4 x 5 array

Some Data for the WPI Full LEU Assembly (from wpi_leu2g_calcs with 2012 data)

Assembly Average Density (atom/b-cm) & Microscopic Cross Sections (barns) (micro data from 2012):

Nuclide	density	tr1	tr2	fis1	fis2	abs1	abs2	nufis1	nufis2	scat12
U235	1.187e-04	1.285e+01	3.791e+02	8.102e+00	3.836e+02	1.245e+01	4.494e+02	1.986e+01	9.348e+02	5.482e-03
U238	4.761e-04	9.374e+00	1.056e+01	1.342e-01	1.161e-05	3.149e+00	1.860e+00	3.743e-01	2.894e-05	3.793e-03
H	3.879e-02	2.721e+00	2.519e+01	0.000e+00	0.000e+00	3.469e-03	2.451e-01	0.000e+00	0.000e+00	6.410e-01
O16	1.939e-02	2.629e+00	3.827e+00	0.000e+00	0.000e+00	3.299e-03	1.403e-04	0.000e+00	0.000e+00	1.513e-02
Al27	2.337e-02	2.135e+00	1.511e+00	0.000e+00	0.000e+00	5.091e-03	1.622e-01	0.000e+00	0.000e+00	3.433e-03

Macroscopic Cross Sections (1/cm):

	tr1	tr2	fis1	fis2	abs1	abs2	nufis1	nufis2	scat12
	2.124e-01	1.137e+00	1.025e-03	4.552e-02	3.294e-03	6.751e-02	2.535e-03	1.109e-01	2.524e-02
Diff. Coeffs:	1.569e+00	2.933e-01	(cm)						

UMLRR Criticality Calculations (infinite, bare, and fully reflected systems):

Infinite System		Finite System (4x5 BARE array)		Finite System (4x5 REFLECTED array)	
eta =	2.0464	L1sq (cm^2) =	55.0009		
f =	0.8030	tau (cm^2) =	62.1799		
p =	0.8845	L2sq (cm^2) =	4.3443		
epsilon =	1.0611	MTsq (cm^2) =	66.5242	del (cm) =	9.8524
		Bsq (1/cm^2) =	0.0182	Bsq (1/cm^2) =	0.0083
		PF =	0.4687	PF =	0.6604
		PT =	0.9266	PT =	0.9653
phi1/phi2 =	2.6747	phi1/phi2 =	2.8865	phi1/phi2 =	2.7708
kinf (2-group) =	1.5423	keff (2-group) =	0.7169	keff (2-group) =	1.0255
kinf (4-factor) =	1.5423	keff (6-factor) =	0.6699	keff (6-factor) =	0.9833
		keff (modified 1-g) =	0.6970	keff (modified 1-g) =	0.9950

Thermal Flux for the WPI fuelled UMLRR at 1 MW:

	Finite System (4x5 BARE array)	Finite System (4x5 REFLECTED array)
sigfeff (1/cm) ==>	4.848e-02	4.836e-02
thmflxave (neuts/cm^2-s) ==>	8.927e+12	8.948e+12
thmflxpeak (neuts/cm^2-s) ==>	3.347e+13 (F = 3.75)	2.461e+13 (F = 2.75)

4 x 6 array

Some Data for the WPI Full LEU Assembly (from wpi_leu2g_calcs with 2012 data)

Assembly Average Density (atom/b-cm) & Microscopic Cross Sections (barns) (micro data from 2012):

Nuclide	density	tr1	tr2	fis1	fis2	abs1	abs2	nufis1	nufis2	scat12
U235	1.187e-04	1.285e+01	3.791e+02	8.102e+00	3.836e+02	1.245e+01	4.494e+02	1.986e+01	9.348e+02	5.482e-03
U238	4.761e-04	9.374e+00	1.056e+01	1.342e-01	1.161e-05	3.149e+00	1.860e+00	3.743e-01	2.894e-05	3.793e-03
H	3.879e-02	2.721e+00	2.519e+01	0.000e+00	0.000e+00	3.469e-03	2.451e-01	0.000e+00	0.000e+00	6.410e-01
O16	1.939e-02	2.629e+00	3.827e+00	0.000e+00	0.000e+00	3.299e-03	1.403e-04	0.000e+00	0.000e+00	1.513e-02
Al27	2.337e-02	2.135e+00	1.511e+00	0.000e+00	0.000e+00	5.091e-03	1.622e-01	0.000e+00	0.000e+00	3.433e-03

Macroscopic Cross Sections (1/cm):

	tr1	tr2	fis1	fis2	abs1	abs2	nufis1	nufis2	scat12
	2.124e-01	1.137e+00	1.025e-03	4.552e-02	3.294e-03	6.751e-02	2.535e-03	1.109e-01	2.524e-02
Diff. Coeffs:	1.569e+00	2.933e-01	(cm)						

UMLRR Criticality Calculations (infinite, bare, and fully reflected systems):

Infinite System		Finite System (4x6 BARE array)		Finite System (4x6 REFLECTED array)	
eta	= 2.0464	L1sq (cm^2)	= 55.0009		
f	= 0.8030	tau (cm^2)	= 62.1799		
p	= 0.8845	L2sq (cm^2)	= 4.3443		
epsilon	= 1.0611	MTsq (cm^2)	= 66.5242	del (cm)	= 9.8524
		Bsq (1/cm^2)	= 0.0164	Bsq (1/cm^2)	= 0.0076
		PF	= 0.4951	PF	= 0.6781
		PT	= 0.9335	PT	= 0.9679
phi1/phi2	= 2.6747	phi1/phi2	= 2.8653	phi1/phi2	= 2.7634
kinf (2-group)	= 1.5423	keff (2-group)	= 0.7601	keff (2-group)	= 1.0534
kinf (4-factor)	= 1.5423	keff (6-factor)	= 0.7128	keff (6-factor)	= 1.0123
		keff (modified 1-g)	= 0.7376	keff (modified 1-g)	= 1.0229

Thermal Flux for the WPI fuelled UMLRR at 1 MW:

	Finite System (4x6 BARE array)	Finite System (4x6 REFLECTED array)
sigfeff (1/cm) ==>	4.846e-02	4.836e-02
thmflxave (neuts/cm^2-s) ==>	7.442e+12	7.458e+12
thmflxpeak (neuts/cm^2-s) ==>	2.791e+13 (F = 3.75)	2.051e+13 (F = 2.75)

5x5 array

Some Data for the WPI Full LEU Assembly (from wpi_leu2g_calcs with 2012 data)

Assembly Average Density (atom/b-cm) & Microscopic Cross Sections (barns) (micro data from 2012):

Nuclide	density	tr1	tr2	fis1	fis2	abs1	abs2	nufis1	nufis2	scat12
U235	1.187e-04	1.285e+01	3.791e+02	8.102e+00	3.836e+02	1.245e+01	4.494e+02	1.986e+01	9.348e+02	5.482e-03
U238	4.761e-04	9.374e+00	1.056e+01	1.342e-01	1.161e-05	3.149e+00	1.860e+00	3.743e-01	2.894e-05	3.793e-03
H	3.879e-02	2.721e+00	2.519e+01	0.000e+00	0.000e+00	3.469e-03	2.451e-01	0.000e+00	0.000e+00	6.410e-01
O16	1.939e-02	2.629e+00	3.827e+00	0.000e+00	0.000e+00	3.299e-03	1.403e-04	0.000e+00	0.000e+00	1.513e-02
Al27	2.337e-02	2.135e+00	1.511e+00	0.000e+00	0.000e+00	5.091e-03	1.622e-01	0.000e+00	0.000e+00	3.433e-03

Macroscopic Cross Sections (1/cm):

	tr1	tr2	fis1	fis2	abs1	abs2	nufis1	nufis2	scat12
	2.124e-01	1.137e+00	1.025e-03	4.552e-02	3.294e-03	6.751e-02	2.535e-03	1.109e-01	2.524e-02
Diff. Coeffs:	1.569e+00	2.933e-01	(cm)						

UMLRR Criticality Calculations (infinite, bare, and fully reflected systems):

Infinite System		Finite System (5x5 BARE array)		Finite System (5x5 REFLECTED array)	
eta =	2.0464	L1sq (cm^2) =	55.0009		
f =	0.8030	tau (cm^2) =	62.1799		
p =	0.8845	L2sq (cm^2) =	4.3443		
epsilon =	1.0611	MTsq (cm^2) =	66.5242	del (cm) =	9.8524
		Bsq (1/cm^2) =	0.0149	Bsq (1/cm^2) =	0.0073
		PF =	0.5186	PF =	0.6872
		PT =	0.9391	PT =	0.9692
phi1/phi2 =	2.6747	phi1/phi2 =	2.8481	phi1/phi2 =	2.7598
kinf (2-group) =	1.5423	keff (2-group) =	0.7984	keff (2-group) =	1.0676
kinf (4-factor) =	1.5423	keff (6-factor) =	0.7512	keff (6-factor) =	1.0272
		keff (modified 1-g) =	0.7739	keff (modified 1-g) =	1.0372

Thermal Flux for the WPI fuelled UMLRR at 1 MW:

	Finite System (5x5 BARE array)	Finite System (5x5 REFLECTED array)
sigfeff (1/cm) ==>	4.844e-02	4.835e-02
thmflxave (neuts/cm^2-s) ==>	7.147e+12	7.160e+12
thmflxpeak (neuts/cm^2-s) ==>	2.680e+13 (F = 3.75)	1.969e+13 (F = 2.75)

```
%   WPI_MICROS_2012.M    Matlab Script File with Homogeneized Densities and
%                  Microscopic Cross Sections for the WPI LEU Fuel Assembly
%
%   This file contains 2-group microscopic data and assembly average nuclide
%   densities for the WPI LEU fuel assembly.  The format of the variables
%   is defined in the comments within the script file.  This file can be used
%   within other Matlab codes that need these data for various computations for
%   the UMLRR with the WPI fuel assembly.
%
%   Data Ref: 1. micro xsec data from wpi2gvxs_v7n238.bcdlib (generated Aug. 2012)
%             2. assembly average densities from umlrrden.m and wpifdata.m
%
%   File prepared by J. R. White, UMass-Lowell (last update:  November 2106)
%

%
%   define the micro xsecs for 5 isotopes (from wpi2gvxs_v7n238.bcdlib)
%   units:  all cross sections have units of barns (where 1 b = 1e-24 cm^2)
%   format:  [ tr1       tr2;   fis1   fis2;   abs1      abs2;
%              nufis1  nufis2;   tot1   tot2;   scat11  scat22;
%                0     scat12]
%   U235   WPI LEU fuel assy
  U235 = [1.28524E+01 3.79064E+02; 8.10212E+00 3.83641E+02; 1.24539E+01 4.49357E+02;
          1.98614E+01 9.34819E+02; 2.12437E+01 4.63669E+02; 8.79051E+00 1.43125E+01;
          0.00000E+00 5.48160E-03];
%   U238   full LEU fuel assy
  U238 = [9.37397E+00 1.05592E+01; 1.34232E-01 1.16138E-05; 3.14884E+00 1.86039E+00;
          3.74304E-01 2.89426E-05; 1.50334E+01 1.08353E+01; 1.18871E+01 8.97487E+00;
          0.00000E+00 3.79322E-03];
%   H1     full LEU fuel assy
    H1 = [2.72080E+00 2.51899E+01; 0.00000E+00 0.00000E+00; 3.46903E-03 2.45124E-01;
          0.00000E+00 0.00000E+00; 1.10472E+01 4.17276E+01; 1.04025E+01 4.14824E+01;
          0.00000E+00 6.40995E-01];
%   O-16   full LEU fuel assy
   O16 = [2.62927E+00 3.82666E+00; 0.00000E+00 0.00000E+00; 3.29889E-03 1.40274E-04;
          0.00000E+00 0.00000E+00; 3.36376E+00 4.00749E+00; 3.34533E+00 4.00735E+00;
          0.00000E+00 1.51274E-02];
%   Al27   full LEU fuel assy
  Al27 = [2.13458E+00 1.51099E+00; 0.00000E+00 0.00000E+00; 5.09056E-03 1.62161E-01;
          0.00000E+00 0.00000E+00; 2.69290E+00 1.56598E+00; 2.68437E+00 1.40382E+00;
          0.00000E+00 3.43263E-03];
%
%   now define the assembly averaged densities (data from umlrrden.m & leufdata.m)
%   units: N has units of atoms/b-cm  (multiply by 1e24 to convert to atoms/cm^3)
%   nuclide order: U235, U238, H1, O16, Al27
   nam = ['U235';'U238';'H   ';'O16 ';'Al27'];  nam = char(nam);
   den = [1.1866e-004 4.7606e-004 3.8788e-002 1.9394e-002 2.3371e-002];
%
%   end of data
```

```
%   WPI_LEU2G_CALCS.M
%       Compute keff and several intermediate quantities for a Nx x Ny array of WPI
%           LEU full fuel elements (both bare and reflected configurations)
%
%   This file computes several properties for the WPI LEU fuel assembly.  It uses
%   2-group microscopic data and assembly averaged nuclide densities to first
%   compute the needed macroscopic cross sections. Then, several different
%   approximations (formal 2-group theory, the 4 and 6-factor formulas, and modified
%   1-group theory) are used to compute keff for a Nx x Ny array for both the bare
%   and reflected configurations.  The values of Nx and Ny are set by the user. The
%   data are edited in tabular form for future use in other studies.
%
%   Data Ref: 1. micro xsec data from wpi2gvxs_v7n238.bcdlib (generated Aug. 2012)
%             2. assembly average densities from umlrrden.m and wpifdata.m
%             (these data are contained in the wpi_micros_2012.m script file)
%
%   File prepared by J. R. White, UMass-Lowell (last update: November 2016)
%

    clear all,   close all
%
%   **********************
%   *   Cross Sections   *
%   **********************

%   define the micro xsecs and densities for 6 isotopes (wpi_micros_2012.m)
    wpi_micros_2012
%
%   now compute the assembly macros xsecs
    g1mic = [U235(:,1)'; U238(:,1)'; H1(:,1)'; O16(:,1)'; Al27(:,1)'];
    g1mac = den*g1mic;
    g2mic = [U235(:,2)'; U238(:,2)'; H1(:,2)'; O16(:,2)'; Al27(:,2)'];
    g2mac = den*g2mic;
%
%   for ease in subsequent calcs, let's define the individual cross sections
    sigtr1 = g1mac(1);   sigtr2 = g2mac(1);
    dc1 = 1/(3*sigtr1);  dc2 = 1/(3*sigtr2);
    fis1 = g1mac(2);     fis2 = g2mac(2);
    abs1 = g1mac(3);     abs2 = g2mac(3);
    nufis1 = g1mac(4);   nufis2 = g2mac(4);
    sig12 = g2mac(7);
%
%   edit micros xsecs, densities, and macro xsecs
    fid = fopen('wpi_results.out','w');
    fprintf(fid,'\n           Some Data for the WPI Full LEU Assembly (from↙
wpi_leu2g_calcs with 2012 data)\n\n');
    fprintf(fid,'  Assembly Average Density (atom/b-cm) & Microscopic Cross Sections↙
(barns) (micro data from 2012):\n');
    fprintf(fid,'Nuclide  density      tr1        tr2       fis1       fis2       abs1↙
abs2       nufis1     nufis2     scat12\n');
```

```
    for i = 1:length(den);
      fprintf(fid,' %s   %10.3e %10.3e %10.3e %10.3e %10.3e %10.3e %10.3e %10.3e %10.3e\n', ...
                  nam(i,:),den(i),g1mic(i,1),g2mic(i,1),g1mic(i,2),g2mic(i,2), ...
                  g1mic(i,3),g2mic(i,3),g1mic(i,4),g2mic(i,4),g2mic(i,7));
    end
    fprintf(fid,'\n  Macroscopic Cross Sections (1/cm):\n');
    fprintf(fid,'                       tr1        tr2       fis1       fis2       abs1       abs2       nufis1     nufis2     scat12\n');
    fprintf(fid,'                    %10.3e %10.3e %10.3e %10.3e %10.3e %10.3e %10.3e %10.3e %10.3e\n', ...
                  sigtr1,sigtr2,fis1,fis2,abs1,abs2,nufis1,nufis2,sig12);
    fprintf(fid,'     Diff. Coeffs: %10.3e %10.3e  (cm)\n',dc1,dc2);
    fprintf(fid,'\n  ');
%
%   **********************
%   *   Infinite System   *
%   **********************
%
%   compute kinf via 2-group theory and via the elements of the 4-factor formula
    sigR1 = abs1+sig12;                          % sigR1 = sa1+s12
    kinf_2g = (nufis1*abs2+nufis2*sig12)/(sigR1*abs2); % 2-grp kinf
%
    SaF = den(1)*U235(3,2)+den(2)*U238(3,2);     % U235+U238 thermal abs
    eta = nufis2/SaF;                            % eta = nufis2/sa2 fuel
    f = SaF/abs2;                                % thm util = sa2 fuel/sa2 tot
    p = sig12/sigR1;                             % res escape prob = s12/sigR1
    ratio = abs2/sig12;                          % infinite fast/thm flux = sa2/s12
    epp = (nufis1*ratio+nufis2)/nufis2;          % fast fiss factor = totfis/thmfis
    kinf_4factor = eta*f*p*epp;                  % multiplication factor (inf syst)
%
%   *************************
%   *   BARE Finite System   *
%   *************************
%
%   compute 2-grp keff and factors for calculation of non-leakage probabilities
%   and approx keff (assumes a BARE NX x Ny arrangement of fuel assemblies)
    Nx = input('  Input the number of elements in the x-direction: ');
    Ny = input('  Input the number of elements in the y-direction: ');
    d = 2.13*dc2;                                % rough extrapolation dist(thermal)
    assydim = 7.7724;                            % assy square dimension (cm)
    fuelht = 59.69;                              % fuel heigth (cm)
    Xb = Nx*assydim+2*d;                         % effective x-dimension
    Yb = Ny*assydim+2*d;                         % effective y-dimension
    Zb = fuelht+2*d;                             % effective z-dimension
    Bsq_b = (pi/Xb)^2 + (pi/Yb)^2 + (pi/Zb)^2;   % estimate of buckling
%
    top = nufis1*(dc2*Bsq_b+abs2)+nufis2*sig12;
    bot = (dc1*Bsq_b+sigR1)*(dc2*Bsq_b+abs2);
    keff_2g_b = top/bot;                         % keff via formal 2-group theory
%
```

```
  L1sq = dc1/sigR1;                          % fast diff area = D1/(sa1+s12)
  tau = dc1/sig12;                           % neutron age = D1/s12
  L2sq = dc2/abs2;                           % thm diff area = D2/sa2
  MTsq = L2sq+tau;                           % migration area = L2sq + tau
  ratio_b = (dc2*Bsq_b+abs2)/sig12;          % finite fast/thm flux
  PF_b = 1/(1 + Bsq_b*tau);                  % fast non-leakage prob
  PT_b = 1/(1 + Bsq_b*L2sq);                 % thermal non-leakage prob
  keff1_b = kinf_4factor*PF_b*PT_b;          % keff via six factor formula
  keff2_b = kinf_4factor/(1+Bsq_b*MTsq);     % keff via modified 1-g theory
%
% ******************************
% *   REFLECTED Finite System   *
% ******************************
%
% compute 2-grp keff and factors for calculation of non-leakage probabilities
% and approx keff (assumes a REFLECTED Nx x Ny arrangement of fuel assemblies)
  del = 7.2 + 0.1*(MTsq - 40);               % water refl savings (see Lamarsh)
  Xr = Nx*assydim+2*del;                     % effective x-dimension
  Yr = Ny*assydim+2*del;                     % effective y-dimension
  Zr = fuelht+2*del;                         % effective z-dimension
  Bsq_r = (pi/Xr)^2 + (pi/Yr)^2 + (pi/Zr)^2; % estimate of buckling
%
  top = nufis1*(dc2*Bsq_r+abs2) + nufis2*sig12;
  bot = (dc1*Bsq_r+sigR1)*(dc2*Bsq_r+abs2);
  keff_2g_r = top/bot;                       % keff via formal 2-group theory

  ratio_r = (dc2*Bsq_r+abs2)/sig12;          % finite fast/thm flux
  PF_r = 1/(1 + Bsq_r*tau);                  % fast non-leakage prob
  PT_r = 1/(1 + Bsq_r*L2sq);                 % thermal non-leakage prob
  keff1_r = kinf_4factor*PF_r*PT_r;          % keff via six factor formula
  keff2_r = kinf_4factor/(1+Bsq_r*MTsq);     % keff via modified 1-g theory
%
% ********************
% %   Thermal Flux   *
% ********************
%
% compute the full power (1 MW) thermal flux (bare and reflected)
  Pfull = 1e+6;                              % full power level (W)
  kappa = 200*1.602e-13;                     % energy per fission (J = W-s)
  Vcore = Nx*Ny*assydim^2*fuelht;            % core vol for Nx x Ny array (cm^3)
% bare
  sfeff_b = fis1*ratio_b+fis2;               % eff fiss xs (sf1*phi1/phi2 + sf2)
  thmflxave_b = Pfull/(kappa*sfeff_b*Vcore); % ave thm flux (neuts/cm^2-s)
  thmflxpeak_b = 3.75*thmflxave_b;           % peak thm flux (use F = 3.75)
% reflected
  sfeff_r = fis1*ratio_r+fis2;               % eff fiss xs (sf1*phi1/phi2 + sf2)
  thmflxave_r = Pfull/(kappa*sfeff_r*Vcore); % ave thm flux (neuts/cm^2-s)
  thmflxpeak_r = 2.75*thmflxave_r;           % peak thm flux (use F = 2.75)
%
% ********************
% %   Edit Results   *
```

```
    ********************
%
%   edit results
      fprintf(fid,'\n  UMLRR Criticality Calculations (infinite, bare, and fully
reflected systems):\n');
      fprintf(fid,'          Infinite System      Finite System (%ix%i BARE array)
Finite System (%ix%i REFLECTED array)\n',Nx,Ny,Nx,Ny);
      fprintf(fid,'           eta    = %7.4f          L1sq (cm^2) = %7.4f\n',eta,L1sq);
      fprintf(fid,'            f     = %7.4f           tau (cm^2) = %7.4f\n',f,tau);
      fprintf(fid,'            p     = %7.4f          L2sq (cm^2) = %7.4f\n',p,L2sq);
      fprintf(fid,'         epsilon = %7.4f          MTsq (cm^2) = %7.4f
del (cm) = %7.4f\n',epp,MTsq,del);
      fprintf(fid,'                                   Bsq (1/cm^2) = %7.4f
Bsq (1/cm^2) = %7.4f\n',Bsq_b,Bsq_r);
      fprintf(fid,'                                          PF    = %7.4f
PF   = %7.4f\n',PF_b,PF_r);
      fprintf(fid,'                                          PT    = %7.4f
PT   = %7.4f\n',PT_b,PT_r);
      fprintf(fid,'       phi1/phi2 = %7.4f            phi1/phi2 = %7.4f
phi1/phi2 = %7.4f\n',ratio,ratio_b,ratio_r);
      fprintf(fid,'  kinf (2-group) = %7.4f       keff (2-group) = %7.4f            keff
(2-group) = %7.4f\n',kinf_2g,keff_2g_b,keff_2g_r);
      fprintf(fid,' kinf (4-factor) = %7.4f      keff (6-factor) = %7.4f           keff
(6-factor) = %7.4f\n',kinf_4factor,keff1_b,keff1_r);
      fprintf(fid,'                              keff (modified 1-g) = %7.4f       keff
(modified 1-g) = %7.4f\n',keff2_b,keff2_r);
      fprintf(fid,'\n  Thermal Flux for the WPI fuelled UMLRR at 1 MW:\n');
      fprintf(fid,'                                 Finite System (%ix%i BARE array)
Finite System (%ix%i REFLECTED array)\n',Nx,Ny,Nx,Ny);
      fprintf(fid,'                    sigfeff (1/cm) ==>    %10.3e
%10.3e \n',sfeff_b,sfeff_r);
      fprintf(fid,'          thmflxave (neuts/cm^2-s) ==>    %10.3e
%10.3e \n',thmflxave_b,thmflxave_r);
      fprintf(fid,'         thmflxpeak (neuts/cm^2-s) ==>    %10.3e (F = 3.75)
%10.3e (F = 2.75) \n',thmflxpeak_b,thmflxpeak_r);
      fclose(fid);
%
%   end of program
```