Biological and Agricultural Engineering Department

Modeling and Analysis of Physical and Biological Processes: EBS 270 Homework No. 1 - Due Date: April 26, 2019
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Contents


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close all; clear all; clc;
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Problem 1 a

```
%Performed in hand notes. Summary: Both unit check and limit check
%converged.
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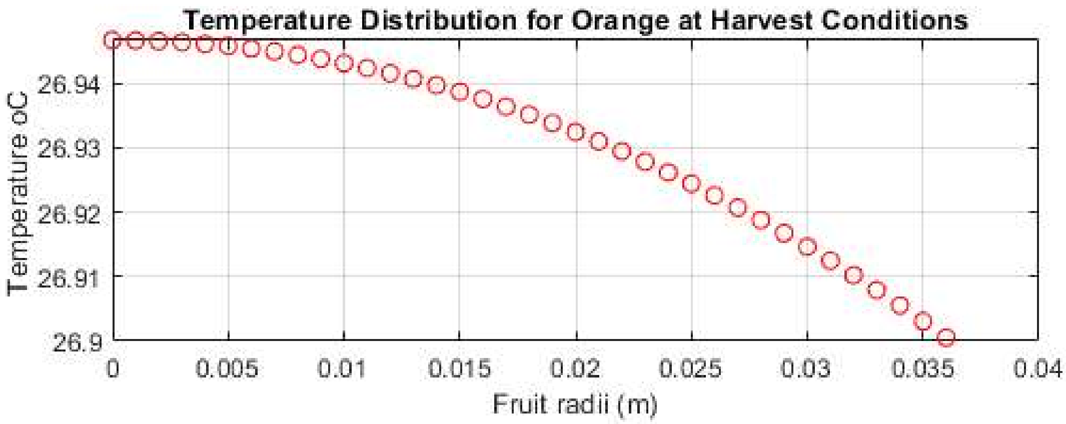
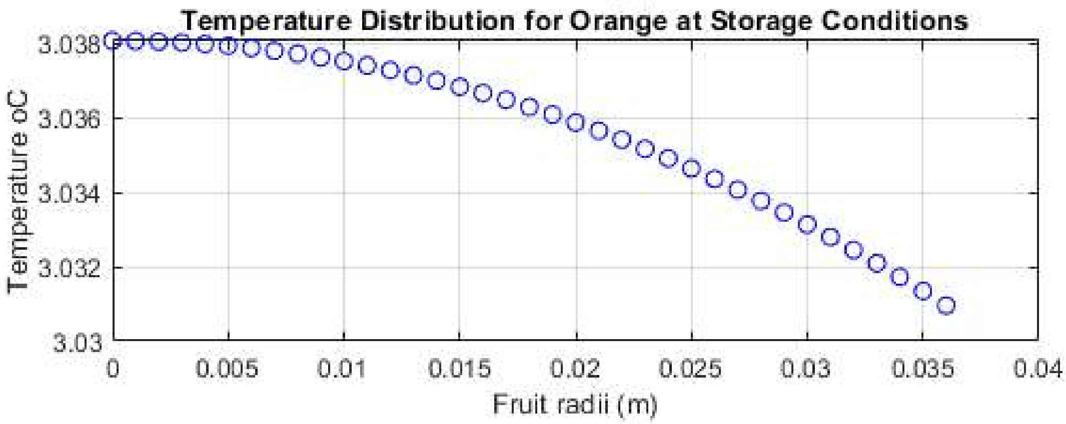
Problem 1 b

```
%Constants of the problem
T_Harvest = 26.7; % Ambiente Temperature at Harvest, (oC)
T_Storage = 3; % Storage temperature (oC)
rho = 998; % Density of orange (km/m3)
cp = 3900; % Specific heat of orange (J/kg/oC)
a = 0.036; % Radius of fruit (m)
a0 = 4.71;
a1 = 3.55;
%A = a0 + a1*T; % Heat production due to respiration (J/(s-m3))
k = 0.47; % Thermal Conductivity of the fruit (W/m/oC)
h = 6; % Convective heat transfer coefficient at the fruit surface (W/m2/oC)
w = sqrt(a1/k);
he = h-k/a;
dr = 0.001; %Random value adopted by student
%---------------------------------------------------------------------------
% Harvesting condiions
T_Inf = T_Harvest;
alpha = -(a0 + a1*T_Inf)/a1;
A = -(alpha*(k+he*a))/(he*sin(w*a)+k*w*cos(w*a));
j = 1;
for r=0:dr:a
    if r == 0
      T_H(j) = A*w-((a0+a1*T_Inf)/a1)+T_Inf;
    else
    u_H(j) = A*sin(w*r)+alpha*r;
    T_H(j) = u_H(j)/r+T_Inf;
```

```
    end
    j = j+1;
end
%----------------------------------------------------------------------
% Storage conditions
T_Inf = T_Storage;
alpha = -(a0 + a1*T_Inf)/a1;
A = (-alpha*(k+he*a))/(he*sin(w*a)+k*w*cos(w*a));
j = 1;
for r=0:dr:a
    if r == 0
      T_S(j) = A*w-((a0+a1*T_Inf)/a1)+T_Inf;
    else
    u_S(j) = A*sin(w*r)+alpha*r;
    T_S(j) = u_S(j)/r+T_Inf;
    end
    j = j+1;
end
%---------------------------------------------------------------------
%PLOTS
g = 0:dr:a;
subplot(2,1,1)
plot(g,T_H,'ro');
title('Temperature Distribution for Orange at Harvest Conditions');
xlabel('Fruit radii (m)');ylabel('Temperature oC');
grid
subplot(2,1,2)
plot(g,T_S,'bo');
title('Temperature Distribution for Orange at Storage Conditions');
xlabel('Fruit radii (m)');ylabel('Temperature oC');
grid
```





Problem 1 c

```
%The heat that needs to be removed is the heat generated by respiration of
%the fruit. However, the total heat is the same heat that scapes the fruit
%through its surface (convection heat transfer). Therefore we can apply the
%following equation:
%Q [J/s] = h [W/m2-oC] * Area [m2] * dT [oC]; Where dT is the actual
%temperature of the fruit minus the storage temperature.
T_Inf = T_Storage;
area = 4*pi*a^2;
r = a;
u = A*sin(w*r)+alpha*r;
T = u/r+T_Inf;
Q = h*area*(T-T_Inf);
fprintf('Heat required to be removed: Q = %.5f J/s\n',Q);
```

```
Heat required to be removed: Q = 0.00303 J/s
```

Problem 1 d

```
%The heat that needs to be removed is the heat required to take the fruit
%outer temperature from 26.7 to 3 oC. Therefore we can apply the following
%equation:
%Q [J] = m [kg] * Cp [J/kg-oC] * dT [oC]; m = rho * volume
%For a sphere: dV = area*dr
%The integral and final results are in the hand notes.
```

Problem 1e

```
%We can calculate the rate of heat per mass, since we know both the fruit
%density (rho) and volume (4/3*pi*a^3), therefore we estimate the amount of
%heat for 600*500 kg of fruits. As good engineers we must ALWAYS design
%facilities, machines, equipment, etc. with a certain margin of error.
%Let's say, 10%. So the calculus is as following:
%Part c: 600*500*4/3*pi*(0.036)^3*998*-0.003*1.1 = -228.97 W
%Part d: 600*500*4/3*pi*(0.036)^3*998*54000*1.1 = 3.50 GW
```

Problem 1f

```
%The main limitation is that we're not considering other sources of heat
%transfer, such as radiation. In addition, there will be fruits touching
%each other, which adds more complexibility to the problem.
```