**ME 3345 Heat Transfer Project**

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**Problem 1 is chosen. Answer:**

Assume the solar panel is at 45° with the sun, .

Now calculate the absorbed and reflected irradiation from the sun.

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Visible light:

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So irradiation in the visible range is

Assume the absorber plates to be black, these are all absorbed by the plates.

Infrared:

∵ Diffuse gray, ∴ for infrared.

Total infrared Irradiation:

Infrared irradiation absorbed by glass: ;

Infrared irradiation reflected by glass: ;

Assume for Ultraviolet,

UV irradiation absorbed by glass: ;

UV irradiation reflected by glass: ;

This design involved the consideration of all the important heat exchanges in the system: irradiation from the sun, radiation between the glass panel and the surroundings, radiation between the glass panel and the absorber plates, and natural convection on the outer surface of the glass panel. Energy balance of the glass panel and the energy balance of the whole system was used to solve this problem. The natural convection between the glass panel and the absorber plates was not considered due to calculation complexity and the insignificance of this process (estimated to be <10 W).

One of the design requirements is that the absorber plates must have a temperature higher than 85 °C, so that energy can be transferred from the plate to the water to raise water temperature to 85 °C.

The temperature of the absorber plate was first assumed to be 14 °C lower than the glass panel’s temperature (verified later). To achieve this assumption, the thermal resistance from water to the absorber plate has to be 0.0783 K/W, and the number of pipes was calculated to be 3.37, which was incorrect since it should be 6. Therefore, this assumption is incorrect. Make another assumption: absorber plate’s temperature is 13.12 °C lower than the glass panel’s temperature. Redo the whole process and the number of pipes was 6. So this assumption is correct.

Under these assumptions, mass flow rate was calculated to be 1.21 g/s. Since this method include all important aspects of the system, it is a good design.

% ME 3345 Project

% Problem 1

% Yatong Bai

clear;

% Calculate constant terms

Ang = 45/180\*pi; % Angle with sun = 45 deg

G = 1400; % Total Irradiation

Vis = 591; % Visible Irradiation

Infr = 668; % Infrared Irradiation

UV = G-Infr-Vis; % Ultravoilet Irradiation

qIn = (G-Infr\*.3)\*cos(Ang); % Energy absorbed by whole system

sig = 5.67e-8; % sigma

TDiff = 13.12; % Tplate - Tglass, assumed

qGlass = (Infr+UV)\*.7\*cos(Ang); % Energy absorbed by glass

L = sin(Ang); % Height of the plate, used in Churchill & Chu relationship

syms Mdot Tg Tp;

% Solve the equations to find Mdot

[Mdot, Tg, Tp] = solve(...

... Energy balance for whole system

4182\*70\*Mdot==qIn-.7\*sig\*(Tg^4-300^4), ...

... Energy balance for the glass panel

qGlass-.7\*sig\*(Tg^4-300^4)==.7\*sig\*(Tg^4-Tp^4), ...

... Assumption of Tp = Tg + 14 celsius

Tg==Tp-TDiff, Tg>200);

Mdot = eval(vpa(Mdot));

Tg = eval(vpa(Tg));

Tp = eval(vpa(Tp));

% Calculate Natural Convection

Teff = (Tg+300)/2;

% Air Properties evaluated @ Teff = 325K

alpha = (38.3+29.9)/2\*1e-6;

nu = (15.89+20.92)/2/1e6;

beta = 1/Teff;

Pr = 0.7035;

k = (26.3+30)/2/1000;

% Calculate Ra and Nu

Ra = 9.81\*beta\*(Tg-300)\*L^3/nu/alpha;

Nu = (.825 + 0.387\*Ra^(1/6) / (1+ (0.492/Pr)^(9/16) )^(8/27) )^2;

h = Nu\*k/L;

qNat = h\*(Tg-300); % Natural Convection

TgC = Tg - 273.157; % Convert to Celsius

TpC = Tp - 273.157; % Convert to Celsius

% Plug in Natural Convection and reevaluate Mdot

Tg2 = Tg-.006;

Mdot2 = Mdot;

i = 0; % Counter

while abs(Tg2-Tg)>.005 % Define answer accuracy

Tg = Tg2;

oldM2 = Mdot2;

i = i + 1;

% Solve Equation again with qNat

syms Mdot2 Tg2 Tp2;

[Mdot2, Tg2, ~] = solve(...

... Energy balance for whole system

4182\*70\*Mdot2==qIn-.7\*sig\*(Tg2^4-300^4)-qNat, ...

... Energy balance for the glass panel

qGlass-qNat-.7\*sig\*(Tg2^4-300^4)+.7\*sig\*(Tp2^4-Tg2^4)==0, ...

... Assumption of Tp = Tg + 14 celsius

Tg2==Tp2-TDiff, Tg2>200);

Mdot2 = eval(vpa(Mdot2));

Tg2 = eval(vpa(Tg2));

Mdot2 = (Mdot2+oldM2)/2;

Tg2 = (Tg2+Tg)/2; % This line is for faster convergence

Tp2 = Tg2+TDiff;

Teff2 = (Tg2+300)/2;

% Recalculate Natural Convection

Ra2 = 9.81\*beta\*(Tg2-300)\*L^3/nu/alpha;

Nu2 = (.825 + 0.387\*Ra2^(1/6) / (1+ (0.492/Pr)^(9/16) )^(8/27) )^2;

h2 = Nu2\*k/L;

qNat = h2\*(Tg2-300);

end

TgC2 = Tg2 - 273.157; % Convert to Celsius

TpC2 = Tp2 - 273.157; % Convert to Celsius

% Print Results

fprintf('Corrected Glass Temperature: %.2f Celsius.\n', TgC2);

fprintf('Corrected Plate Temperature: %.2f Celsius.\n', TpC2);

if TpC2 < 85

fprintf('Plate temperature lower than 85 Celsius.\n');

fprintf('Cannot heat water to 85 Celsius.\n');

end

fprintf('Uncorrected Mass Flow Rate: %.2f g/s.\n', Mdot\*1000);

fprintf('Corrected Mass Flow Rate: %.2f g/s.\n', Mdot2\*1000);

qRad = .7\*sig\*(Tg2^4-300^4); % Energy lost by glass radiation

% Energy transmitted to water

qWater = Mdot2\*4182\*(min(85,TpC2)-15);

% Calculate Average water temperature

syms c;

c = solve(TpC2-(TpC2-15)\*exp(c)==min(85, TpC2));

c = eval(c);

TwAvg = TpC2-(TpC2-15)\*exp(c)/c+(TpC2-15)/c+273.157;

% Calculate Thermal Resistivity of the plates

R = (Tp2-TwAvg) / qWater;

% Evaluate Water Property @ 63.6 Celsius (337K)

kw = 656e-3;

Nuw = 3.66; % Assume laminar flow

Ntubes = 1/R/Nuw/kw;

fprintf('Number of tubes: %.3f\n', Ntubes)

% Assume tube diameter to be 1cm and check if flow is laminar

D = 0.01;

v = Mdot2/6/1000/(pi\*D^2/4);

mu = 453e-6;

Re = D\*v\*1000/mu;