The University of Calgary
Department of Chemical & Petroleum Engineering

ENCH 501: Mathematical Methods in Chemical Engineering
Quiz #4

Time Allowed: 50 mins. **October 31, 2000**

Student's Name: _____

The surface of a thick block of metal is to be decontaminated and disinfected. This is to be accomplished by heating the surface to a temperature of 160°C or higher for a minimum of 5 minutes. Infra-red radiation at an energy level of 600 W is available from a hand-held source. The face of the source is circular, 4 cm diameter. The angle of beam divergence is 10° and the block was initially at 18°C.

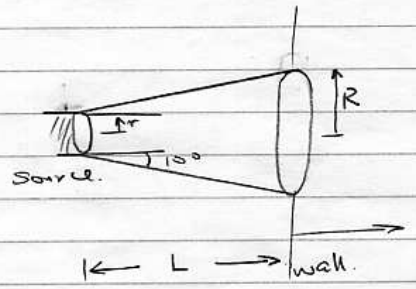
(a) If the heating is to be done in a vacuum and the diameter of the patch to be cleaned on the metal block is 10 cm, estimate how far the source must be from the surface in order to "clean" the surface in 30 minutes. Use the integral method.

(b) How deep has heat penetrated into the block by this time?

Data: Properties of the block material:

ρ = 7865 kg/m^3 ; C_p = 0.46 kJ/kg K ; k = 19 W/mK

ENCH 501 Quiz # 4 Solution 31 Oct, 2000



The source is to be located at a distance such that the flux at the wall is sufficient to raise the surface temperature from 18°C to 160°C in 25 minutes.

(a)

Block is semi-infinite. Can use case 2, p 107-108 in Notes. For constant heat flux, the temperature profile is eq. 5.59 (integral method)

$$T - T_o = \sqrt{\frac{3}{2}} \frac{q_o}{k} \sqrt{\alpha t} \left[1 - 0.4082 \frac{x}{\sqrt{\alpha t}} \right]^2$$

At the surface $x = 0$.

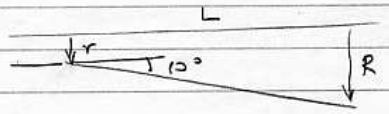
When $t = 25$ min or 1500s, $T = 160\,^\circ C$. $T_o = 18\,^\circ C$

$$\alpha = \frac{k}{\rho c_p} = 5.25\,(10^{-6})\ m^2/s$$

Substitute $q_o = 2.482\,(10^4)\ W/m^2$

But $q_o = \frac{600}{\pi R^2}$, $\therefore R = 0.0877$ m.

(This is greater than the 0.05 m radius to be cleaned.)



$\frac{R - r}{L} = \tan 10^\circ$; $r = 0.02$ m

$\therefore L = 0.384$ m →

(b) Penetration depth

Const heat flux problem:

$$\delta(t) = \sqrt{6\alpha t}$$

$t = 30_{min}$ or $1800\ s$

$\delta = 0.238\ m$ ⟶