Quizz 2 - Question 3

how do you solve the problem when you have 2D heat transfer problems using the Heisler charts?

Heisler charts $Y = \frac{T(\text{location}, t^*) - T_\infty}{T_i - T_\infty}$ ← time.

X, or r

↑ slab

↳ for cylinder or sphere

when $h \to \infty$ $m \to 0$ $T_\infty \to T_s$

↑ surface temperature.

location needs to be identified

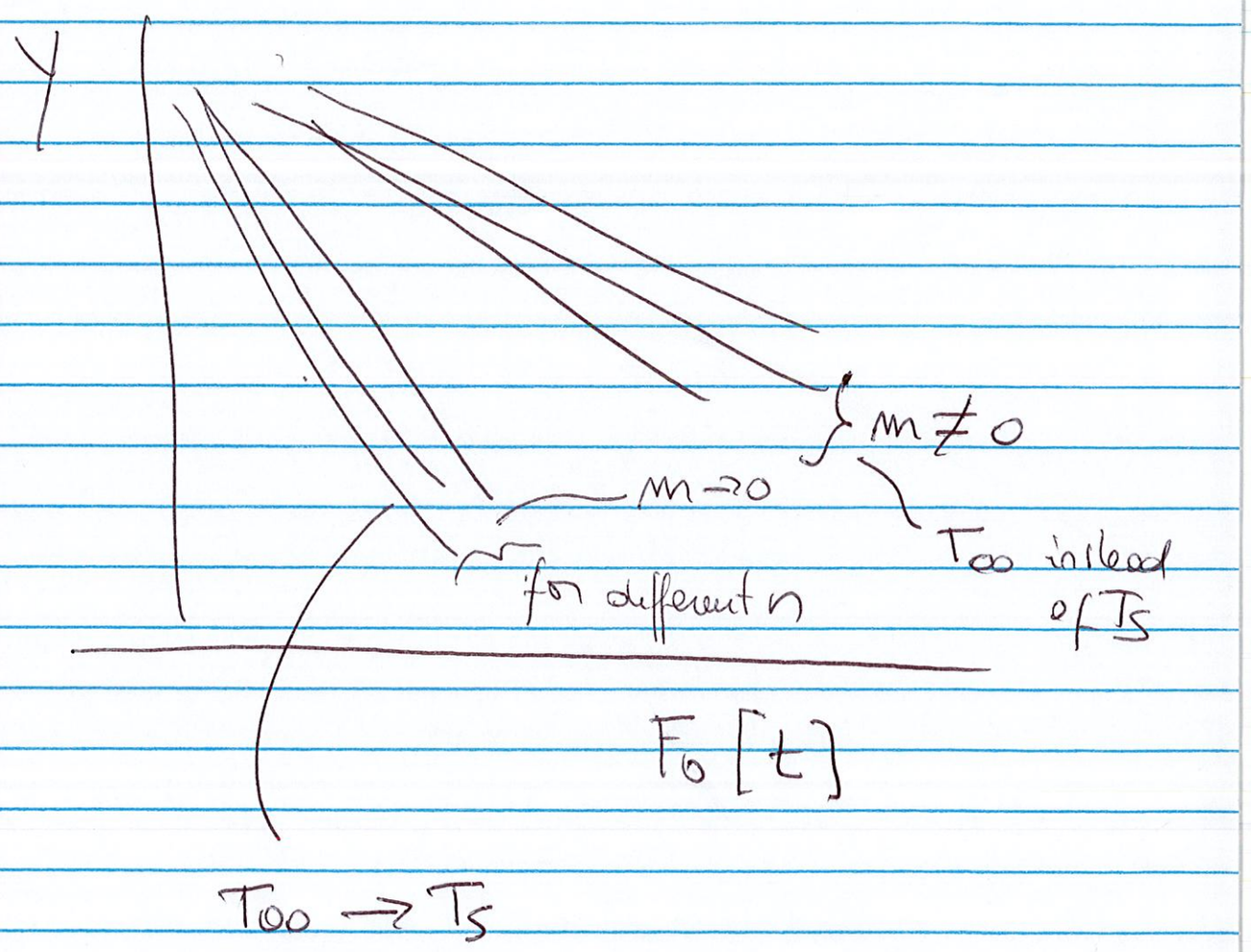
For a slab $n = \frac{x}{L}$ ← location; L ← characteristic length.

↳ dimensionless location

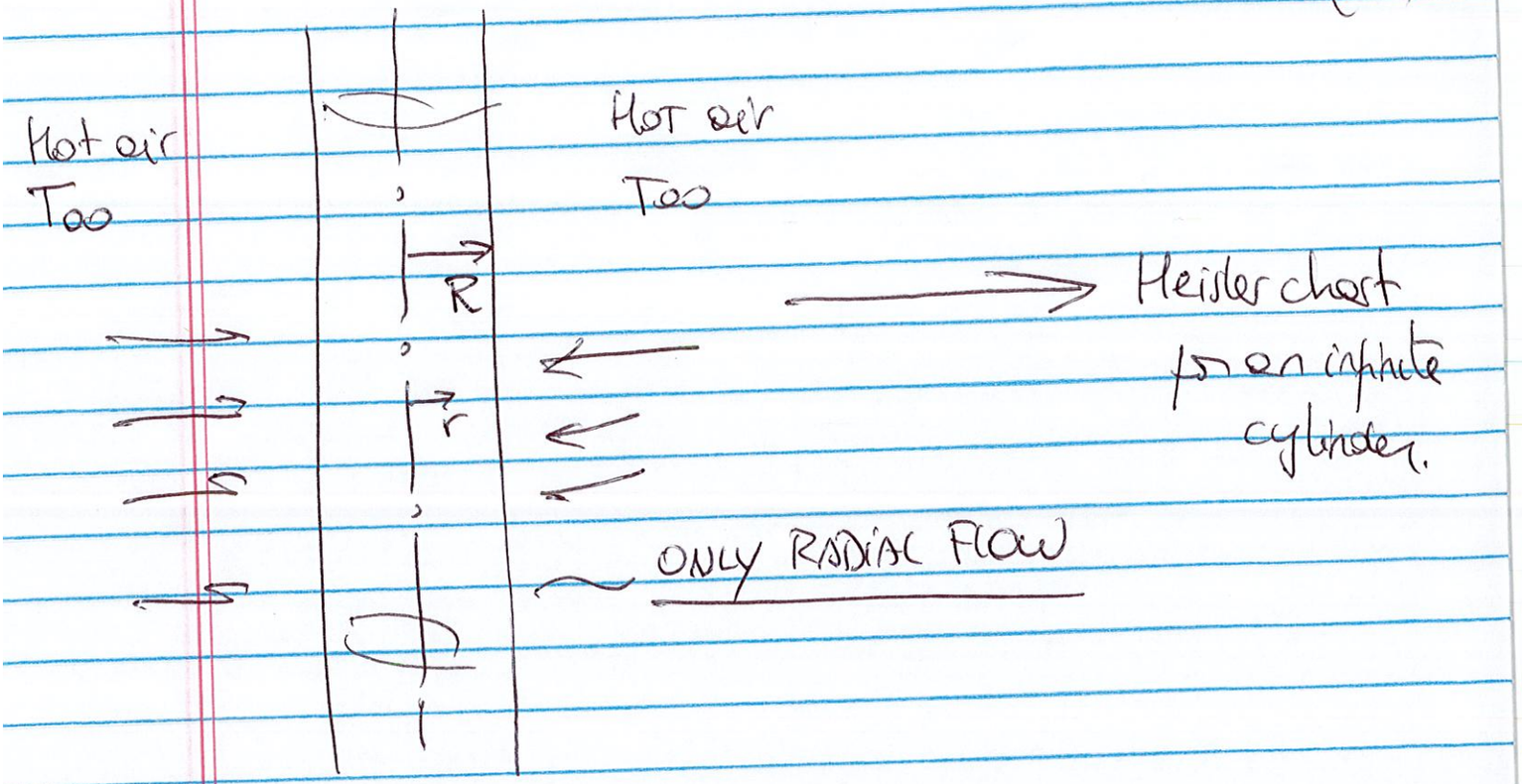
For a cylinder or sphere $n = \frac{r}{R}$ ← location; R ← radius

$$m = \frac{\lambda}{Bi} \qquad Bi = \frac{hL}{K} \qquad (2)$$

when $h \to \infty$ $Bi \to \infty$ $m \to 0$

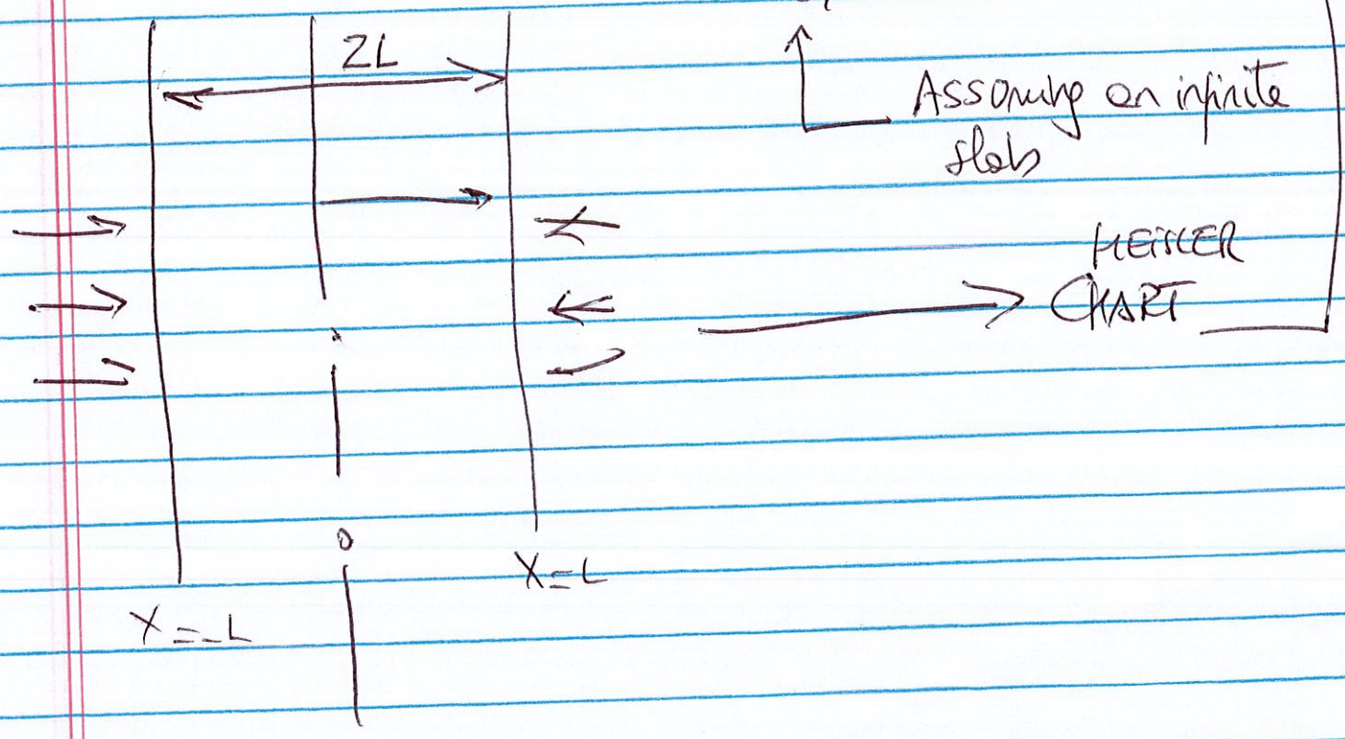


INFINITE CYLINDER "MODEL"

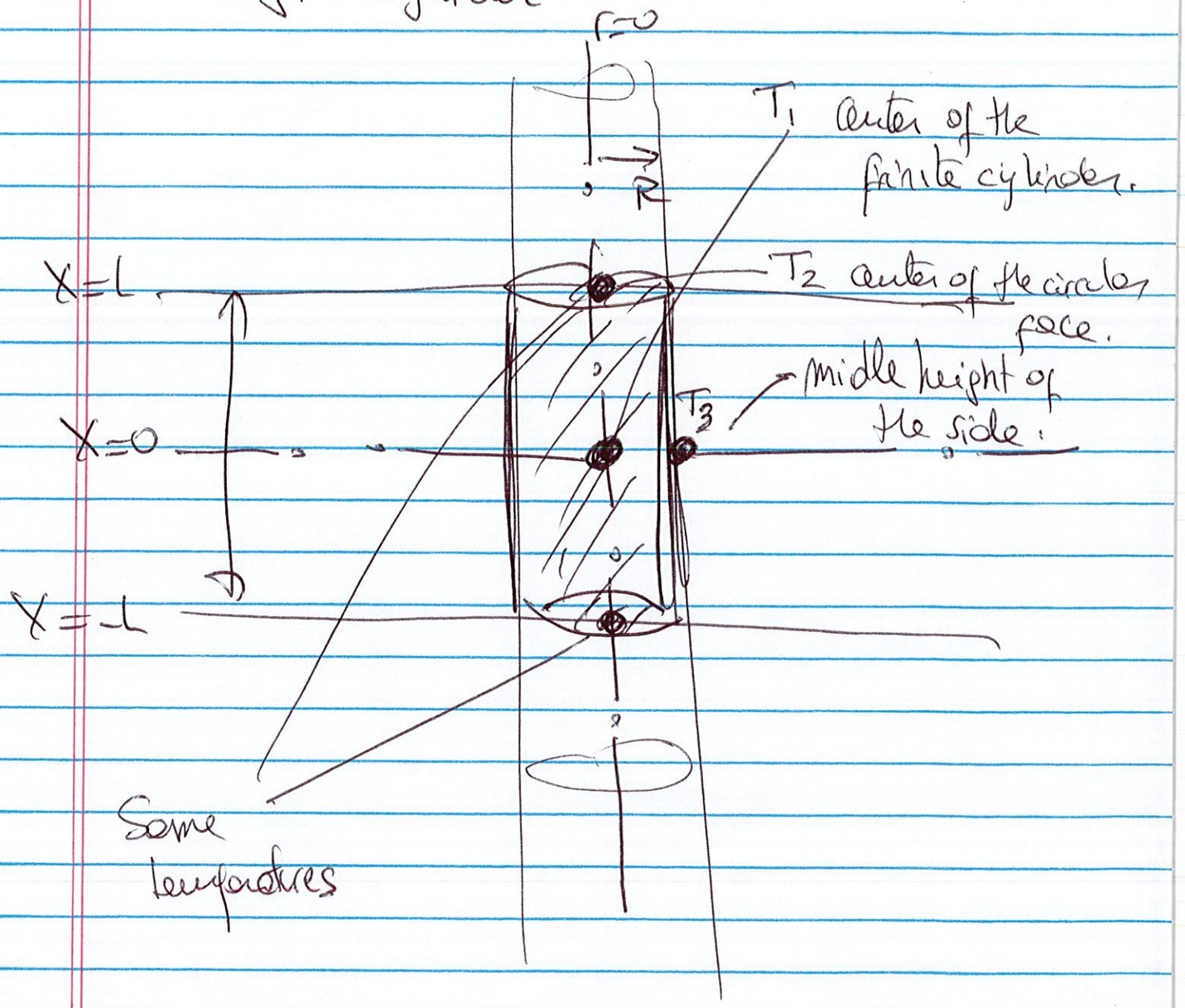


cylinder.

$$\frac{\partial T}{\partial t} = \alpha \frac{\partial^2 T}{\partial x^2} \Rightarrow T(x,t)$$

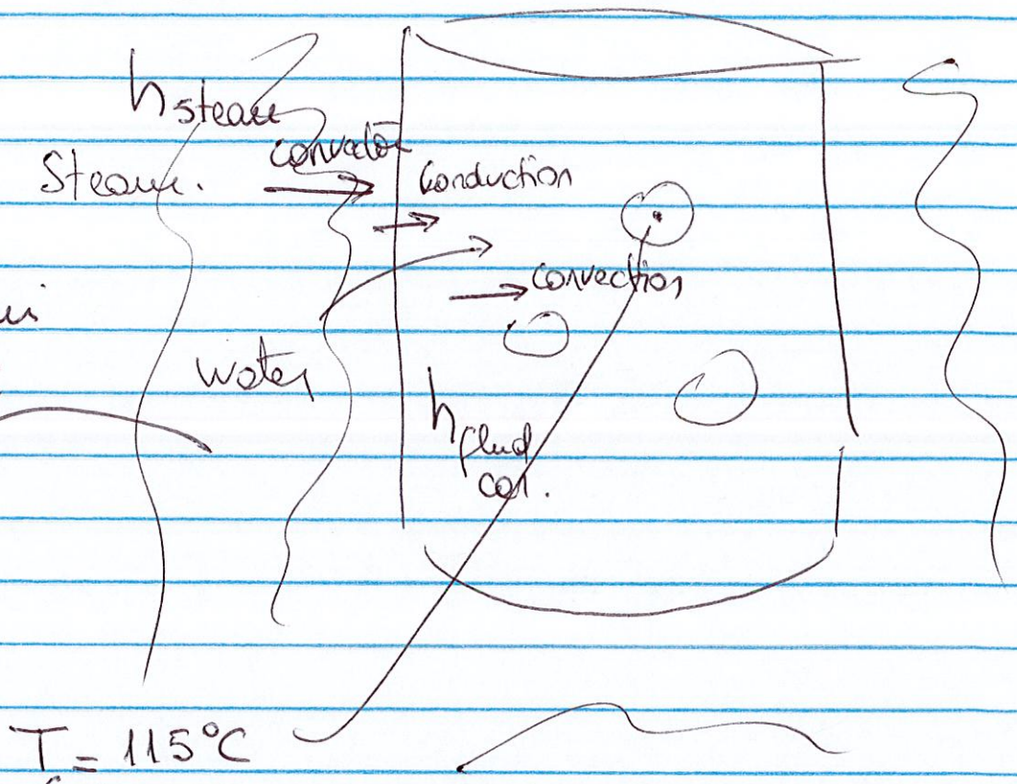


What happens when we have a finite length cylinder. (4)

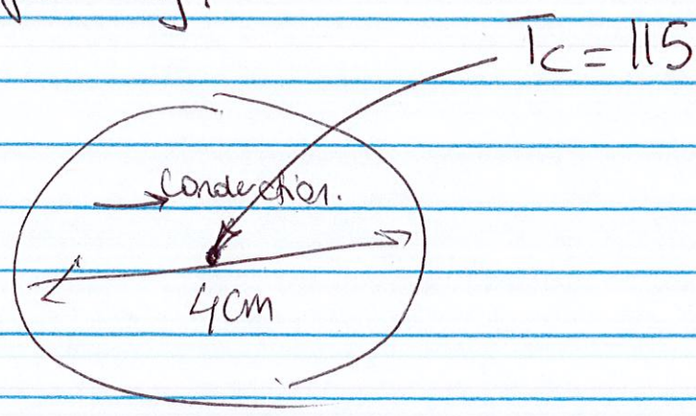


SOLUTION = SOLUTION FOR INFINITE CYLINDER X SOLUTION FOR INFINE SLAB

EXAMPLE 3



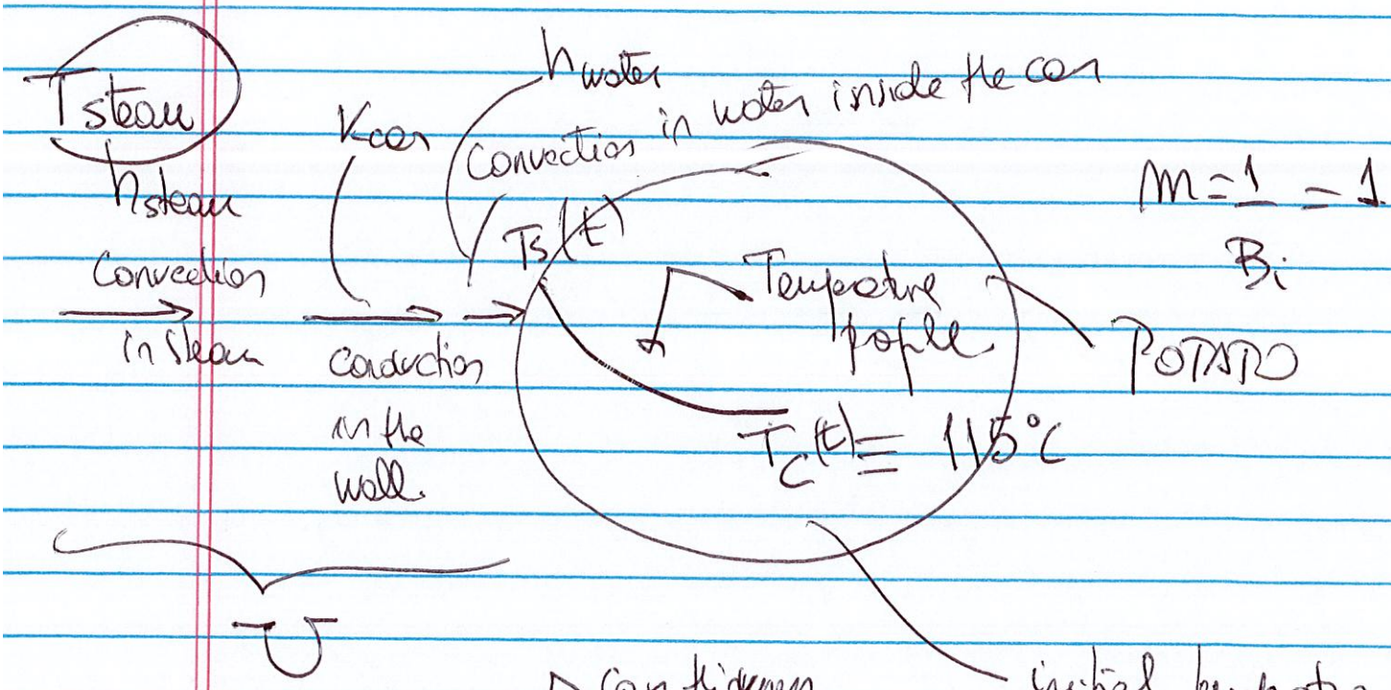
slowest heating point. for an assumed spherical geometry is the center of the geometry.



overall heat transfer coefficient

$$Bi = \frac{hR}{K} = \frac{20\ W/m^2K \times 0.02m}{0.4\ W/mK} = 1 \quad (6)$$

$Bi > 0.1$ [10 times larger]

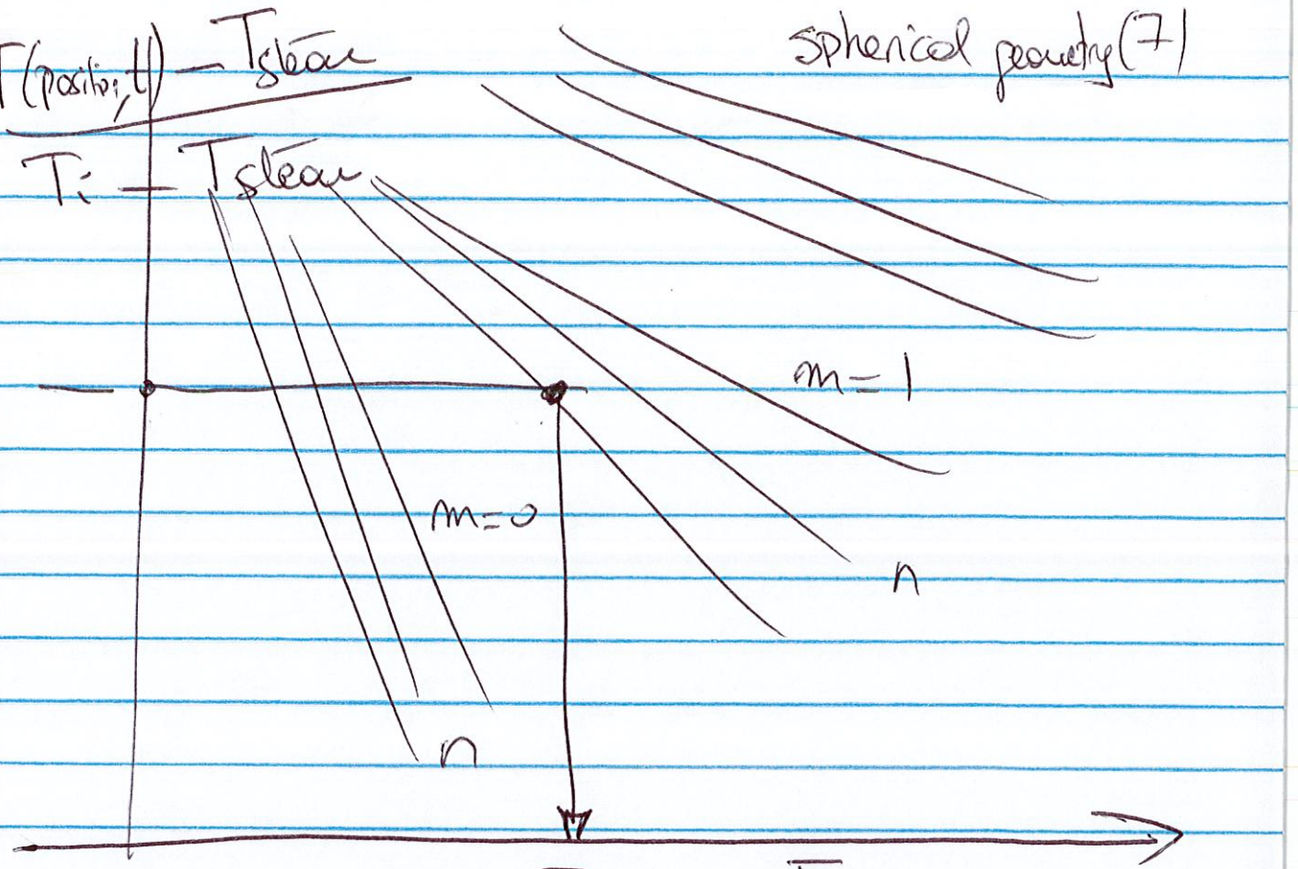


$$\frac{1}{U} \cong \frac{1}{h_{steam}} + \frac{\ell}{K_{can}} + \frac{1}{h_{water}}$$

$$m = \frac{1}{Bi} = 1$$

Time is what we need time from Heisler chart because $Bi = 1$

$$Y = \frac{T(position, t) - T_{steam}}{T_i - T_{steam}}$$



T_{center} : F_o F_o

$$Y = \frac{115 - 121}{30 - 121} \qquad m = 1 \qquad n = \frac{r}{R} = 0$$

α : thermal diffusivity of the potato

$$F_o = \frac{\alpha t}{R^2} = 1.2$$

$$t = \frac{1.2 \times (0.02)^2 \, m^2}{1.5 \times 10^{-7} \, m^2} = 3200 \, s$$

$t \simeq 53$ minutes

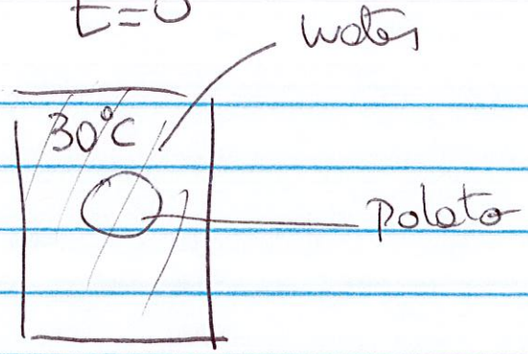
if we use the approximation: $\gamma_1^2 F_0$ ↑ get from tables (8)

$$\frac{T_c - T_\infty}{T_i - T_\infty} = C_1 \, l^{-\gamma_1 F_0} \cdot \frac{\sin(\gamma_1 r/R)}{\gamma_1 r/R}$$

Know ↑ — From tables. ↑ — For center $r=0$ ↑

look in your very old notes in Calculus what is $\lim_{x \to 0} \frac{\sin x}{x}$ $\neq 0$ $\neq \infty$

$t=0$

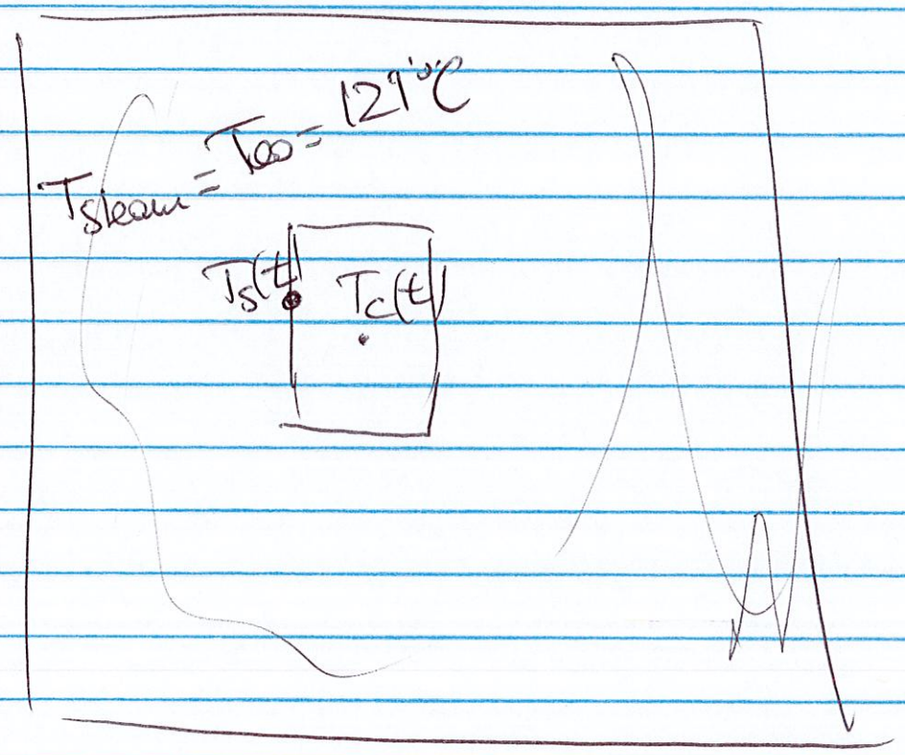


$T_s = 30°C$

$T_c = 30°C$

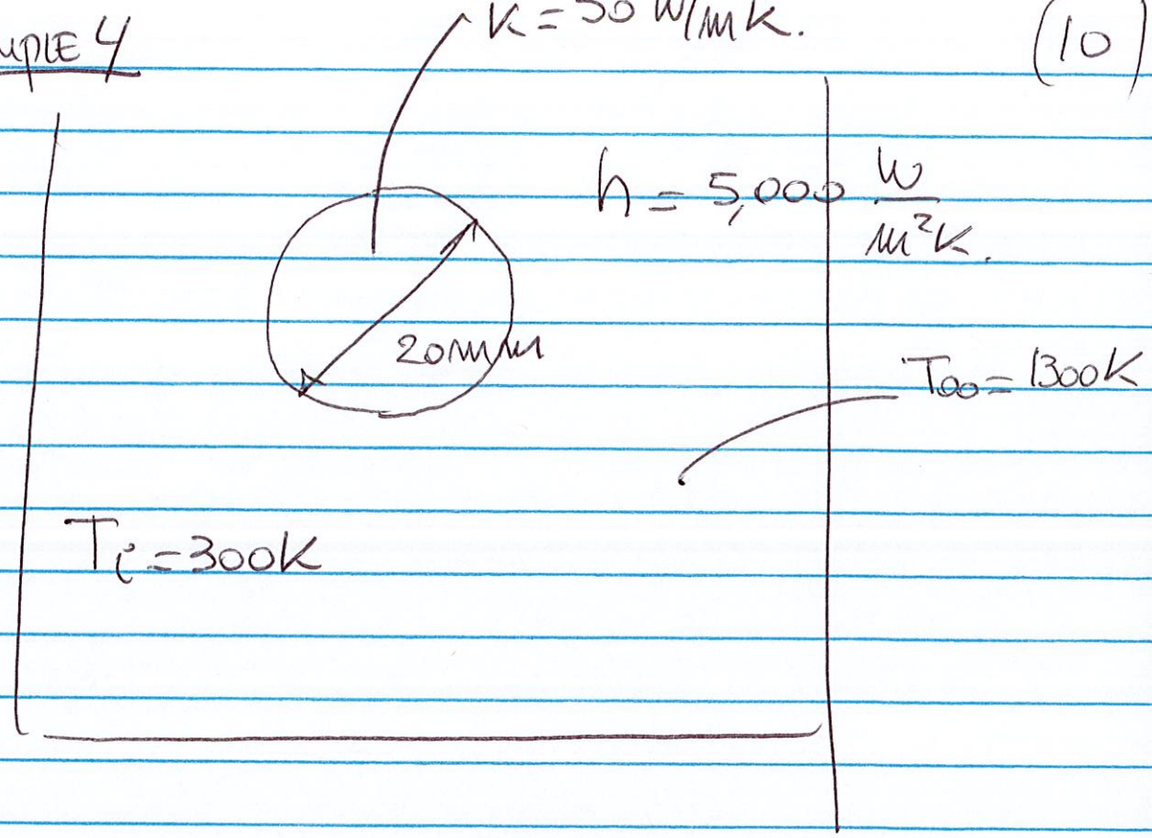
(9)

$t > 0$



if $h \Rightarrow \infty$ $T_s = 121°C$

EXAMPLE 4

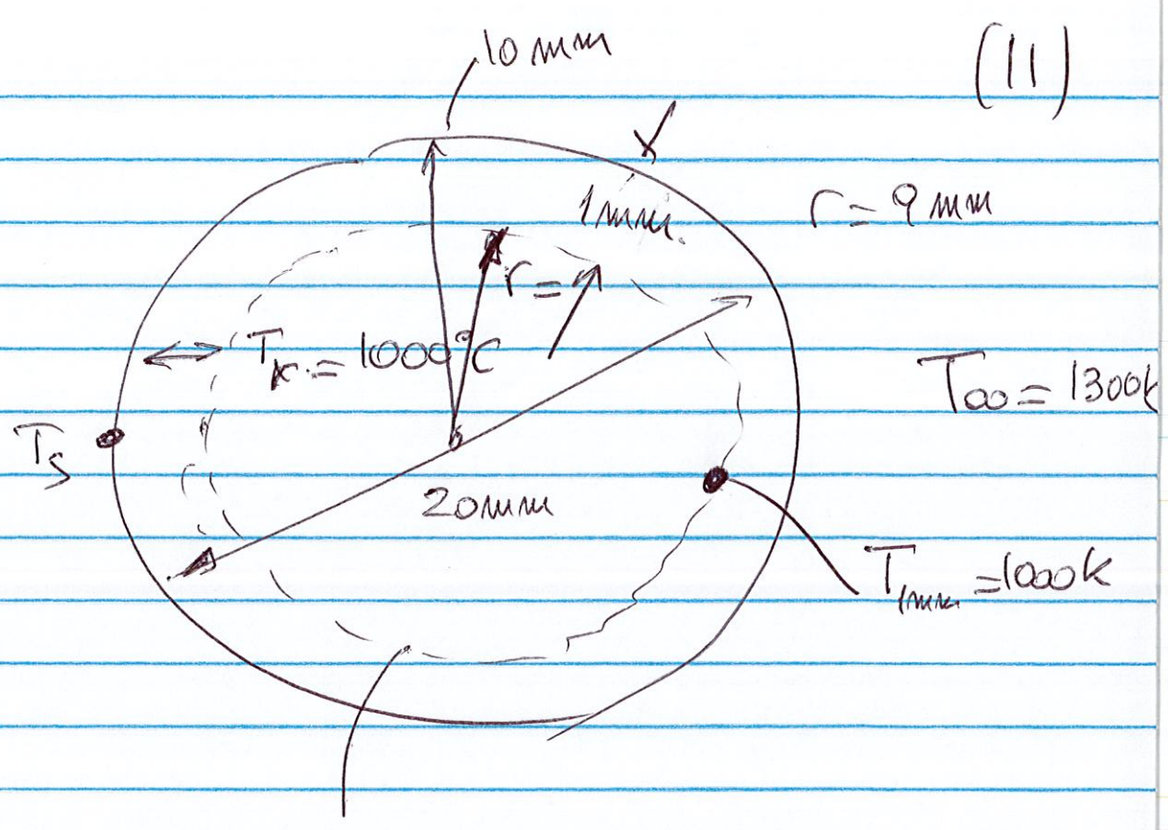


$$Bi = \frac{hR}{K} = \frac{5000\ W/m^2K \times 10\times10^{-3}\ m}{50\ W/mK.} = 1$$

We need to use charts. !!

ASIDE FOR QUIZ

$$Bi = \frac{hL}{K} = \frac{\frac{L}{K}}{\frac{1}{h}} = \frac{\frac{L}{KA}}{\frac{1}{hA}} = \frac{\text{Resistance to cond}}{\text{Resistance to Conv.}}$$



Sphere. r

$\Pi = \frac{9mm}{10mm} = 0.9$ ↑ R

$y = \frac{1000 - 1300}{300 - 1300}$

$M = 1 = 1$
B_i

$F_o \Rightarrow$ time.