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> # Mean free path calculation for neutrons bombarding a slab
restart;

# References
# Reed, section 2.1

# Slab calculations
###################
# Reactions per second
# R[0] = rate of neutron bombardment (neutrons / (m^2 * s))
# sigma = effective cross-sectional area of nucleus
# Sigma = cross-sectional area (m^2)
# n = number density of nuclei (1/m^3)
# s = depth of slab (m)

R[N] := R[0] * Sigma * s * n * sigma; # (1/s)

# Probability of a reaction
P[react] := R[N] / (R[0] * Sigma); # (-)

# Probability of escape
P[escape] := 1 - P[react]; # (-)

# Block calculations
#####################
# Neutrons that emerge from a block made up of m slabs
# x = depth of block (m)
# N[0] = number of neutrons incident on block

m := x / s;

# Equation 1
eqn1 := N[escape] = N[0] * P^m;

# Substitute escape probability in the equation
N[escape] := subs(P = P[escape], rhs(eqn1));

restart;

# Limit as z -> 0
#################
# Define z = -s * n * sigma, then we have:
eqn2 := N[escape] = N[0] * (1 + z) ^ (-sigma * n * x / z);

# Therefore:
N[escape] := N[0] * [(1 + z) ^ (1 / z)] ^ (-sigma * n * x);

# Let z -> 0
k := limit((1 + z) ^ (1 / z), z = 0);
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# Final expression for N[escape] as z approaches 0
N[escape] := N[0] * exp(-sigma * n * x);

# Reactions that occurred
N[react] := N[0] - N[escape];

# Probability a neutron will travel a distance x
P[directEscape] := N[escape] / N[0];
P[react] := 1 - N[escape] / N[0];

# Probability density function for reaction
#############################################
p[react] := diff(P[react], x);

# Mean value of x
##################
xm := simplify(int(x * p[react], x = 0 ..L), symbolic) assuming sigma :: positive, n :: positive;

# Number density
#################
n := 10^6 * (rho * N[A] / At); # (1/m^3)

# Data for U235
rho := 18.71; # (g/cm^3) Bulk density
N[A] := 6.022e23; # (1/mole) Avogadro's number
At := 235.04; # (g/mole) Atomic weight
sigma := 1.235e-28; # (m^2) Neutron cross-sectional area

# Neutron mean free path
############################
x[meanFreePath] := limit(xm, L = infinity); # (m)

# Plotting results
plot(xm, L = 0 ..2);
plot(P[directEscape], x = 0 ..2);
plot(P[react], x = 0 ..2);
```

$$R_N := R_0 \Sigma s n \sigma$$

$$P_{react} := s n \sigma$$

$$P_{escape} := -s n \sigma + 1$$

$$m := \frac{x}{s}$$

$$eqn1 := N_{escape} = N_0 P^{\frac{x}{s}}$$

$$N_{escape} := N_0 \left(-s\,n\,\sigma + 1 \right)^{\frac{x}{s}}$$

$$eqn2 := N_{escape} = N_0 \, (1 + z)^{-\frac{\sigma\,n\,x}{z}}$$

$$N_{escape} := N_0 \left[(1 + z)^{\frac{1}{z}} \right]^{-\sigma\,n\,x}$$

$$k := \mathrm{e}$$

$$N_{escape} := N_0 \, \mathrm{e}^{-\sigma\,n\,x}$$

$$N_{react} := N_0 - N_0 \, \mathrm{e}^{-\sigma\,n\,x}$$

$$P_{directEscape} := \mathrm{e}^{-\sigma\,n\,x}$$

$$P_{react} := 1 - \mathrm{e}^{-\sigma\,n\,x}$$

$$p_{react} := \sigma\,n\,\mathrm{e}^{-\sigma\,n\,x}$$

$$xm := \frac{-L\,\mathrm{e}^{-\sigma\,n\,L}\,n\,\sigma - \mathrm{e}^{-\sigma\,n\,L} + 1}{\sigma\,n}$$

$$n := \frac{1000000\,\rho\,N_A}{At}$$

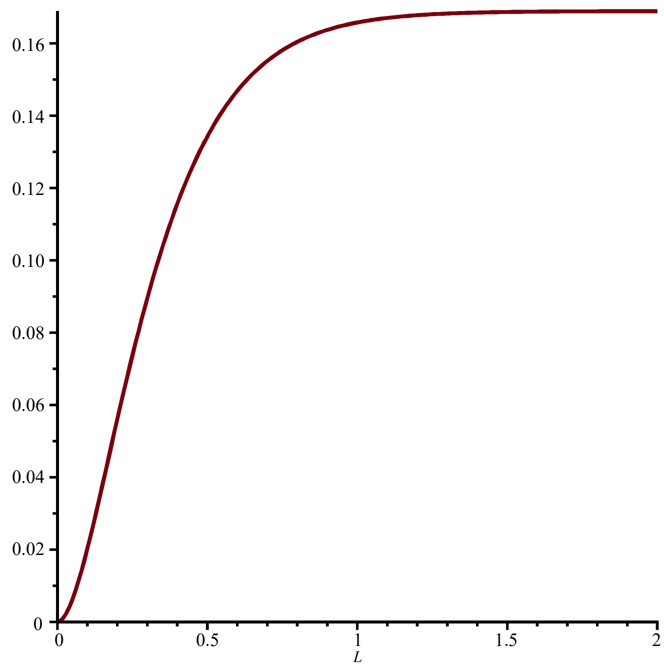
$$\rho := 18.71$$

$$N_A := 6.022 \times 10^{23}$$

$$At := 235.04$$

$$\sigma := 1.235 \times 10^{-28}$$

$$x_{meanFreePath} := 0.1689119136$$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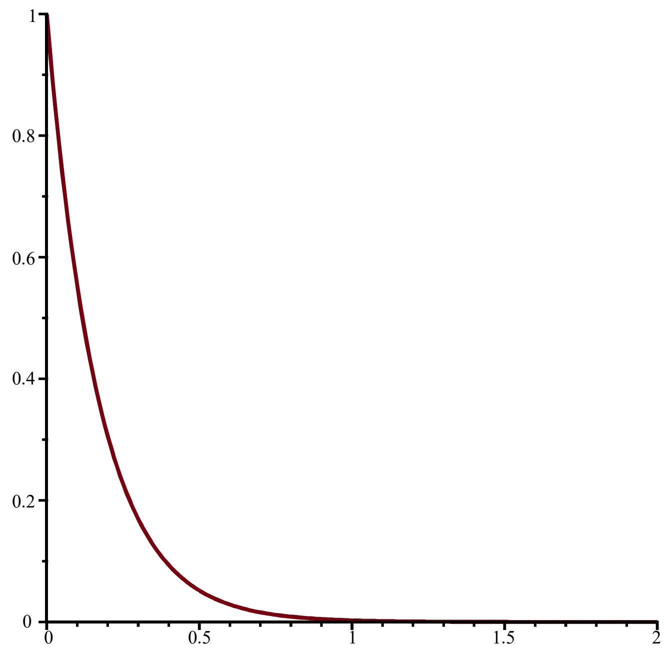
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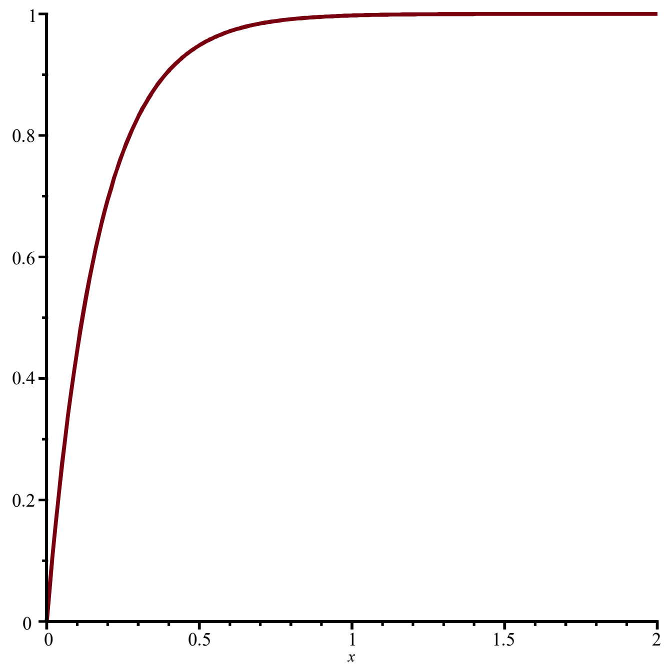

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