ME634
END-SEMESTER

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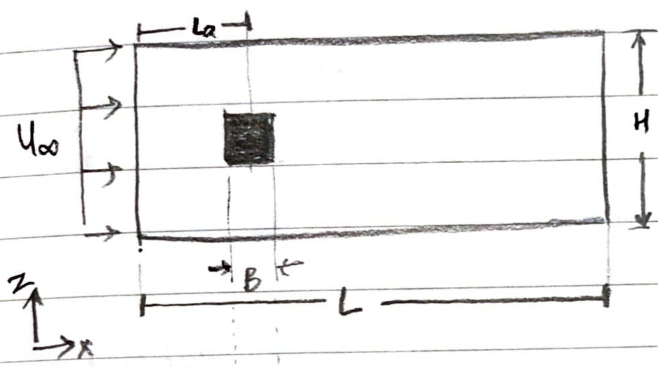
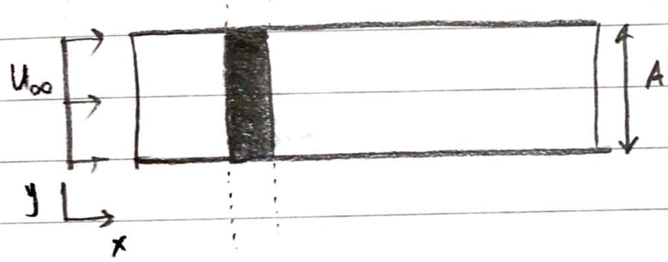
# FLOW PAST A SQUARE CYLINDER
(C-using RK3-CN Alg.)

## A. SETUP




| $N_x$ | $N_y$ | $N_z$ | nxp2 | nyp2 | nzp2 |
|---|---|---|---|---|---|
| 178 × 32 × 80 | | | 180 | 34 | 82 |

$B = 1$ $\quad L_a = 6$

$L = 24 \quad A = 6 \quad H = 10$

$\quad \| \quad\quad \| \quad\quad \|$

$\quad L_x \quad\quad L_y \quad\quad L_z$

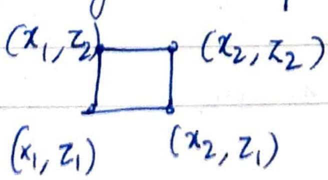
$\Rightarrow dx = \quad , dy = \quad , dz =$

Now, $B/dx \neq$ natural number
$\Rightarrow$ can do either of the following

(a) Adjust the dimensions of the square to match appropriately with the grid.
OR
(b) Redefine mesh according to the square-length such that the nodes of the mesh lie exactly on the edges.
OR
(c) Use interpolation to make-up for the disparity

→ done (a) as an initial estimate

New nodes of the square are

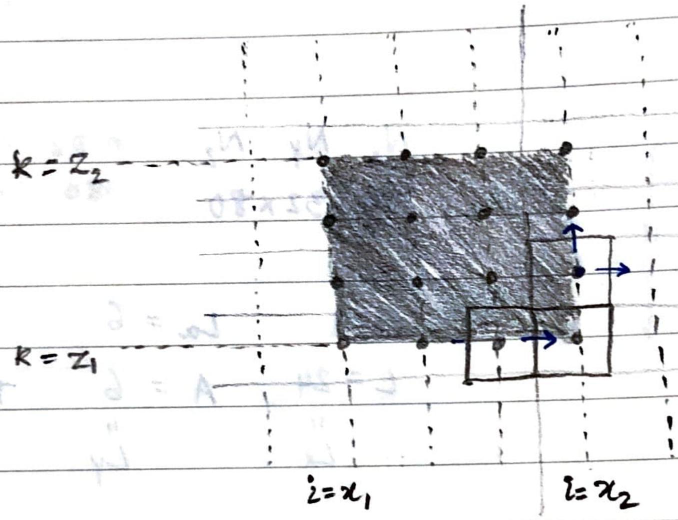


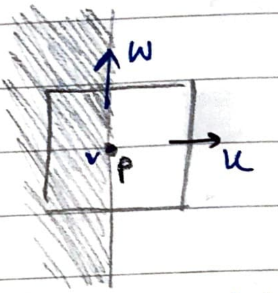

$x_1 = \quad\quad x_2 =$

$z_1 = \quad\quad z_2 =$

## B. BOUNDARY CONDITIONS

**SQUARE**




(v is outwards)

| | | |
|---|---|---|
| ⓛ | left face | $(x_2, :, z_1 : z_2)$ |
| ⓡ | right face | $(x_2, :, z_1 : z_2)$ |
| ⓑ | bottom face | $(x_1 : x_2, :, z_1)$ |
| ⓣ | top face | $(x_1 : x_2, :, z_2)$ |
| ⓘ | interior | $(x_1+1 : x_2-1, :, z_1+1 : z_2-1)$ |

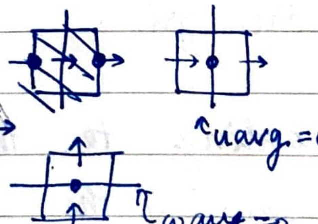
} Pressure centers ⇒ square.

u for left and right faces :     $u(\text{interior}) = -u(\text{exterior})$

u=0 for top and bottom     $u(\text{both top nodes}) = 0$

w for top and bottom faces :     $w(\text{interior}) = -w(\text{exterior})$

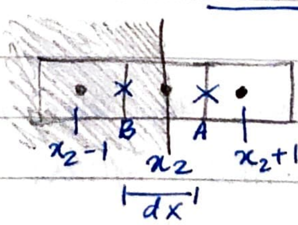
w=0 for left & right.     $w(\text{left or r nodes}) = 0$




v for all nodes : $v(x_1 : x_2, :, z_1 : z_2) = 0$

interior velocities are also made zero for u and w.

ⓡ Pressure $\left.\partial P/\partial x\right|_{\text{face } ⓡ} = 0$ ⇒




$\frac{P_A - P_B}{dx} = 0$

$\Rightarrow P_A = P_B$

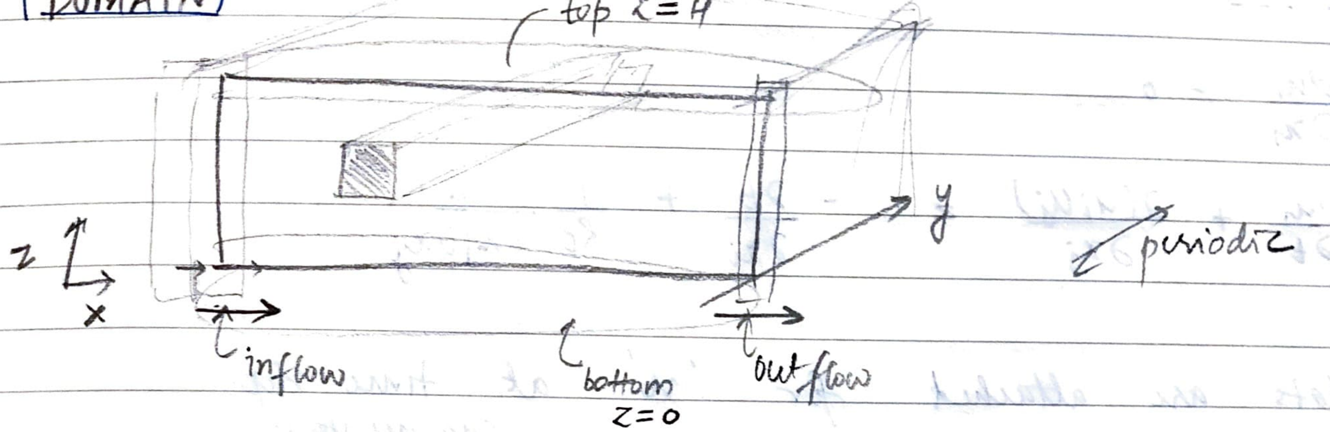
$\Rightarrow 0.5(P(x_2+1) + P(x_2)) = 0.5(P(x_2) + P(x_2-1))$

$\Rightarrow P(x_2-1) = P(x_2+1)$

similarly for z dirxⁿ as well.

see updatebc.m file.

DOMAIN




(inf) inflow $\frac{u(1)+u(2)}{2} = U_\infty \Rightarrow u(1) = 2U_\infty - u(2)$

$u(1) = 2U_\infty - u(2)$, $v=0$, $w=0$ $\quad \partial p/\partial x = 0 \Rightarrow P(1) = P(2)$

(out) outflow $\frac{\partial u}{\partial x}, \frac{\partial v}{\partial x}, \frac{\partial w}{\partial x} = 0 \Rightarrow$ u(i=nxp2,:,:) = u(i-1, )

v( " ) = v( " )

w( " ) = w( " )

$p=0 \Rightarrow p(nxp2) = 0$

(p) periodic in y: var(:,1,:) = var(:,nyp2-1,:)

~~var(:,nyp2,:) = var(:,ny~~

var(:,nyp2,:) = var(:,2,:).

(t) top : $\frac{\partial u}{\partial z}, \frac{\partial v}{\partial z}, \frac{\partial w}{\partial z}, p = 0$. (similar to outflow)

$\downarrow$

u(k=1) = u(k=2) $\qquad$ v(k=1) = v(k=2)

u(k=nzp2) = u(k=nzp2-1) $\qquad$ ← same.

w(k=1) = w(k=2)

w(k=nzp2-1) = w(k=nzp2-2).

p(k=1) = 0

p(k=nzp2) = 0.

## Gov Eqns

$$\frac{\partial u_i}{\partial x_j} = 0$$

$$\frac{\partial u_i}{\partial t} + \frac{\partial (u_i u_j)}{\partial x_j} = -\frac{\partial p}{\partial x_i} + \frac{1}{Re}\frac{\partial^2 u_i}{\partial x_j \partial x_j}$$

Plots are attached for 'u' at time steps (as mentioned)

Further, $Re = 20$ (flow parameter).

Pseudo code for plotting FFT:

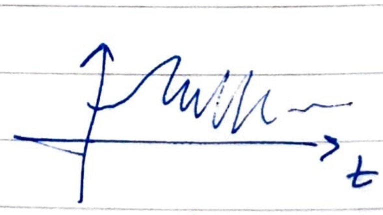
$L_1 = 8 \Rightarrow nx_1 = 8/dx$
$L_2 = 10 \Rightarrow nx_2 = 10/dx$

val 1 = $u(nx_1, 17, 41)$
val 2 = $u(nx_2, 17, 41)$

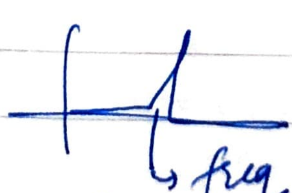
we'll get these values at each timestep.
store in ureq( ) array $t, u$
wreq( ) array $t, w$

↓

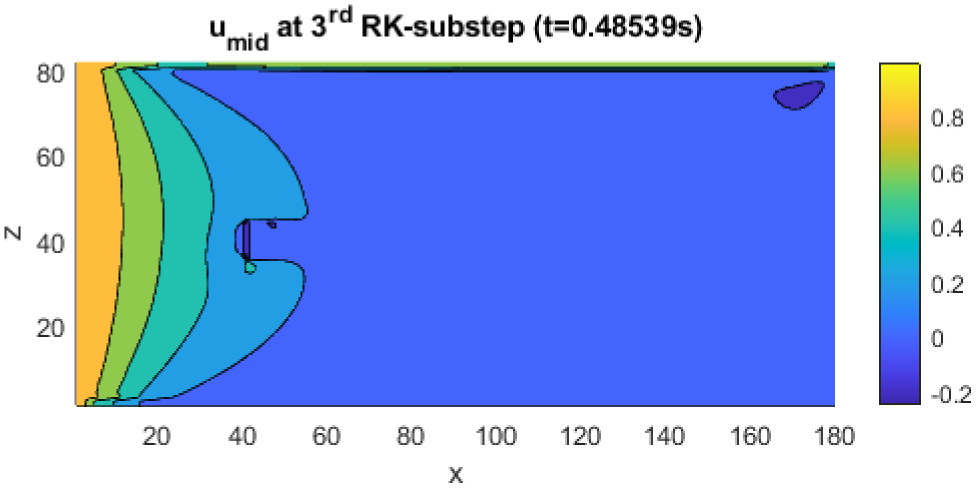
plot ($t$, $u$)
plot ($t$, $w$)



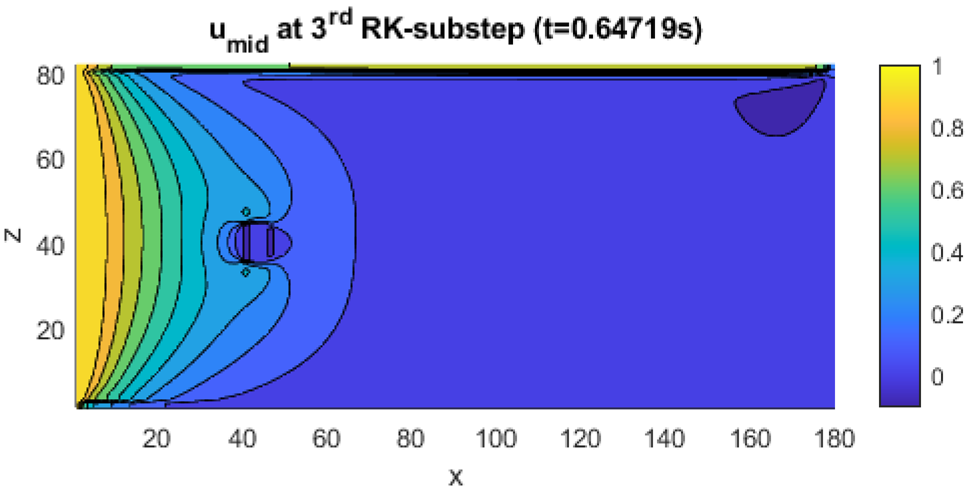

↓ FFT (ureq)



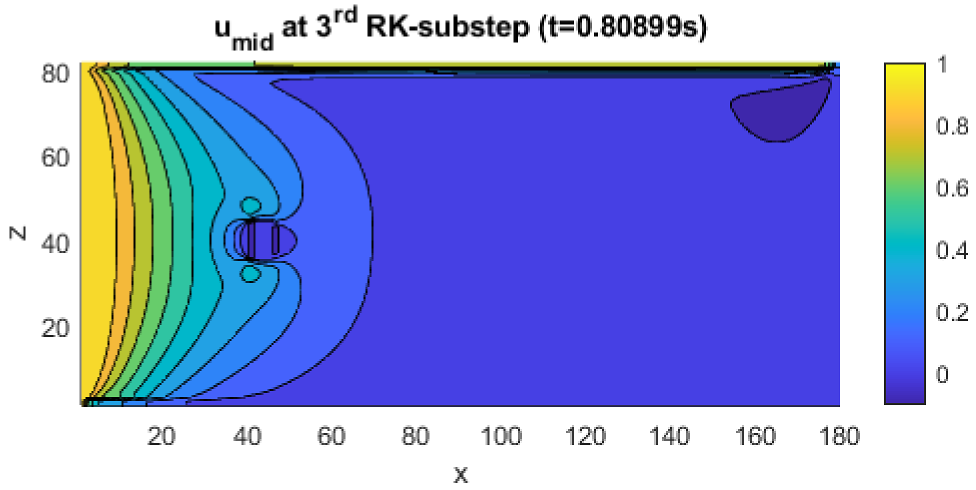

when freq = constant ⇒ fully developed vortex shedding.

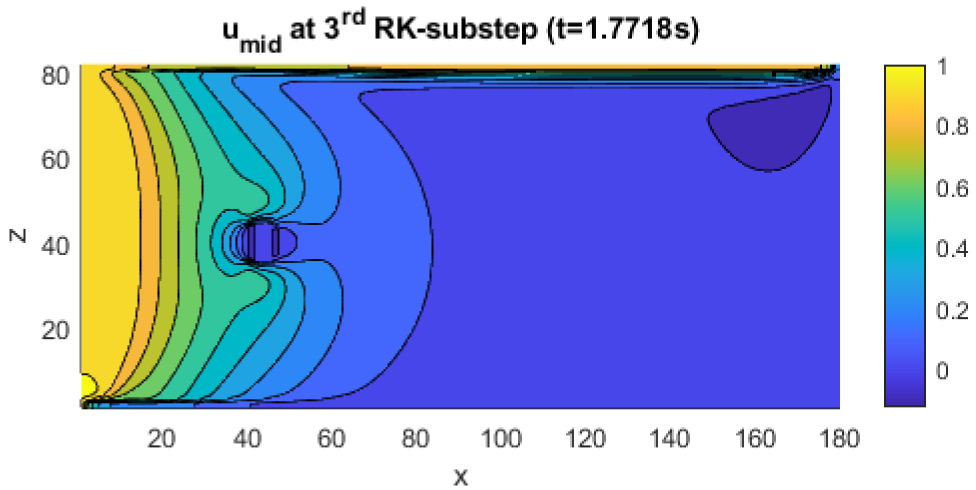


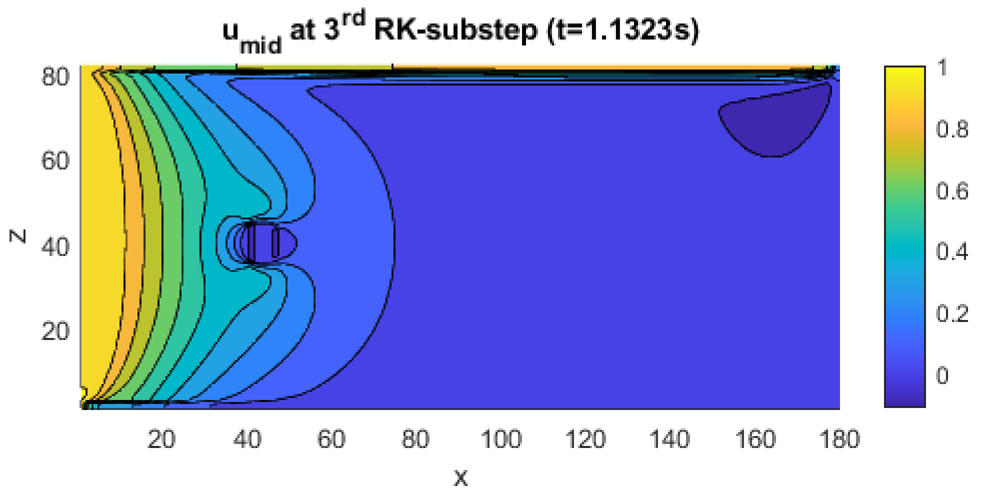
$u_{mid}$ at 3rd RK-substep (t=0.48539s)
z
x
80
60
40
20
20
40
60
80
100
120
140
160
180
0.8
0.6
0.4
0.2
0
-0.2

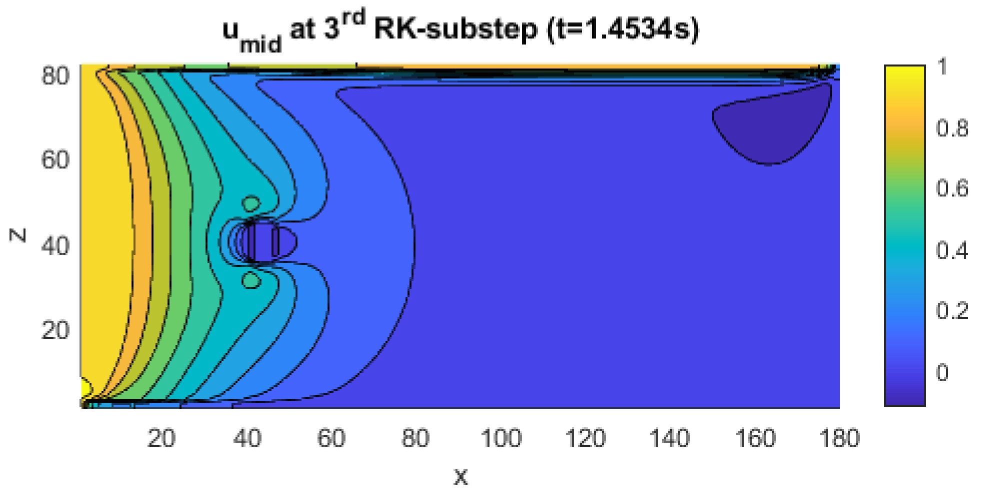



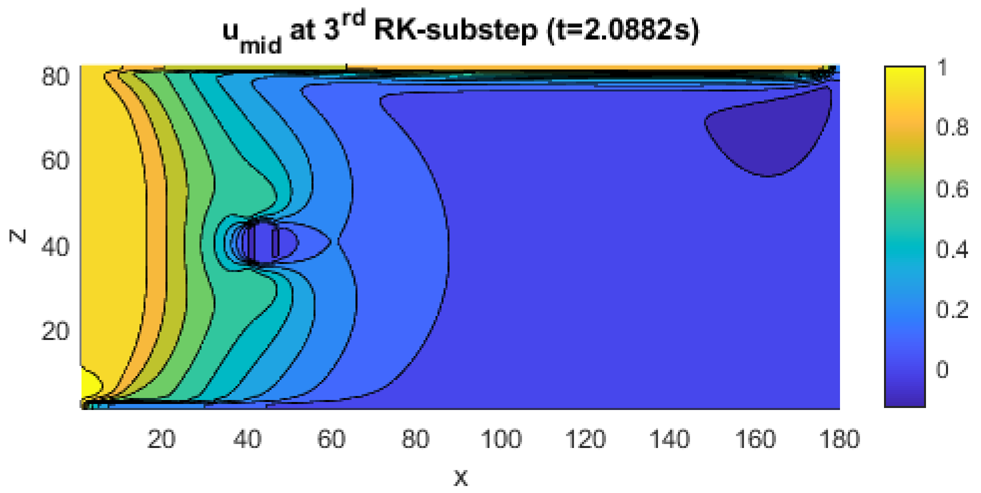
$u_{mid}$ at 3rd RK-substep (t=0.64719s)
z
x
80
60
40
20
20
40
60
80
100
120
140
160
180
1
0.8
0.6
0.4
0.2
0

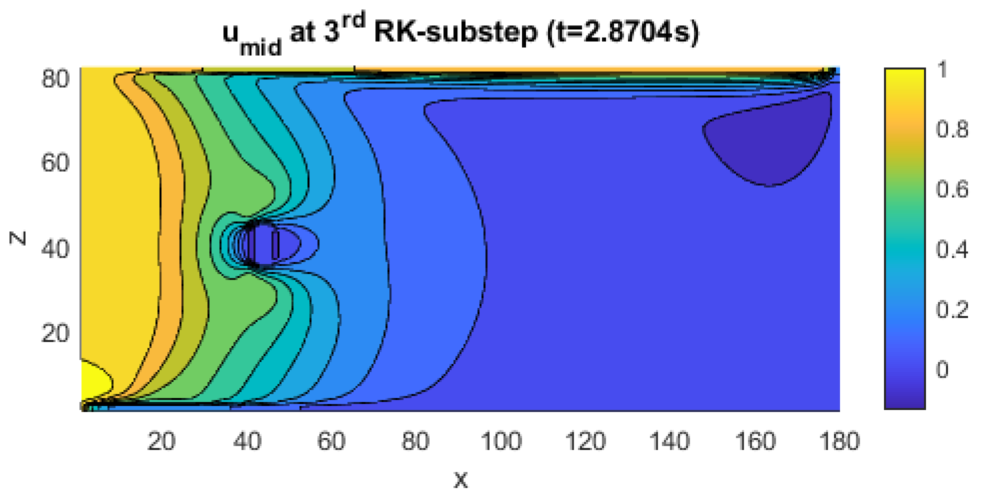

$u_{mid}$ at $3^{rd}$ RK-substep (t=0.80899s)
z
80
60
40
20
x
20
40
60
80
100
120
140
160
180
1
0.8
0.6
0.4
0.2
0


$u_{mid}$ at $3^{rd}$ RK-substep (t=1.7718s)
z
80
60
40
20
x
20
40
60
80
100
120
140
160
180
1
0.8
0.6
0.4
0.2
0


$u_{mid}$ at $3^{rd}$ RK-substep (t=1.1323s)
z
x
80
60
40
20
20
40
60
80
100
120
140
160
180
1
0.8
0.6
0.4
0.2
0


$u_{mid}$ at $3^{rd}$ RK-substep (t=1.4534s)
z
x
80
60
40
20
20
40
60
80
100
120
140
160
180
1
0.8
0.6
0.4
0.2
0


$u_{mid}$ at $3^{rd}$ RK-substep (t=2.0882s)
z
x
20
40
60
80
100
120
140
160
180
0
0.2
0.4
0.6
0.8
1


$u_{mid}$ at $3^{rd}$ RK-substep (t=2.8704s)
z
x
20
40
60
80
100
120
140
160
180
0
0.2
0.4
0.6
0.8
1