```
% Welcome to GREENHOUSEHEAT MatLab transfer file
%This file was designed to track a batch based residential greenhouse


%This project was designed by Queen's University student L.Gardner
%VERSION V1 - Completed April 23

%Designed for Queen's U MECH 425 - Sustainable Development and for
%APPROPEDIA.ORG


%CHEERS FROM CANADA!!





%CONSTANTS DEFINED

%Assuming constant properties at approximately 280.5 the midpoint of the
%range of temperature values computed

%thermal conductivity of air , kair (W/m*K)
%alpha, m2/s
%side area of the greenhouse, As (m2)
%front area of the greenhouse, Af (m2)
%viscosity of air at temperature, vis (kg/m s)
% air density at temperature, rho (kg/m3)
%average air velocity based on Canadian Climate Normals (CCN) for Kingston, vel (m/s)
% Canadian Climate Normals Website :
% http://climate.weatheroffice.gc.ca/climate_normals/results_e.html?↙
Province=ALL&StationName=kingston&SearchType=BeginsWith&LocateBy=Province&Proximity=25&P↙
roximityFrom=City&StationNumber=&IDType=MSC&CityName=&ParkName=&LatitudeDegrees=&Latitud↙
eMinutes=&LongitudeDegrees=&LongitudeMinutes=&NormalsClass=A&SelNormals=&StnId=4295&
% heat capacity of air at temp, Cp (J/kg K)
% the thermal conductivity of PVC film, kPVC (W/m*K)

kair = 0.02474;
alpha = 1.9926*10^-5;
As = 0.5842 * 1.30/2;
Af = 0.9652*1.42;
vis = 1.77*10^-5;
rho = 1.246;
vel = 4.45;
Cp = 1.00661*10^3;
kPVC = 0.19;
```

```
%GREENHOUSE DIMENSIONS
% width - east west length of window, m
%depth - north south, component pertruding from window, m
%height - total greenhouse height, z component, m
%hyp - hypotenuse dimension, m
%theta - angle of triangule, degrees



width = 0.9652;
depth = 0.5842;
height = 1.30;
hyp = 1.42;
theta = 65.75;




%distance thickness of air layer assuming it's a conductive medium
% air is stagnant and this is a batch system so assumption is OKAY
% FOR THE ASSUMPTION AS AIR AS A SOLID AS VELOCITY IS MINIMAL INSIDE THE
%THE GREENHOUSE -NOT CONSIDERED FOR THIS CASE
%assumptions were pulled out of the assumption of signficant heat transfer
%the closer the distance to the center and location of actual steady state
%in the greenhouse


%distF = depth*sind(theta);  %should be 0.266 m

%distS = width/4;  %should be 0.2413 m

%Pradl's Number for air
Pr = Cp*vis/kair;


%thickness of PVC film, thick (m)

thick = 0.15*10^-3;


%subscript f and s denote front and side

% length of average side for flow reynold's number flow development

Ls = height*0.5/tand(theta); %0.293 m

Lf = width;  %0.9652

Res = rho*vel*Ls/vis

Ref = rho*vel*Lf/vis
```

```
%NO TURBULENT FLOW FOR THIS DEFINITION, ONLY LAMINAR!! - may proceed even if does not
% meet spec


%if statement for side Reynold's Number

if Res>5*10^5
    'error, Reynolds SIDE RESET'

    Res=5*10^5
end

if Res<=5*10^5

    Nus = 0.664*(Pr^(1/3))*(Res^0.5)
end


%if statement for FRONT Reynold's Number

if Ref>5*10^5
    'error, Reynolds FRONT RESET'

    Ref=5*10^5
end

if Ref<=5*10^5

    Nuf = 0.664*(Pr^(1/3))*(Ref^0.5)
end




%if statement for THHHHHHE inside stagnant air flow assumed to be 0.25m/s
%m/s

veli = 0.1;


Reis = rho*veli*Ls/vis;

Reif = rho*veli*Lf/vis;
```

```
%if statement for side Reynold's Number

if Reis>5*10^5
    'error, Reynolds SIDE RESET'

    Reis=5*10^5
end

if Reis<=5*10^5

    Nuis = 0.664*(Pr^(1/3))*(Reis^0.5)
end


%if statement for FRONT Reynold's Number

if Reif>5*10^5
    'error, Reynolds FRONT RESET'

    Reif=5*10^5
end

if Reif<=5*10^5

    Nuif = 0.664*(Pr^(1/3))*(Reif^0.5)
end


%average local convection coefficient, h (W/m2 K)
% o = outisde with air, i = inside the greenhouse
%s = side    ,     f = front


hos = kair*Nus/Ls

hof = kair*Nuf/Lf;

his = kair*Nuis/Ls

hif = kair*Nuif/Lf

Uside = 1/((1/(his*As))+(1/(hos*As))+(thick/(kPVC*As)))

Ufront = 1/((1/(hif*Af))+(1/(hof*Af))+(thick/(kPVC*Af)));

%total heat transfer coefficient, UL (W/m2 K)

UL = Ufront + 2*Uside
```

```
% AREA FUNCTION
% is the surface area of the greenhouse cover per unit ground area, AG (unitless)
SAGreenH = hyp*width + 2*height*depth/2;

SAGround = width*depth;

AG = SAGreenH/SAGround;



%Internal Temperature requirement not to limit plant growth
% the watermelon package indicated minimum of 13 degrees celsius
% only journals indicate minimum of 12-14 degrees celsius for cucumber
%growth

%internal greenhouse temperature minimum, if exceeded Q requirement no
%longer matters, Ti  (degree C)

Ti = 13;

%OUTSIDE TEMPERATURE VARIYING
% COLUMN = AVERAGE MONTHLY TEMPERATURE (12)
%ROW = TIME midnight - MIDNIGHT (24)
%values from Queen's University, Beamish-Munro Hall - Engineering
%Integrated Learning Centre

To = [-6.7  -7.7    -3  1.6 9.6 13.7    17.9    19  13.9    8.9 2.5 -6.1;
-6.8    -7.9    -3.2    1.3 9.1 13.1    17.6    18.7    14  8.6 2.3 -6;
-7  -8.3    -3.4    1   8.9 12.8    17.2    18.3    13.8    8.6 2.2 -5.7;
-7.1    -8.6    -3.7    0.9 8.7 12.6    16.9    18  13.4    8.3 2.2 -5.9;
-7.3    -8.8    -3.8    0.6 8.4 12.6    16.4    17.6    12.9    8.4 2.1 -5.9;
-7.7    -8.9    -4.1    0.7 8.7 13.5    17.3    17.9    12.5    8.3 2   -6.1;
-7.9    -9.1    -4.2    1.6 9.6 14.7    18.5    18.9    13.2    8.5 2.2 -6.3;
-7.9    -8.9    -3.6    3   10.5    15.7    19.8    20.1    14.6    9.6 2.5 -6.3;
-7.5    -8.1    -2.7    4   11.2    16.2    20.5    21.1    15.6    10.6    3.1 -5.7;
-6.9    -7.4    -2.1    4.5 11.4    16.9    21.3    21.8    16.2    11.5    3.8 -5;
-6.1    -6.5    -1.4    5.1 12  17.4    22.2    22.3    16.7    12.1    4.5 -4.2;
-5.6    -6  -0.8    5.5 13  17.8    22.4    22.6    17.1    12.6    4.8 -3.9;
-5.2    -5.6    -0.2    5.8 13.2    18.3    22.7    22.9    17.5    12.8    5.2 -3.6;
-5  -5.3    0.2 6   13.6    18.6    22.8    23.1    17.8    13  5.4 -3.3;
-4.7    -5.2    0.3 6.3 14  19  23.4    23.4    17.8    13  5.3 -3.5;
-4.7    -5.1    0.1 6.1 13.6    18.8    23.4    23.1    17.9    12.9    4.8 -3.7;
-5  -5.5    0   6.2 13.6    18.6    23.3    23.1    17.6    12.4    4.1 -4.3;
-5.3    -6  -0.8    5.8 13  18.7    23.1    22.6    16.9    11.6    3.6 -4.4;
-5.7    -6.2    -1.2    4.7 12.8    18.2    22.4    21.6    16  11.1    3.3 -4.8;
-6.1    -6.4    -1.7    3.9 11.9    16.9    21.3    20.8    15.3    10.4    3.1 -5.4;
-6.3    -6.5    -2  3.1 11.3    16  20.4    20.1    14.9    10.1    2.9 -5.9;
-6.4    -6.8    -2.2    2.6 10.9    15.4    19.7    19.6    14.3    9.7 2.4 -5.9;
-6.4    -7.1    -2.5    2.3 10.3    14.8    19.1    19.3    14.1    9.3 2.3 -6.2;
-6.6    -7.5    -2.7    2   10.1    14.3    18.6    19  14  9.1 2.1 -6.3];
```

```
%SOLAR CALCULATIONS

%constant on the absorbtion to the greenhouse from journal article
%

beta =0.73;

%solar radiation instantaneous solar radiation over an hour time period,
%averaged, W/m2 hr
%values from Queen's University, Beamish-Munro Hall - Engineering
%Integrated Learning Centre

Sol = [0    0   0   0   0   0   0   0   0   0   0   0;
0   0   0   0   0   0   0   0   0   0   0   0;
0   0   0   0   0   0   0   0   0   0   0   0;
0   0   0   0   0   0   0   0   0   0   0   0;
0   0   0   0   0   0   0   0   0   0   0   0;
0   0   0   0   2.135   7.654   0   0   0   0   0   0;
0   0   0   15.639  69.09   89.951  0   0   0   0   0   0;
4.73    33.219  39.539  119.064 152.468 222.939 259.048 0   0   67.467  46.472  16.153;
73.502  174.516 192.861 280.713 391.871 311.633 340.197 211.679 184.23  146.813 140.179↙
55.593;
169.531 299.546 368.578 448.556 473.793 277.435 499.318 447.799 334.404 299.622 267.696↙
154.524;
231.056 407.358 524.483 592.827 423.362 656.827 621.839 590.652 472.445 406.372 359.553↙
286.438;
178.083 358.559 644.704 701.012 674.921 743.231 711.403 705.102 576.321 550.739 404.377↙
313.433;
196.448 378.852 715.151 760.365 823.639 828.985 749.064 811.396 632.056 582.476 403.226↙
354.499;
166.117 355.004 730.11  764.096 876.268 846.156 765.222 850.456 632.786 573.089 336.073↙
258.385;
180.621 228.926 687.301 730.806 556.146 804.303 744.623 422.868 580.563 506.144 240.867↙
188.113;
74.636  141.484 589.701 626.38  389.382 718.035 665.019 666.986 483.428 403.506 129.927↙
119.77;
11.848  57.221  454.259 502.412 499.579 604.423 535.681 507.873 355.618 296.107 29.228↙
25.013;
0   7.639   293.307 337.163 325.272 459.728 398.757 231.005 199.532 129.561 0   0;
0   0   123.175 176.682 170.496 295.721 174.567 204.304 86.909  27.131  0   0;
0   0   8.653   30.065  69.735  139.069 0   29.868  0   0   0   0;
0   0   0   0.029   4.072   12.809  0   21  0   0   0   0;
0   0   0   0   0   0   0   0   0   0   0   0;
0   0   0   0   0   0   0   0   0   0   0   0;
0   0   0   0   0   0   0   0   0   0   0   0];
```

```
SolJ = 3600*Sol;

%HEAT TRANSFER FROM HOUSE TO GLASS



%CONSTANTS
% surface area of glass side, facing house, Agl
% thickness of glass, GLthick, m
% thermal conductivity of glass,kGL (W/m K)
% total heattransfer coefficient for glass
%- SUM OF THERMAL RESISTANCE CIRCULT, m2 K/W


Agl = height*width;

GLthick = 0.7*10^2;
kGL = 1.4;

Ugl = 1/((1/(hif*Agl))+(1/(hif*Agl))+(GLthick/(kGL*Agl)))


%glass input, the house is at a minimum of 18 on average, so this parameter
%is used to calculate the heat transfer in from the house, degree celsius

Tih = 18 ;



%Heat requirement calculation

Timat=zeros(24, 12);

for i=1:1:24
    Ti=13;
    for j=1:1:12

        Ti=13;

         Timat(i,j)=Ti;
    end
end

Tihmat=zeros(24,12);

for i=1:1:24
    Tih=18;
    for j=1:1:12

        Tih=18;
```

```
          Tihmat(i,j)=Tih;
    end
end

%surface area test parameters - SAGreenH, AG

qGL = Agl*Ugl*(Tihmat-Ti);
% %
part1 = ((AG*UL)*(Timat-To))
% %
part2 = ((-beta*width*depth)*Sol)
% %
part3 = ((-Agl*Ugl)*(Tihmat-Ti))

qGL = (Agl*Ugl)*(Tihmat-Ti)
% Agl
%
% Ugl
%
% Timat
%
% Tihmat
%
Q=part1 + part2 + part3;
%
% % 'watts'
% % %part1 =
% %  To
% %
% %  Timat


% Qcostm=zeros(24,12);
%
% for i=1:1:24
%
%
%     for j=1:1:12
%
% if Q(i,j) < 0
%
%     Qcost = 0;
% else
%     Qcost = Q(i,j);
%
%
%          Qcostm(i,j)=Qcost;
%     end
% end
%
%
```

```
% end
%
% Qcost
%
% Q
%
% SAGreenH
%
% AG

figure(1)
surf(SolJ)
title('ILC Sunlight Energy for an hour period (Joule), monitored per month for 1 year')
xlabel('month')
ylabel('time, hours')
zlabel('Radiation, J/m2')
figure(2)
surf(Q)
title('Theoretical Watts Required to Greenhouse for Year')
xlabel('month')
ylabel('time, hours')
zlabel('Required Radiation,Watts')
figure(3)
surf(Qcost)
title('Q paying for')
xlabel('month')
ylabel('time, hours')
zlabel('Required Radiation,Watts')
```