EE-580 Space Mechanisms

Exercise 2.1 - Solar Wind

v.02

Problem Statement

Numerical data

Mass of the sun [kg]:

In[•]:= $M_S = 1.99 \times 10^{30}$;

Mass flux of particles [Sun mass/year]:

In[•]:= $F_m = 1.6 \times 10^{-14}$;

Earth-Sun distance [km]:

In[•]:= $L = 150\,000\,000$;

Speed of the particles [m/s]:

In[•]:= $v = 450 \times 10^{3}$;

Type of particles: H_2 : 95%, He : 4%, O_2 : 1%

Earth radius [km]:

In[•]:= $R_{earth} = 6360$;

Questions

- Evaluate the total mass of particles arriving on Earth every day.
- Evaluate the number of solar wind particles impacting a 5 x 2 m^2 solar array every day.

Hint

The solar wind is composed of ionised particles.

Solution

Number of seconds in one year [s]:

```
In[•]:= Nb = 365 × 24 × 60 × 60
Out[•]=
31 536 000
```

Mass flux [kg/s]:

```
In[•]:= F_m = F_m M_S / Nb
Out[•]=
1.00964 × 10^9
```

Earth-Sun distance [m]:

```
In[•]:= L = L 10^3;
```

Molecular masses [g/mole] and percentage [%] of the particles:

- Hydrogen:

```
In[•]:= μ_0 = 1;
        ξ_0 = 0.95;
```

- Helium:

```
In[•]:= μ_1 = 4;
        ξ_1 = 0.04;
```

- Oxygen:

```
In[•]:= μ_2 = 16;
        ξ_2 = 0.01;
```

Average mass for one particle (consisting of the H, He and O molecules here above) [g/mole]:

```
In[•]:= M_avg = Σ_{i=0}^{2} (μ_i ξ_i)
Out[•]=
1.27
```

Average mass for one particle [kg/mole]:

```
In[•]:= M_avg = M_avg / 1000;
```

Avogadro constant $\left[\text{mole}^{-1}\right]$:

```
In[•]:= N_A = 6.022 × 10^23;
```

Number of particles emitted by the Sun per time unit [1/s]:

In[•]:= $N_S = \frac{F_m N_A}{M_{avg}}$

Out[•]=

4.78744×10^{35}

Particle flux at Earth orbit level [1/m ^{2}·s]:

In[•]:= $n_{Earth} = N_S \frac{1}{4 \pi L^2}$

Note: surface of the sphere or radius Sun-Earth, centered on the Sun

Out[•]=

1.69321×10^{12}

Particle flux of:

- H [1/m ^{2}·s]:

In[•]:= $n_H = n_{Earth}\, \xi_0$

Out[•]=

1.60855×10^{12}

- He [1/m ^{2}·s]:

In[•]:= $n_{He} = n_{Earth}\, \xi_1$

Out[•]=

6.77284×10^{10}

- O [1/m ^{2}·s]:

In[•]:= $n_O = n_{Earth}\, \xi_2$

Out[•]=

1.69321×10^{10}

Number of particles arriving on Earth every day

Earth radius [m]:

In[•]:= $R_{earth} = R_{earth}\, 1000;$

Earth disk surface [m ^{2}]:

In[•]:= $A_{earth} = \pi R_{earth}^2;$

Solar wind particle mass flux on the Earth per day [kg]:

In[•]:= $F_{earth} = M_{avg} \frac{n_{Earth}}{N_A} A_{earth}\, (24 \times 3600)$

Out[•]=

39 205.9

Number of impacts on the solar array

Solar array surface [m ^{2}]:

In[•]:=
```
A_sa = 2 × 5
```

Out[•]=
```
10
```

Number of impacts per day:

In[•]:=
```
i_sa = n_Earth A_sa (24 × 3600)
```

Out[•]=
```
1.46293 × 10^18
```