Faculty of Engineering at Shubra . Mechanical Engineering Department

Fluid Dynamics 2nd- Year Power April 2013 Time 1 hour

1)Choose the most appropriate statement for each of the following statement

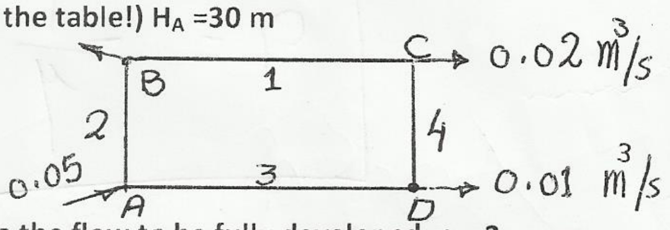
a) for fully turbulent pipe flow the friction coefficient f is function of 1) Reynolds number only. 2) both Re and relative roughness ε/D. 3) ε/D only

b) Separation may take place if the pressure gradient is 1)zero. 2) positive. 3) negative

c)The pressure increase due to sudden valve closure equals 1) $\rho V^2/2$ 2)$\rho V C$ 3) $2\rho VL/t_c$

2 - Use Hardy Cross method to find the discharge in each pipe and the head at B and D.

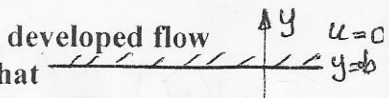
Given below are the characteristics of pipes (fill the table!) H_A =30 m



Pipe	Є/D	L m	D cm	Σk	leq	R
1,3	0.001	50	20	2		
2,4	0.001	30	20	4		

Assume the flow to be fully developed, n = 2

3) Use Navier –Stokes equation for 2-dimensional incompressible steady developed flow between two parallel fixed plates separated by a distance b to show that



$$u = \frac{1}{2}\left(\frac{dp\,b^2}{dx\,\mu}\right)\left[\left(\frac{y}{b}\right)^2 - \left(\frac{y}{b}\right)\right]$$

Evaluate the discharge in a duct 100 cm wide and 30 cm deep if the pressure drop is 4.27 Pa per 100 m length of duct. Viscosity is 2.4 $(10)^{-5}$ Pa.s neglect end effects.

(3-b)Velocity profile in a boundary layer is given by $\frac{u}{U} = a + b\frac{y}{\delta} + c\left(\frac{y}{\delta}\right)^2$ Find a,b, and c to satisfy the boundary conditions.

4-a Explain briefly the followings:

a) Water hammer phenomena.
B) Harmful effect of Water hammer.

4-b Water is flowing in a pipe of 150 mm diameter D with velocity of 2.5 m/s, when it is suddenly brought to rest by closing the valve. Find the pressure rise assuming pipe is elastic, E=206 GN/m^2, Poisson ratio 0.25 and K for water = 2.06 GN/m^2. Pipe wall thickness t = 5 mm. Expansion joints are used every where

$$C^2 = \frac{K/\rho}{1 + (K/E)(D/t)}$$ Where C is the wave speed

Faculty of Engineering at shoubra

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Model Answer of [Mid-Term exam]

April 2013

1- choose the most appropriate statement For each of the following statement:-

a- For fully turbulent pipe flow the friction coefficient f is function of $\frac{\varepsilon}{D}$ only.

b- Separation may take place if the pressure gradient is positive.

c- ~~The~~ pressure increase due to sudden value closure equal ρVC

2- Find discharge in each pipe [1,2,3,4] and H_B, H_D

pipe	$\frac{\epsilon}{D}$	L(m)	D(cm)	ΣK	f	L_{eqv}	R
1,3	0.001	50	20	2	0.02	20	361.8
2,4	0.001	30	20	4	0.02	40	361.8

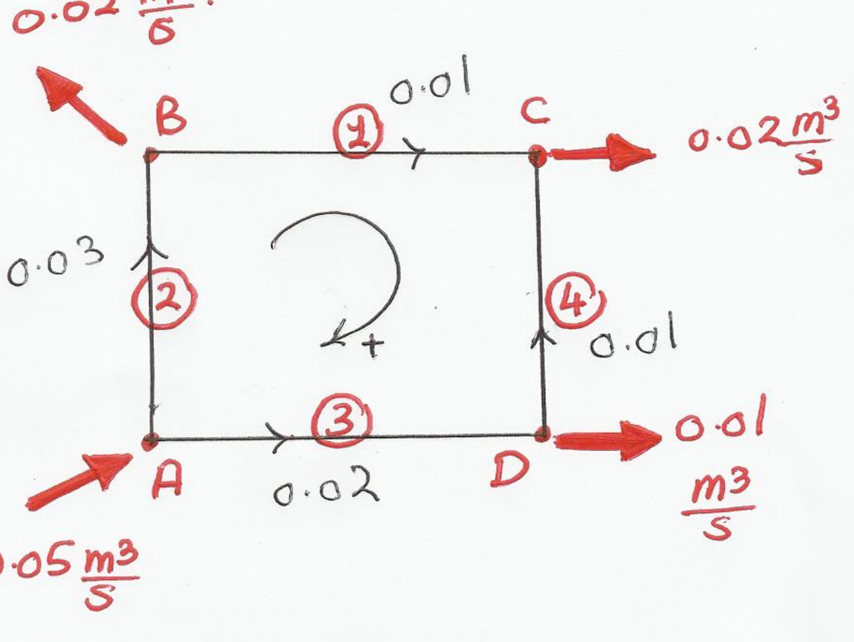
- $h_{major} = h_{minor}$

$$\frac{f.L}{D}\cancel{\frac{v^2}{2g}} = \Sigma K.\cancel{\frac{V^2}{2g}} \rightarrow \therefore L_{eqv} = \frac{\Sigma K.D}{f} \rightarrow \boxed{1}$$

$$\rightarrow R = \frac{8F(L+L_{eqv})}{\pi^2 \cdot g \cdot D^5} \rightarrow \boxed{2}$$

- From moody chart by using $\frac{\varepsilon}{D} = 0.001$

$\therefore f = 0.02$

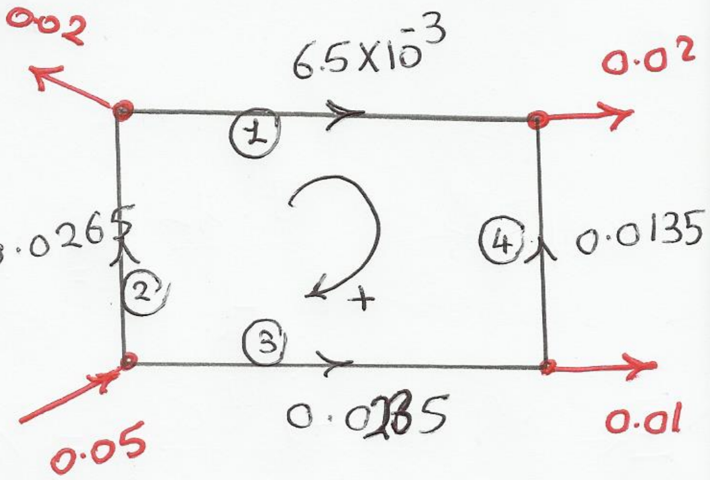


pipe	Q	R	RQ^2	$2RQ$
1	0.01	361.8	0.03618	7.236
2	0.03	361.8	0.32562	21.708
3	-0.02	361.8	-0.14472	14.472
4	-0.01	361.8	-0.03618	7.236

$\sum RQ^2 = 0.1809$ $\qquad \sum 2RQ = 50.652$

$$\therefore \Delta Q = -\frac{\sum RQ^2}{\sum 2RQ}$$

$$= -\frac{0.1809}{50.652} = -0.0035$$



pipe	Q	R	RQ^2	$2RQ$
1	+0.0065	361.8	+0.0152	4.7034
2	+0.0265	361.8	+0.254	19.1754
3	-0.0235	361.8	-0.1998	17.0046
4	-0.0135	361.8	-0.0659	9.7686

$\sum RQ^2 = 3.5 \times 10^{-3}$ $\qquad \sum 2RQ = 50.652$

$$\therefore \Delta Q = -\frac{\sum RQ^2}{\sum 2RQ}$$

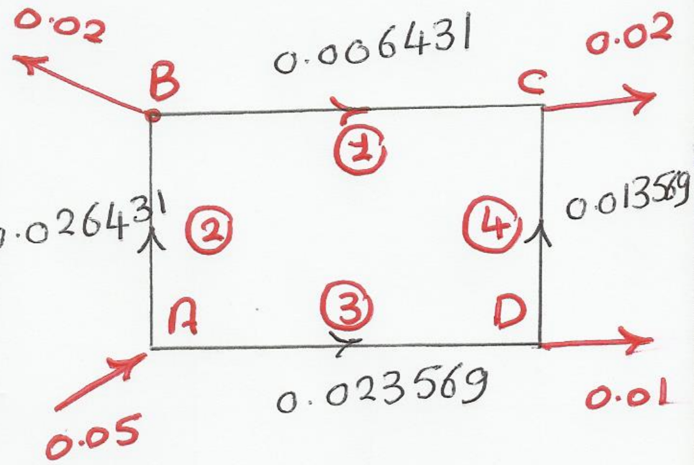
$$= -\frac{3.5 \times 10^{-3}}{50.625} = -6.9 \times 10^{-5}$$

$\therefore Q_1 = 0.006431 \ \frac{m^3}{s}$.

$Q_2 = 0.026431 \ \frac{m^3}{s}$.

$Q_3 = 0.023569 \ \frac{m^3}{s}$.

$Q_4 = 0.013569 \ \frac{m^3}{s}$.



For pipe no. 2

$$H_A - H_B = R_2 Q_2^2 \Rightarrow \therefore H_B = H_A - RQ^2$$
$$= 30 - 361.8(0.026431)^2$$
$$= 29.74\,m$$

For pipe no. 3

$$H_D = H_A - R_3 Q_3^2 = 30 - (361.8)(0.023569)^2$$
$$= 29.79\ m.$$

3- Solution :-

using navier- stokes equation

$$\rho\left[\cancel{\frac{\partial u}{\partial t}}+\cancel{u\frac{\partial u}{\partial x}}+\cancel{v\frac{\partial u}{\partial y}}+\cancel{w\frac{\partial u}{\partial z}}\right]=-\frac{\partial P}{\partial x}+\mu\left[\cancel{\frac{\partial^2 u}{\partial x^2}}+\frac{\partial^2 u}{\partial y^2}+\cancel{\frac{\partial^2 u}{\partial z^2}}\right].$$

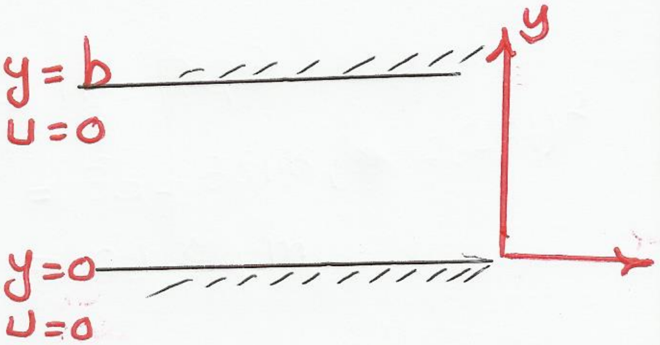
$$\therefore \frac{1}{\mu}\frac{\partial P}{\partial x}=\frac{\partial^2 u}{\partial y^2} \Rightarrow \therefore \frac{\partial u}{\partial y}=\frac{1}{\mu}\frac{\partial P}{\partial x}y+C_1$$

$$\Rightarrow \therefore u(y)=\frac{1}{\mu}\frac{\partial P}{\partial x}\frac{y^2}{2}+C_1 y+C_2$$

To get the B.C's

at $y=0 \rightarrow u=0 \Rightarrow \therefore C_2=0$

at $y=b \rightarrow u=0$



$$\therefore 0=\frac{1}{\mu}\frac{\partial P}{\partial x}\frac{b^{\cancel{2}}}{2}+C_1\cdot\cancel{b}$$

$$\therefore C_1=-\frac{1}{2\mu}\frac{\partial P}{\partial x}b$$

$$\therefore u(y)=\frac{1}{2\mu}\frac{\partial P}{\partial x}y^2-\frac{1}{2\mu}\frac{\partial P}{\partial x}b.y$$

$$\therefore u(y)=\frac{1}{2}\left(\frac{\partial P}{\partial x}\cdot\frac{b^2}{\mu}\right)\left[\frac{y^2}{b^2}-\frac{y}{b}\right] \#$$

• Dischange $(Q)=\int u(y).\,dy=\frac{\partial P}{\partial x}\frac{b^2}{2\mu}\left[\frac{y^3}{3b^2}-\frac{y^2}{2b}\right]_0^b$

$$=\frac{b^2}{2\mu}\frac{\partial P}{\partial x}\left[\frac{b}{3}-\frac{b}{2}\right]=-\frac{1}{12}\frac{b^3}{\mu}\frac{\partial P}{\partial x}$$

$$\therefore Q=\frac{-1}{12}\frac{(30\times10^{-2})^3}{2.4\times10^{-5}}\cdot\left(\frac{-4.27}{100}\right)=4.003\ \frac{m^3}{s}.$$

3.b $\frac{u}{U} = a + b\left(\frac{y}{\delta}\right) + c\left(\frac{y}{\delta}\right)^2$ Find a, b, c

- at $y = 0 \rightarrow u = 0 \Rightarrow \therefore a = 0$ #
- at $y = \delta \rightarrow u = U \Rightarrow 1 = \cancel{a} + b + c$

$\therefore 1 = b + c \rightarrow ①$

- at $y = \delta \rightarrow \frac{\partial u}{\partial y} = 0$

$\frac{\partial(\frac{u}{U})}{\partial(y/\delta)} = 0$ $\quad \therefore 0 = b + 2c$

$\therefore b = -2c$

$\therefore 1 = -2c + c$

$\therefore c = -1$ #

$\therefore b = 2$ #

4.a Explain briefly the following

a- water hammer phenomena

is a pressure surge or wave cased when fluid in motion is forced to stop or change direction suddenly

B- Harmful effect of water hammer.

- Damage in Equipments.
- pipe broken
- Reverse pressure.

4.b

$D = 150\ mm.$ Find ΔP

$V = 2.5\ \frac{m}{s}.$

$E = 206\ GN/m^2$

$\nu = 0.25$

$k = 2.06\ \frac{GN}{m^2}$

$t = 5mm$

$$C^2 = \frac{K/\rho}{1+\left(\frac{K}{E}\right)\left(\frac{D}{t}\right)} = \frac{(2.06 \times 10^9)/1000}{1+\left(\frac{2.06}{206}\right)\left(\frac{150}{5}\right)}$$

$$= 1584615.385$$

$$\therefore C = 1258.81\ \frac{m}{s}$$

$$\therefore \Delta P = \rho V C$$

$$= 1000 \times 2.5 \times 1258.81 = 3147037.679\ Pa$$

$$= 3147.03\ kPa$$