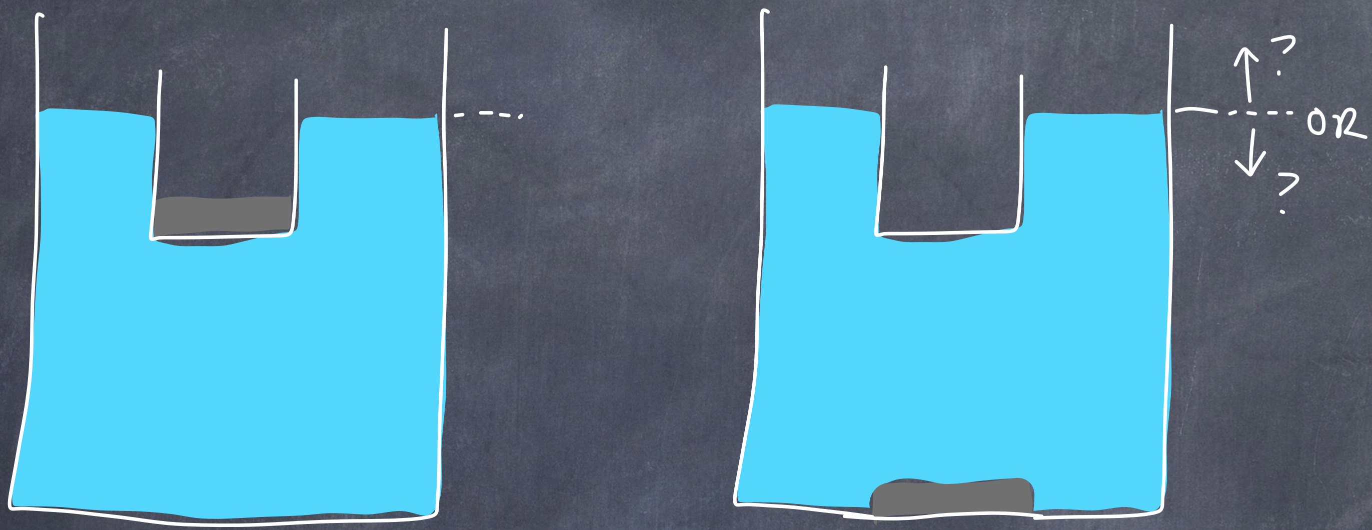
PHY 117 HS2023

Week 5, Lecture 2

Oct. 18th, 2023

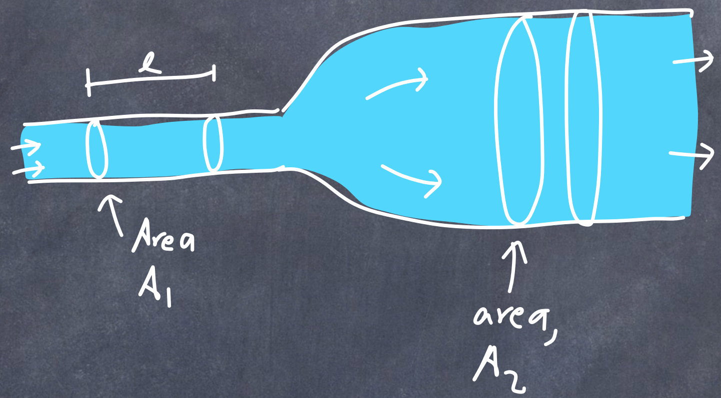
Prof. Ben Kilminster

Man overboard !

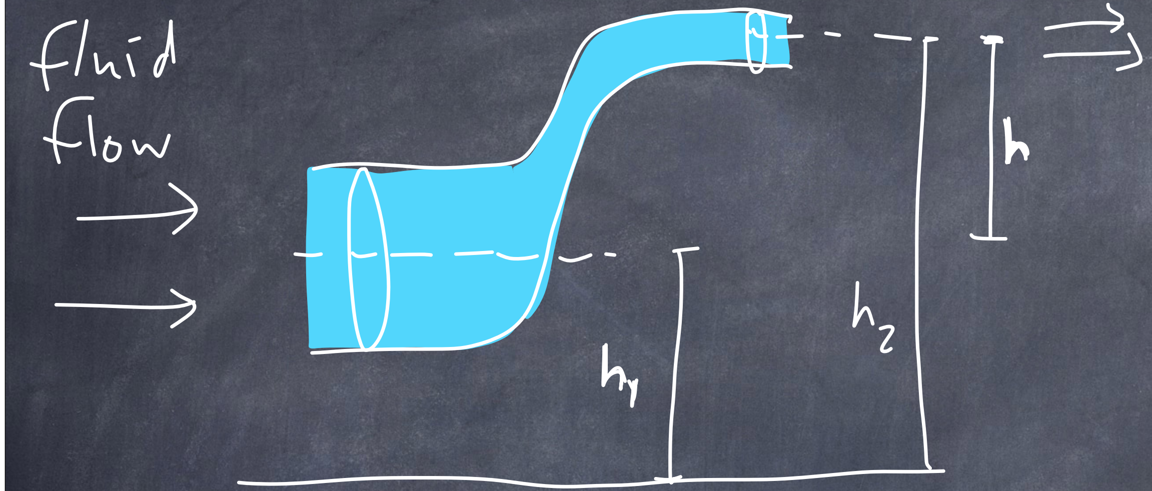


Fluids. In. Motion!

pipe with fluid inside



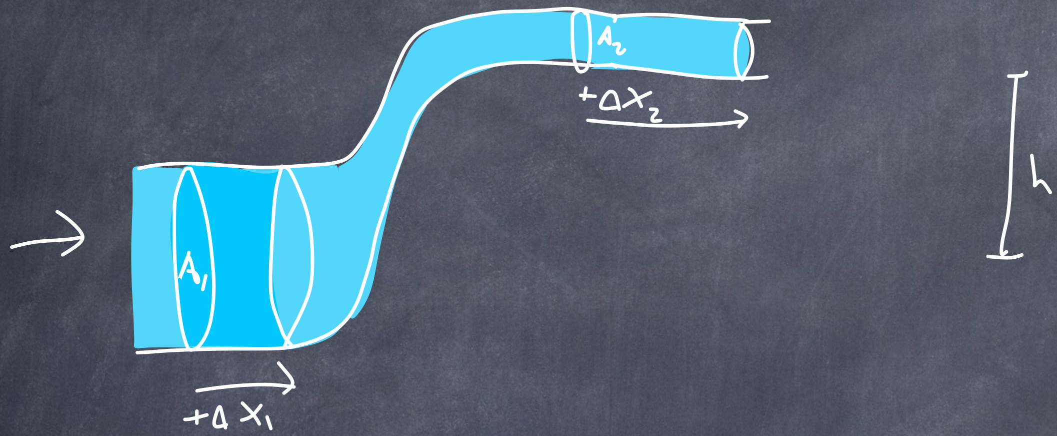
What if it changes height?

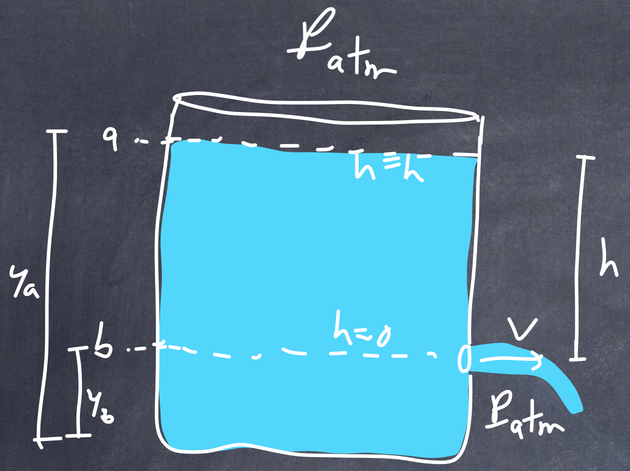


fluid flow

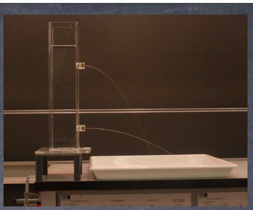
$$h = h_2 - h_1$$

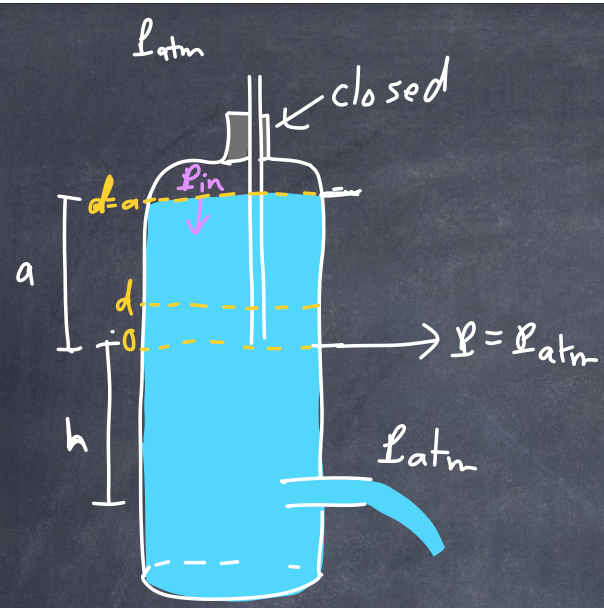
What if it changes height ?

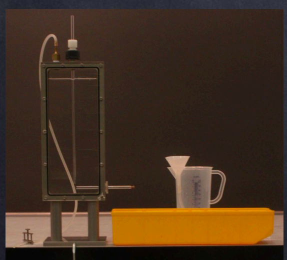


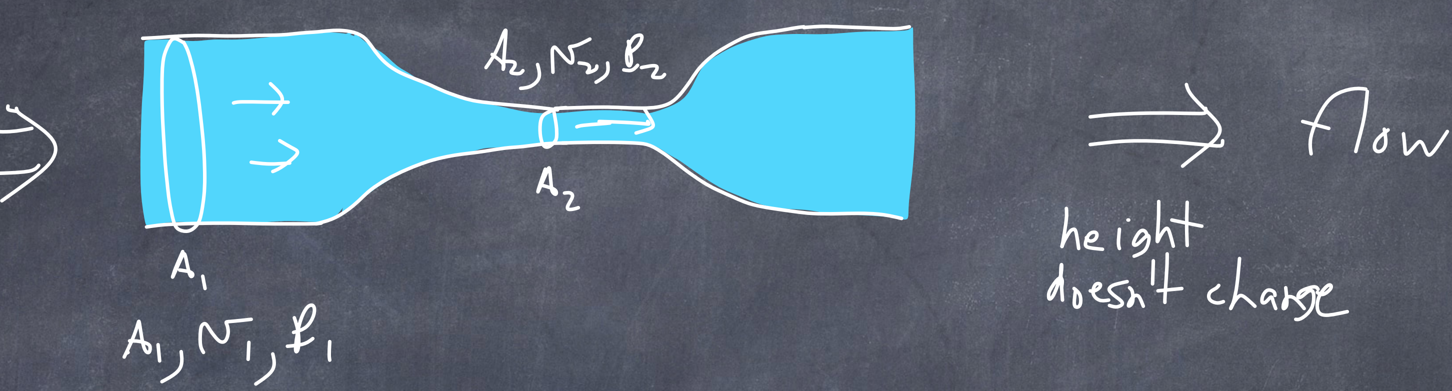


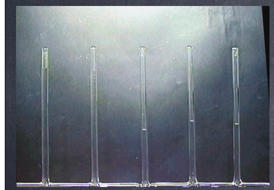
Patm
a
b
h = h
h = 0
h
v
ya
yb
Patm

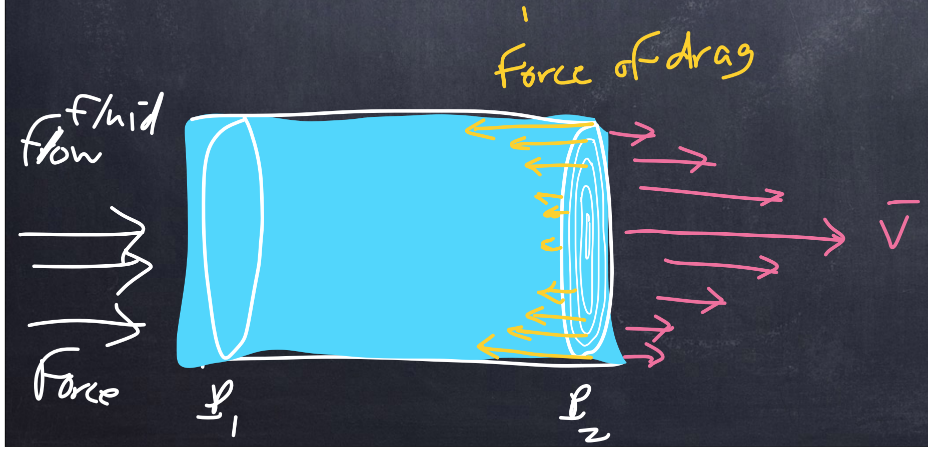


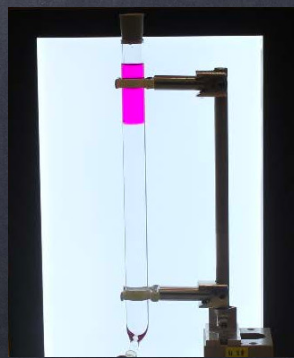

P_atm
closed
P_in
d=a
a
d
0
h
P = P_atm
P_atm

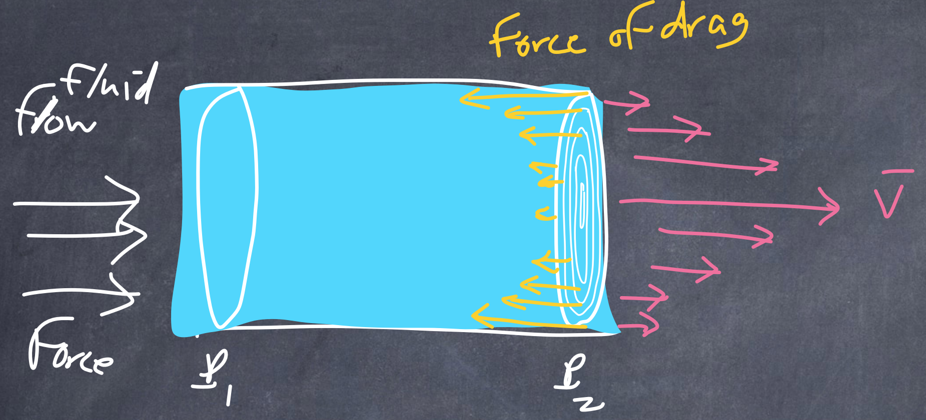



flow
A_2, v_2, P_2
A_2
A_1
A_1, v_1, P_1
flow
height doesn't change



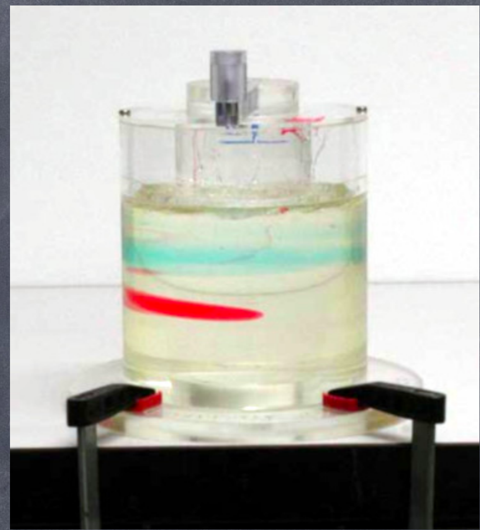

Force of drag
fluid flow
Force

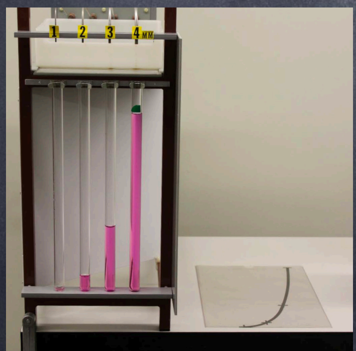




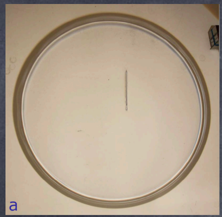
velocity faster in center

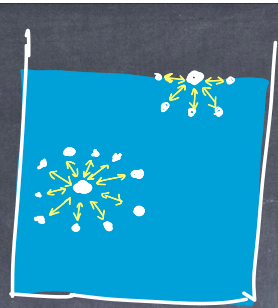

a

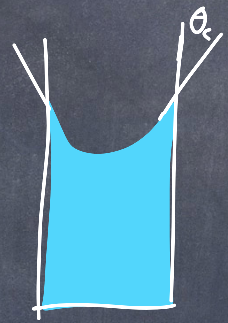




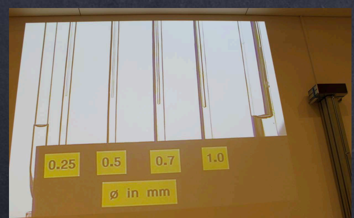
surface tension





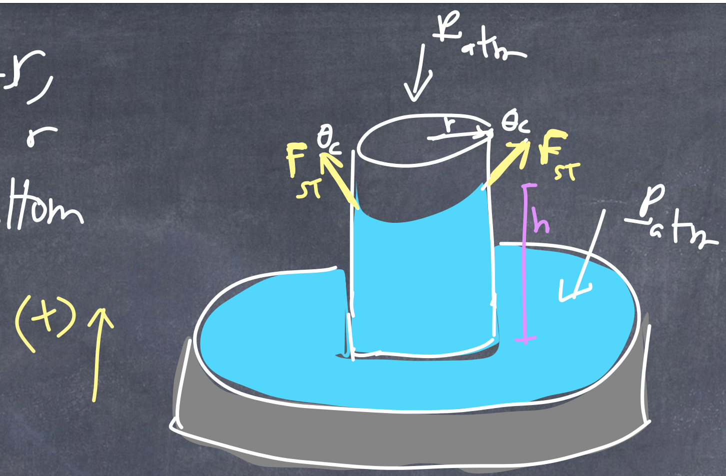

θc

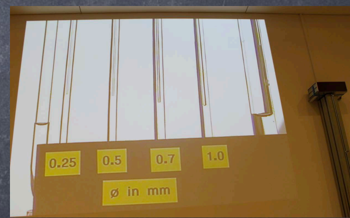

θc
θc


0.25
0.5
0.7
1.0
ø in mm

Consider cylinder, radius r

open on top + bottom





end

Pressure difference $P_1 - P_2 = I_v R$

$I_v = vA$: current flow of fluid

R: constant of resistance

The resistance for steady flow in a pipe (cylindrical) is

$$R = \frac{8 \eta L}{\pi r^4}$$

L: length of the pipe

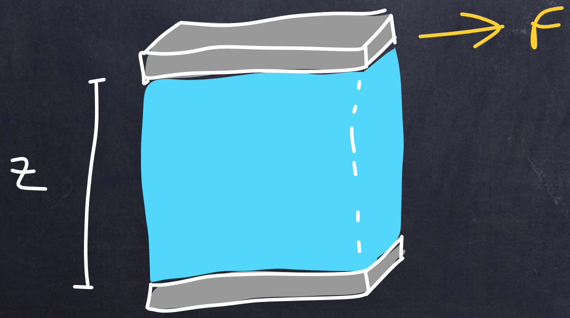
r: radius of the pipe

η: coefficient of viscosity

To define η, we take 2 plates. We pull on top plate, with a force F, at constant velocity, v. It is found that

$$F = \frac{\eta v A}{z}$$

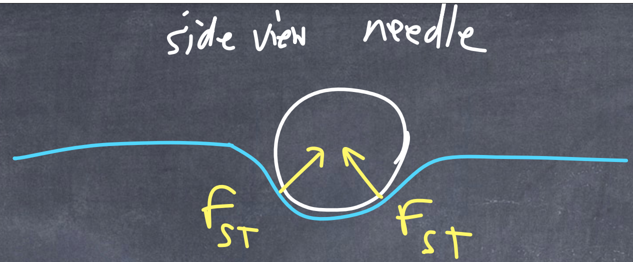
z: height

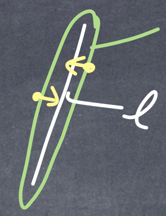


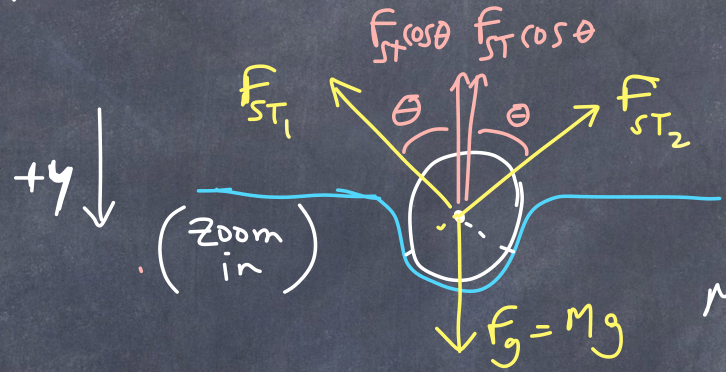
There is a surface force on both sides of the needle, so

$$F_{ST} = \gamma L = \gamma 2\ell$$

ℓ, length of the needle







$\longleftrightarrow$ in horizontal direction, these forces (F_{ST}) cancel out.

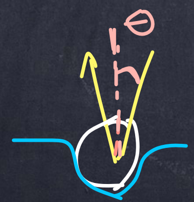
M: total mass of needle

In the y-direction, the total surface tension is

$$F_{ST_y} = \underbrace{F_{ST_1}\cos\theta}_{(\gamma\ell\cos\theta)} + \underbrace{F_{ST_2}\cos\theta}_{(\gamma\ell\cos\theta)} = 2F_{ST}\cos\theta = 2\gamma\ell\cos\theta$$

The needle floats as long as $F_{ST_y} > F_g$

M small



M big

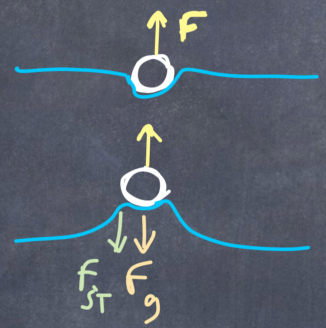
As M gets larger, θ decreases.

When $\theta = 0°$, $\cos\theta = 1 \Rightarrow F_{ST} = 2\gamma\ell$

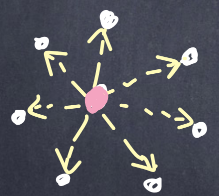
The maximum mass allowed is when

$Mg = 2\gamma\ell\cos 0°$ $\quad m_{max} = 2\gamma\ell/g$

The force to lift the needle off the surface is $F = mg + \gamma 2L$



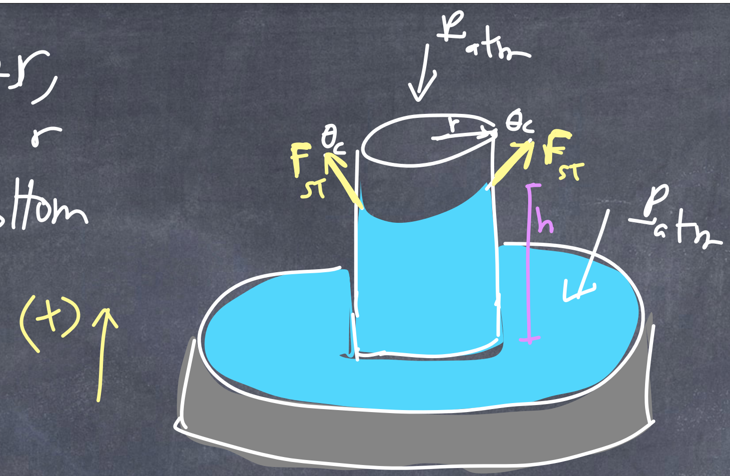
In this case, the surface tension resists us pulling the needle up, because we are stretching the fluid membrane upward.



cohesive force on one molecule is coming from the surrounding molecules.

Consider cylinder, radius r

open on top + bottom



Adhesive force pulls fluid upward

F_{ST} : adhesive force pulling upward

vertical direction $\left\{ \sum F = F_{ST} \cos\theta_c - mg = 0 \right.$

$$\gamma L \cos\theta_c = mg$$

$$\gamma 2\pi r \cos\theta_c = \rho V g$$

$$\gamma 2\pi r \cos\theta_c = \rho(\pi r^2 h) g$$

what is L? It's the length of contact between fluid + container

$L = 2\pi r$

$$h = \frac{2\gamma\cos\theta_c}{\rho r g}$$

: The height that the adhesive force raises a fluid in a container

when $\theta_c < 90°$, $\cos\theta_c > 0 \Rightarrow h$ is (+)

when $\theta_c > 90°$, $\cos\theta_c < 0 \Rightarrow h$ is (−)