Convection Heat Transfer over a Cylinder

Free Convection:

First, calculate the *Rayleigh number* using Equation [1],

$$Ra_D = \frac{g\beta(T_S - T_a)D^3}{\nu\alpha} \quad [1]$$

where g is the acceleration of gravity, $\beta = \frac{1}{T_f}$ is the volumetric thermal expansion coefficient for gases, $T_f = \frac{T_s + T_a}{2}$ is the film temperature, T_s is the surface temperature, T_a is the ambient temperature, D is the cylinder diameter, ν is the kinematic viscosity, and α is the thermal diffusivity.

Note: Make sure that you convert your film temperature to Kelvin before calculating β. Evaluate all air properties at T_f.

Now, calculate the average *Nusselt number* using Equation [2] and Table [1],

$$Nu_D = \frac{hD}{k} = CRa_D^n \quad [2]$$

Table [1]

Ra_D	C	n
$10^{-10} - 10^{-2}$	0.675	0.058
$10^{-2} - 10^{2}$	1.02	0.148
$10^{2} - 10^{4}$	0.850	0.188
$10^{4} - 10^{7}$	0.480	0.250
$10^{7} - 10^{12}$	0.125	0.333

From Equation [2], you can solve for the convection heat transfer coefficient (h) and use it to calculate the heat transfer rate using Equation [3],

$$Q_C = hA(T_S - T_a) \quad [3]$$

Calculate the heat transfer due to radiation using the following equation:

$$Q_R = \varepsilon\sigma A(T_S^4 + T_A^4) \quad [4]$$

Finally, the total heat transfer from the surface of the cylinder is then equal to the heat transfer by convection and radiation,

$$Q_{Total} = Q_C + Q_r \quad [5]$$

Forced Convection:

First calculate the *Reynold's number* using Equation [5],

$$Re_D = \frac{VD}{\nu} \quad [6]$$

where v is the kinematic viscosity, V is the flow velocity, and D is the diameter of the cylinder.

Now, using Equation [6] and Table [2], calculate the average *Nusselt number,*

$$Nu_D = \frac{hD}{k} = CRe_D^m Pr^{1/3} \quad [7]$$

Table [2]

Re_D	C	m
0.4 – 4	0.989	0.330
4 – 40	0.911	0.385
40 – 4000	0.683	0.466
4000 – 40,000	0.193	0.618
40,000 – 400,000	0.027	0.805

Finally, calculate the convection, radiation, and total heat transfer rates from Equation [3], [4], and [5], respectively.

Note: All properties of air should be evaluated at the film temperature (T_f). Use your heat transfer book to get the properties.