# Advanced Heat Transfer Assignment

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# 1 Check for dominance of Natural Convection

$$\begin{aligned} \mathrm{Ra_H} &= \frac{H^3 g \beta_\infty (T_0 - T_\infty)}{\nu \alpha} \\ &= 2.34 \text{ x } 10^{13} \\ v_c &= \frac{\alpha}{H} \mathrm{Ra_H^{1/2}} \\ &= 5.73 \text{ m/s} \\ \mathrm{Ri} &= \frac{H g \beta_\infty (T_0 - T_\infty)}{v_c^2} \\ &= 0.80 \end{aligned}$$

# 2 Results

## 2.1 $\theta$

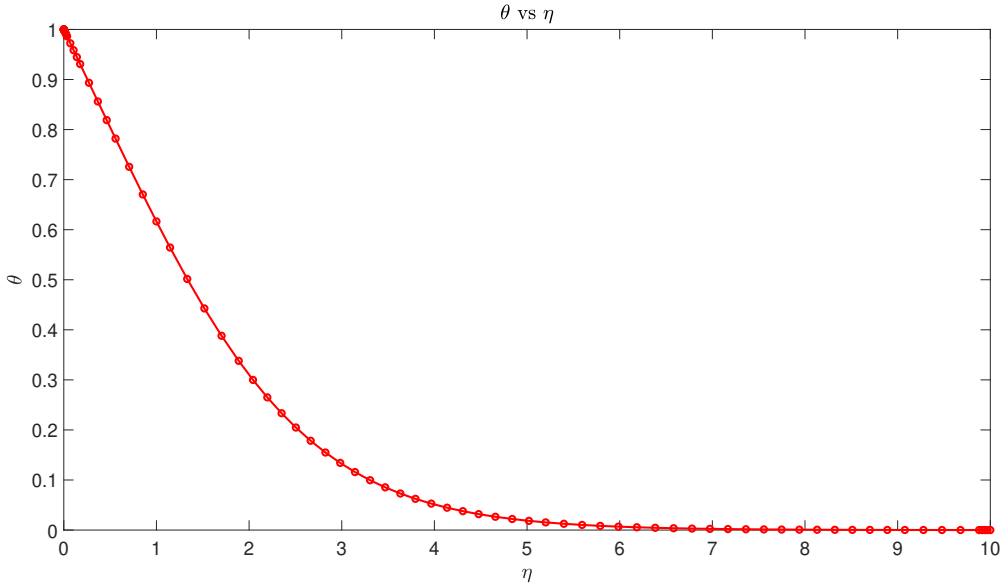


Figure 1: Non Dimensional Temperature, $\theta$ as a function of $\eta$

## 2.2 $G$

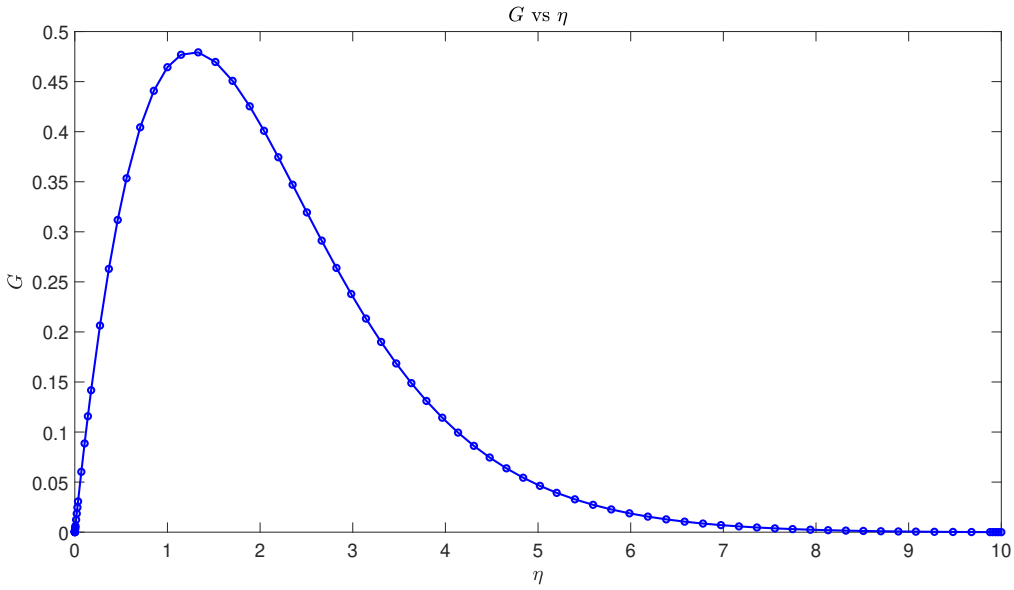


Figure 2: $G$ as a function of $\eta$

## 2.3 Heat Transfer Coefficient

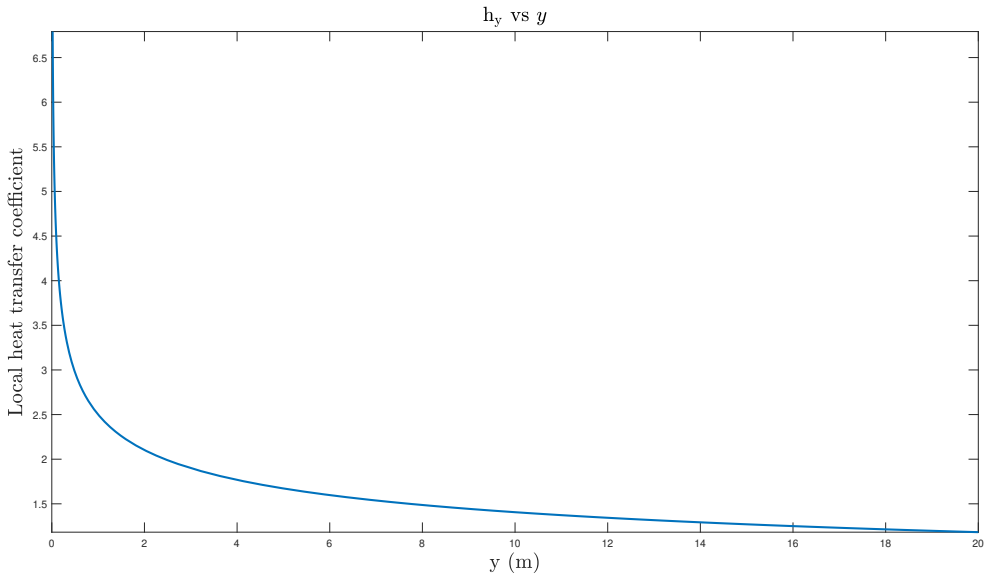


Figure 3: Heat Transfer Coefficient

$$\mathrm{Nu_y} = 0.3920\ \mathrm{Ra_y^{1/4}}$$
$$h_y = k_{\mathrm{air}}\mathrm{Nu_y}/y = Cy^{-1/4}$$
$$h = \frac{\int_0^H h\mathrm{dy}}{H} = 1.5765\ \mathrm{W/m^2K}$$

## 2.4 Heat Flux

$q_0'' = h(T_0 - T_) = 63.06\ \mathrm{W/m^2}$

## 2.5 Thermal Boundary Layer

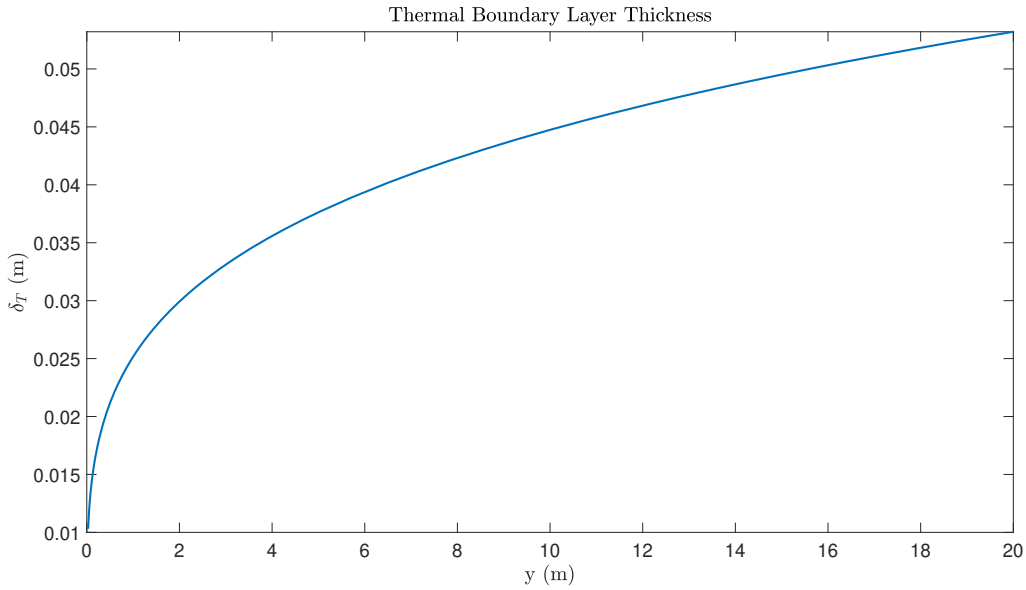


Figure 4: Thermal Boundary Layer

$\delta_t(y) = 4.6727\ y\mathrm{Ra}_{\mathrm{y}}^{-1/4}$

## 2.6 Streamlines

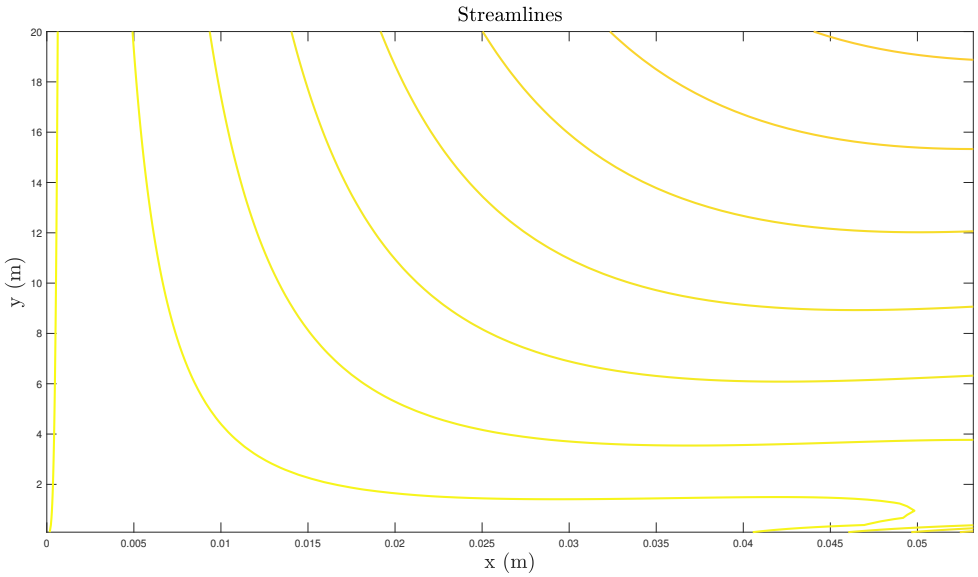


Figure 5: Streamlines

### 2.7 Heatlines

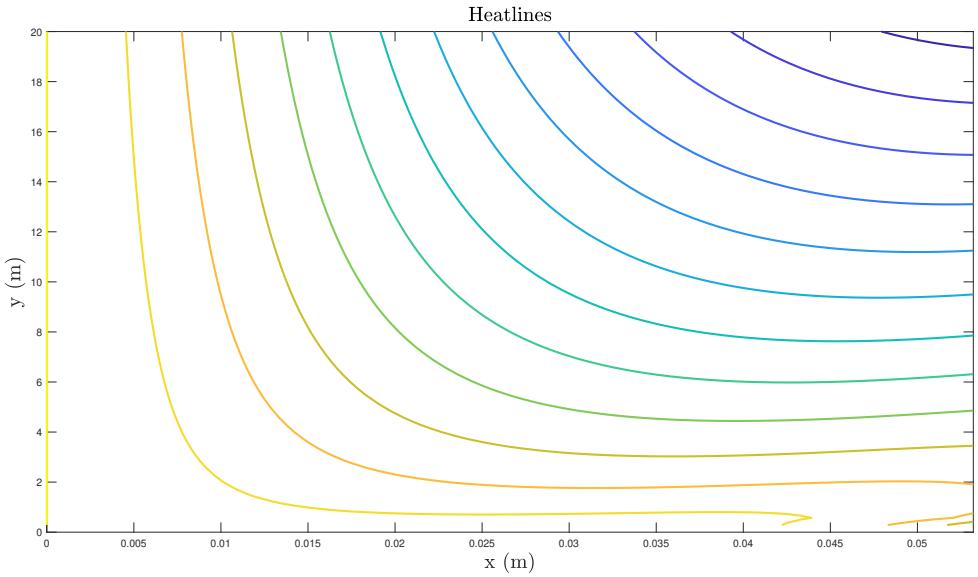


Figure 6: Heatlines

## 3 Comparison with Scaling Analysis

### 3.1 Thermal Boundary Layer Thickness

from scaling analysis:
$\delta_t \sim H\mathrm{Ra}_{\mathrm{H}}^{-1/4}$
$\delta_t \sim 0.0092$ m

from similarity solution:
$\delta_t(y) = 4.6727\ y\mathrm{Ra}_{\mathrm{y}}^{-1/4}$
$\delta_{t,\max} = \delta_t(H) = 0.0532$ m

### 3.2 Characteristic Velocity

from scaling analysis:
$v_c \sim \frac{\alpha}{H}\mathrm{Ra}_H^{1/2}$
$v_c \sim 5.73$ m/s

from similarity solution:
$v_c(y) = \frac{\alpha}{y}\mathrm{Ra}_y^{1/2}$

$v_{c,\max} = v_c(H) = 5.73$ m/s

### 3.3 Nusselt Number

from scaling analysis:
$\mathrm{Nu} \sim \mathrm{Ra}_\mathrm{H}^{1/4}$
$\mathrm{Nu} \sim 2180$

from similarity solution:
$\mathrm{Nu}_\mathrm{y} = -\theta(0)\mathrm{Ra}_\mathrm{y}^{1/4}$
$\mathrm{Nu}_\mathrm{H} = 853$