

```
% 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
%APPROVEDIA.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&ProximityFrom=City&StationNumber=&IDType=MSC&CityName=&ParkName=&LatitudeDegrees=&LatitudeMinutes=&LongitudeDegrees=&LongitudeMinutes=&NormalsClass=A&SelNormals=&StnId=4295&
```

```
Province=ALL&StationName=kingston&SearchType=BeginsWith&LocateBy=Province&Proximity=25&ProximityFrom=City&StationNumber=&IDType=MSC&CityName=&ParkName=&LatitudeDegrees=&LatitudeMinutes=&LongitudeDegrees=&LongitudeMinutes=&NormalsClass=A&SelNormals=&StnId=4295&
```

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Province=ALL&StationName=kingston&SearchType=BeginsWith&LocateBy=Province&Proximity=25&ProximityFrom=City&StationNumber=&IDType=MSC&CityName=&ParkName=&LatitudeDegrees=&LatitudeMinutes=&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*103;
```

```
kPVC = 0.19;
```

%GREENHOUSE DIMENSIONS

% width - east west length of window, m
%depth - north south, component protruding from window, m
%height - total greenhouse height, z component, m
%hyp - hypotenuse dimension, m
%theta - angle of triangle, 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 significant 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*105
    'error, Reynolds SIDE RESET'

    Reis=5*105
end

if Reis<=5*105

    Nuis = 0.664*(Pr(1/3))*(Reis0.5)
end

%if statement for FRONT Reynold's Number

if Reif>5*105
    'error, Reynolds FRONT RESET'

    Reif=5*105
end

if Reif<=5*105

    Nuif = 0.664*(Pr(1/3))*(Reif0.5)
end

%average local convection coefficient, h (W/m2 K)
% o = outside 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];
```



```
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*Ag1))+(1/(hif*Ag1))+(GLthick/(kGL*Ag1)))
```

```
%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

            Qcostm(i,j) = 0;
        else
            Qcostm(i,j) = Q(i,j);
        end

    end

end

end

Qcost

```



```
Qmoney=Qcostm*3600*0.08*10^-3/30.42
%
% 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(Qcostm)
title('Q paying for')
xlabel('month')
ylabel('time, hours')
zlabel('Required Radiation,Watts')
figure(4);
surf(Qmoney)
title('$$$')
xlabel('month')
ylabel('time, hours')
zlabel('$$$ per hour for daily total')
```