APB Giancoli

Ch10 Fluids (Young & Freedman, main reference)

10.1
- Phases / States of matter - solid, liquid, gas, plasma (ionized), colloids
  - liquid ← water is incompressible (changes little over hundreds atm pressure difference only a few %)
  - gas ← density decreases with altitude
  - ★ but air $\rho_{Mt\,everest} \approx \frac{1}{3}\rho_{sea\,level}$ → ★ ρ

10-2 ~ 10-3
- Density $\boxed{\rho = \frac{m}{V}}$ (rho) $1\ g/cm^3 = 1000\ kg/m^3$ (mL)

- Specific Gravity $= \frac{\rho_{gold}}{\rho_{water}}$ of gold is 19.3 ("relative density") is better, nothing to do with gravity

ρ_{water} at 4°C	$1.0\ g/cm^3 \approx 1000 \times \rho_{air}$
sea water	$1.03\ g/cm^3$
ice	$0.917\ g/cm^3$
CO_2	$1.98\ kg/m^3$
He	$0.179\ kg/m^3$
air	$1.29\ kg/m^3$
concrete	$2\ g/cm^3$
Gold	$19.3\ g/cm^3$
Platinum	$21.4\ g/cm^3$
neutron star	$10^{15}\ g/cm^3$

- Pressure $\boxed{P = \frac{F}{A}}$

molecules hit sides

$1\ \text{Pascal} = \frac{1\ N}{m^2}$ meteorology $1\ \text{bar} = 100\ kPa$

1 atm (atmosphere) $= 101{,}325\ Pa$ ★ $\approx 10{,}000\ N \approx 5000$ elephants$/m^2$

101 kPa at sea level, Show G7 ppt

- Going up, pressure decreases nonlinearly) Guess this
- down under sea $P(d) \approx 101\ kPa + 10d$

ex air at 20° C

room $4.0\ m \times 5.0\ m$ (floor) $\times 3.0\ m$ (ceiling)

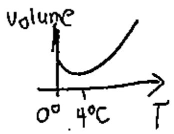
a) mass? b) total downward force on floor due to air pressure at 1.00 atm?

a) $m = \rho V = 1.290\ \frac{kg}{m^3} \times 60\ m^3 = \boxed{77.4\ kg}$

b) air above & below supports floor.

$F = PA = 101\,325\ \frac{N}{m^2} \times 20\ m^2 = 2026500\ N \approx \boxed{2.0 \times 10^6\ N}$

$\Sigma F = 0$

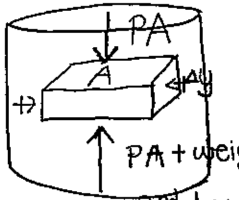


Lake & Life

Substance	Density kg/m^3
water (4°C)	$1.0\ g/cm^3 = 1000\ kg/m^3$ ($\rho_{water} \approx 1000\ \rho_{air}$)
ice	$0.917 \times 10^3\ kg/m^3$
sea water	1.03×10^3
mercury	13.6×10^3
gasoline	0.7×10^3
concrete	2.0×10^3
gold	19.3×10^3
platinum	21.4×10^3
He	0.179×10^0
air	1.29
CO_2	1.98

Guess from list

10-3 ~ 10-6 Pressure, Depth, and Pascal's Principle



- how does pressure increase with depth?
- Incompressible fluid (water, not air)

PA + weight of object $= PA + (\rho A \Delta y) g$

3rd Law & equilibrium — ($A\Delta y$) mass; ($\rho A \Delta y\, g$) force/weight

$= (P + \rho g \Delta y) A$ — ($\rho g \Delta y$ = ΔP)

$\Rightarrow$ $\boxed{\frac{\Delta P}{\Delta y} = \rho g}$ $\left(\frac{kg}{m^3} \cdot m/s^2 = \frac{N}{m}\right)$

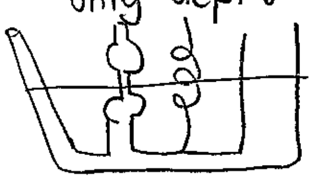
☆ Pressure changes linearly with depth (incompressible fluid)

$P(d) = 101\,kPa + 10d$?

$101\times10^3 \frac{N}{m^2}$ $\quad \frac{\Delta P}{\Delta y} = \rho_{water}\, g \quad d$

$\left(\frac{kg\, m}{m^2 s^2}\right.$ OK $\quad = 1.0\times10^3 \frac{kg}{m^3} \cdot 10\, m/s^2 \quad \left. m \right)$

☆ Pressure does not depend on shape of container, only depth



YF
← show figure
same height in each column
(same fluid above height, equilibrium)
else H → L flow

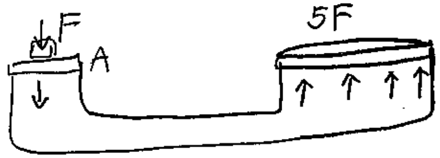
$\boxed{P(h) = P_0 + \rho g h}$
↑
101 kPa + 10 h
under sea

Car tires 120 kPa ← Gauge Pressure (how much more than atm)
actually +101 = 221 kPa ← Absolute Pressure

(☆ In an enclosed fluid, Increasing pressure P_0 at surface (or anywhere) will transmit undiminished to every portion of the fluid & walls of the container.)

☆ Pascal's principle - If an external pressure is applied to a confined fluid, pressure at every point increases by that amount.

- See G7 PPt. Hydraulic lift

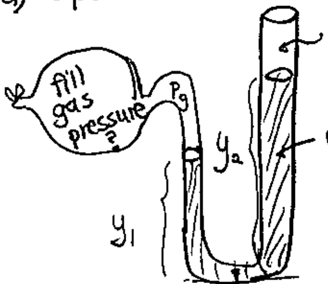


$P_{in} = P_{out}$

$\frac{F}{A} = \frac{5F}{5A}$ $\Rightarrow$ Mechanical Advantage $= \frac{A_2}{A_1} = \frac{F_2}{F_1}$

- Pressure Gauges

a) Open Tube manometer

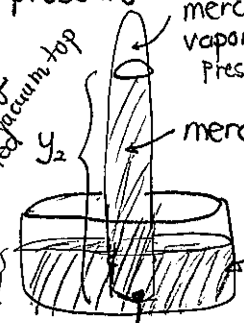


Pressure same
$P_g + \rho g y_1 = P_0 + \rho g y_2$
↑ 1atm

$\boxed{P_g - P_0 = \rho g (y_2 - y_1)}$
Gauge Pressure

☆ not that vacuum sucks up. It's atm below pushes up

b) Mercury barometer to measure atmospheric pressure
(water would be too high) & not dense enough



Pressure same

ⓐ atm can support Hg column 76cm exactly - fill more, will vacuum top when inverted

$0 + \rho g y_2 = P_{atm} + \rho g y_1$

$P_{atm} = \rho g (y_2 - y_1)$
$\rho_{Hg}\, g \times 0.76\,m$

☆ cannot have really long straw b/c won't work

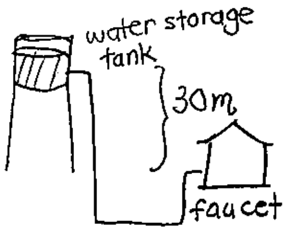
ⓐ water 10.3m Vacuum pump, mine, cannot make water rise > 10 m, Need stages

- Pressure = 1 mm Hg
  (↑ height in millimeters of mercury rise)
  = 1 torr (Torricelli. invented mercury barometer)
  but depends on ρ_{Hg} / temperature
  - Pascal preferred

Show Pix

- Blood pressure - mercury filled manometer
  130/80 give max/min gauge pressure of artery in mm Hg
  Left upper arm
- fire extinguisher
  coil unwraps with more pressure.

ex10-3



$\Delta P ? = \rho g y$

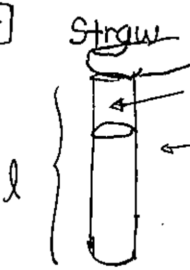
$= 1000 \frac{kg}{m^3} \times 10 \frac{m}{s^2} \times 30 m$

$= 300\,000 \frac{N}{m^2}$

Δh = pressure head

diameter no effect, only height

ex4

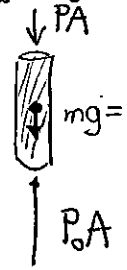


a) $P \overset{<}{\underset{>}{=}} P_o(atm)$? ← b) why
goes down a bit
air more space less dence
fluid H to L Pressure
stays up.

← lift out of cup
most water still there

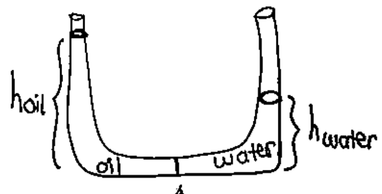
c) free-body

★



ex (YF 4)

manometer filled with water partly
oil less dense, won't mix
poured until at midway point
both arms open to air
h_{oil}, h_{water} relationship?

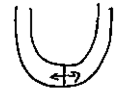


OK if flat & meet

Pressure same

$\rho_{oil} g h_{oil} = \rho_w g h_w$ (same density area)

$$\boxed{h_{oil} = \frac{\rho_w}{\rho_{oil}} h_w}$$

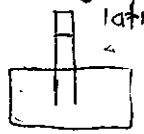


u-tube in middle needed
equilib. P same

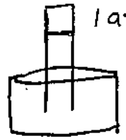
TYU ② Mercury $\rho_{HOT} < \rho_{cold}$

- Move mercury barometer from sealed fridge to outside summer day
- Column height stays the same. (Glass does not change)
- $P_{fridge} \overset{\textcircled{<}}{\underset{\textcircled{>}}{=}} P_{outside}$

fridge



outside

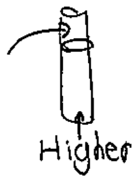


should be higher
expands
so lower

$\Delta P = \rho g h$
↑ lower, ↑ smaller, ↖ same

ex5 Giancoli

Suction. Low pressure



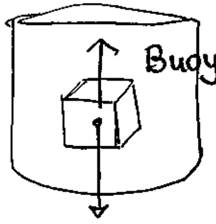
Pushes upward til balances weight down

- Suction cup shoes for astronauts?

a) Won't work. Suction cup forces air out, Low pressure.
It's outside air pressure that gives force
b) On Earth, 10cm diameter ⇒ $7.9 \times 10^{-3}\ m^2 \times 1000$ kg

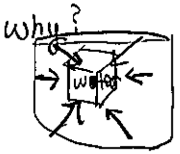
force = PA = $100\ kPa \times \pi\, 0.05^2$
= 785 N

10-7 Archimedes' Principle



Buoyant force = weight of displaced water

weight



$\Sigma F = 0$

$\Sigma F_x = 0$

$\Sigma F_y = B_y - \text{weight water} = 0$

$\Sigma \tau = 0$, Arrows thru CG

②

rises until

displaced = duck weight

①

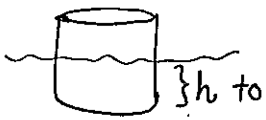
Same shape steel. Pressure same at all points forces from water around it same. Buoyant force same, (CG of steel maybe different)

③ Denser sinks. From B to ρ ?

rise		$>$	
float	B	$=$	Weight
sink		$<$	

$\rho_w V g \gtreqless \rho_{steel} V g$

④



}h to float in water?

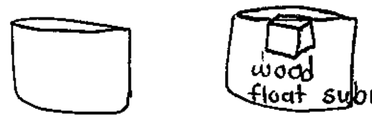
$\rho_w V_{under} = \rho_{object} V_{total}$

★ $\dfrac{V_{under}}{V_{total}} = \dfrac{\rho_{object}}{\rho_{water}}$ = specific gravity! (fraction under)

a) G7 ppt

35N 3.5kg

ex6 Giancoli — Identical pails filled to brim. which has greater weight?

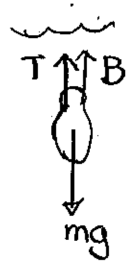


same weight displaced = weight of wood (floats)

ex5 YF — 15.0kg gold statue being raised from sunken ship. Tension in hoisting cable when

a) at rest & completely immersed

b) at rest & out of water?



$\rho_{gold} = \dfrac{m}{V}$

$T = mg - B$

$= mg - \rho_w V g$

$= g\left(m - \rho_w \dfrac{m}{\rho_G}\right)$

$= mg\left(1 - \dfrac{\rho_w}{\rho_G}\right) = 15 \times 9.8 \left(1 - \dfrac{1.03}{19.2}\right)$ (seawater)

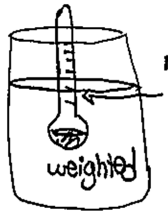
$= \boxed{139\,N}$

b) $T = mg = \boxed{147\,N}$

ex9 Hydrometer calibration, Measuring density

Lab?

Show pic YF



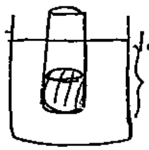
(weight total = weight water displaced)

$$\rho_T g h_{Total} = \rho_F g h_L$$

height = specific gravity × h_{total} of tube

Glass tube 25.0cm long, 2.00cm² area

45.0 g



$$\frac{x}{25.0\text{cm}} = \frac{\rho_{Tube}}{\rho_F} = \frac{45.0\text{ g}/(25 \times 2\text{ cm}^3)}{1.0\text{ g/cm}^3}$$

$$x = \boxed{22.5\text{cm}}$$

QC Which when submerged in water has biggest buoyant force?

a) 1kg (He) balloon — $1m^3$

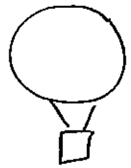
b) 1kg wood

c) 1kg ice

d) 1kg iron

e) same — (same)

ex10 Helium balloon



Total weight of load & empty balloon = 180kg

Volume = ?

$$\rho_{air} V g = (\rho_H V + 180) g$$

$$V = \frac{180}{\rho_{air} - \rho_H} = \frac{180\text{ kg}}{1.29\text{ kg/m}^3 - 0.179} = \boxed{160m^3}$$

ex11

Granite rock

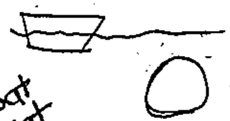
SG ≈ 3

specific gravity

- throw overboard & sinks
- Lake water level ↑ = (↓) ?

V_i water displaced $\rho_w h_i$ = $(m_{boat} + m_{Rock}) g$

new water displ. = $m_{boat}\, g$



so drops

Serway & Beichner air bubble

ex

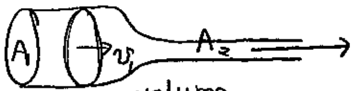
10-8 fluid dynamics (motion). PPt Pix ideas first

wing. air foil.

- no friction between layers of fluid (no viscosity)

- laminar flow:

what comes in must go out



$\frac{\text{volume}}{\text{time}}$

$$\rho_1 A_1 \frac{\Delta x_1}{\Delta t} = \rho_2 A_2 \frac{\Delta x_2}{\Delta t}$$

if incompressible $\boxed{\rho_1 A_1 v_1 = \rho_2 A_2 v_2}$ Equation of continuity

(if $\rho_2 > \rho_1$, $A_2 v_2 < A_1 v_1$)

volume flow rate = constant m^3/S

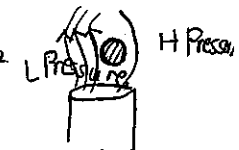
★ Small area, Larger v faster

-see ppt Boat question

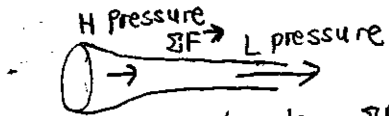
10-9 Bernoulli's Equation -Show video

★ Fluid flows without turbulence,
faster flow, less pressure (on sides of container)
slower flow, more pressure

- Like running in a crowded tunnel. Faster, less pushing at sides of walls.
- A hose to spray off grime is NOT the same. It's blocked, there's turbulence.
- Ping pong ball video, air flows around

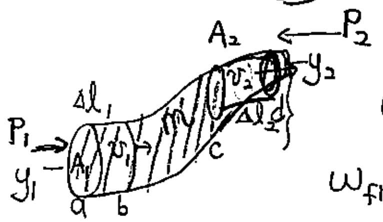


- pressure difference air pushes it back in (ΣF)



- accelerates, $\Sigma F \neq 0$
- work done by fluid

- accelerates
- w done by fluid > 0
- w done by gravity < 0



In time, a c → b d

$\Delta V = A_1 \Delta l_1 = A_2 \Delta l_2$ incompressible

$$W = \Delta K$$

$$W_{fluid} + W_{gravity} = \Delta K$$

$$F_1 \Delta l_1 - F_2 \Delta l_2$$

$$P_1 \underbrace{A_1 \Delta l_1}_{\Delta V} - P_2 \underbrace{A_2 \Delta l_2}_{\Delta V} - mg(y_2 - y_1) = \frac{1}{2} m v_2^2 - \frac{1}{2} m v_1^2$$

$$(P_1 - P_2)\Delta V - mg(y_2 - y_1) = \frac{1}{2} m (v_2^2 - v_1^2)$$

$$P_1 - P_2 - \underbrace{\frac{m}{\Delta V}}_{\rho} g (y_2 - y_1) = \frac{1}{2} \underbrace{\frac{m}{\Delta V}}_{\rho} (v_2^2 - v_1^2)$$

$$P_1 - P_2 - \rho g (y_2 - y_1) = \frac{1}{2} \rho v_2^2 - \frac{1}{2} \rho v_1^2$$

like KE PE

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2 = \text{constant}$$

(Bernoulli's Equation)
- incompressible, laminar flow, no viscosity fluid
- fluid in large pipe, air around wing, water around fish, bulk fluid (flow in)

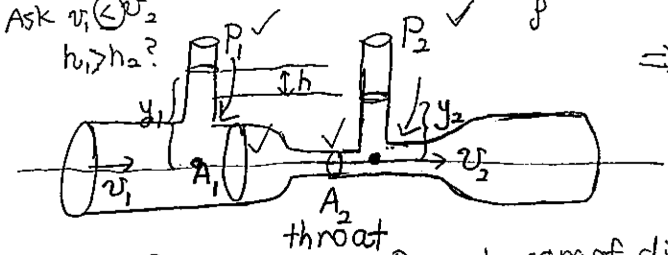
• when $v_1 = v_2 = 0$, statics, same

$$\Delta P = \rho g h$$

(YF ex9)
③ Venturi Tube

a) Ask $v_1 < v_2$, $h_1 > h_2$?

b) (A gives v ratio) measure/know ρ ⇒ find v_1

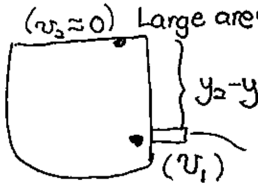


★ & instead of measuring P, only care of difference from heights

10-10 Examples

① Torricelli's Theorem

Velocity water gains is as if PE → KE



$v_1 = ?$

$$\cancel{P_1} + \frac{1}{2}\rho v_1^2 + \rho g y_1 = \cancel{P_2} + \frac{1}{2}\rho \cancel{v_2^2}^{\,0} + \rho g y_2$$

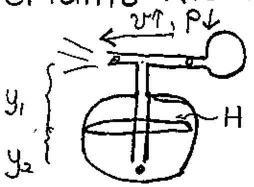
atm, open to atmosphere; atm, open

$$\frac{1}{2}v_1^2 = g\Delta y$$

$$\boxed{v_1 = \sqrt{2g\Delta y}}$$

② Perfume Atomizer

a) idea



b) $P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$ ($y_1 = y_2$)

Bernoulli $v\uparrow \Rightarrow P\downarrow$

c)

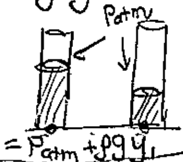
Goes up

d) $P_{\text{air in tube}} + \rho_{Air} g y_1 + \cancel{\rho_{Perf} g y_2} = \cancel{\rho_{Perf} g y_2} + P_{bottle}$ (same)

Find v_1 in terms of A_1, A_2, h

• $P_1 + \frac{1}{2}\rho v_1^2 + \rho g\, 0 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g\, 0$ at red dot

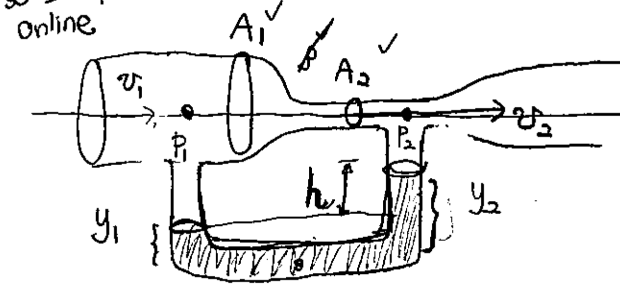
$P_1 + \rho g y_1 = P_2 + \rho g y_2$ ← OR ★



↑ up down same pressure! even if accelerating left/right? not $1\,atm$??

• Eqn of Continuity: $\cancel{\rho} A_1 v_1 = \cancel{\rho} A_2 v_2$ flow rate mass/time

★ Use this pic online



$P_{atm} = P_{atm}$

$P_1 - \rho g y_1 = P_2 - \rho g y_2$

$P_1 - P_2 = \rho g (y_1 - y_2)$ (h)

$$P_1 - P_2 = \frac{1}{2}\rho (v_2^2 - v_1^2)$$

$$\cancel{\rho} g (y_2 - y_1) = \frac{1}{2}\cancel{\rho}\left(\left(\frac{A_1}{A_2}\right)^2 - 1\right) v_1^2$$

$$\boxed{v_1 = \sqrt{\frac{2gh}{\left(\frac{A_1}{A_2}\right)^2 - 1}}}$$

Student Questions

(ex12) Blood flow

aorta (at heart) $r = 1.2\,cm$

$v \approx 40\,cm/s$

capillary $r = 4\times10^{-4}\,cm$ ~ red bloodcell size

$v = 5\times10^{-4}\,m/s$

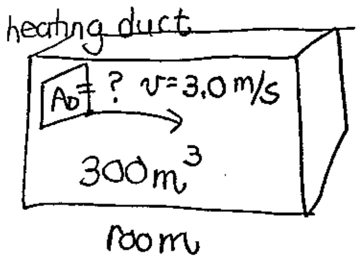
How many capillaries are in the body?

flow out = flow in

$$\pi R^2 v_A = \pi r^2 v_C N$$

$$N = \frac{v_A}{v_C}\left(\frac{R_A}{r_C}\right)^2 = 7\times10^9$$

(ex13)

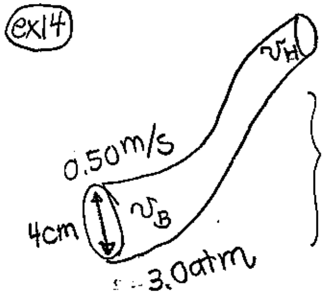


A_D = ? to replenish air every 15 minutes

$$\frac{\text{volume}}{\text{time}} = \frac{300\,m^3}{15\times60\,s} = Av_3$$

$$A = \frac{10}{15\times6} = \boxed{0.11\,m^2}$$

(ex14)



$$\pi 2^2 v_B = \pi 1.3^2 v_H$$

$$v_H = \left(\frac{4}{1.3^2}\right)0.50\,m/s = \boxed{1.2\,m/s}$$

ratio same cm or m

$$P + \tfrac{1}{2}\rho v^2 + \rho g 5 = 3\times101\,kPa + \tfrac{1}{2}\rho(.5)^2 + 0$$

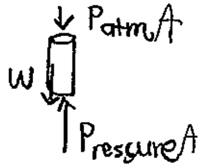
$$P = 3\times101k + \tfrac{1}{2}\times1000\frac{kg}{m^3}(0.5^2 - 1.2^2) - 1000\times9.8\times5$$

$$= 253{,}405\,Pa \times \frac{1\,atm}{101\,kPa}$$

$$\approx \boxed{2.5\,atm}$$

- Can a really long straw get all the oceans to go up into space's vacuum?

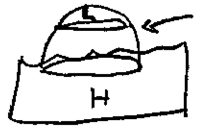
No,



} 10.3 m H_2O, 76 cm Hg

cannot overcome weight

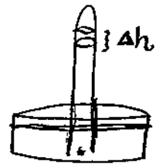
- Bernoulli seems to contradict a spray cleaner. Condition: no turbulence
- float lab



Why? Suction

- How to measure density? See hydrometer. Archimedes, sink til balance weight
- Barometer. $\Delta P = \rho g h$
- Online: Bottle of water under ocean, bring up explodes? (No. Pressure due to weight above. Water incompressible)
  - Bottle at sea, then to vacuum. explodes?
  - vacuum in glass at sea, implodes with 101 kPa?
  - deep sea fish at surface explode?

• 1 mmHg = ? atm



$\Delta h = 1\,mm$

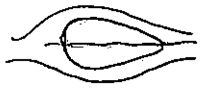
$$\Delta P = \rho_{mercury}\, g\, \Delta h$$

$$= 13.6\times10^3\,\frac{kg}{m^3}\times9.80\times10^{-3}\,m$$

$$= \boxed{133.28\,Pa}$$

- How to change liquid density? Salt. Or Temperature.
- why dead fish float?

④ Airplane Wing



push lines, force together

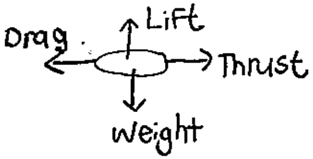
Less 'area'] continuity
More speed

less Pressure (Bernoulli)
- Lift

need attack angle

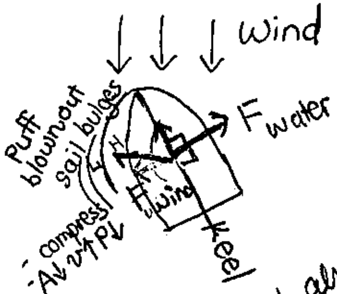
doesn't need attack angle

upside down OK if attack angle enough to deflect streamlines up



- Also 3rd Law helps lift too

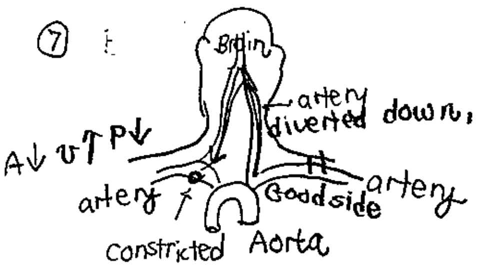
⑤ Sailboat . Sail against the wind



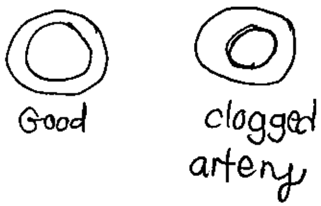
resultant almost directly forward

⑥ Curveball . Ball moves thru air (no wind) see ppt

⑦



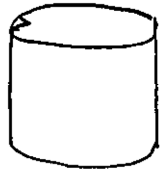
down, not to brain. Dizzy



Physics of blood
Poiseuille's eqn.

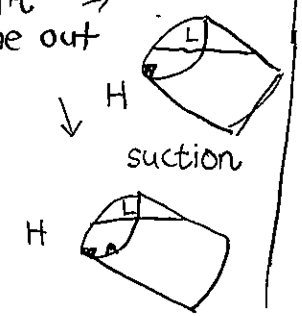
- flow rate (v) $\sim \boxed{R^4(P_1 - P_2)}$
- clog, v maintain by $\Delta P\uparrow$ ($R^4\downarrow$), heart works harder, High blood pressure

⑧ Kitchen can chicken soup

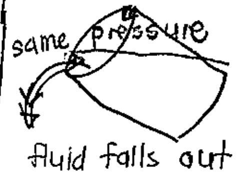


won't come out →

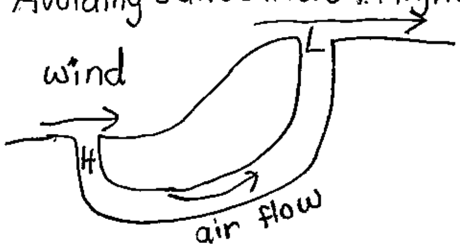
1 puncture



2 punctures comes out

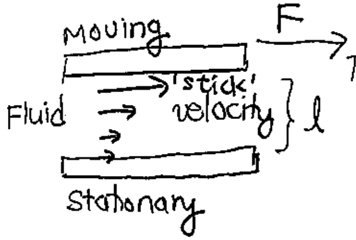


⑨ Avoiding suffocation . Higher, better, faster v (like wing)



burrows always have at least 2 entrances

10-11 Viscosity = 'friction' between layers of liquid (electrical cohesive forces)
or collisions in gas

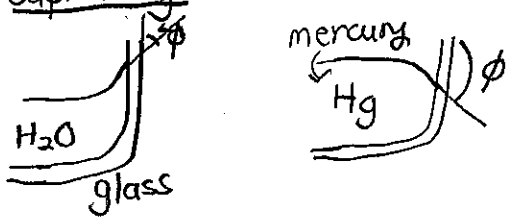


To measure

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

eta
coeff of viscosity
Pa·S

• Capillarity



• cohesion ~ force between same type molecules
• adhesion ~ different

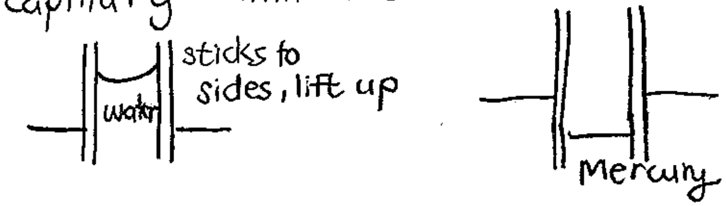
H_2O cohesive force weaker than adhesion to glass
Hg stronger

10-13 Surface Tension ~ steel paper clip $\rho > 1.0 g/cm^3$ but floats on surface
γ gamma ~ attractive force between molecules
surface acts as if under tension

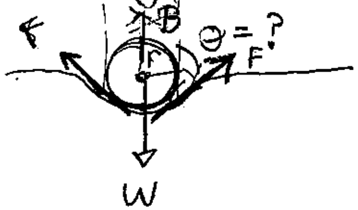
$\gamma = \frac{F}{l}$

• soap & higher temp reduce H_2O surface tension
easier to get in clothes' fibers for washing

• capillary = thin tube



ex 15 bug foot Walking on Water



$r = 2.0 \times 10^{-5} m$
$m_{bug} = 0.0030 g$
6 legs

on 20°C Water
($\gamma = 0.072$)

$\Sigma F_y = 0$ $\quad 2F\cos\theta + B = W$

$2(\gamma l)\cos\theta + \rho_{water} V_{bottom\ half}\, g = \frac{m_{bug}}{6} g$
(surface length πr)

$2 \times 0.072 \times \pi (2 \times 10^{-5}) \cos\theta + 1000 \times \frac{2}{3}\pi (2\times10^{-5})^3 \times 9.8 = \frac{3\times10^{-6}}{6} \times 9.8 \Rightarrow \theta = 89°$

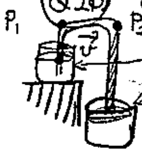
Q3) 
W = B
- the ice material has a weight that doesn't change, (solid or liquid)
- the displaced water balances, so level stays same.
(But ice takes less space as it melts, V drops? but the water it became adds it back)
(No. Ice takes less space)

Q8) 

Need barge to get lower. Add or remove sand?
-Add, more weight, lower
more B disp. water

Q10) How about balloon w/helium. Apparent weight partially lighter.

Q20) fill tube first, then it siphons water away



P_{atm} same
$\therefore P_1 > P_2$
$\therefore v \rightarrow$

$\cos\theta = 0.54$
$\theta = \boxed{57°}$

Q21) Above, Pressure too low
Bellow, Pressure = $P_{Heart} + \rho g h$ (blood) too high

★Hint others

Hints Continued from P10

Problems 9, 13, 7, 18 *21

ρgh

31
Archimedes
SG

39
Archi

55

56

57
$a=\frac{\Delta v}{\Delta t}$
vA continuity

75

77
Pascal

78
ρgh

89
projectile
vA

92
ΣF PA
Bernoulli

93
PE→KE
vA

97
Archi

98
Bernoulli
vA

Search/Learn
*1, *2
3, 5, 6