**Nuclear Engineering Data and Formulae**

**Forms of the Laplacian operator**

|  |  |
| --- | --- |
| Cartesian |  |
| Cylindrical |    |
| Spherical |    |

**General solutions of differential equations** (where *D*=*d/dx*)

|  |  |
| --- | --- |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

**Bessel functions of zero order: assorted useful values**

|  |
| --- |
|  |
|  |
|  |

**Geometric bucklings for unreflected geometries:**

|  |  |
| --- | --- |
| Cuboid, sides *a, b, c* |  |
| Cylinder, radius *R*, height *H* |  |
| Sphere, radius *R* |  |

**Thermal Neutron Cross Sections (barns, 10-28 m2)**

-natural elemental composition unless indicated

- 'capture cross section + fission cross section = absorption cross section '

|  |  |  |  |
| --- | --- | --- | --- |
| Species | Fission | Absorption | Neutrons per fission |
| Al |  | 0.24100 |  |
| B-10 |  | 3410.00000 |  |
| Be |  | 0.01000 |  |
| Boron (natural) |  | 759.00000 |  |
| C |  | 0.00400 |  |
| D |  | 0.00046 |  |
| Fe |  | 2.62000 |  |
| Gd |  | 49000.00000 |  |
| H |  | 0.33000 |  |
| Mg |  | 0.06900 |  |
| O |  | 0.00020 |  |
| Pu-239 | 749 | 1029.00000 | 2.90 |
| S |  | 0.52000 |  |
| Na |  | 0.52500 |  |
| U-233 | 529 | 581.00000 | 2.50 |
| U-235 | 587 | 683.00000 | 2.43 |
| U-238 |  | 2.71000 |  |
| Zr |  | 0.18500 |  |

Take natural uranium as 0.7% 235-U, 99.3% 238-U

**Assorted physical data:-**

Typical energy release on fission (eV) 200 x 106

Speed of light (ms-1) 2.9979 x 108

Electron volt (J) 1.602 x 10-19

Avogadro's number (kmol-1) 6.02214199 x 1026

Avogadro's number is the number of atoms in 12kg of pure isotope 12C. It is also the number of molecules in one kmol of any substance.

Atomic mass unit:

The atomic mass unit is defined as one twelfth of the mass of the most abundant isotope of carbon: C12.

1 AMU is 1.66053873 x 10-27 kg

**Masses in kg x 10-27**

|  |  |
| --- | --- |
| proton | 1.67261 |
| neutron | 1.67492 |
| 1H | 1.67238 |
| 2H | 3.34401 |
| 3H | 5.00846 |
| 4He | 6.64461 |

**Selected thermophysical properties**

(Many of these vary considerably over the wide range of temperatures of interest. Values quoted are suitable averages.)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | UO2 | U-metal | Liquid sodium(400 C) | Saturatedwater(300 C) | Stainlesssteel | Zircalloy |
|  |  |  |  |  |  |  |  |
| Density | kg m-3 | 10.97 x 103 | 19.3 x 103 | 856 | 713 | 7.81 x 103 | 6.55 x 103 |
| Conductivity | W m-1 K-1 | 3 | 30 | 72.2 | 0.541 | 16 | 21.5 |
| Specific heat | J kg-1 K-1 | 250 | 120 | 1.27 x 103 | 5.794 x 103 | 460 | 285 |
| Melting point | K | 3100 |  |  |  |  |  |
| Heat of fusion | J kg-1 | 277 x 103 |  |  |  |  |  |
| Viscosity | kg m-1 s-1 |  |  | 2.85x10-4 | 0.907 x 10-4 |  |  |
| Prandtl No |  |  |  | 0.00501 | 0.971 |  |  |

Carbon dioxide at 4 MPa

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | 300 K | 600 K | 900 K |
| Density | kg m-3 | use **=*Mp/RT* (*M*=44.01) |
| Conductivity | W m-1 K-1 | 0.022 | 0.042 | 0.064 |
| Specific heat | J kg-1 K-1 | 1047 | 1110 | 1215 |
| Viscosity | kg m-1 s-1 | 16.6 x 10-6 | 28.7 x 10-6 | 38.6 x 10-6 |
| Prandtl No |  | 1.05 | 0.762 | 0.737 |

**Definitions**

 Equivalent diameter 

 Prandtl number 

 Stanton number 

 Nusselt number 

 Peclet number 

 Fanning friction factor 

(The Darcy-Weisbach friction factor, as generally used in Moody charts, is four times bigger).

**Correlations**

 Fanning friction factor



 Darcy-Weisbach friction factor as generally used in Moody charts) (four times bigger)



 Dittus-Boelter, water & gas; smooth channels

 

 Dittus-Boelter, ribbed AGR pins

 

Liquid metals, where ** is the pin pitch to diameter ratio

