Problem VI.2 ... bombarded organizer

3 points; průměr 2,12; řešilo 42 studentů

Estimate how many antineutrinos created in Czech nuclear power plants pass through the body of an average FYKOS organizer in one meeting held for a FYKOS camp. The meeting is 4 hours long and takes place on the tenth floor of the Matfyz building at the Troja campus in Prague.

Jarda felt under pressure at the meeting.

On average, there are approximately six electron antineutrinos per fissioned uranium-235 nucleus. This information is difficult to find; we take our value from the decay series given here.[1] However, artificial intelligence estimates it at around three. Therefore, while correcting, we will consider the process and the order of magnitude of the result rather than its exact match with our final value.

Temelín nuclear power plant[2] consumes around $m = 3\,\mathrm{kg}$ of uranium 235 each day, which coresponds to

$$N_\mathrm{T} = 6\frac{m}{M_\mathrm{U}}\frac{1}{T} \doteq 5 \cdot 10^{20}\,\mathrm{s}^{-1}$$

antineutrinos per second, where M_U is the atomic mass of $^{235}\mathrm{U}$ and $T = 86\,400\,\mathrm{s}$ is the length of one day.

We repeat the same calculation for the Dukovany nuclear power plant, where the annual uranium consumption is about $m_\mathrm{r} = 35\,\mathrm{t}$, while uranium 235 makes about $4.25\,\%$ from this amount.[3] The number of antineutrinos per second is then

$$N_\mathrm{D} = 6\frac{0.042\,5 \cdot m_\mathrm{r}}{M_\mathrm{U}}\frac{1}{365 \cdot T} \doteq 7 \cdot 10^{20}\,\mathrm{s}^{-1}\,.$$

We locate the positions of Temelín and the Matfyz building on the map[4] and learn that they are 104 km appart. The plant in Dukovany is 167 km away from the Matfyz building. Considering our inaccuracies, the height of the building is negligible.

Since antineutrinos hardly interact with the surrounding matter and we consider the power plant as an isotropic source of these particles, we can estimate the particle flux from each power plant at Matfyz as

$$j_i = \frac{N_i}{4\pi r_i^2}\,,$$

where i denotes the index of the powerplant. We estimate the cross-section of an organizer to be (at most) $S = 0.5\,\mathrm{m}^2$, which can be even lower depending on his stance. The antineutrino flux from both plants does not have the same direction. Still, we will neglect that because we have already made a significant error in estimating the organizer's cross-section. The time of the meeting is $t = 14\,400\,\mathrm{s}$. The number of antineutrinos is thus

$$N = St\,(j_\mathrm{T} + j_\mathrm{D}) = St\left(\frac{N_\mathrm{T}}{4\pi r_\mathrm{T}^2} + \frac{N_\mathrm{D}}{4\pi r_\mathrm{D}^2}\right) \doteq 4 \cdot 10^{13}\,.$$

[1] `http://hyperphysics.phy-astr.gsu.edu/hbase/NucEne/fisfrag.html`

[2] `https://www.svetenergie.cz/cz/energetika-zblizka/jaderne-elektrarny/jaderne-elektrarny-cez/jaderna-elektrarna-temelin`

[3] `https://cs.wikipedia.org/wiki/Jaderná_elektrárna_Dukovany`

[4] `https://mapy.cz/`

All in all, about ten trillion antineutrinos produced in Czech nuclear power plants will pass through the organizer during the meeting.

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