PROBLEM 1

COOKING WITH STEANLESS-STEEL

MATERIALS

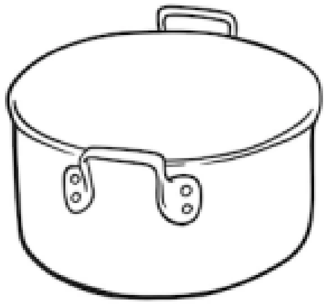
- Copper
- Aluminium
- Carbon Steel
- Cast Iron
- Clay and Stoneware
- Ceramic
- **Stainless Steel**

Iron
Carbon
Manganese
Phosphorus
Nickel
Chromium

COMPOSITION

Exercise 1: Stainless Steel

1) Calculate the stainless-steel amount [in g] used in one pot. Determine the amount of chromium and nickel [in g] present in the stainless-steel of the pot.



2) Calculate the stainless-steel amount used in all pots of Austria (2 pots per family). Determine the amount of chromium and nickel [in Kg] present in the stainless-steel of the pots.

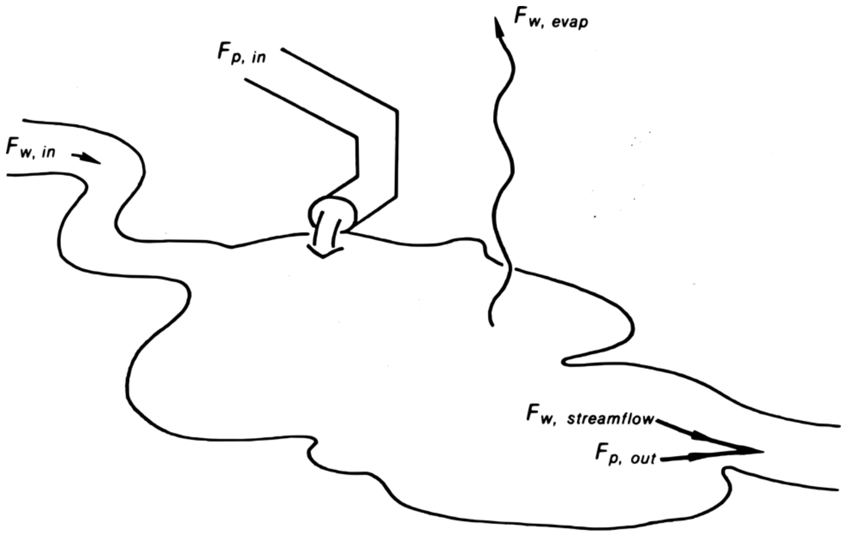
3) According to the release of chromium from stainless-steel in specific environmental conditions (0.6 mg Cr m^{-2} $year^{-1}$), determine the total amount of chromium released into the environment in these conditions from all pots used in Austria in 10 years.

Important:

- For this exercise, you may ignore the pots handless for calculations. Also ignore the pots of restaurants and similar.
- Describe each step in your calculation so anyone could follow it.
- State any and all sources for values you use in your calculations.

PROBLEM 2

A Polluted Lake



Pollutant Flow – through (F_p) ➡ BALANCE 1

Water flow – through (F_w) ➡ BALANCE 2

Flows:

- Inlet
- Outlet
- Evaporation
- Stream flow

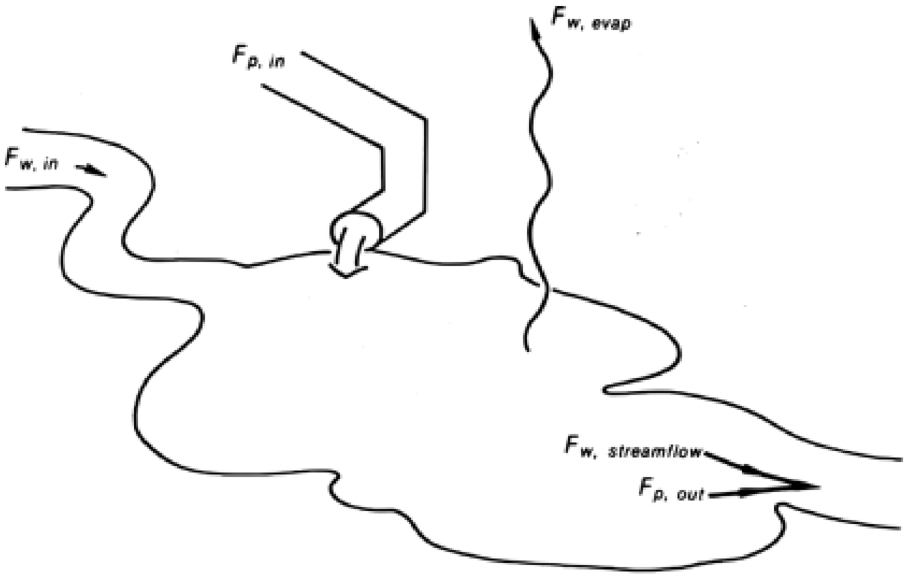
RESIDENCE TIME

$$\frac{Volume\ of\ water}{Flow - through\ of\ water}$$

CONCENTRATION

$$\frac{Residence\ time\ * Pollutant\ Flow}{Volume\ of\ water}$$

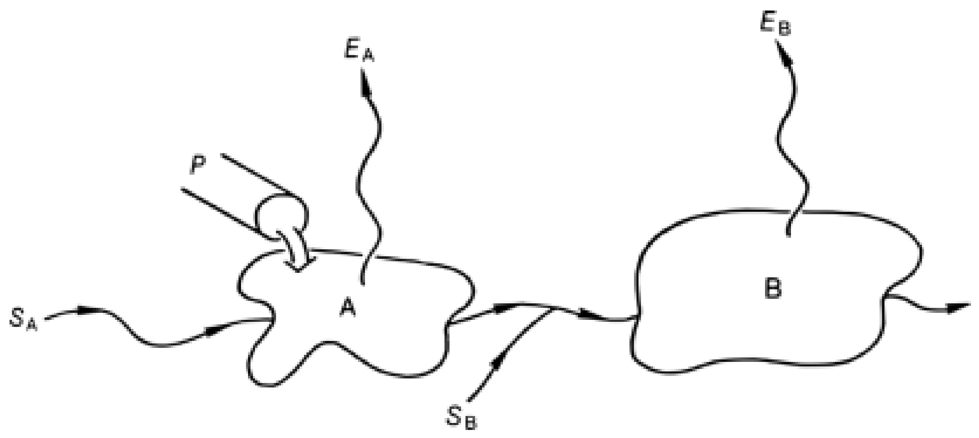
A stable and highly soluble pollutant is dumped into a lake at the rate of $F_{P,\,in}$ = 0.16 tons per day. The lake volume is 4 x 10^7 m^3 and the average water flow-through rate is 8 x 10^3 m^3/day. Ignore evaporation from the lake surface ($F_{W,\,evap}$) and assume the pollutant is uniformly mixed in the lake.



$$F_{p,\,in} = F_{p,\,out}$$
$$F_{w,\,evap} + F_{w,\,streamflow} = F_{w,\,out} = F_{w,\,in}$$

1) What is the residence time of the pollutant in the lake?
2) What is the total mass of pollutant in the lake at steady-state?
3) Assume the pollutant is chromium. What would be the molarity of the pollutant in the lake?
4) By how much does the steady-state concentration change if 1/3 of the outflow is instead lost to evaporation? Would this principally be true for all pollutants?

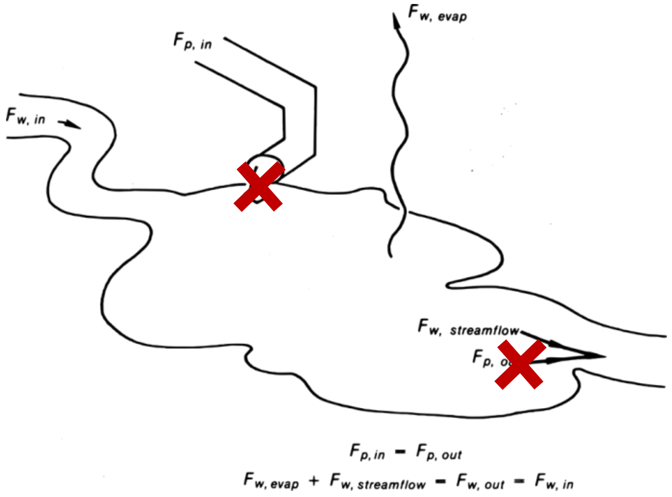
Two lakes are located on the same river, as shown in the figure below. A is upstream of B. Water flows into A at a rate S_A; it evaporates from A at a rate E_A and from B at a rate E_B. A tributary flows into the river between A and B at a rate S_B. Evaporation from the streams can be ignored. A soluble pollutant flows into the lake A at rate P. There are no other sources of the pollutant, it is well mixed in both lakes, and it does not codistill. The lakes have water volume V_A and V_B, respectively, and are in hydrological steady states.



5) What is the rate of stream flow out of lake A? Into lake B?
6) What is the residence time of water in lake A? In lake B?
7) In the steady-state, what concentration of pollutant will be found in each lake if P is given in units of grams per second, the S's and E's are in units of liters per second, and the V's are in units of liters?

PROBLEM 3

A Polluted Lake



STEADY - STATE

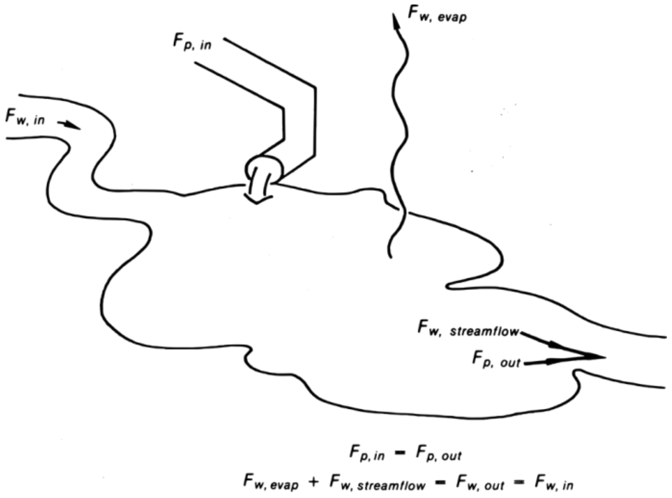
RESIDENCE TIME

$$\frac{Volume\ of\ water}{Flow - through\ of\ water}$$

CONCENTRATION

$$\frac{Residence\ time\ * Pollutant\ Flow}{Volume\ of\ water}$$

Fp, in = 40 tons/year



NOT STEADY - STATE

$$Fp, out = Cp * Fw, out = \frac{Mp}{Volume\ of\ water} * Fw,\ out$$

$$\frac{dMp}{dt} = Fp, in - Fp, out$$

Exercise 3: Pollution buildup in a lake

A lake has a volume of 10^6 m^3 and a surface area of 6 x 10^4 m^2. Water flows into the lake at an average rate of 0.005 m^3/sec. The amount of water that evaporates yearly from the lake is equivalent in volume to the lake's top meter of water. Initially, the lake water is pristine, but at a certain time a soluble, non-codistilling pollutant is discharged into the lake at a steady state rate of 40 tons/yr. [Assume a density of water of 1000 kg/m^3.]

1) How high is the stream and seepage outflow from the lake? [in tons/year]
2) What is the rate of pollutant outflow, $F_{p,out}$? [in mass/time] (Hint: Your result won't be a numerical value as in 1) but instead be dependent on a variable.)

The differential equation describing the mass of pollutant in the lake [in tons] at any time t is:

$$\frac{dM_p}{dt} = F_{p,in} - F_{p,out}$$

1) Enter the mass fluxes $F_{p,in}$ and $F_{p,out}$. What is the general form of this differential equation? What is its general solution?
2) Solve the differential equation. What amount and what concentration of pollutant will exist in the lake as t approaches infinity?
3) Draw a plot of the concentration build-up over 40 years, in 2-year intervals, starting at t = 0.

PROBLEM 4

Aluminium in the Himalaya

Variation on the stock-flow-residence time problem

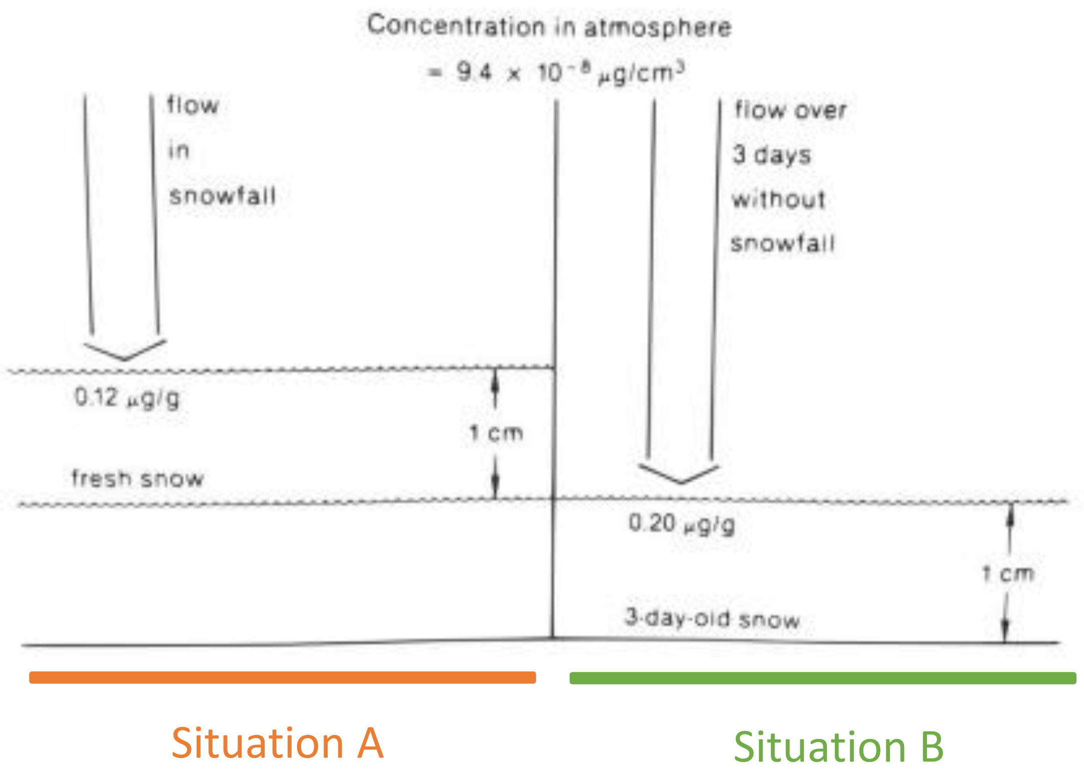
Deposition flow (μg/(cm^2 x day))

Situation B – Situation A

Density, time and accumulation

Deposition velocity (cm/day)

Deposition flow and initial concentration in atmosphere



Stokes Law

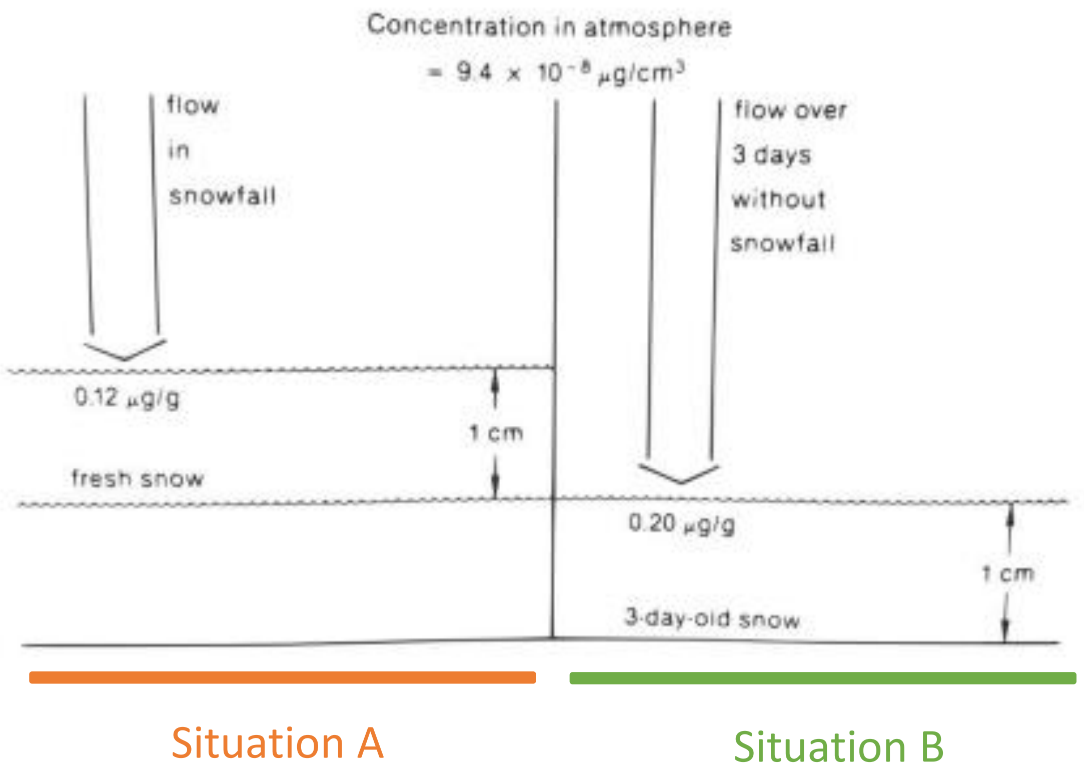
Describes the rate at which objects fall through a medium like air or water.

$$F = 6 \text{ pi } r \, n \, v = m \, g$$

Average mass of a particle

$$M_{particle} = 4/3 \times \text{pi} \times r^3 \times \text{rho}_{aerosol}$$

Particle Size



Exercise 4: Aluminium in the Himalaya

In a remote area in Nepal, the concentration of aluminium (Al) in outdoor air at ground level averages 9.4×10^{-8} µg/cm^3. (It is much higher inside the Sherpa dwellings because of wood and yak dung burning.) At the same site, the Al concentration in the top 1 cm of fresh snow averages 0.12 µg/g, while in the top 1 cm of three-day-old snow it averages 0.20 µg/g.

1) Calculate the average deposition velocity of the Al falling to the ground when it is not snowing. [in cm/s]
   Hint:
   - this is a variation on the stock-flow-residence time problem from earlier exercises

2) How large are the particles to which the falling aluminium is attached? [in µm]
   Hint:
   - Stokes Law describes the rate at which objects fall through a medium like air or water
   [assume: viscosity of air = 1.68×10^{-4} poise]