
Hvorfor faller ikke ørnen ned?

Fluidmekanikk

Fluider = gass og væske

Væske: Kan ikke trykkes sammen, inkompressibel

Gass: Fyller volumet til beholderen, kompressibel

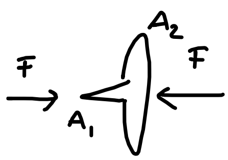
Massetetthet

$$\rho = \frac{m}{V}$$

$\rho_{vann} = 1{,}0 \cdot 10^3 \text{ kg/m}^3$

$\rho_{luft} = 1{,}3 \text{ kg/m}^3$

Trykk



$A_1 << A_2$

$p_1 >> p_2$

$$p = \frac{F}{A}$$

$$[p] = \frac{N}{m^2} = Pa$$ pascal

$kPa = 10^3 Pa$

$MPa = 10^6 Pa$

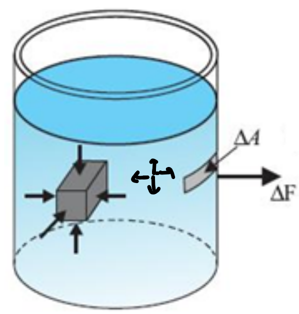
Hydrostatisk trykk

Klosser

normalkrefter

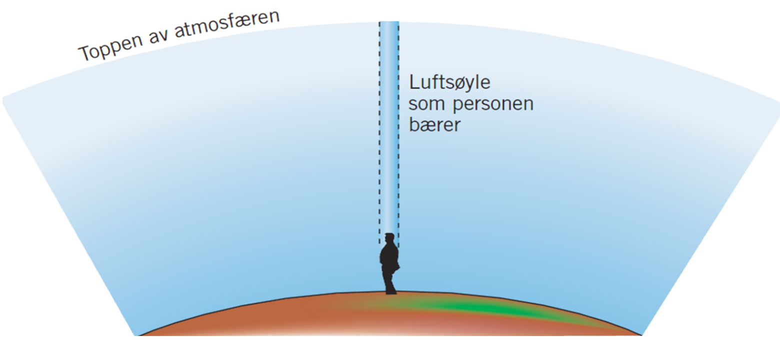
og skjærkrefter

Væske



Trykket er lik i alle retninger og vinkelrett på overflaten

Lufttrykk



$p_0 = 101\ kPa = 1\ atm$

vekt på $1\ m^2$

$F = p_0 A$

$= 101 \cdot 10^3 N$

$F = G = mg$

$m = \frac{G}{g} = \frac{100 \cdot 10^3 N}{10\ m/s^2} = 10\,000\ kg$

Hold pusten og dykk ned i vannet.

Hva kjenner du?

Hvorfor?

Trykket øker med dybden

$$\Sigma F_y = 0$$

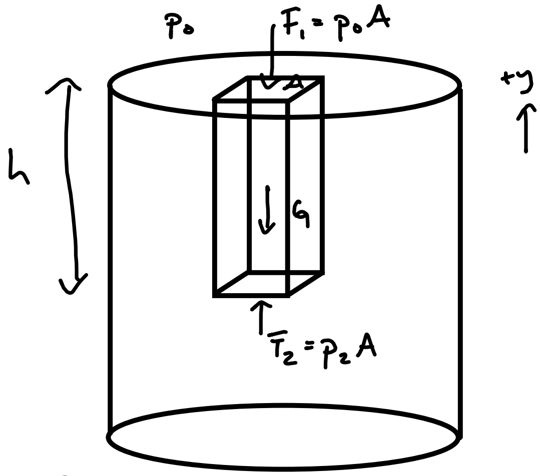
$$-F_1 - G + F_2 = 0$$

$$F_2 = F_1 + G$$

$$G = mg = \rho V g = \rho h A g \quad (V = hA)$$

$$p_2 \cancel{A} = p_0 \cancel{A} + \rho h \cancel{A} g$$

$$p_2 = p_0 + \rho h g$$



Hydrostatisk trykk

$$p = p_0 + \rho g h$$

Hvor dypt må du dykke for at trykket skal bli dobbelt så stort som ved overflaten?

$$p = p_0 + \rho g h$$

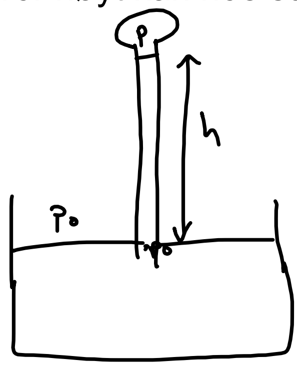
$$p = 2p_0 \Rightarrow h = ?$$

$$2p_0 = p_0 + \rho g h$$

$$\rho g h = p_0$$

$$h = \frac{p_0}{\rho g} \approx \frac{100 \cdot 10^3\,\text{Pa}}{10^3\,\text{kg/m}^3 \cdot 10\,\text{m/s}^2} = 10\,\text{m}$$

Hvor høyt kan noe suges opp med et sugerør?

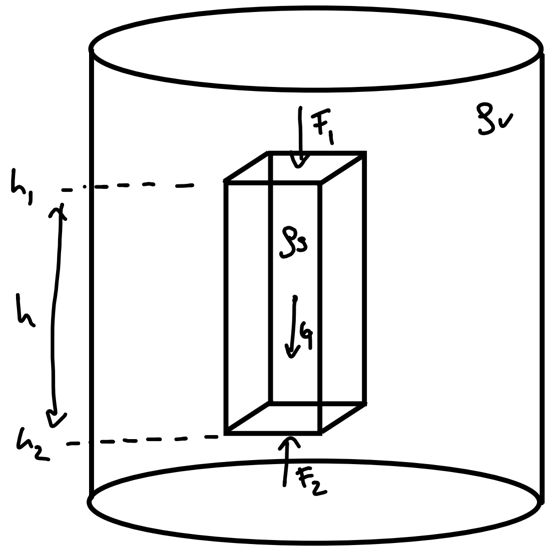


$$\min(p) = 0$$

$$p_0 = \not{p} + \rho g h$$

$$h = \frac{p_0}{\rho g} = 10\,m$$

Oppdrift: Arkimedes' lov



$$F_1 = p_1 A = (p_0 + \rho g h_1) A$$

$$F_2 = p_2 A = (p_0 + \rho g h_2) A$$

Kraften oppover fra vannet

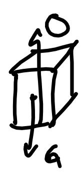
$$F_2 - F_1 = (\cancel{p_0} + \rho g h_2) A - (\cancel{p_0} + \rho g h_1) A$$

$$= \rho_v g (h_2 - h_1) A$$

$$= \rho_v g \underbrace{hA}_{V} = \rho_v V g$$

Oppdrift

$$O = \rho_v V g$$



$$\Sigma F_y = O - G$$

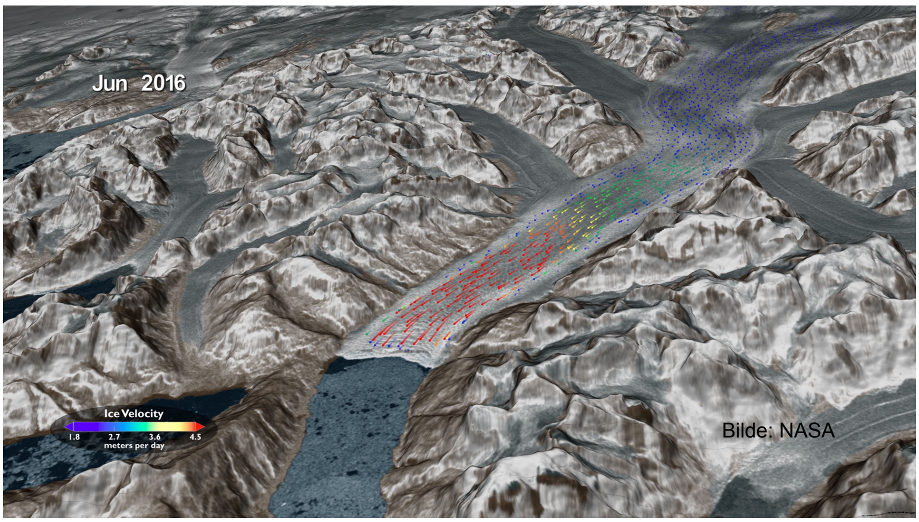
$$= \rho_v V g - \rho_s V g$$

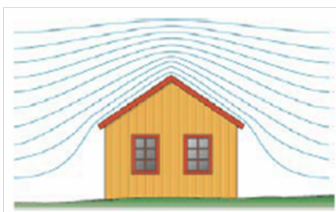
$$= (\rho_v - \rho_s) V g$$

$\rho_v > \rho_s \Rightarrow$ flyte

$\rho_v < \rho_s \Rightarrow$ synke

Hvordan skal vi beskrive en væskestrøm?





Volumstrøm

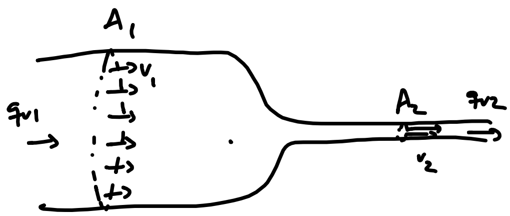
$$q_v = \frac{V}{t}$$

$$[q_v] = \frac{m^3}{s}$$

massestrøm

$$q_m = \rho q_v$$

Hva skjer med volumstrømmen når tverrsnittet forandrer seg?



Kontinuitetslikningen

$q_{v1} = q_{v2}$

$q_v = Av$

$A_1 v_1 = A_2 v_2$

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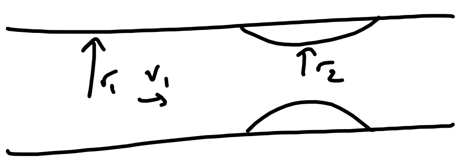
En blodåre transporterer 45 mL/min. Den indre radien i blodåren er normalt 2,1 mm.

a) Beregn farten til blodet i åren

b) En åreforkalkning har lengre fremme i blodåren halvert diameteren. Hvor stor er farten til blodet her?



$r_1 = 2{,}1\,mm$

$r_2 = \frac{1}{2} r_1$

$q_v = 45\,mL/min = 7{,}5 \cdot 10^{-7}\,m^3/s$

$q_v = A_1 v_1$

$v_1 = \frac{q_v}{A_1} = 5{,}4\,cm/s$

$A_1 v_1 = A_2 v_2$

$v_2 = v_1 \frac{A_1}{A_2} = v_1 \frac{\pi r_1^2}{\frac{1}{4}\pi r_1^2} = 4 v_1 = 22\,cm/s$

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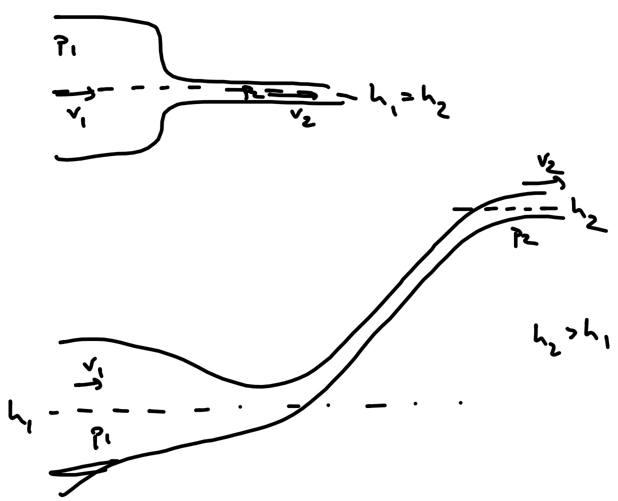
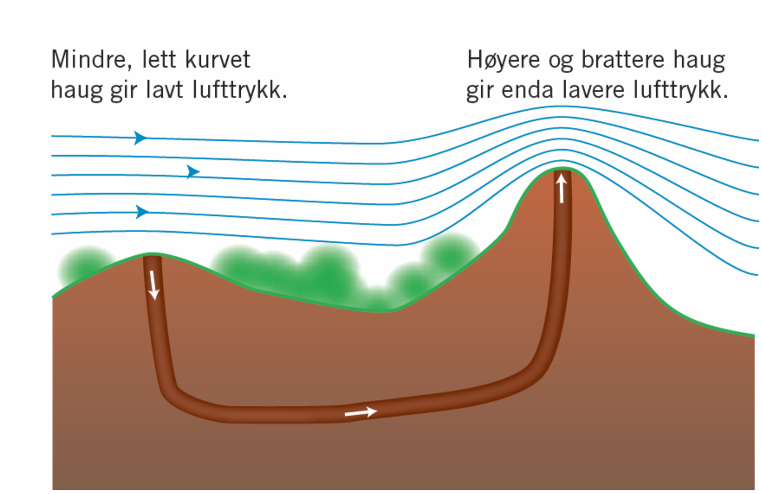
Bernoulli-likningen



$$p_1 + \rho g h_1 + \frac{1}{2}\rho v_1^2 = p_2 + \rho g h_2 + \frac{1}{2}\rho v_2^2$$

Præriehundens hule



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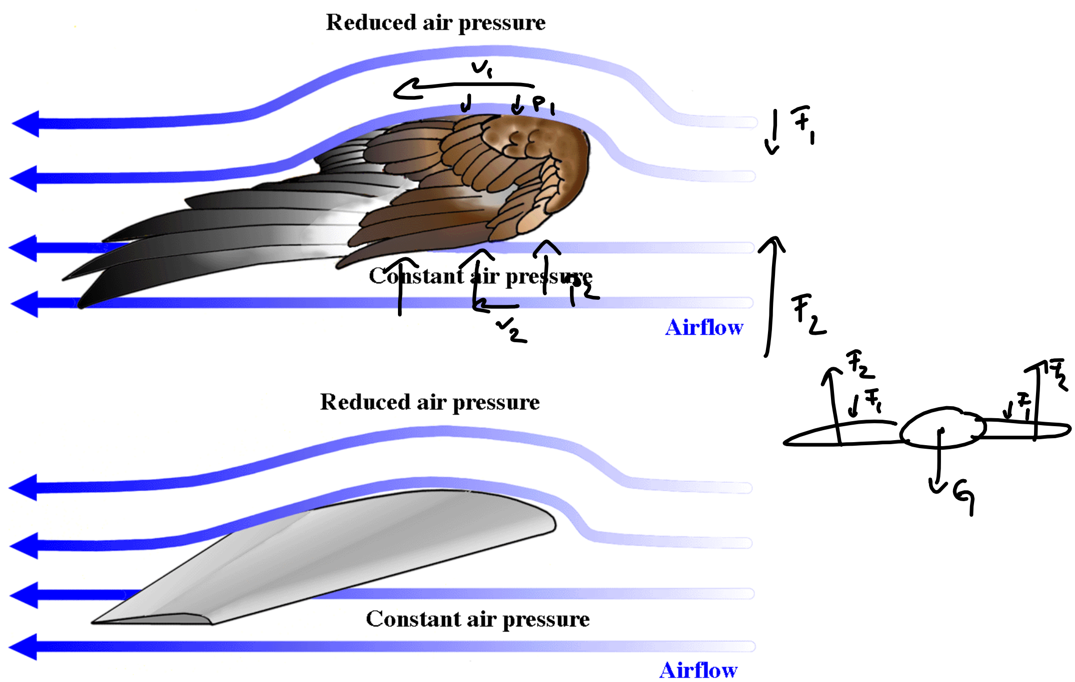


Bilde: http://www.science20.com/science_motherhood/we_can_put_man_moon_we're_still_figuring_out_how_birds_fly


Hvordan kommer vannet seg opp i toppen av trærne?

En blodåre transporterer 45 mL/min. Den indre radien i blodåren er normalt 2,1 mm.

a) Beregn farten til blodet i åren

b) En åreforkalkning har lengre fremme i blodåren halvert diameteren. Hvor stor er farten til blodet her?

c) Hvor mye høyere er trykket før innsnevringen enn inne i den?

$v_1 = 5{,}4 \text{ cm/s}$

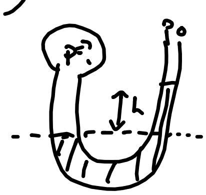
$v_2 = 22 \text{ cm/s}$

$p_1 + \frac{1}{2}\rho v_1^2 = p_2 + \frac{1}{2}\rho v_2^2$

$p_1 - p_2 = \frac{1}{2}\rho(v_2^2 - v_1^2) = 23 \text{ Pa}$

Blodtrykk

mm Hg



$p = p_0 + \rho g h$

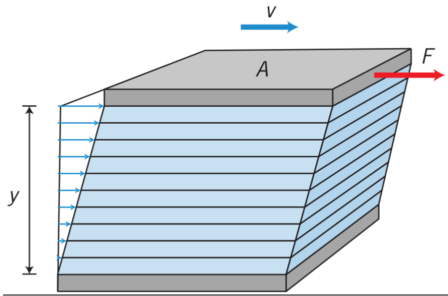
$p - p_0 = \rho g h$

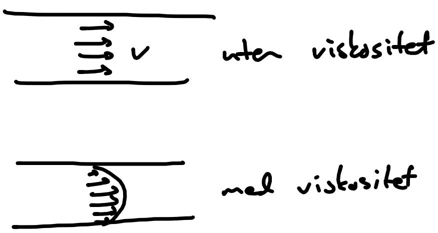
$p - p_0 = 9{,}4 \text{ kPa}$

$\rho_{Hg} = 13{,}69 \cdot 10^3 \text{ kg/m}^3$

$h = 80 \text{ mm}$

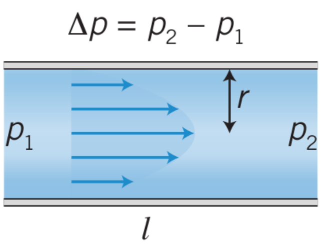
Viskositet





	T/°C	η/Pas
Hydrogen	20	$8,4 \cdot 10^{-6}$
Luft	0	$17 \cdot 10^{-6}$
	20	$18 \cdot 10^{-6}$
	100	$22 \cdot 10^{-6}$
Etanol	20	0,00012
Vann	0	0,0018
	20	0,0010
	100	0,00028
Blod	37	0,0025
Smøreolje	0	5,3
	20	0,99
	100	0,017
Glass	400	10^{12}

Viskøs væskestrøm i rør



Hagen-Poiseuille-likningen

$$q_v = \frac{\pi r^4 \Delta p}{8 \eta l}$$

Viskositet η

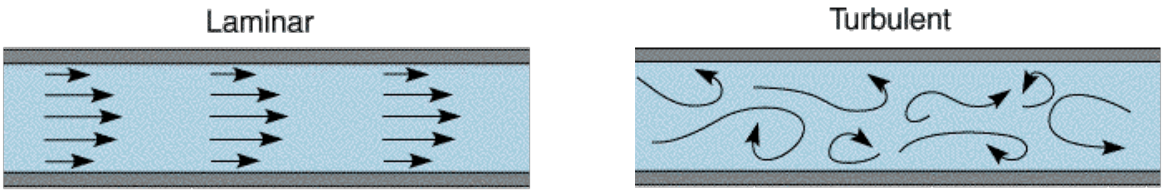
$$[\eta] = \frac{m^4 \, Pa}{m^3/s \; m} = Pa \, s$$

Øke blodstrømmen:

- øke r → øke 20%
- øke Δp
  ↳ ×2

$1{,}2^4 = 2$

Laminær og turbulent strømning



Re lite

Reynolds tall

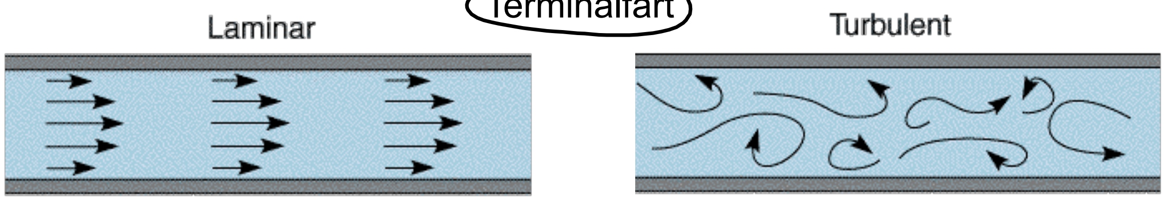
$$Re = \frac{\rho v d}{\eta}$$

Re stort

bilde: NASA

Luftmotstand og vannmotstand

Terminalfart



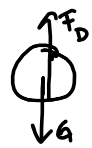
$Re \ll 1$

$F_D = 6\pi\eta r v$

$Re \gg 1$

$F_D = \frac{1}{2}\rho c_D A v^2$

↑ avhenger av geometri



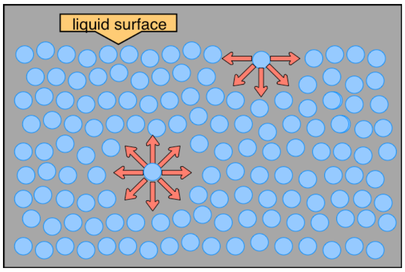
$\Sigma F_y = 0$

$F_D = G$

$6\pi\eta r v = mg$

$v = \frac{mg}{6\pi\eta r}$

Skyte under vann



Overflatespenning

$$[\gamma] = \frac{J}{m^2} = \frac{N}{m}$$

noen ganger σ

$$E_{overflaten} = \gamma A$$

overflater i luft

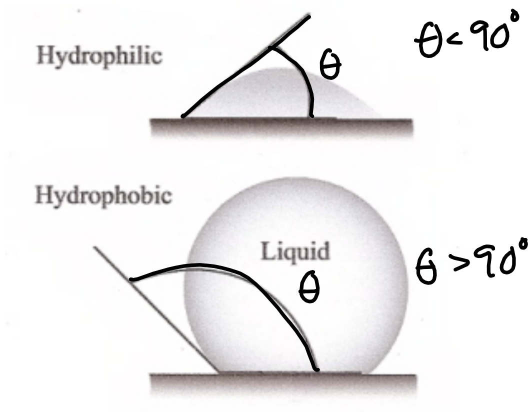
$\gamma_{vann} = 72{,}75\ mJ/m^2$

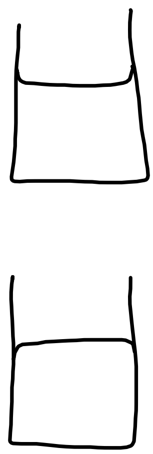
$\gamma_{olje} = 30\ mJ/m^2$

vann på ISS

vann på ISS

Kontaktvinkel og fukting





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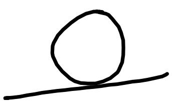
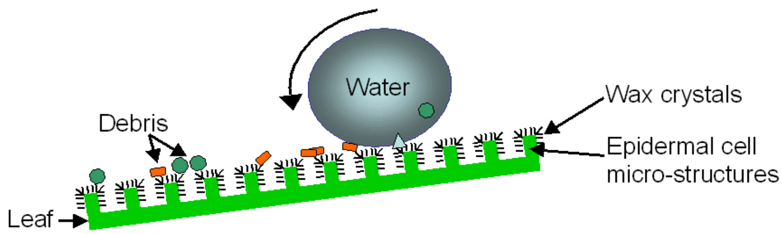
Superhydrofobe overflater





Vannedderkopp

Krumme overflater:

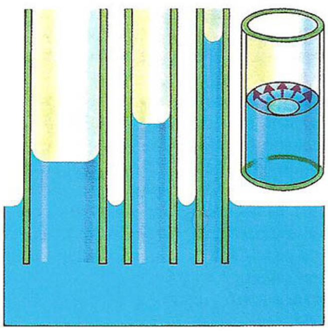
Young-Laplace likningen

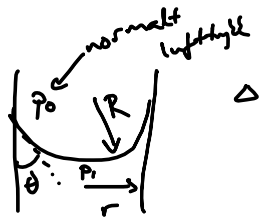
$p_i > p_o$

$\Delta p = p_i - p_o$

$$\boxed{\Delta p = \frac{2\gamma}{r}}$$

Kapillærkrefter

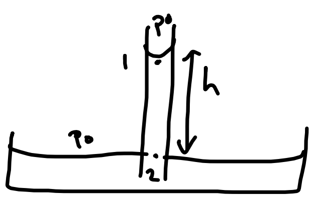




$$\Delta p = p_0 - p_1 = \frac{2\gamma}{R}$$

$$R = \frac{r}{\cos\theta}$$

$$\Delta p = \frac{2\gamma\cos\theta}{r}$$



$$p_2 = p_0 = p_1 + \rho g h \Rightarrow p_1 = p_0 - \rho g h$$

$$p_1 = p_0 - \frac{2\gamma\cos\theta}{r}$$

$$\cancel{p_0} + \rho g h = \cancel{p_0} + \frac{2\gamma\cos\theta}{r}$$

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

$r\downarrow \Rightarrow h\uparrow$

$\gamma\uparrow \Rightarrow h\uparrow$

$\theta\downarrow \Rightarrow h\uparrow$

$h = 100\,m$

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

$\cos\theta = 1$

$$r = \frac{2\gamma}{\rho g h} \approx 2\cdot 10^{-6}\,m = 2\,\mu m$$