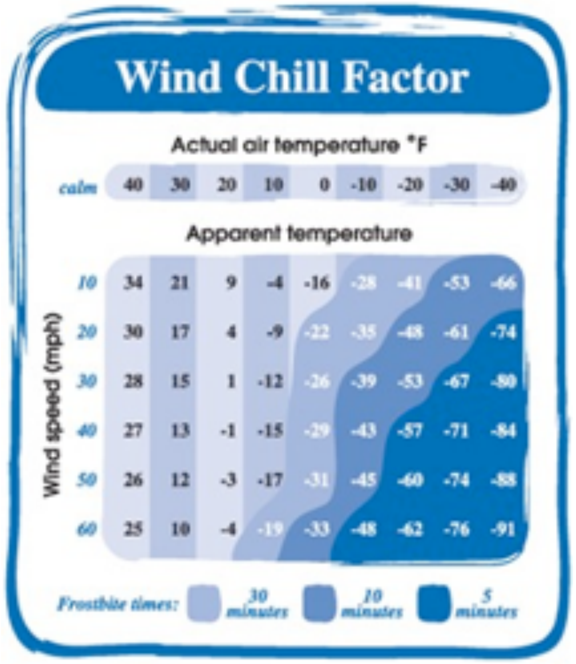
The Maurice Herzog problem II

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								
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

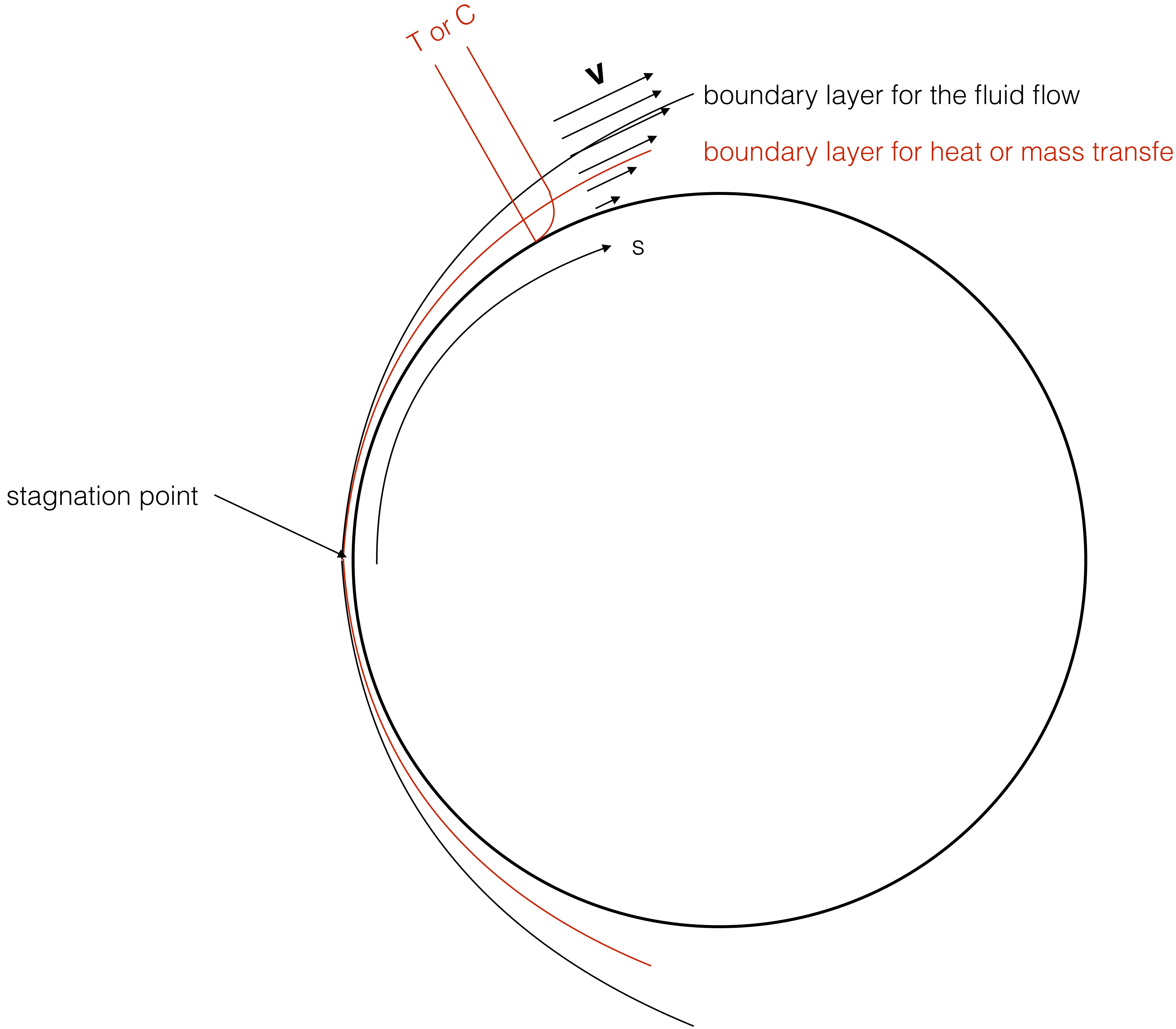
WIND CHILL FORMULA

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

$$\delta T(x) \sim x\, Re_x^{-1/2}\, Pr^{-1/3}$$

$$\text{total flux} \sim \lambda\, \Delta T\, Pr^{1/3}\, Re_L^{1/2}$$

$$\text{purely diffusive flux} \sim \lambda\, (\Delta T/L)\, L = \lambda\, \Delta T$$

$$\text{Nusselt number} = \text{total/diffusive} = Pr^{1/3}\, Re_L^{1/2}$$

effective heat transfer coefficient h :

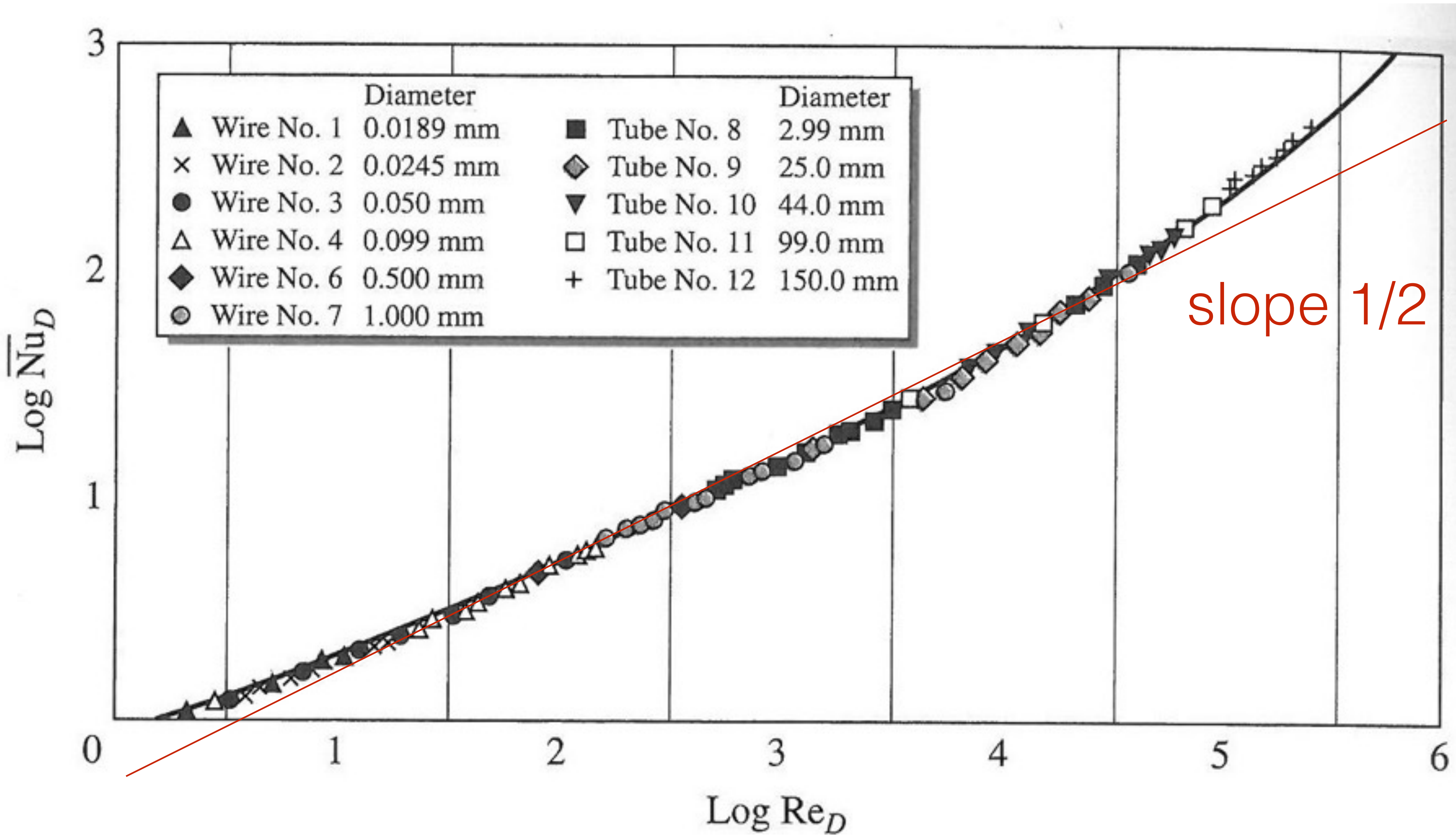
$$\text{total flux} = h\, \Delta T\, L$$

$$h = \lambda/L\, Pr^{1/3}\, Re_L^{1/2}$$

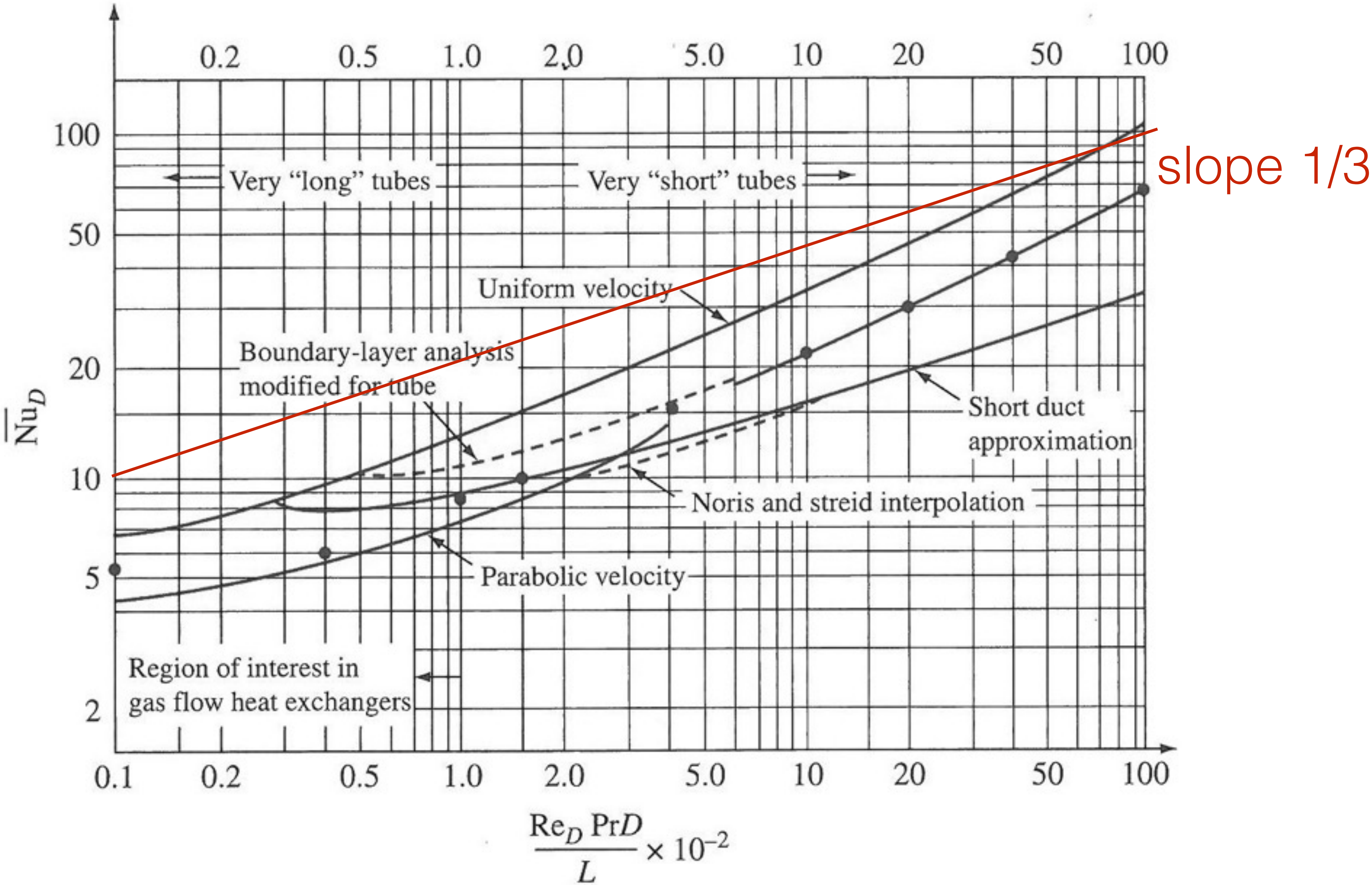
WIND CHILL FORMULA

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

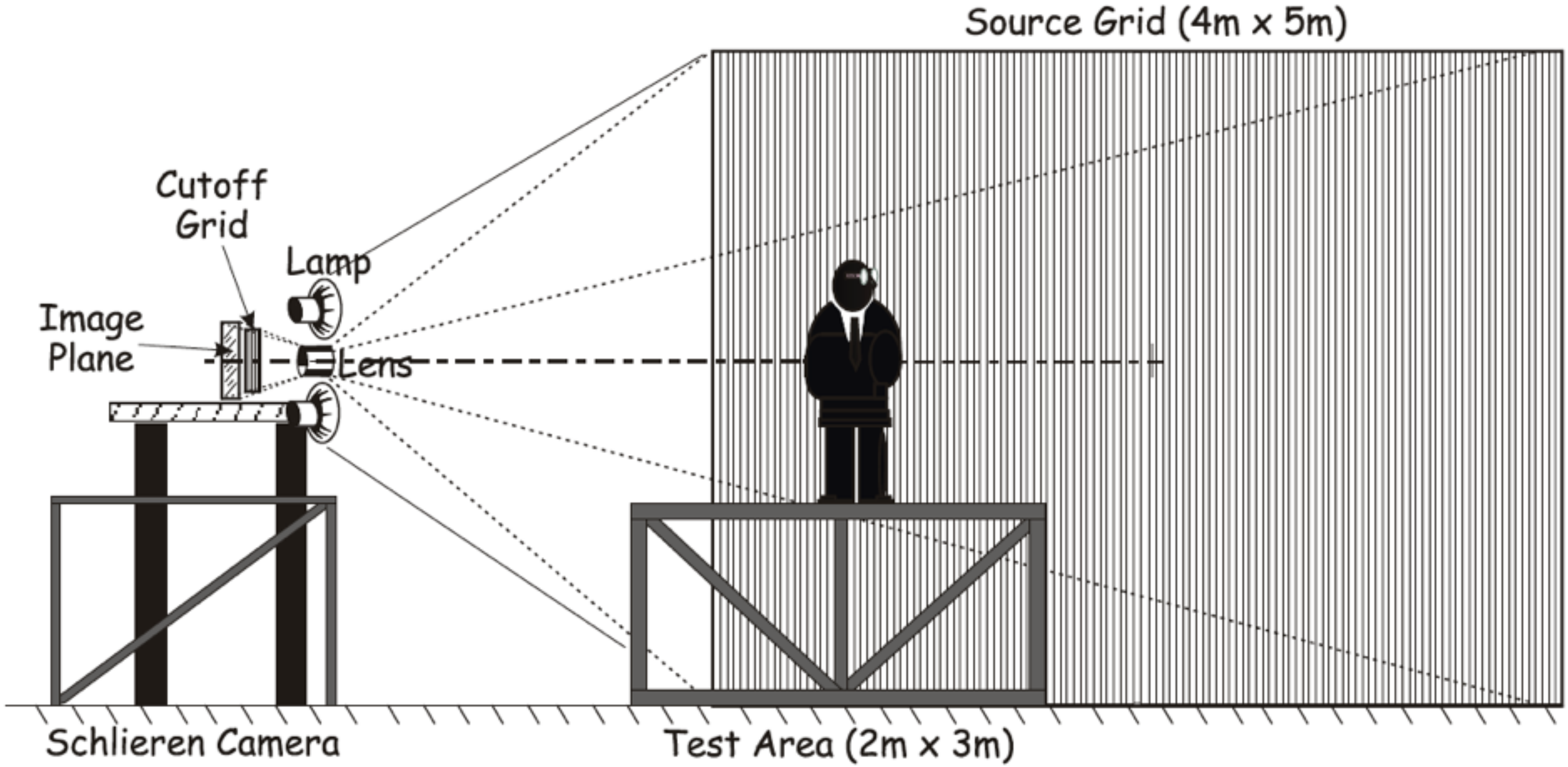
$$35.74 + 0.6215(T) + V^{0.16}\,[0.4275(T) - 35.75]$$

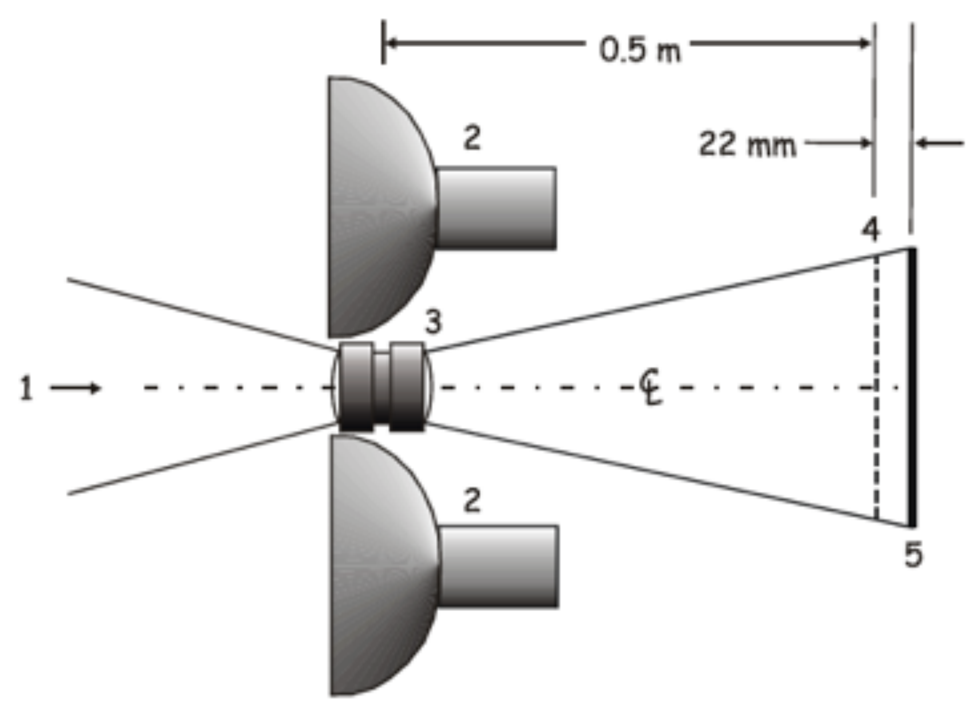


Nusselt number $Nu_D = J_{eff}/J_D = J_{eff}\, R/\Delta T\, \kappa$
vs Reynolds number $Re = UR/\nu$
for a cylinder in a cross flow



Nusselt number $Nu_D = J_{eff}/J_D = J_{eff}\, D/\Delta T\, \kappa$
vs modified Pellet number $Re\ Pr\ (D/L) = UD/\kappa\ (D/L)$
for heat transfer inside a cylindrical tube


Source Grid (4m x 5m)
Cutoff Grid
Lamp
Image Plane
Lens
Schlieren Camera
Test Area (2m x 3m)


0.5 m
22 mm
1
2
3
4
5
2

$$\frac{\partial \mathbf{u}}{\partial t} + \mathbf{u}.\nabla \mathbf{u} = -\frac{\nabla p^*}{\rho_0} + \nu \Delta \mathbf{u} - \alpha (T - T_0) \mathbf{g}$$

inertia **viscosity** **buoyancy**

$$\frac{\partial T}{\partial t} + \mathbf{u}.\nabla T = \kappa \Delta T$$

heat diffusivity

7 physical quantities U,L,g,α, ΔT,v,κ

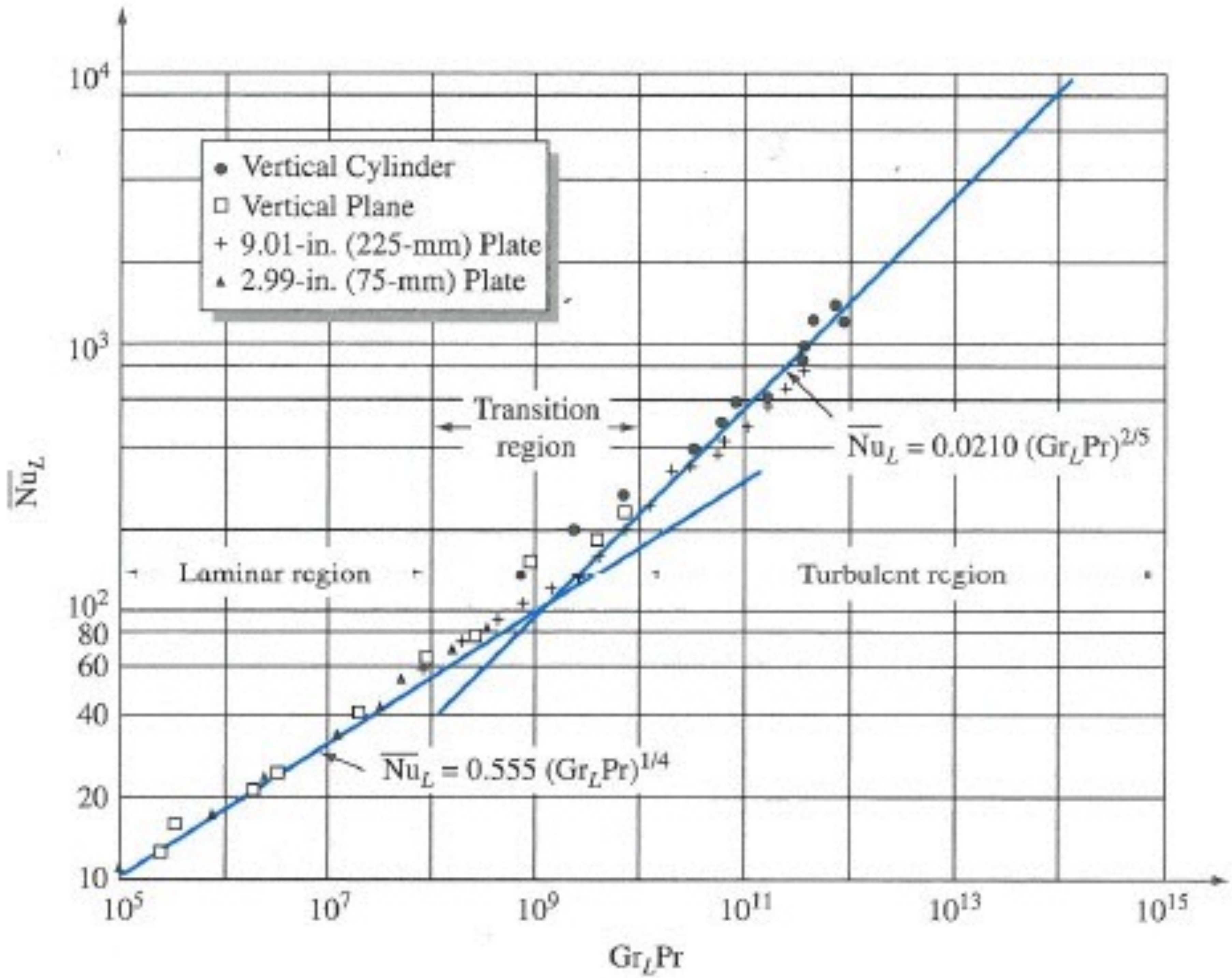
4 primary dimensions : mass, length,time,temperature

7-4=3 dimensionless groups

Re = UL/v = inertia/viscosity (not independent)

Pr = v/κ = viscosity/heat diffusivity

Gr = α g ΔT L^3/v^2 =buoyancy force/viscous force at Re=1



Vertical Cylinder
Vertical Plane
9.01-in. (225-mm) Plate
2.99-in. (75-mm) Plate
Transition region
Laminar region
Turbulent region
$\overline{Nu}_L = 0.0210\ (Gr_L Pr)^{2/5}$
$\overline{Nu}_L = 0.555\ (Gr_L Pr)^{1/4}$
$\overline{Nu}_L$
$Gr_L Pr$
10^4
10^3
10^2
80
60
40
20
10
10^5
10^7
10^9
10^{11}
10^{13}
10^{15}

The coffee cup problem

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

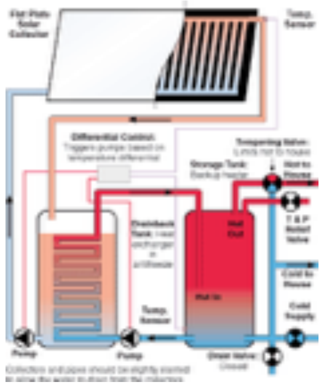
How long does it take for the sucrose to diffuse to the top ?
At least weeks, months for a big cup.

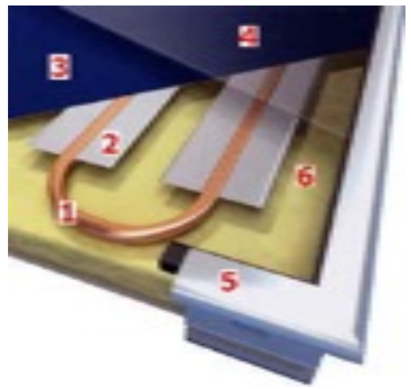
If diffusion in air is the only mechanism, it takes 6 hours to cool down to room temperature …. we need something else.
Something else is thermal convection

Estimate the Rayleigh number for the coffee cup, deduce the relevant Nusselt number and estimate the heat flux due to thermal convection

Physical properties of air :
density 1 kg/m^3
Prandtl number : 0.7
kinematic viscosity 1.5 10^{-5} m^2/s
coefficient of thermal expansion : 3.5 10^{-3}

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

- estimate the Rayleigh number for thermal convection outside the collector, deduce the relevant Nusselt number and estimate the heat flux due to thermal convection

Physical properties of air :

density 1 kg/m^3

Prandtl number : 0.7

kinematic viscosity 1.5 10^{-5} m^2/s

coefficient of thermal expansion : 3.5 10^{-3}