

# **APP N05-2**

Engineering 1282.02H

Spring 2020

**Rohan Deshpande, Seat 31**

M. Parke 12:40

Date of Submission: 02/21/2020

### Program Code:

```
%*****  
%* Name: Rohan Deshpande Date: 02/18/20 *  
%* Seat: 31 File: APP_N05_2.m *  
%* Instructor: MEP 12:40 *  
%*****  
  
clear  
clc  
  
fprintf ('\n*****')  
fprintf ('\n* Name: Rohan Deshpande Date: 02/18/20 *')  
fprintf ('\n* Seat: 31 File: APP_N05_2.m *')  
fprintf ('\n* Instructor: MEP 12:40 *')  
fprintf ('\n*****\n')  
  
%Description of program  
fprintf('This program calculates parameters and properties of fluid flow in a  
rectangular channel.\n');  
fprintf ('The user inputs 5 known values of the following 6 parameters:');  
fprintf ('\n\tVolumetric Flow Rate \n\tChannel Width \n\tChannel Height  
\n\tChannel Length \n\tPressure Differential \n\tViscosity\n');  
fprintf ('The program calculates and displays the missing 6th parameter and  
also:');  
fprintf (" \n\tAverage Velocity \n\tShear Stress at the Wall\n\tReynold's  
Number\n\tViscosity\n");  
fprintf ('The program also creates plots of: ');  
fprintf ('\n\tFluid Velocity across the Channel Height\n\tShear Stress across  
the Channel Height');  
  
  
  
  
  
%Instructions for program  
%Extra line  
fprintf ('\n\n');  
fprintf ('Instructions:\n');  
fprintf ('Enter the number corresponding to the missing 6th parameter when  
prompted.\n');  
fprintf ('For each of the 5 known parameters, enter the value (with the  
respective units) when prompted.\n');  
fprintf ('The program will display the known and calculated parameter  
values.\n');  
fprintf ('The program will also open plots of Velocity across Channel Height  
and Shear Stress across Channel Height.\n');  
  
%TEST  
%extra-testing region start
```

```

%Prompt user for missing parameter
    %Extra line
    fprintf ('\n');
%display integer choices for each type
fprintf ('Enter 1 for Volumetric Flow Rate (Q)\n');
fprintf ('Enter 2 for Width (W)\n');
fprintf ('Enter 3 for Height (H)\n');
fprintf ('Enter 4 for Length (L))\n');
fprintf ('Enter 5 for Pressure Differential (DeltaP)\n');
fprintf ('Enter 6 for Viscosity (mu)\n');

%User's missing parameter --> missing = variable to use in switch
missing = input ('Which of the sixth paramters is missing?: ');

%switch case for each possible input scenario
switch missing

    %1 --> Q
    case 1

        %Prompt user for the rest and user inputs the rest
        fprintf ('Enter the known parameters\n');
        W = input ('\nEnter Width (W) in cm: ');
        H = input ('\nEnter Height (H) in cm: ');
        L = input ('\nEnter Length (L) in cm: ');
        DeltaP = input ('\nEnter Pressure Differential (DeltaP) in
dynes/cm^2: ');
        mu = input ('\nEnter Viscosity (mu) in g/cm*s: ');

        %Calculate Q
        Q = (W * H^3 * DeltaP) / (12 * mu * L);

    %2 --> W
    case 2

        %Prompt user for the rest and user inputs the rest
        fprintf ('Enter the known parameters\n');
        Q = input ('Enter Volumetric Flow Rate (Q) in cm^3/s: ');
        H = input ('Enter Height (H) in cm: ');
        L = input ('Enter Length (L) in cm: ');
        DeltaP = input ('Enter Pressure Differential (DeltaP) in dynes/cm^2:
');
        mu = input ('Enter Viscosity (mu) in g/cm*s: ');

        %Calculate W
        W = (Q * 12 * mu * L) / (H^3 * DeltaP);

    %3 --> H
    case 3

```

```

%Prompt user for the rest and user inputs the rest
fprintf ('Enter the known parameters\n');
Q = input ('Enter Volumetric Flow Rate (Q) in cm^3/s: ');
W = input ('Enter Width (W) in cm: ');
L = input ('Enter Length (L) in cm: ');
DeltaP = input ('Enter Pressure Differential (DeltaP) in dynes/cm^2:
');

mu = input ('Enter Viscosity (mu) in g/cm*s: ');

%Calculate H
H = ((Q * 12 * mu * L) / (W * DeltaP))^(1/3);

%4 --> L
case 4

%Prompt user for the rest and user inputs the rest
fprintf ('Enter the known parameters\n');
Q = input ('Enter Volumetric Flow Rate (Q) in cm^3/s: ');
W = input ('Enter Width (W) in cm: ');
H = input ('Enter Height (H) in cm: ');
DeltaP = input ('Enter Pressure Differential (DeltaP) in dynes/cm^2:
');

mu = input ('Enter Viscosity (mu) in g/cm*s: ');

%Calculate L
L = (W * H^3 * DeltaP) / (12 * mu * Q);

%5 --> DeltaP
case 5

%Prompt user for the rest and user inputs the rest
fprintf ('Enter the known parameters\n');
Q = input ('Enter Volumetric Flow Rate (Q) in cm^3/s: ');
W = input ('Enter Width (W) in cm: ');
H = input ('Enter Height (H) in cm: ');
L = input ('Enter Length (L) in cm: ');
mu = input ('Enter Viscosity (mu) in g/cm*s: ');

%Calculate DeltaP
DeltaP = (Q * 12 * mu * L) / (H^3 * W);

%6 --> mu
case 6

%Prompt user for the rest and user inputs the rest
fprintf ('Enter the known parameters\n');
Q = input ('Enter Volumetric Flow Rate (Q) in cm^3/s: ');

```

```

W = input ('Enter Width (W) in cm: ');
H = input ('Enter Height (H) in cm: ');
L = input ('Enter Length (L) in cm: ');
DeltaP = input ('Enter Pressure Differential (DeltaP) in dynes/cm^2:
');

%Calculate mu
mu = (W * H^3 * DeltaP) / (12 * Q * L);

%end of switch
end

% % %extra testing region end
% % %testing variables
% Q = 8;
% W = 3;
% H = 0.2;
% L = 25;
% mu = 0.01;
% DeltaP = 1000;
% %%TEST

%calculate V_avg
V_avg = (H^2 * DeltaP) / (12 * mu * L);

%Calculate T_wall
T_wall = (H/2 * DeltaP)/(L);

%calculate D_h for intermediate step
D_h = (4 * W * H) / (2*W + 2*H);

%density of water (rho) assumed to be 1.0 g / cm^3 to avoid integer math
rho = 1.0;

%Calculate Re
Re = (rho * V_avg * D_h) / (mu);

%Calculate L_e
L_e = 0.06 * Re * D_h;

%Display all values in a neat table
%extra line

```

```

fprintf('\n');
fprintf ('Volumetric Flow Rate (Q): \t\t\t %.2f cm^3/s\n', Q);
fprintf ('Width (W): \t\t\t\t\t\t\t\t %.2f cm\n', W);
fprintf ('Height (H): \t\t\t\t\t\t\t\t %.2f cm\n', H);
fprintf ('Length (L): \t\t\t\t\t\t\t\t %.2f cm\n', L);
fprintf ('Pressure Differential (DeltaP): \t\t\t\t\t\t\t\t\t %.2f dynes/cm^2\n', DeltaP);
fprintf ('Viscosity (mu): \t\t\t\t\t\t\t\t\t %.2f g/cm*s\n', mu);
fprintf ('Average Velocity (V_avg): \t\t\t\t\t\t\t\t\t %.2f cm/s\n', V_avg);
fprintf ('Shear Stress at Wall (T_wall): \t\t\t\t\t\t\t\t %.2f dynes/cm^2\n', T_wall);
fprintf ("Reynold's Number (Re): \t\t\t\t\t\t\t\t\t\t %.1f\n", Re);
fprintf ('Entrance Length (L_e): \t\t\t\t\t\t\t\t\t %.2f cm\n', L_e);

%TEST
%Create vector y from -H/2 to H/2 w/ 50 even increments
y = linspace (-H/2,H/2,50);

%Create V_y vector from vector math w/ y and equation for v(y)
V_y = (DeltaP)/(8 * mu * L)* (H^2 - 4 .* y .* y);

%Create T_y vector from vector math w/ y and equation for T(y)
T_y = (DeltaP)/(L) * abs(y);

%Plot V_y and y
plot (V_y,y);

%Format plot 1
title ('Velocity Distribution Across Channel Height');
ylabel ('Height (cm)');
xlabel ('Velocity (cm/s)');

%Plot T_y vs y
%plot T_y and y on a new figure
figure;
plot (T_y,y);

%format plot 2
title ('Shear Stress Distribution Across Channel Height');
ylabel ('Height (cm)');
xlabel ('Shear Stress (dynes/cm^2)');

%TEST

```

## Sample Output 1

### Command Window:

```
*****
* Name: Rohan Deshpande Date: 02/18/20      *
* Seat: 31   File: APP_N05_2.m               *
* Instructor: MEP 12:40                      *
*****
```

This program calculates parameters and properties of fluid flow in a rectangular channel.

The user inputs 5 known values of the following 6 parameters:

- Volumetric Flow Rate
- Channel Width
- Channel Height
- Channel Length
- Pressure Differential
- Viscosity

The program calculates and displays the missing 6th parameter and also:

- Average Velocity
- Shear Stress at the Wall
- Reynold's Number
- Viscosity

The program also creates plots of:

- Fluid Velocity across the Channel Height
- Shear Stress across the Channel Height

### Instructions:

Enter the number corresponding to the missing 6th parameter when prompted.

For each of the 5 known parameters, enter the value (with the respective units) when prompted.

The program will display the known and calculated parameter values.

The program will also open plots of Velocity across Channel Height and Shear Stress across Channel Height.

Enter 1 for Volumetric Flow Rate (Q)

Enter 2 for Width (W)

Enter 3 for Height (H)

Enter 4 for Length (L))

Enter 5 for Pressure Differential (DeltaP)

Enter 6 for Viscosity (mu)

Which of the sixth paramters is missing?: 4

Enter the known parameters

Enter Volumetric Flow Rate (Q) in cm^3/s: 8

Enter Width (W) in cm: 3

Enter Height (H) in cm: 0.2

Enter Pressure Differential (DeltaP) in dynes/cm^2: 1000

Enter Viscosity (mu) in g/cm\*s: 0.01

Volumetric Flow Rate (Q): 8.00 cm^3/s

Width (W): 3.00 cm

Height (H): 0.20 cm

Length (L): 25.00 cm

Pressure Differential (DeltaP): 1000.00 dynes/cm^2

Viscosity (mu): 0.01 g/cm\*s

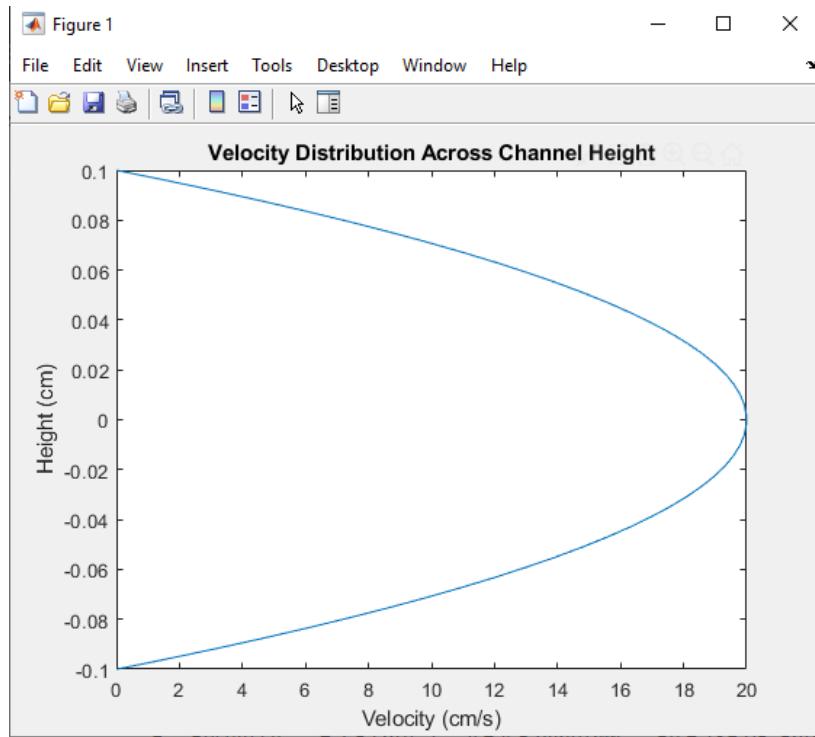
Average Velocity (V\_avg): 13.33 cm/s

Shear Stress at Wall (T\_wall): 4.00 dynes/cm^2

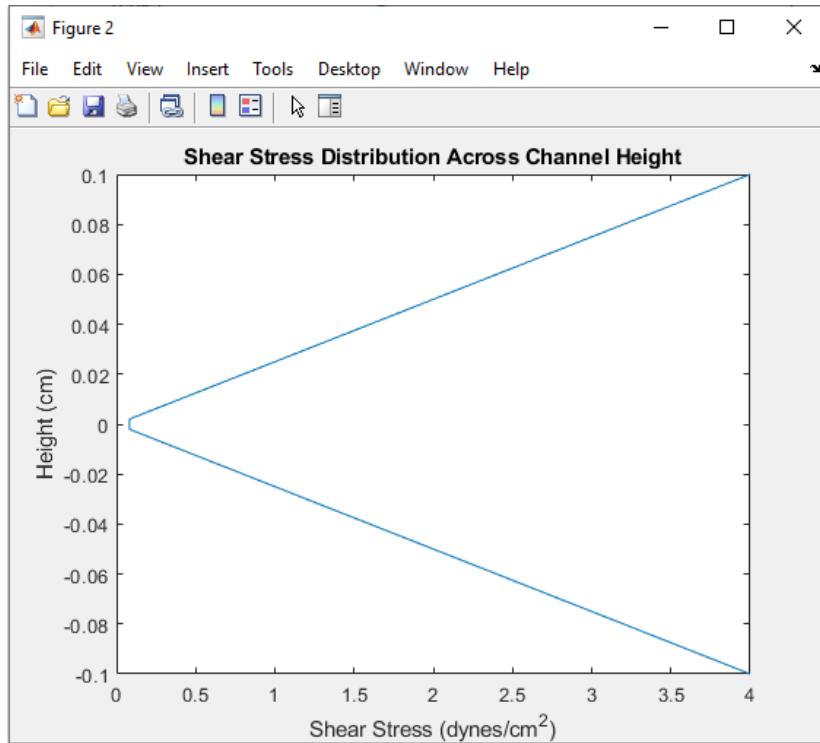
Reynold's Number (Re): 500.0

Entrance Length (L\_e): 11.25 cm

Graphs 1:



**Figure 1:** 1<sup>st</sup> MATLAB plot of velocity throughout channel height.



**Figure 2:** 1<sup>st</sup> MATLAB plot of shear stress throughout channel height

## Sample Output 2

### Command Window:

```
*****
* Name: Rohan Deshpande Date: 02/18/20      *
* Seat: 31   File: APP_N05_2.m               *
* Instructor: MEP 12:40                      *
*****
```

This program calculates parameters and properties of fluid flow in a rectangular channel.

The user inputs 5 known values of the following 6 parameters:

- Volumetric Flow Rate
- Channel Width
- Channel Height
- Channel Length
- Pressure Differential
- Viscosity

The program calculates and displays the missing 6th parameter and also:

- Average Velocity
- Shear Stress at the Wall
- Reynold's Number
- Viscosity

The program also creates plots of:

- Fluid Velocity across the Channel Height
- Shear Stress across the Channel Height

### Instructions:

Enter the number corresponding to the missing 6th parameter when prompted.

For each of the 5 known parameters, enter the value (with the respective units) when prompted.

The program will display the known and calculated parameter values.

The program will also open plots of Velocity across Channel Height and Shear Stress across Channel Height.

Enter 1 for Volumetric Flow Rate (Q)

Enter 2 for Width (W)

Enter 3 for Height (H)

Enter 4 for Length (L))

Enter 5 for Pressure Differential (DeltaP)

Enter 6 for Viscosity (mu)

Which of the sixth paramters is missing?: 6

Enter the known parameters

Enter Volumetric Flow Rate (Q) in cm^3/s: 0.75

Enter Width (W) in cm: 1

Enter Height (H) in cm: 0.1

Enter Length (L) in cm: 20

Enter Pressure Differential (DeltaP) in dynes/cm^2: 1800

Volumetric Flow Rate (Q): 0.75 cm^3/s

Width (W): 1.00 cm

Height (H): 0.10 cm

Length (L): 20.00 cm

Pressure Differential (DeltaP): 1800.00 dynes/cm^2

Viscosity (mu): 0.01 g/cm\*s

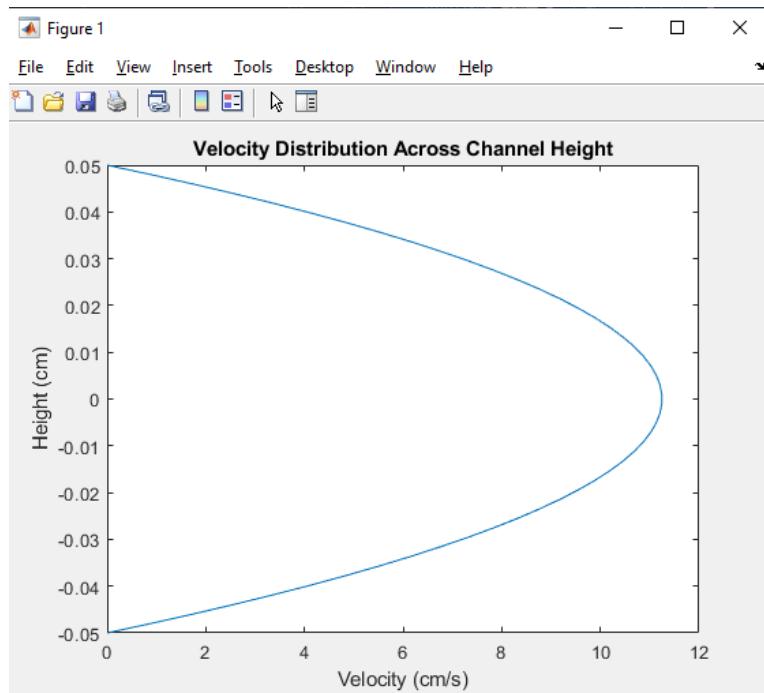
Average Velocity (V\_avg): 7.50 cm/s

Shear Stress at Wall (T\_wall): 4.50 dynes/cm^2

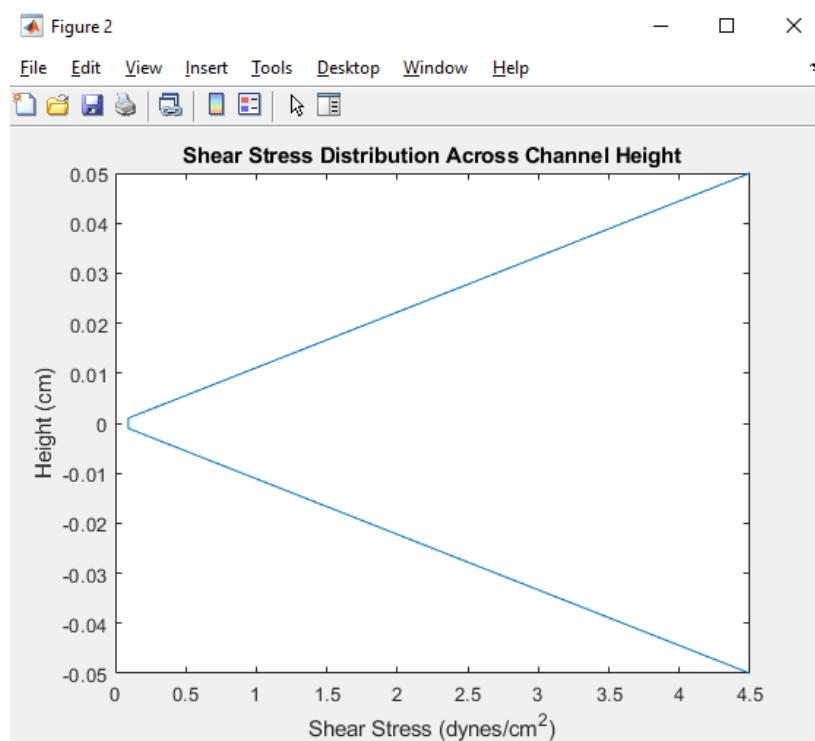
Reynold's Number (Re): 136.4

Entrance Length (L\_e): 1.49 cm

## Graphs 2:



**Figure 3:** 2<sup>nd</sup> MATLAB plot of velocity throughout channel height.



**Figure 4:** 2<sup>nd</sup> MATLAB plot of shear stress throughout channel height

## Equations

Note: equations from Fluid Mechanics Equations sheet on Carmen

### **General Volumetric Flow Rate**

$$Q = \frac{WH^3\Delta P}{12\mu L}$$

### **Average Velocity**

$$v_{avg} = \frac{H^2\Delta P}{12\mu L}$$

### **Velocity Function**

$$v(y) = \frac{\Delta P}{8\mu L} (H^2 - 4y^2)$$

### **Shear Stress at the Wall**

$$\tau_{wall} = \frac{\left(\frac{H}{2}\right)\Delta P}{L}$$

### **Shear Stress Function**

$$\tau(y) = \frac{\Delta|y|}{L}$$

### **Reynolds Number**

$$Re = \frac{\rho v_{avg} D_h}{\mu}$$

### **Entrance Length**

$$L_e = 0.06 Re D_h$$

### **Hydraulic/Effective Diameter**

$$D_h = \frac{4WH}{2W + 2H}$$

Defined Variables:

Note: table taken from Fluid Mechanics Equations sheet on Carmen

VARIABLES	
$Q$ = volumetric flow rate ( $\text{cm}^3/\text{s}$ )	$v(y)$ = velocity function ( $\text{cm}/\text{s}$ )
$\Delta P$ = change in pressure (dynes/ $\text{cm}^2$ )	$V_{\text{avg}}$ = average velocity ( $\text{cm}/\text{s}$ )
$W$ = width (cm)	$\tau(y)$ = shear stress function (dynes/ $\text{cm}^2$ )
$H$ = height (cm)	$\tau_{\text{wall}}$ = shear stress at the wall (dynes/ $\text{cm}^2$ )
$L$ = length (cm)	$y$ = position in the channel (cm)
$D_h$ = hydraulic diameter	$Re$ = Reynold's Number (unitless)
$\mu$ = dynamic viscosity ( $\text{g}/\text{cm} \cdot \text{s}$ )	$L_e$ = entrance length (cm)
$\rho$ = density ( $\text{g}/\text{cm}^3$ )	

Sample Calculations:

Inputs

$$Q = 8 \frac{cm^3}{s} \quad W = 3 \text{ cm} \quad H = 0.2 \text{ cm}$$

$$\Delta P = 1000 \frac{dynes}{cm^2} \quad \mu = 0.01 \frac{g}{cm * s}$$

General Volumetric Flow Rate

$$L = \frac{WH^3\Delta P}{12\mu Q} = \frac{(3 \text{ cm})(0.2 \text{ cm})^3(1000 \frac{dynes}{cm^2})}{12(\frac{0.01 g}{cm * s})(\frac{8 cm^3}{s})} = 25 \text{ cm}$$

Average Velocity

$$v_{avg} = \frac{H^2\Delta P}{12\mu L} = \frac{(0.2 \text{ cm})^2(1000 \frac{dynes}{cm^2})}{12(\frac{0.01 g}{cm * s})(25 \text{ cm})} = 13.33 \text{ cm/s}$$

Shear Stress at the Wall

$$\tau_{wall} = \frac{\left(\frac{H}{2}\right)\Delta P}{L} = \frac{\left(\frac{0.2 \text{ cm}}{2}\right)\left(1000 \frac{dynes}{cm^2}\right)}{(25 \text{ cm})} = 4 \frac{dynes}{cm^2}$$

Reynolds Number

$$Re = \frac{\rho v_{avg} D_h}{\mu} = \frac{(1.0 \frac{g}{cm^3})(13.33 \frac{cm}{s})(0.375 \text{ cm})}{(0.01 \frac{g}{cm * s})} = 500$$

Entrance Length

$$L_e = 0.06 Re D_h = 0.06(500)(0.375 \text{ cm}) = 11.25 \text{ cm}$$

Hydraulic/Effective Diameter

$$D_h = \frac{4WH}{2W + 2H} = \frac{4(3 \text{ cm})(0.2 \text{ cm})}{2(3 \text{ cm}) + 2(0.2 \text{ cm})} = 0.375 \text{ cm}$$