EE-580 Space Mechanisms

Exercise 2.2 - x-ray dose

v.03

Problem Statement

Evaluate the dose deposited on a high-density polyethylene (HDPE) by an x-ray radiation (MoKα : 17'375eV) of intensity $5 \cdot 10^{-5}$ W/m ^{2} during 15 years.

The calculation shall be done for thicknesses ranging from 0 to 100mm
The result shall be expressed in [Gy], [rad] and [J/kg]

Mass attenuation coefficient [cm ^{2}/g], [RD1]:
https://www.rpcirkus.org/images/pdf/donneesdebase/DOC-DB-1_1_Attenuation_Massique.pdf
Note: Mass attenuation coefficient (EN) = Coefficient d'atténuation massique (FR)

Solution

Note: MoKα : type of x-ray radiation. Naming comes from the target material and type of emission line when an x-ray tube is used for the production of the x-ray. Here a molybdenum type target with Kα line. Hence a photon energy of 17'375 eV.

Incident flux [W/m ^{2}]:

In[•]:=
```
I0 = 5 × 10^-5;
```

in [eV/m ^{2}·s] (note: 1 eV = 1.602 176 634 × 10^−19 J), for information only:

In[•]:=
```
Iev = I0 1 / (1.602176634 × 10^-19)
```

Out[•]=

3.12075×10^{14}

Density of HDPE [kg/m ^{3}]:

In[•]:=
```
ρHDPE = 950;
```

Approximate mass attenuation coefficient in polyethylene at 17'375 eV [m ^{2}/kg] (cf. [RD1]):

In[•]:=
```
μHDPE = 0.6 × 10^-1;
```

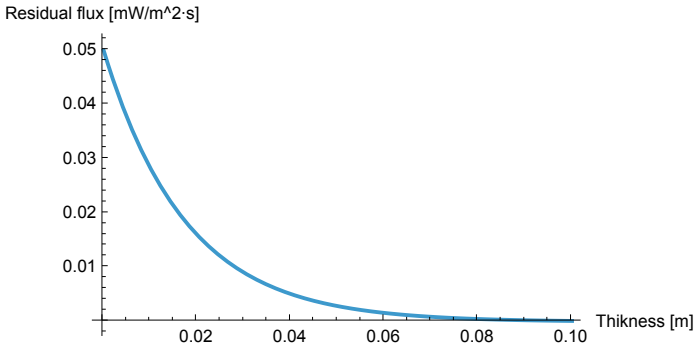
Residual flux after absorption through a sheet of thickness x [W/m ^{2}·s]:

In[•]:=
```
Ir[x_] = I0 Exp[-(μHDPE ρHDPE) x];
```

exponentielle

In[•]:=
```
Plot[1000 Ir[x], {x, 0, 100 × 10^-3},
 AxesLabel → {HoldForm["Thikness [m]"], HoldForm["Residual flux [mW/m^2·s]"]}
]
```

Out[•]=



Total absorbed energy

Total duration [s]:

In[•]:=
```
Δt = 15 × 365 × 24 × 3600;
```

Surface of the HDPE sheet (arbitrary value) [m ^{2}]:

In[•]:=
```
A = 1 (10^-2)^2;
```

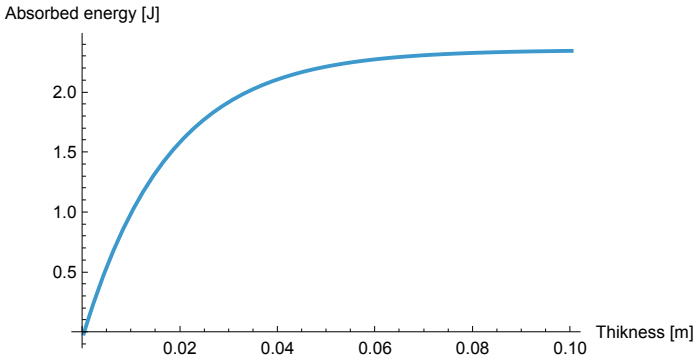
Total absorbed energy as a function of the thickness x of the sheet [J]:

In[•]:=
```
w[x_] = I0 Δt A (1 - Exp[-(μHDPE ρHDPE) x]);
```

Note: The absorbed energy depends on the surface of the absorbing sheet.

In[•]:=
```
Plot[w[x], {x, 0, 100 × 10^-3},
 AxesLabel → {HoldForm["Thikness [m]"], HoldForm["Absorbed energy [J]"]}
]
```

Out[•]=



Mass of the sheet [kg]:

In[•]:=
```
mHDPE[x_] = A x ρHDPE;
```

Total deposited dose

Total deposited dose [J/kg]:

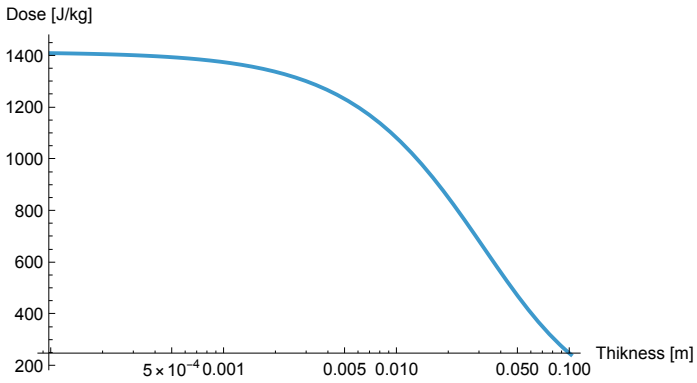
Note: Gy = 1 J/kg

In[•]:=
```
W_tot[x_] = w[x] / m_HDPE[x];
```

Note: The deposited dose not depend on the surface of the absorbing sheet.

In[•]:=
```
LogLinearPlot[W_tot[x], {x, 0, 100 × 10^-3},
 tracé log-linéaire
  AxesLabel → {HoldForm["Thikness [m]"], HoldForm["Dose [J/kg]"]}
  étiquette des axes  maintiens forme          maintiens forme
]
```

Out[•]=



In [Gy] or [J/kg]:

In[•]:=
```
W_tot[0.000001]
```

Out[•]=

```
1419.08
```

In [rad]:

In[•]:=
```
W_tot[0.000001] 10^4
```

Out[•]=

1.41908×10^{7}

Coefficient d'atténuation massique μ/ρ (cm^2/g)

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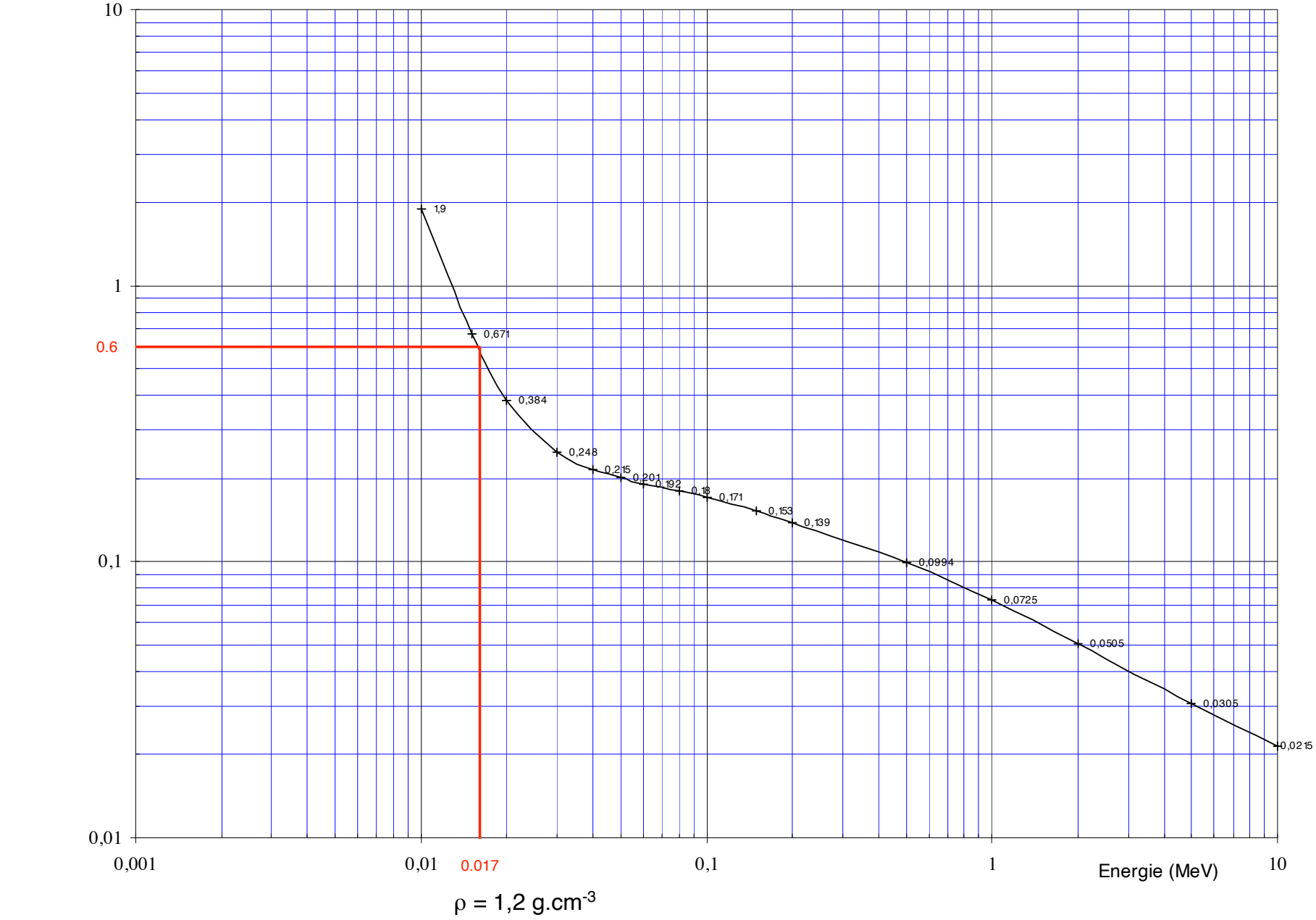

Source: https://www.rpcirkus.org/images/pdf/donneesdebase/DOC-DB-1_1_Attenuation_Massique.pdf