**Problem to be solved:**

Naturally-occurring radioactive minerals accumulate on the sticky surfaces of tobacco leaves as the plant grows, and these minerals remain on the leaves throughout the manufacturing process. Additionally, the use of the phosphate fertilizer Apatite – which contains radium-226, lead-210, and polonium-210 – also increases the amount of radiation in tobacco plants.

The radium-226 that accumulates on the tobacco leaves predominantly emits alpha and gamma radiation. The lead-210 and polonium-210 particles lodge in the smoker’s lungs, where they accumulate for decades (lead-210 has a half-life of 22.3 years). The tar from tobacco builds up on the bronchioles and traps even more of these particles. Over time, these particles can damage the lungs and lead to lung cancer.

![Diagram of how polonium gets into tobacco](image)

**Figure 1: How Polonium Gets Into Tobacco, [Melpor]**

Calculate the absorbed dose, dose equivalent and effective dose for bronchial tubes from polonium-210, which a heavy smoker (1.5 packs of cigarettes per day) will obtain in one year. Neglect other radiation sources in tobacco, like lead.
Assumptions & Hints:

1) Over time, the radiation level emitted from cigarette smoking approaches a steady-state level. The steady state level is reached when the $^{210}\text{Po}$ that decays each day is exactly cancelled by the amount of $^{210}\text{Po}$ that is being inhaled every day. Assume that the smoker has reached steady state.


3) Number of cigarettes in a pack of cigarettes is 20.

4) Assume the mass for bronchial tubes to be 1kg.

5) $^{222}\text{Rn}$ belongs to the radium and uranium-238 decay chain, and has a half-life of 3.8235 days. Its four first products (excluding marginal decay schemes) are very short-lived, meaning that the corresponding disintegrations are indicative of the initial radon distribution. Its decay goes through the following sequence:
   - $^{222}\text{Rn}$, 3.8 days, alpha decaying to...
   - $^{218}\text{Po}$, 3.10 minutes, alpha decaying to...
   - $^{214}\text{Pb}$, 26.8 minutes, beta decaying to...
   - $^{214}\text{Bi}$, 19.9 minutes, beta decaying to...
   - $^{214}\text{Po}$, 0.1643 ms, alpha decaying to...
   - $^{210}\text{Pb}$, which has a much longer half-life of 22.3 years, beta decaying to...
   - $^{210}\text{Bi}$, 5.013 days, beta decaying to...
   - $^{210}\text{Po}$, 138.376 days, alpha decaying to...
   - $^{206}\text{Pb}$, stable.

6) Polonium-210 alpha decay energy is $E_\alpha = 5.307\text{ MeV}$. 