**SA1 Interim Report 1**

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**Exercise 1:**

**Listing of ueintbit.m:**

function f = ueintbit(xa,ua,xb,ub)

u\_bar = (ua+ub)/2;

du = ub-ua;

dx = xb-xa;

f = dx \* (u\_bar^5 + (5 \* u\_bar^3 \*du^2)/6 + (u\_bar \* du^4)/16);

**Listing of script:**

clear

close all

x = (0:.01:1);

ue = ones(length(x));

Re = 2500;

thwaites = 0;

theta\_t = zeros(1,length(x));

theta\_b = zeros(1,length(x));

for i = 2:length(x)

thwaites = thwaites + ueintbit(x(i-1),ue(i-1),x(i),ue(i));

theta\_t(i) = (0.45/Re \* ue(i)^(-6) \* thwaites)^0.5;

theta\_b(i) = 0.664/(Re^0.5) \* x(i)^0.5;

end

mycolors = [1 0 0; 0 0 1];

hold on

plot(x,theta\_t)

plot(x,theta\_b)

**A graph of a curve

AI-generated content may be incorrect.**legend('Thwaites', 'Blasius','Location','southeast')

ax = gca;

ax.ColorOrder = mycolors;

ylabel('θ/L')

xlabel('x/L')

**Momentum thickness plot:**

**Exercise 2:**

**Listing of script:**

clear

close all

dx = .01;

x = (0:dx:1);

ue = zeros(1,length(x));

Re = 1 \* 10^6;

duedx = -0.2;

n = length(x);

laminar = true;

for i = 1:length(x)

ue(i) = 1 + x(i)\*duedx;

end

thwaites = 0;

theta\_t = zeros(1,length(x));

i = 1;

while laminar && i < n

i = i + 1;

thwaites = thwaites + ueintbit(x(i-1),ue(i-1),x(i),ue(i));

theta\_t(i) = (0.45/Re \* ue(i)^(-6) \* thwaites)^0.5;

Rethet = Re \* ue(i) \* theta\_t(i);

m = -Re \* theta\_t(i)^2 \* duedx;

H = thwaites\_lookup(m);

He = laminar\_He(H);

if log(Rethet) >= 18.4\*He - 21.74

laminar = false;

disp([x(i) Rethet/1000])

end

end

**Transition locations and Reϴ value:**

|  |  |  |  |
| --- | --- | --- | --- |
|  | d(ue/U)/d(x/L) | | |
| ReL | -0.2 | 0 | 0.2 |
| 1 x 106 | x/L = 0.58 , Reϴ = 567 | No Transition | No Transition |
| 10 x 106 | x/L = 0.24 , Reϴ = 1080 | x/L = 0.37 , Reϴ = 1290 | No Transition |
| 100 x 106 | x/L = 0.04 , Reϴ = 1350 | x/L = 0.04 , Reϴ = 1342 | x/L = 0.04 , Reϴ = 1334 |

**Exercise 3:**

**Listing of script:**

clear

close all

dx = .01;

x = (0:dx:1);

ue = zeros(1,length(x));

Re = 1.8 \* 10^6;

duedx = -0.5;

n = length(x);

laminar = true;

int = 0;

ils = 0;

for i = 1:length(x)

ue(i) = 1 + x(i)\*duedx;

end

thwaites = 0;

theta\_t = zeros(1,length(x));

i = 1;

while laminar && i < n

i = i + 1;

thwaites = thwaites + ueintbit(x(i-1),ue(i-1),x(i),ue(i));

theta\_t(i) = ( 0.45/Re \* ue(i)^(-6) \* thwaites)^0.5;

Rethet = Re \* ue(i) \* theta\_t(i);

m = -Re \* theta\_t(i)^2 \* duedx;

H = thwaites\_lookup(m);

He = laminar\_He(H);

if log(Rethet) >= 18.4\*He - 21.74

int = i;

laminar = false;

elseif m >= 0.09

ils = i;

laminar = false;

end

end

format shortE;

if int ~= 0

disp(['Natural transition at ' num2str(x(int)) ...

' with Rethet ' sprintf('%.1e', Rethet)]) %2sf

end

if ils ~= 0

disp(['Separation at ' num2str(x(ils)) ...

' with Rethet ' sprintf('%.1e', Rethet)])

end

**Separation locations:**

|  |  |
| --- | --- |
| ReL | x/L location at separation |
| 103 | 0.25 |
| 104 | 0.25 |
| 105 | 0.25 |

Transition supplants separation at ReL = 1.8 x 106.

**Exercise 4:**

**Listing of thickdash.m**

function dthickdx = thickdash(xmx0,thick)

global Re ue0 duedx

He = thick(2)/thick(1);

if He >= 1.46

H = (11\*He + 15)/(48\*He - 59);

elseif He < 1.46

H = 2.803;

end

ue = ue0 + duedx \* xmx0;

Rethet = Re \* ue \* thick(1);

cf = 0.091448 \* ((H-1) \* Rethet)^(-0.232) \* exp(-1.26\*H);

cdiss = 0.010025 \* ((H-1) \* Rethet)^(-1/6);

a = cf/2 - (H+2) \* duedx \* thick(1)/ue;

b = cdiss - 3 \* duedx \* thick(2)/ue;

dthickdx = zeros(2,1);

dthickdx(1,1) = a;

dthickdx(2,1) = b;

**Listing of script:**

clear

close all

global Re ue0 duedx

Re = 10^7;

ue0 = 1;

duedx = 0;

x0 = 0.01;

thick0(1) = 0.037\*x0\*(Re\*x0)^(-1/5);

thick0(2) = 1.80\*thick0(1);

[delx, thickhist] = ode45(@thickdash,[0 0.99],thick0);

theta7 = zeros(length(delx),1);

theta9 = zeros(length(delx),1);

x = x0 + delx;

for i = 1:length(delx)

theta7(i) = 0.037 \* x(i) \* (Re \* x(i))^(-1/5);

theta9(i) = 0.023 \* x(i) \* (Re \* x(i))^(-1/6);

end

mycolors = [1 0 0; 0 1 0; 0 0 1];

hold on

plot(x,thickhist(:,1))

plot(x,theta7)

plot(x,theta9)

legend('θ','θ\_7', 'θ\_9','Location','southeast')

ax = gca;

ax.ColorOrder = mycolors;

ylabel('θ/L')

xlabel('x/L')

**Result graph:**

A graph with a line

AI-generated content may be incorrect.

**Exercise 5:**

**Listing of script:**

clear

close all

global Re ue0 duedx

Re = 10^7;

ue0 = 1;

duedx = -0.25;

x0 = 0.01;

thick0(1) = 0.037\*x0\*(Re\*x0)^(-1/5);

thick0(2) = 1.80\*thick0(1);

[delx, thickhist] = ode45(@thickdash,[0 0.99],thick0);

He = thickhist(:,2)./thickhist(:,1);

He = He(:);

threshold\_He = 1.46;

cross\_idx = find((He(1:end-1) > threshold\_He) & (He(2:end) <= threshold\_He), 1);

x = x0 + delx;

threshold = ones(length(x))\*threshold\_He;

cross\_flag = true;

if ~isempty(cross\_idx)

idx\_before = cross\_idx;

idx\_after = cross\_idx + 1;

else

cross\_flag = false;

end

if cross\_flag == true

fprintf('Separation occurs between x/L = %.2e and x/L = %.2e\n', x(idx\_before), x(idx\_after));

end

mycolors = [1 0 0; 0 0 1];

figure;

hold on

plot(x,He)

plot(x,threshold)

ax = gca;

ax.ColorOrder = mycolors;

ylabel('He')

xlabel('x/L')

hold off

figure;

hold on

plot(x,thickhist(:,1))

plot(x,thickhist(:,2))

legend('θ','δ\_e','Location','southeast')

ax = gca;

ax.ColorOrder = mycolors;

ylabel('θ/L')

xlabel('x/L')

**tabulated separation locations:**

|  |  |  |
| --- | --- | --- |
| **d(ue/u)/d(x/L)** | **Re** | **Separation** |
| **-0.3** | **1e7** | **No** |
| **-0.6** | **1e7** | **x/L = 0.802** |
| **-0.9** | **1e7** | **x/L = 0.512** |
| **-0.6** | **1e6** | **x/L = 0.719** |
| **-0.6** | **1e8** | **x/L = 0.930** |

**Result graph for d(ue/u)/d(x/L) = -0.6, Re = 1e7**

**A graph with a red line

AI-generated content may be incorrect.A graph of a line

AI-generated content may be incorrect.**

**Exercise 6:**

**Flow chart:**

A diagram of a flowchart

AI-generated content may be incorrect.

**Listing of script:**

clear

close all

global Re ue0 duedx

Re\_list = [1e5, 1e6, 1e4];

legend\_labels = cell(1, numel(Re\_list));

figure(1); clf; hold on;

figure(2); clf; hold on;

for j = 1:length(Re\_list)

Re = Re\_list(j);

ue0 = 1;

duedx = -0.25;

dx = .01;

x = (0:dx:1);

ue = zeros(1,length(x));

duedx = -0.25;

n = length(x);

laminar = true;

int = 0;

ils = 0;

itr = 0;

its = 0;

for i = 1:length(x)

ue(i) = 1 + x(i)\*duedx;

end

thwaites = 0;

theta\_t = zeros(1,length(x));

theta\_b = zeros(1,length(x));

He = zeros(n,1);

He(1) = 1.57258;

i = 1;

while laminar && i < n

i = i + 1;

thwaites = thwaites + ueintbit(x(i-1),ue(i-1),x(i),ue(i));

theta\_t(i) = ( 0.45/Re \* ue(i)^(-6) \* thwaites)^0.5;

Rethet = Re \* ue(i) \* theta\_t(i);

m = -Re \* theta\_t(i)^2 \* duedx;

H = thwaites\_lookup(m);

He(i) = laminar\_He(H);

if log(Rethet) >= 18.4\*He - 21.74

int = i;

laminar = false;

elseif m >= 0.09

ils = i;

laminar = false;

He(i) = 1.51509; %set to exact value

end

end

delta\_e = He(i).\*theta\_t(i);

while its == 0 && i<n

i = i+1;

thick0(1) = theta\_t(i-1);

thick0(2) = delta\_e;

ue0 = ue(i-1);

[delx, thickhist] = ode45(@thickdash,[0,x(i)-x(i-1)],thick0);

theta\_t(i) = thickhist(end,1);

delta\_e = thickhist(end,2);

He(i) = delta\_e/theta\_t(i);

if He(i)>1.58 && ils~=0 && itr == 0

itr = i;

end

if He(i)<1.46

its = i;

end

end

He(i:n) = He(i);

for m =i:n-1

theta\_t(m+1) = theta\_t(m)\*(ue(m)/ue(m+1))^(2.803+2);

end

format shortE;

if int ~= 0

disp(['Natural transition at ' num2str(x(int)) ...

' with Rethet ' sprintf('%.1e', Rethet)]) %2sf

end

if ils ~= 0

disp(['Separation at ' num2str(x(ils)) ...

' with Rethet ' sprintf('%.1e', Rethet)])

end

if itr ~= 0

disp(['Turbulent reattachment at ' num2str(x(itr))]);

end

if its ~= 0

disp(['Turbulent separation at ' num2str(x(its))]);

end

% Combine into a full color list

figure(1);

plot(x,He);

figure(2);

plot(x,theta\_t);

legend\_labels{j} = sprintf('Re = %.0e', Re);

end

line\_color = [0.5 0.1 0.4]; % pure red

all\_colors = [lines(3); line\_color; line\_color]; % 5 total

threshold\_1 = ones(length(x))\*1.46;

threshold\_2 = ones(length(x))\*1.58;

figure(1);

ax = gca;

ax.ColorOrder = all\_colors;

ylabel('He')

xlabel('x/L')

plot(x,threshold\_1)

plot(x,threshold\_2)

legend(legend\_labels, 'Location', 'northeast');

figure(2);

ax = gca;

ax.ColorOrder = all\_colors;

ylabel('θ/L')

xlabel('x/L')

legend(legend\_labels, 'Location', 'northeast');

**plots:**

**(a) θ/L vs x/L, for ReL = 10^6 and 10^7 , with zero pressure gradient;**

**A graph with a red line and blue line

AI-generated content may be incorrect.**

**(b) HE vs x/L for ReL = 10^6 and 10^7 , with zero pressure gradient;**

A graph of a function

AI-generated content may be incorrect.

**(c) θ/L vs x/L, for ReL = 10^4 , 10^5 and 10^6 , with d(ue/U)/d(x/L) = –0.25;**

**A graph of a function

AI-generated content may be incorrect.**

**(d) HE vs x/L for ReL = 10^4 , 10^5 and 10^6 , with d(ue/U)/d(x/L) = –0.25.**

A graph with lines and text

AI-generated content may be incorrect.

**critical velocity gradient for Re = 10^5**

**d(ue/U)/d(x/L) = -0.383 = -0.38: A graph with a line

AI-generated content may be incorrect.**