NE506 HW5: Part II

Matthew Klebenow

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Abstract

What follows is a compilation of the responses to questions posed in Part II of homework #5 for NE506. All answers are already contained in the `readme.txt` files of the appropriate part's subdirectory, but they have been copied here for convenience.

Part 1

Question

Establish an energy grid for all tallies with 44 bins spaced logarithmically between 1e-10 and 10 MeV and 4 bins spaced linearly between 10 and 20 MeV.

Response

Energy binning has been addressed in the following line of code:

```
c Energy grid for all tallies (1)
E0 1e-10 44ILOG 10 4I 20
```

Part 2

Question

Plot the energy spectrum of the current leaving the Be sphere and compare to the energy spectrum of the current reentering the Be sphere. Arrange your output in a table with energy and direction.

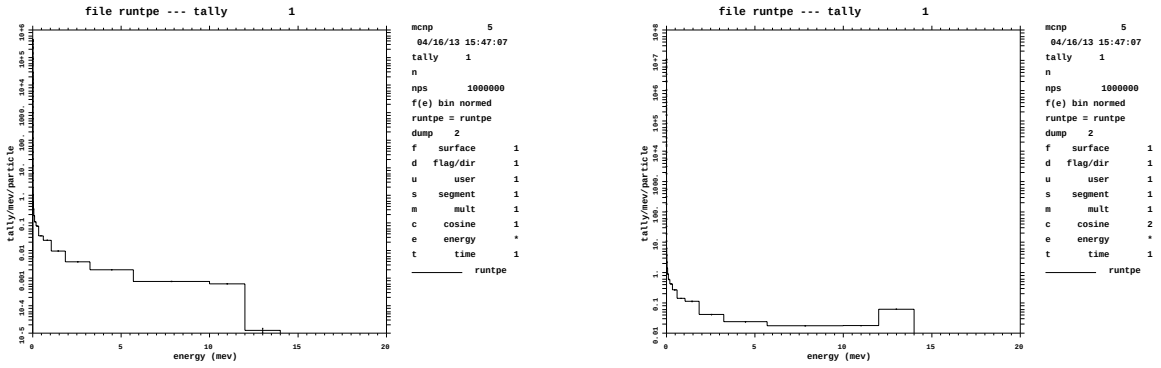
Code

The following tally card addresses this question:

```
c Be sphere current
F1:n 1 $ Surface current
C1 0 1 $ Cosine bins (entering if <0, exiting if >0)
```

Plots

Below are two plots of the energy spectrum of the current on the sphere (Fig 1). Both are results of tally 1.



(a) Neutrons entering the sphere.

(b) Neutrons exiting the sphere.

Figure 1: Neutron current on sphere.

Tables

First we have a table of the energy spectrum entering the sphere.

cosine bin: -1. to 0.00000E+00

energy		
1.0000E-10	0.00000E+00	0.0000
1.7557E-10	8.60890E-07	1.0000
3.0824E-10	2.49773E-06	0.5780
5.4117E-10	4.82218E-06	0.4101
9.5012E-10	2.48534E-05	0.1789
1.6681E-09	6.88581E-05	0.1061
2.9286E-09	1.80607E-04	0.0664
5.1418E-09	4.85822E-04	0.0404
9.0273E-09	1.18353E-03	0.0260
1.5849E-08	2.65908E-03	0.0174
2.7826E-08	5.39931E-03	0.0122
4.8853E-08	8.64838E-03	0.0097
8.5770E-08	8.99338E-03	0.0096
1.5058E-07	5.84678E-03	0.0120
2.6438E-07	3.17145E-03	0.0166
4.6416E-07	3.26836E-03	0.0165
8.1491E-07	4.12371E-03	0.0147
1.4307E-06	5.12009E-03	0.0132
2.5119E-06	6.40537E-03	0.0118
4.4101E-06	7.48115E-03	0.0109
7.7426E-06	8.63979E-03	0.0101
1.3594E-05	9.49308E-03	0.0096
2.3866E-05	1.02808E-02	0.0093
4.1901E-05	1.09828E-02	0.0090
7.3564E-05	1.13087E-02	0.0088

```
  1.2915E-04   1.13996E-02 0.0088
  2.2675E-04   1.17495E-02 0.0087
  3.9811E-04   1.15033E-02 0.0087
  6.9895E-04   1.12506E-02 0.0088
  1.2271E-03   1.11707E-02 0.0089
  2.1544E-03   1.09781E-02 0.0089
  3.7825E-03   1.05273E-02 0.0091
  6.6408E-03   1.00489E-02 0.0093
  1.1659E-02   9.73645E-03 0.0095
  2.0470E-02   9.32924E-03 0.0097
  3.5938E-02   8.94149E-03 0.0099
  6.3096E-02   8.73190E-03 0.0100
  1.1078E-01   8.77276E-03 0.0100
  1.9449E-01   9.15712E-03 0.0098
  3.4145E-01   1.13031E-02 0.0088
  5.9948E-01   8.80270E-03 0.0100
  1.0525E+00   1.06506E-02 0.0090
  1.8478E+00   7.61817E-03 0.0106
  3.2442E+00   5.43114E-03 0.0125
  5.6958E+00   4.90828E-03 0.0130
  1.0000E+01   3.24328E-03 0.0155
  1.2000E+01   1.23648E-03 0.0254
  1.4000E+01   2.55256E-05 0.1800
  1.6000E+01   0.00000E+00 0.0000
  1.8000E+01   0.00000E+00 0.0000
  2.0000E+01   0.00000E+00 0.0000
    total      3.10291E-01 0.0019
```

Now we have a table of the energy spectrum exiting the sphere.

```
 cosine bin:   0.00000E+00 to  1.00000E+00
     energy
  1.0000E-10   7.20972E-07 1.0000
  1.7557E-10   3.15585E-06 0.5035
  3.0824E-10   2.63546E-05 0.1736
  5.4117E-10   6.88555E-05 0.1072
  9.5012E-10   2.81125E-04 0.0536
  1.6681E-09   7.54476E-04 0.0324
  2.9286E-09   2.47001E-03 0.0179
  5.1418E-09   7.72335E-03 0.0102
  9.0273E-09   2.20861E-02 0.0060
  1.5849E-08   5.88074E-02 0.0037
  2.7826E-08   1.29772E-01 0.0025
  4.8853E-08   2.17745E-01 0.0019
  8.5770E-08   2.35567E-01 0.0019
  1.5058E-07   1.34339E-01 0.0025
  2.6438E-07   4.72491E-02 0.0043
  4.6416E-07   3.07368E-02 0.0054
  8.1491E-07   2.92454E-02 0.0055
```

```
1.4307E-06   2.91695E-02 0.0056
2.5119E-06   2.99019E-02 0.0055
4.4101E-06   3.06248E-02 0.0054
7.7426E-06   3.10953E-02 0.0054
1.3594E-05   3.21047E-02 0.0053
2.3866E-05   3.23762E-02 0.0053
4.1901E-05   3.26661E-02 0.0052
7.3564E-05   3.17333E-02 0.0053
1.2915E-04   3.09042E-02 0.0054
2.2675E-04   3.09802E-02 0.0054
3.9811E-04   3.09472E-02 0.0054
6.9895E-04   3.12291E-02 0.0053
1.2271E-03   3.06352E-02 0.0054
2.1544E-03   3.08941E-02 0.0054
3.7825E-03   3.06274E-02 0.0054
6.6408E-03   3.12062E-02 0.0053
1.1659E-02   3.19792E-02 0.0053
2.0470E-02   3.33127E-02 0.0052
3.5938E-02   3.43323E-02 0.0051
6.3096E-02   3.76470E-02 0.0049
1.1078E-01   4.23494E-02 0.0046
1.9449E-01   4.96532E-02 0.0043
3.4145E-01   6.24131E-02 0.0038
5.9948E-01   6.99500E-02 0.0036
1.0525E+00   6.37600E-02 0.0038
1.8478E+00   8.99501E-02 0.0031
3.2442E+00   5.78936E-02 0.0039
5.6958E+00   5.88816E-02 0.0039
1.0000E+01   7.55455E-02 0.0035
1.2000E+01   3.56089E-02 0.0051
1.4000E+01   1.24053E-01 0.0026
1.6000E+01   0.00000E+00 0.0000
1.8000E+01   0.00000E+00 0.0000
2.0000E+01   0.00000E+00 0.0000
  total      2.28130E+00 0.0005
```

Part 3

Question

Determine what fraction of the flux that reaches the detector has streamed directly from the Be sphere. Plot the flux spectrum that streamed directly in comparison with the total flux spectrum. Arrange your output in a table that makes it easy to make this comparison.

Code

```
c flux at detector
F4:n 7   $ Cell flux at detector
```

```
CF4 1    $ Flag Be sphere
FQ4 E D  $ Order
F14:n 7  $ Cell flux at detector
CF14 5   $ Flag water jacket
FQ14 E D $ Order
```

Response

First we create a detector tally and tag all neutrons that pass through the sphere, yielding the following table:

	total		flagged	
energy				
1.0000E-10	0.00000E+00	0.0000	0.00000E+00	0.0000
1.7557E-10	0.00000E+00	0.0000	0.00000E+00	0.0000
3.0824E-10	0.00000E+00	0.0000	0.00000E+00	0.0000
5.4117E-10	0.00000E+00	0.0000	0.00000E+00	0.0000
9.5012E-10	2.52669E-09	1.0000	2.52669E-09	1.0000
1.6681E-09	0.00000E+00	0.0000	0.00000E+00	0.0000
2.9286E-09	2.20505E-09	1.0000	2.20505E-09	1.0000
5.1418E-09	9.40707E-09	1.0000	9.40707E-09	1.0000
9.0273E-09	2.83513E-08	0.6267	2.83513E-08	0.6267
1.5849E-08	1.29744E-07	0.3001	1.29744E-07	0.3001
2.7826E-08	2.98835E-07	0.1916	2.98835E-07	0.1916
4.8853E-08	5.31022E-07	0.1542	5.31022E-07	0.1542
8.5770E-08	6.35785E-07	0.1507	6.35785E-07	0.1507
1.5058E-07	3.44487E-07	0.1962	3.44487E-07	0.1962
2.6438E-07	2.08501E-07	0.2725	2.08501E-07	0.2725
4.6416E-07	3.69156E-08	0.5773	3.69156E-08	0.5773
8.1491E-07	1.52097E-07	0.3140	1.52097E-07	0.3140
1.4307E-06	1.75018E-07	0.3107	1.75018E-07	0.3107
2.5119E-06	1.40528E-07	0.3347	1.40528E-07	0.3347
4.4101E-06	1.37584E-07	0.3107	1.37584E-07	0.3107
7.7426E-06	2.08632E-07	0.2634	2.08632E-07	0.2634
1.3594E-05	2.95008E-07	0.2173	2.95008E-07	0.2173
2.3866E-05	2.79342E-07	0.2332	2.79342E-07	0.2332
4.1901E-05	1.37728E-07	0.3001	1.37728E-07	0.3001
7.3564E-05	2.37801E-07	0.2415	2.37801E-07	0.2415
1.2915E-04	1.85087E-07	0.2696	1.85087E-07	0.2696
2.2675E-04	1.97368E-07	0.2827	1.97368E-07	0.2827
3.9811E-04	1.69488E-07	0.2490	1.69488E-07	0.2490
6.9895E-04	2.34960E-07	0.2617	2.34960E-07	0.2617
1.2271E-03	3.38734E-07	0.2187	3.38734E-07	0.2187
2.1544E-03	3.39703E-07	0.2276	3.39703E-07	0.2276
3.7825E-03	1.55559E-07	0.2605	1.55559E-07	0.2605
6.6408E-03	1.88855E-07	0.2467	1.88855E-07	0.2467
1.1659E-02	3.32051E-07	0.2082	3.32051E-07	0.2082
2.0470E-02	2.73090E-07	0.2643	2.73090E-07	0.2643

3.5938E-02	3.65808E-07	0.2056	3.65808E-07	0.2056
6.3096E-02	2.87705E-07	0.2339	2.87705E-07	0.2339
1.1078E-01	2.68820E-07	0.2417	2.68820E-07	0.2417
1.9449E-01	4.28748E-07	0.1990	4.28748E-07	0.1990
3.4145E-01	6.43011E-07	0.1642	6.43011E-07	0.1642
5.9948E-01	1.08533E-06	0.1318	1.08533E-06	0.1318
1.0525E+00	1.07325E-06	0.1302	1.07325E-06	0.1302
1.8478E+00	1.13071E-06	0.1173	1.13071E-06	0.1173
3.2442E+00	9.11162E-07	0.1348	9.11162E-07	0.1348
5.6958E+00	1.33621E-06	0.1120	1.33621E-06	0.1120
1.0000E+01	1.45667E-06	0.1049	1.45667E-06	0.1049
1.2000E+01	7.25284E-07	0.1470	7.25284E-07	0.1470
1.4000E+01	1.88229E-06	0.0953	1.88229E-06	0.0953
1.6000E+01	0.00000E+00	0.0000	0.00000E+00	0.0000
1.8000E+01	0.00000E+00	0.0000	0.00000E+00	0.0000
2.0000E+01	0.00000E+00	0.0000	0.00000E+00	0.0000
total	1.80014E-05	0.0327	1.80014E-05	0.0327

Clearly, all neutrons that reach the detector have passed through the sphere. Looking at the geometry, we see that this makes sense. Now we have to determine which have streamed DIRECTLY from the sphere. To do this, we complete another detector tally that tags any neutrons passing through the water.

	total		flagged	
energy				
1.0000E-10	0.00000E+00	0.0000	0.00000E+00	0.0000
1.7557E-10	0.00000E+00	0.0000	0.00000E+00	0.0000
3.0824E-10	0.00000E+00	0.0000	0.00000E+00	0.0000
5.4117E-10	0.00000E+00	0.0000	0.00000E+00	0.0000
9.5012E-10	2.52669E-09	1.0000	2.52669E-09	1.0000
1.6681E-09	0.00000E+00	0.0000	0.00000E+00	0.0000
2.9286E-09	2.20505E-09	1.0000	0.00000E+00	0.0000
5.1418E-09	9.40707E-09	1.0000	0.00000E+00	0.0000
9.0273E-09	2.83513E-08	0.6267	0.00000E+00	0.0000
1.5849E-08	1.29744E-07	0.3001	3.01327E-08	0.4805
2.7826E-08	2.98835E-07	0.1916	3.24178E-08	0.6028
4.8853E-08	5.31022E-07	0.1542	4.84146E-08	0.4282
8.5770E-08	6.35785E-07	0.1507	1.61028E-07	0.3005
1.5058E-07	3.44487E-07	0.1962	3.41188E-08	0.5961
2.6438E-07	2.08501E-07	0.2725	1.10448E-07	0.3685
4.6416E-07	3.69156E-08	0.5773	1.30827E-08	0.8909
8.1491E-07	1.52097E-07	0.3140	1.14591E-07	0.3778
1.4307E-06	1.75018E-07	0.3107	1.09460E-07	0.4011
2.5119E-06	1.40528E-07	0.3347	9.23813E-08	0.4197
4.4101E-06	1.37584E-07	0.3107	1.12716E-07	0.3357
7.7426E-06	2.08632E-07	0.2634	1.52341E-07	0.2908
1.3594E-05	2.95008E-07	0.2173	2.15464E-07	0.2475
2.3866E-05	2.79342E-07	0.2332	2.22455E-07	0.2611
4.1901E-05	1.37728E-07	0.3001	9.27777E-08	0.3348

```
7.3564E-05   2.37801E-07 0.2415   1.53875E-07 0.2881
1.2915E-04   1.85087E-07 0.2696   1.05084E-07 0.3672
2.2675E-04   1.97368E-07 0.2827   1.55803E-07 0.3122
3.9811E-04   1.69488E-07 0.2490   1.32977E-07 0.2858
6.9895E-04   2.34960E-07 0.2617   1.89471E-07 0.2901
1.2271E-03   3.38734E-07 0.2187   2.49234E-07 0.2468
2.1544E-03   3.39703E-07 0.2276   2.53564E-07 0.2667
3.7825E-03   1.55559E-07 0.2605   1.33331E-07 0.2686
6.6408E-03   1.88855E-07 0.2467   1.35868E-07 0.2802
1.1659E-02   3.32051E-07 0.2082   2.64462E-07 0.2380
2.0470E-02   2.73090E-07 0.2643   1.97610E-07 0.3048
3.5938E-02   3.65808E-07 0.2056   2.60206E-07 0.2456
6.3096E-02   2.87705E-07 0.2339   1.94565E-07 0.2679
1.1078E-01   2.68820E-07 0.2417   2.07845E-07 0.2864
1.9449E-01   4.28748E-07 0.1990   3.08120E-07 0.2423
3.4145E-01   6.43011E-07 0.1642   4.72810E-07 0.1957
5.9948E-01   1.08533E-06 0.1318   7.55927E-07 0.1584
1.0525E+00   1.07325E-06 0.1302   7.17652E-07 0.1532
1.8478E+00   1.13071E-06 0.1173   6.12070E-07 0.1562
3.2442E+00   9.11162E-07 0.1348   5.54182E-07 0.1645
5.6958E+00   1.33621E-06 0.1120   9.80465E-07 0.1290
1.0000E+01   1.45667E-06 0.1049   9.81448E-07 0.1264
1.2000E+01   7.25284E-07 0.1470   4.23732E-07 0.1904
1.4000E+01   1.88229E-06 0.0953   6.79623E-07 0.1562
1.6000E+01   0.00000E+00 0.0000   0.00000E+00 0.0000
1.8000E+01   0.00000E+00 0.0000   0.00000E+00 0.0000
2.0000E+01   0.00000E+00 0.0000   0.00000E+00 0.0000
  total      1.80014E-05 0.0327   1.06643E-05 0.0422
```

So, of the 1.8E-5 contribution to flux in the detector, 1.06643E-5 of this came through the water and did not stream **directly** to the detector. So, the total flux that streamed directly is the difference between the total and flagged columns in this second table (i.e. total - flagged). A plot comparing the two fluxes is shown below (Fig 2).

Part 4

Question

Determine the total heating in the NaI detector and what fraction comes from neutrons vs. photons. Report your answers in Watts (W).

Code

```
c heating in detector
F16:n 7             $ Tally neutrons
SD16 1              $ Specify unit mass
FM16 1.6021777e-4   $ Scale to Watts
F26:p 7             $ Tally photons
```

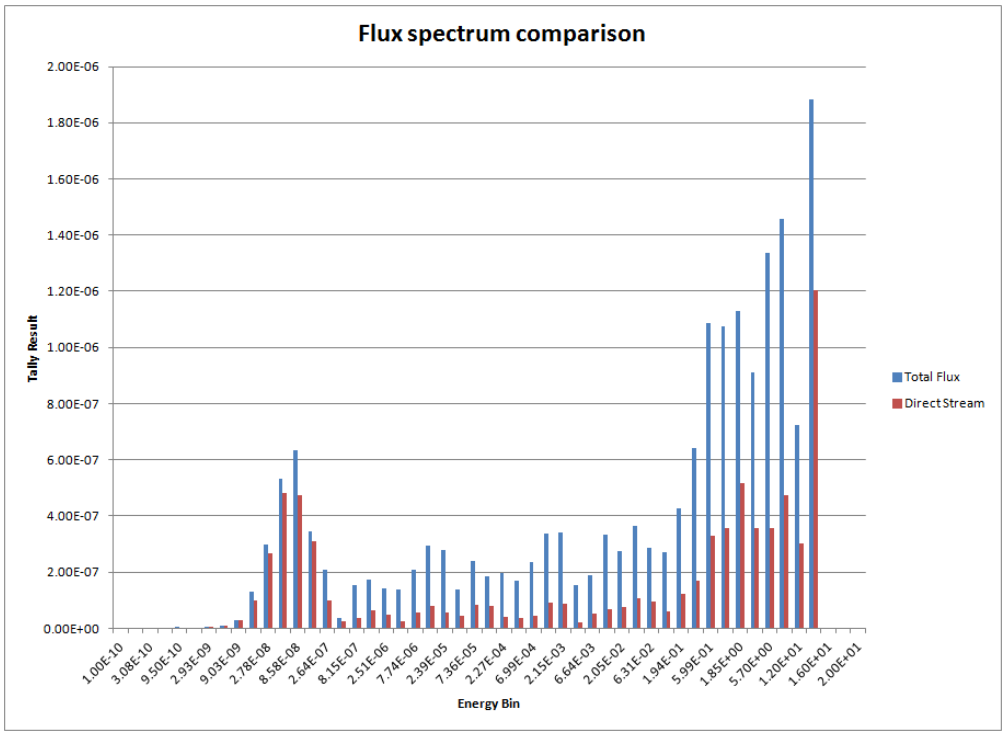


Figure 2: A comparison of the total detector flux and direct detector flux.

```
SD26 1              $ Specify unit mass
FM26 1.6021777e-4   $ Scale to Watts
```

Answer

Total heating due to neutrons [W]:
1.42709×10^{-8} 0.0211
Total heating due to photons [W]:
2.34139×10^{-7} 0.0108
The total heating in the detector is the sum of these two numbers.

Part 5

Question

Determine the rate of (n,2n) reactions occuring in the Be sphere. Report your answer in $\frac{\text{reactions}}{\text{s}}$.

Code

```
c rate of (n,2n) reactions in Be sphere
F34:n 1          $ Tally neutrons in Be sphere
FM34 1e9 1 16      $ Tally multiplier for (n,2n)
```

Response

As shown in line 380 of the outp file, the number of (n,2n) reactions per second is 1.52566×10^5 0.0020.

Part 6

Question

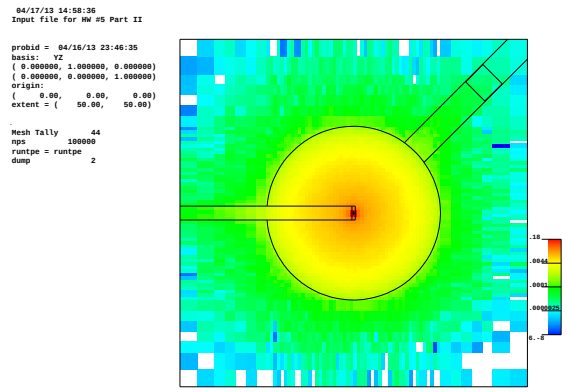
Create a mesh tally in the entire water block. For the region that includes the Be sphere, use 1 cm mesh. For the next 15 cm, use a 3 cm mesh. For the remainder of the mesh, use a 5 cm mesh. Tally both the photon and neutron fluxes. Produce a plot of these mesh tallies in the Y-Z plane.

Code

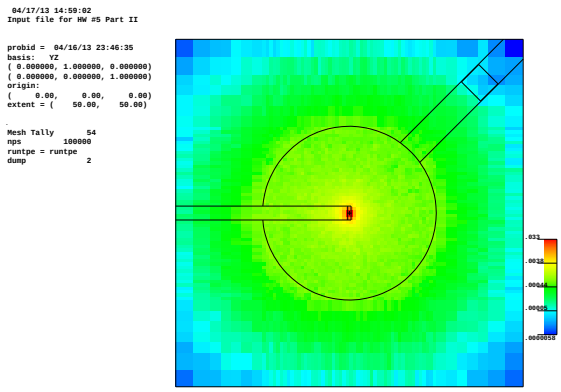
```
c Mesh tally entire water block
FMESH44:n GEOM=xyz ORIGIN=-50 -50 -50
     IMESH=-40 -25 25 40 50 IINTS=2 5 50 5 2
     JMESH=-40 -25 25 40 50 JINTS=2 5 50 5 2
     KMESH=-40 -25 25 40 50 KINTS=2 5 50 5 2
FMESH54:p GEOM=xyz ORIGIN=-50 -50 -50
     IMESH=-40 -25 25 40 50 IINTS=2 5 50 5 2
     JMESH=-40 -25 25 40 50 JINTS=2 5 50 5 2
     KMESH=-40 -25 25 40 50 KINTS=2 5 50 5 2
```

Response

Below are plots of the two mesh tally implementation (Fig 3).



(a) Results of the neutron mesh tally.



(b) Results of the photon mesh tally.

Figure 3: Mesh tally plots.

Part 7

Question

Using the ICRP 21 flux-to-dose conversion factors in Appendix H, calculate the neutron and photon doses at the point (0,49,49).

Code

```
c neutron and photon doses at (0,49,49)
F45:n 0 49 49 0.1
DE45 2.5e-8 1e-7 5ILOG 1e-1 5e-1 1 2 5 10 20
DF45 3.85e-6 4.17e-6 4.55e-6 4.35e-6 4.17e-6 3.7e-6 3.57e-6
     2.08e-5 7.14e-5 1.18e-4 1.43e-4 1.47e-4 1.47e-4 1.54e-4
FM45 1e9 $ Scale by source strength
F55:p 0 49 49 0.1
DE55 0.01 0.015 0.02 3I 0.06 0.08 0.1 0.15 0.2 3I 0.6 0.8 1. 1.5
      2 3I 6 8 10
DF55 2.78e-6 1.11e-6 5.88e-7 2.56e-7 1.56e-7 1.2e-7 1.11e-7 1.2e-7
     1.47e-7 2.38e-7 3.45e-7 5.56e-7 7.69e-7 9.09e7 1.14e-6 1.47e-6
     1.79e-6 2.44e-6 3.03e-6 4e-6 4.76e-6 5.56e-6 6.25e-6 7.69e-6
     9.09e-6
FM55 1e9
```

Response

Neutron dose[1] (line 486): 1.15794×10^{-2} 0.0056.
Photon dose (line 723): 1.09869×10^{8} 0.1153.

[1] Note that the dose for both neutrons and photons has units of $\frac{\text{rem}}{\text{hr}}$