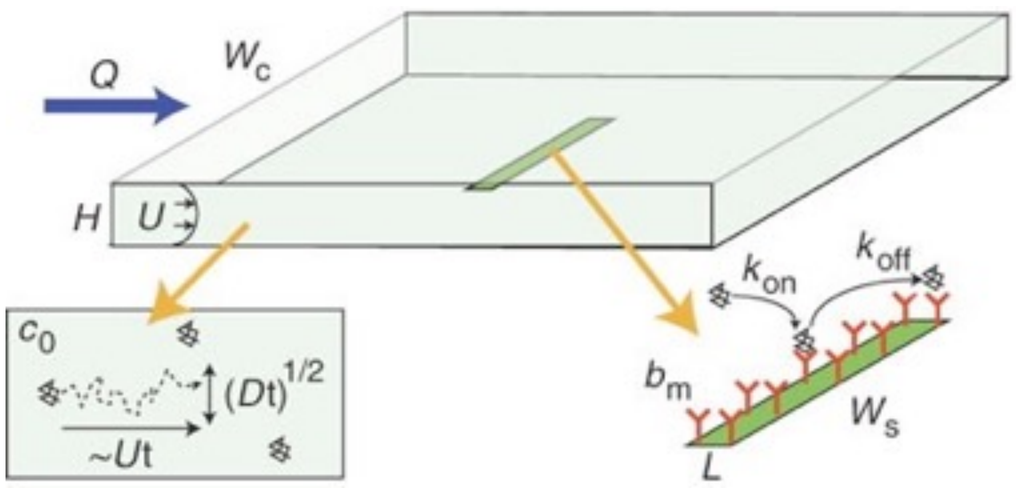
How are we doing on our set of problems ?

The Alex Thomson problem

how much water vapor is permeating through his clothing ?

using the molar fluxes due to diffusion and convection in a binary mixture, we calculated the molar fraction gradient of water vapor and the flux of water vapor through a goretex membrane

The microchip problem



How do you design precisely a biochemical sensor on a microchip ?

There are two relevant dimensionless parameters $Pe_H=UH/D$, $\lambda=L/H$
In the limit Pe >> λ and fast chemical reaction:
Dimensionless mass flux (Sherwood number) = 0.5 $Pe_H^{1/3}\ \lambda^{1/3}$

Transport is determined by the thickness of the concentration boundary layer

Questions remaining :
what is the flux in the reaction limited regime ?
what is the equilibration time in the transport limited regime ?

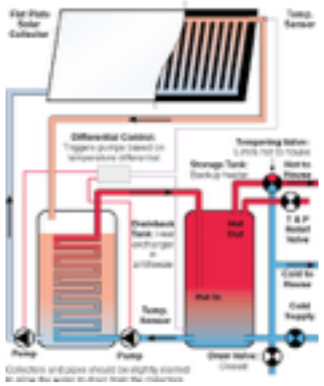
The coffee cup problem

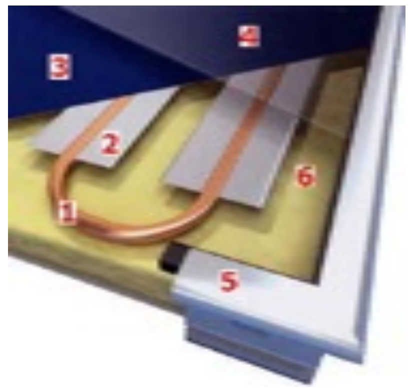
If you don't stir the sugar in your coffee, why does it get cold way before it is sweetened ?

How long does it take for the sucrose to diffuse to the top ?
At least weeks, months for a big cup.

If diffusion in air is the only mechanism, it takes 6 hours to cool down to room temperature …. we need something else.

The solar heater problem





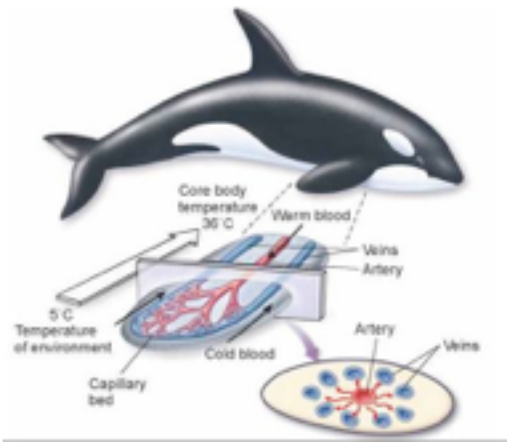
How many showers can you take per week with a 10 m^2 solar water heater ?

- The solar constant is 1300 W/m2
- In France, number of hours of sunshine is between 1500 and 3000 (between 17 and 34% of the time)
- The power collected on a 10m^2 solar heater is on average between 2200 and 4400 W

- remaining questions : how much do we lose by convection and radiation at the collector
- what is the efficiency of the heat exchanger ?

- a single shower : 50 liters at 40°C
  amount of heat required (starting from water at 10°C) : 4 10^3 X 50 X 30 = 6 MJ

The flipper problem



what do cetaceans and solar heaters have in common ?

- what is the efficiency of the heat exchanger in the flippers ?

The microprocessor problem

How do you design the radiator of a $10 cm^2$, 50 W microprocessor ?

If we rely only on diffusion in air,we can dissipate 0,2 W

We can increase the flux by adding a series of fins, but there is an optimum length L_m for fins depending on their thickness e and the heat transfer coefficient h. $L_m \sim (e\ \lambda_{aluminum}/h)^{1/2}$

Remaining questions :
what is the value of the heat transfer coefficient between fins and air ?
what is the flow rate of air required ?

The Maurice Herzog problem

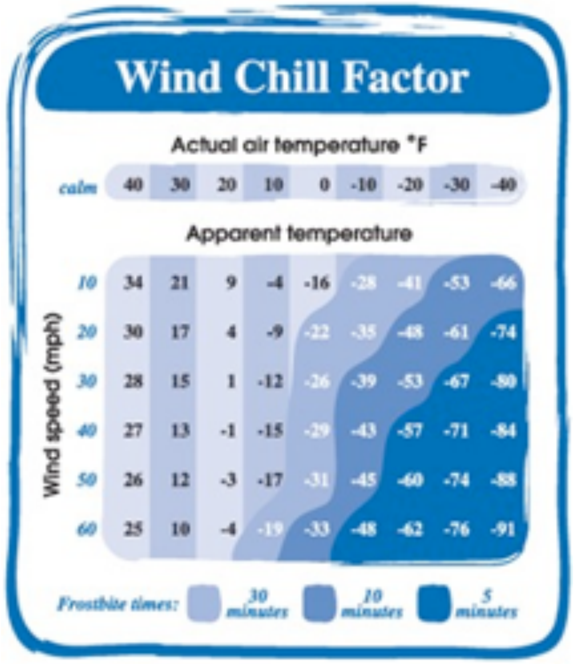
How long can you stand on top of Annapurna without gloves ?
(no wind)

The bioheat equation provides an estimate of the temperature distribution in the fingers at steady state

time to reach the steady state ?

The Maurice Herzog problem II

How long can you stand on top of Annapurna without gloves ?
(with wind)



Wind Chill Factor

Actual air temperature °F

Wind speed (mph)									
calm	40	30	20	10	0	-10	-20	-30	-40

Apparent temperature

Wind speed (mph)									
10	34	21	9	-4	-16	-28	-41	-53	-66
20	30	17	4	-9	-22	-35	-48	-61	-74
30	28	15	1	-12	-26	-39	-53	-67	-80
40	27	13	-1	-15	-29	-43	-57	-71	-84
50	26	12	-3	-17	-31	-45	-60	-74	-88
60	25	10	-4	-19	-33	-48	-62	-76	-91

Frostbite times: 30 minutes, 10 minutes, 5 minutes

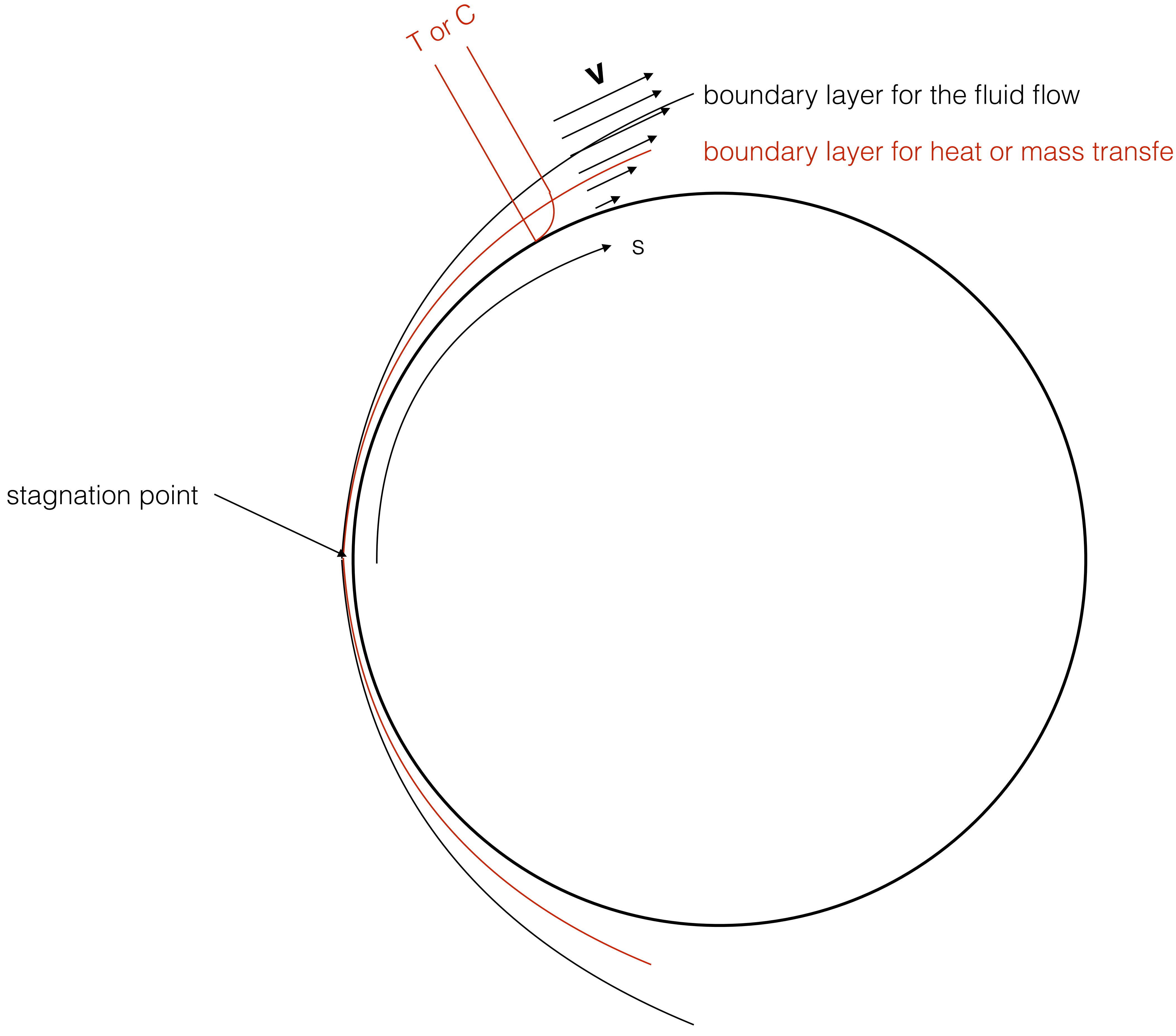
WIND CHILL FORMULA

T – TEMPERATURE (F), V – WIND SPEED (MPH)

$$35.74 + 0.6215(T) + V^{0.16}\,[0.4275(T) - 35.75]$$

estimate the Reynolds number for the flow of air around one finger
estimate the Peclet number for heat transport
simplify the heat transport equation
derive scaling laws for $\delta_V(x)$ and $\delta_T(x)$
estimate the heat flux and the heat transfer coefficient

wind speed U 1 to 10 m/s
Physical properties of air :
  density 1 kg/m^3
  specific heat 1000 J/kg.K
  thermal conductivity 0.025 W/m.K
  kinematic viscosity 1.5 10^{-5} m^2/s


T or C
V
boundary layer for the fluid flow
boundary layer for heat or mass transfer
s
stagnation point