotropically emitting 14 MeV neutrons.

For example, an isotropic point-like source of 1 MeV photons at the location $x = 51$, $y = 2$ and $z = 3$ is stated as "sdef par = p erg = 1 pos = 51 2 3". If a "sdef" parameter contains several inputs, one has to provide a distribution number (preceded by "*d*"). In this way, the source parameter can take several values sampled from the "si" distribution (source information), followed by a "sp" card (source probability), enabling to assign a probability to each of the source parameters. This can be illustrated with the energy definition of the ^{60}Co source considered in the two case studies proposed in this introduction. This radionuclide emits two photons of 1.17 MeV and 1.33 MeV, which will be listed in a "si" card. The 100% emission probability for each of these gamma rays will be specified in an associated "sp" card. The source of the first case is fully defined as follows:

```
SDEF par=p erg=d4 pos=51 2 3
si4 L 1.17 1.33
sp4 1 1
```

The parameter list of the "si" and "sp" cards are always correlated and written in an orderly manner. Particular attention has to be paid to match each of the "si" card input with its probability in the "sp" card. For the second case, the source is cubic

TAB. 4 – List of parameters for the "sdef" source definition card.

Variable	Meaning	Default
CEL	Cell	Determined from *XXX*, *YYY*, *ZZZ* and possibly *UUU*, *VVV*, *WWW*
SUR	Surface	0 (means cell source)
ERG	Energy	14 MeV
DIR	μ, the cosine of the angle between VEC and *UUU*, *VVV*, *WWW* The azimuthal angle is always sampled uniformly in [0, 2π]	Volume case: μ is sampled uniformly in [−1.1] (isotropic). Surface case: $p(\mu) = 2\mu$ for μ [0, 1] (cosine distribution)
VEC	Reference vector for VEC	Volume case: required unless isotropic. Surface case: vector normal to the surface with sign determined by NRM
NRM	Sign of the surface normal	1
POS	Reference point for positioning sampling	0, 0, 0
RAD	Radial distance of the position from POS or AXS	0
EXT	Cell case: distance from POS along AXS Surface case: cosine of angle from AXS	0
AXS	Reference vector for EXT and RAD	Reference vector for EXT and RAD
X	*X*-coordinate of position	No *X*
Y	*Y*-coordinate of position	No *Y*
Z	*Z*-coordinate of position	No *Z*
CCC	Cookie-cutter cell	No cookie-cutter cell
ARA	Area of surface (required only for direct contributions to point detectors from a plane surface source)	None
WGT	Particle weight	1
EFF	Reference efficiency criterion for position sampling	0.01
PAR	Type of particle the source emits	Neutron if MODE N or N P or N P E; photon if MODE P; electron if MODE E

(4 cm edge length cube centered at (1, 2, 3)). If the cell "5" stands for the cube, the source can be written as:

```
SDEF cell=5 x=d1 y=d2 z=d3 erg=d4 par=p
si1 -1 3 $ x-range limits for source volume
sp1 0 1  $ uniform probability over y-range
si2 0 4  $ y-range limits for source volume
sp2 0 1  $ uniform probability over y-range
si3 1 5  $ x-range limits for source volume
sp3 0 1  $ uniform probability over x-range
si4 L 1.17 1.33 $ energy of each Co-60 photons
sp4 1 1         $ intensity of each Co-60 photons
```

(h) Block 3: Tally definition

Within the 3rd block, the assessed quantities are specified with statistical estimators called "tallies" in the MCNP code. These tallies are listed in table 5. Many of these are used in the applications of this book. For the second case, we are seeking the photon fluence at a point located 50 cm away from the cube center, *i.e.*, at the position (51 2 3). The tally is then defined by the instruction "F5:p 51 2 3 1". For the first case, we want to evaluate the "mean" photon fluence in the cube, due to the point-like ^{60}Co source. If the cell 5 stands for the cube, the tally can be written as "F4:p 5".

At this point, we have presented all the elements enabling to build the full input files necessary for the simulation of the two case studies presented.

Tab. 5 – Tally designators in MCNP.

Mnemonic	Tally type	Fn units	*Fn units
F1:pl	Current integrated over a surface	Particles	MeV
F2:pl	Fluence averaged over a surface	particles/cm^2	MeV/cm^2
F4:pl	Fluence averaged over a cell	particles/cm^2	MeV/cm^2
F5a:pl	Fluence at a point or ring detector	particles/cm^2	MeV/cm^2
F6:pl	Energy deposition averaged over a cell	MeV/g	jerks‡/g
+F6	Collision heating	MeV/g	n/a
F7:pl	Fission energy deposition in a cell	MeV/g	jerks/g
F8:pl	Energy distribution of pulses created in a detector by radiation	Pulses	MeV
+F8:pl	Charge deposition	Charges	n/a

‡1 jerks = 10^9 J. 1 jerks/g = 10^{12} Gy.

(i) Input file for the first case

The first case is a ^{60}Co isotropic point-like source located at the position (51 2 3). We want to evaluate the photon fluence at 50 cm from the source, in a 4 cm side water cube centered in (1 2 3).

```
Case 1

c block 1 cells
5    8 -1 5 -10 15 -20 25 -30 $ inside cube material 8 d=1 g/cm3
10  2 -1.3e-3 -40 (-5:10:-15:20:-25:30) $ air mat 2 d=1.3e-3 g/cm3 around the cube
999 0 40 $ outside void

c block 2 geometry
5 PX -1
10 PX 3
15 PY 0
20 PY 4
25 PZ 1
30 PZ 5
40 SO 100 $ sphere centered on (0,0,0) R=100 cm

c block 3 the rest
SDEF par=p erg=d4 pos 51 2 3
si4 L 1.17 1.33
sp4 1 1
m2 6000 -.000124 7000 -.755258 8000 -.23 18000 -.0128 $ air
m8 1000 2 8000 1   $ water
mode p
imp:p 1 1 0 $ transport in cell 5 and cell 10 no transport in cell 999
ctme 10 $ time of the calculation
F4:p 5 $ fluence in the cube - cell 5
```

Generally, the first line of an input file contains the title. It is the only case when it is not mandatory to add "c" as a first line character to indicate a comment.

Note that an infinite cell made of vacuum, where the particle transport is not enabled, has been defined beyond the sphere. Without this cell providing a matter-vacuum boundary, the particles would be continuously transported. This would cause an infinite routine and a calculation break in the code. Vacuum is indicated by setting the instruction 0 instead of the material number and density (refer to cell 999).

(j) Input file for the second case

The second case is about a cubic ^{60}Co source filled with water. The cube has the same dimensions as in the first case. We want to estimate the fluence at a point located at 50 cm from this source.

```
Case 2
c block 1 cells
5    8 -1 5 -10 15 -20 25 -30 $ inside cube material 8 d=1 g/cm3
10   2 -1.3e-3 -40 # 5 $ air d=1.3e-3 g/cm3 around the cube
999 0 40 $ outside void

c block 2 geometry
5 PX -1
10 PX 3
15 PY 0
20 PY 4
25 PZ 1
30 PZ 5
40 SO 100 $ sphere centered on (0,0,0) R=100 cm

c block 3 the rest
SDEF cell=5 x=d1 y=d2 z=d3 erg=d4 par=p
si1 -1 3 $ x-range limits for source volume
sp1 0 1  $ uniform probability over y-range
si2 0 4  $ y-range limits for source volume
sp2 0 1  $ uniform probability over y-range
si3 1 5  $ x-range limits for source volume
sp3 0 1  $ uniform probability over x-range
si4 L 1.17 1.33 $ energy of each Co-60 photons
sp4 1 1          $ intensity of each Co-60 photons
m2 6000 -.000124 7000 -.755258 8000 -.23 18000 -.0128 $ air
m8 1000 2 8000 1 $ water
mode p
imp:p 1 1 0 $ transport in cell 5 and cell 10 no transport in cell 999
ctme 10 $ time of the calculation
F5:p 51 2 3 .1 $ fluence at 50 cm of the center of the cube (in x-axis)
```

In cell 10 parameters, the instruction "#5" provokes the cell 5 exclusion. Thus, writing −40 #5 enables to define the inside of the sphere 40 while excluding the geometry defined in the cell 5, *i.e.*, the cube.

Note that, in this case, "10 2 −1.3e −3 −40 # 5" is equivalent to "10 2 −1.3e −3 −40 (−5:10:−15:20:−25:30)".

The Vised software can be used to visualize the files in a two dimension frame. This software is provided in the MCNP package. For Windows OS, the free software "Xming" (https://sourceforge.net/projects/xming/) can also be employed.

These simple cases allow understanding the general structure of MCNP input files. More complex cases, as well as output file analysis and result normalization will be discussed throughout this book.