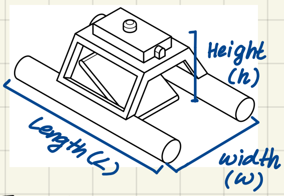
Main focus...

① How diameter of PVC affects buoyancy?
② Estimated drage force ($\vec{F}_D$)?
How shape of boat affects $\vec{F}_D$?
How to choose thruster?
③ General structure
Dimensions for layout
④ Why put everything at center?
⑤ Placement of PVC affects turbulance? Performance?

Total weight
Battery ~ 1.2 kg
Belt ~ 2 kg
Component ~ 0.7 kg

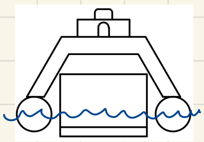
① How diameter of PVC affects buoyancy?

Required dimension of our boat :

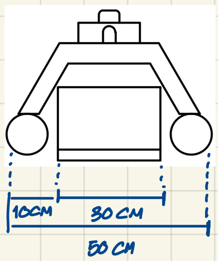


Width (w) = 50 cm
Lenght (L) = 80 cm
Height (h) = unknown

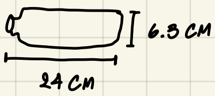
FRONT VIEW



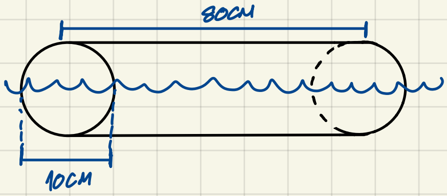
Assuming water level goes up to half of the PVC
Concept : Archimedes' Principle → An object submerged in a fluid experiences upward (buoyant) force = weight of the fluid it replaces



Targeted trash dimension : 24 cm long, 6.3 cm wide



This means The conveyor belt must be at lest 30 cm long to be able to hold the trash
So, PVC has diameter of 10 cm long :)



Again assuming water level goes up to half of the PVC

Volume of water 1 PVC replaces = $\frac{\pi r^2 h}{2}$

$r = 10\,cm \div 2 = 5\,cm$, $h = 80\,cm$

$\frac{\pi r^2 h}{2} = \frac{\pi(5^2)80}{2} = 3{,}141.59\ cm^3$: 1 PVC

$6{,}283.185\ cm^3$: 2 PVC

Volume of water 2 PVC replace ≈ $6{,}283.185\ cm^3$ = 6.283 kg

Conclusion: The approx. load 2 PVC (10 cm diameter, 80 cm long) can hold is 6.283 kg.
Diameter of PVC or Lenght of PVC ∝ load to water surface
Wider PVC, more load we can do to the surface of water
Since, overall weight of components + belt ≈ 6 kg, the PVC will be able to hold the load

สมมติว่าระดับน้ำขึ้นมาครึ่งหนึ่งของท่อ PVC (ยาว 80 cm, เส้นผ่าศูนย์กลาง 10 cm) น้ำหนักของเรือที่กระทำต่อผิวน้ำ คือ 6.283 kg

Recommendation: - Use wider diameter of PVC or longer one :)
- + 25% safety margin

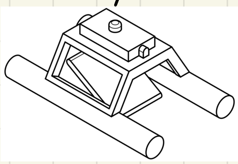
② Estimated Drag Force

Why we need to know $\vec{F}_D$? → To choose the right type of motor thrusters
→ To outline the shape of boat

Formula : $\vec{F}_D = \frac{1}{2} C_D A V^2 \rho$

C_D - Drag coefficient
A - Cross-sectional Area facing the flow (cm^2)
V - Velocity of the object relative to fluid (m/s)
ρ - Density of the fluid (kg/cm^3)

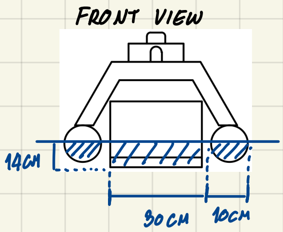
How shape of the boat affects C_D ?



Design: Catamaran-Style vessel with 2 Cylindrical pontoons + sloped belt

$C_D = 0.4$ (Chat-gpt suggestion)

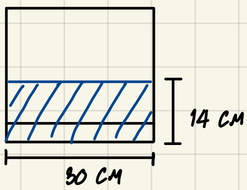
Cross-sectional Area facing the flow?



Assuming half of PVC submerged in water

$\pi r^2 \times 2$: 1 pvc
$39.27\ cm^2$: 1 pvc
$78.54\ cm^2$: 2 pvc

Assuming 14 cm of belt submerged in water



$30 \times 14 = 420\ cm^2$

Total cross-sectional area facing the flow = $78.54 + 420 = 498.54\ cm^2$

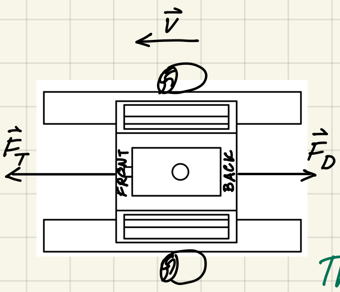
Velocity of the object relative to the fluid?
Assuming $V = 1.5$ m/s in still water condition

Density of the fluid (kg/cm^3)?
Higher temperature, lower density
Assuming 40 °C, $\rho = 992.2\ kg/cm^3$

$C_D = 0.4$
$A = 498.54\ cm^2 = 0.0498\ m^2$
$V = 0.8$ m/s (Avg. Speed)
$\rho = 992.2\ kg/cm^3$

$\vec{F}_D = \frac{1}{2}(0.4)(0.0498)(0.8)^2(992.2) = 6.32\ N$

How to choose the right type of motor thruster?



$\vec{F}_T \geq \vec{F}_D$

Rule of Thumb : $\vec{F}_T = \vec{F}_D \times 2 = 6.32 \times 2 = 12.64\,N$: 2 motors

Each motor should provide 6.32 N .

Thrust-to-Weight Ratio : $TWR = \frac{\text{Total Thrust}}{\text{Weight of boat (N)}} = \frac{44.5\,N}{5.88(9.81)\,N} = 0.771$

TWR = 0.771 ; Our boat is good for stable control, Modest speed ☺

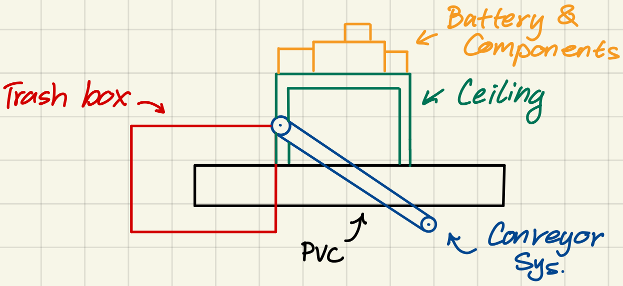
Thruster Model : U1 12V ROV Thruster → approx. Thrust 20N , 12-16 Voltage

https://www.underwaterthruster.com/products/u01-12v-16v-200w-2kg-thrust-brushless-underwater-subsea-thruster-propeller-propulsion-with-bi-directional-control-esc-for-rov-boat

♡ ESC provided
♡ Datasheet provided
♡ Within budget
♡ Reliable Source

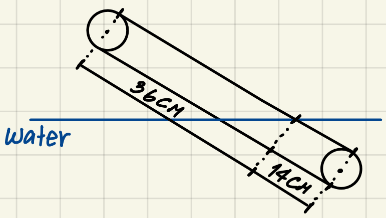
③ General Structure (Hardware only)

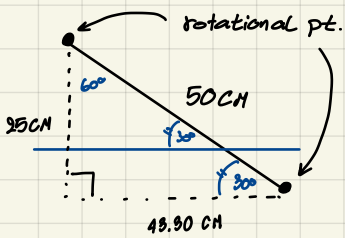
Our boat is devided into 4 main parts
- Conveyor Sys. (Belt, Motor, gears, Supports)
- Trash box (Supports, Plastic Net)
- PVC
- Ceiling Structure (Supports, PVC, Acrylic)



Conveyor belt

50 cm long conveyor belt (counted from rotational pt.)



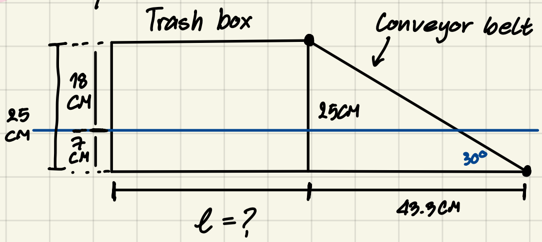


There 're some part (y) of conveyor belt submerged in water.

Trash box

Requirement : Store 600 ML bottle (6.3 diameter, 24 cm tall) 5 ++ bottles

Placement

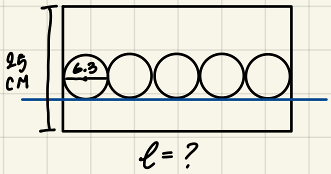


Assuming water comes in trash box 7 CM, 14 CM of Conveyor belt must sumerged in water.

$y = \frac{7}{\sin 30} = 14$ CM

Material used

Assuming the bottles come in trash box doesn't lean on each other,

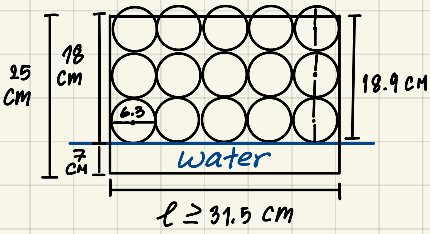


6.3 CM × 5 bottles = 31.5 CM

∴ The lenght of trash box (ℓ) must be ≥ 31.5 CM

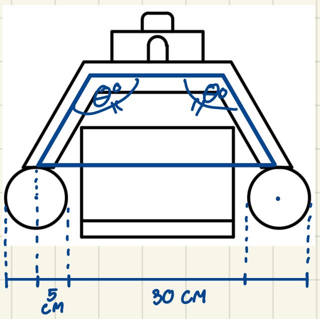
Ideal Conditions

If bottles collected are placed in perfect condition, our trash box will be able to hold ≤ 15 bottes

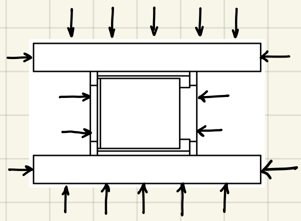


Ceiling Structure

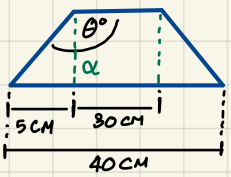
After knowing trash box & Belt Dimen., we can estimate Ceiling Structure



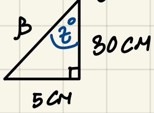
Wider θ°, better the boat can fight hydrostatic Pressure
But, wider θ°, less space for trash box and belt.



* Not our main focus

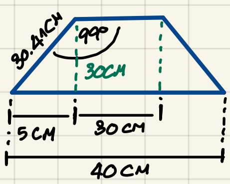


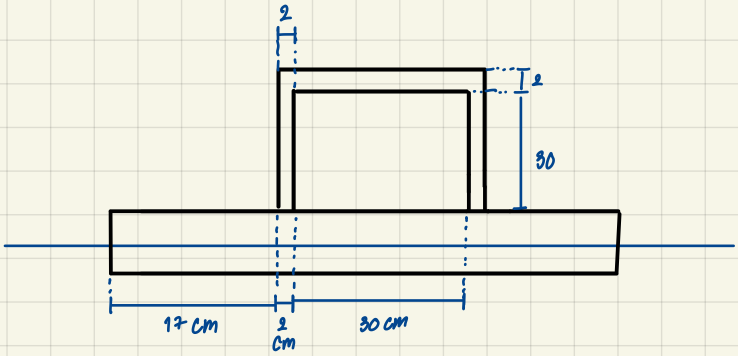
Assuming α = 30CM, β = ?



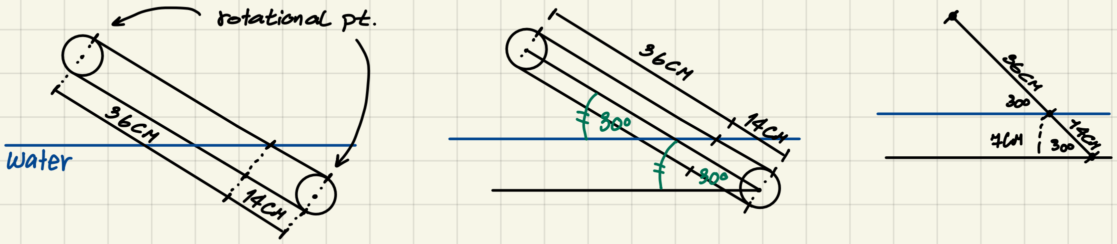
β = 30.41 CM

$z° = \tan^{-1}\left(\frac{5}{30}\right) = 9.46°$

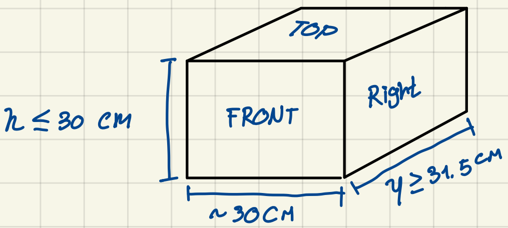




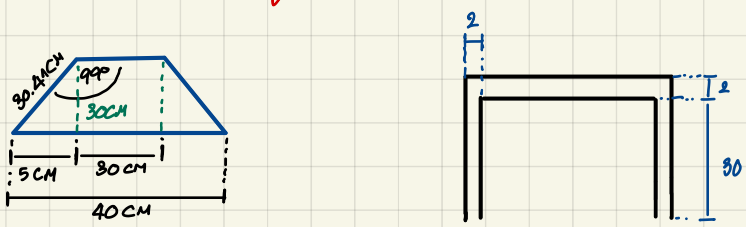
Conclusion 1 : Dimension of Conveyor belt



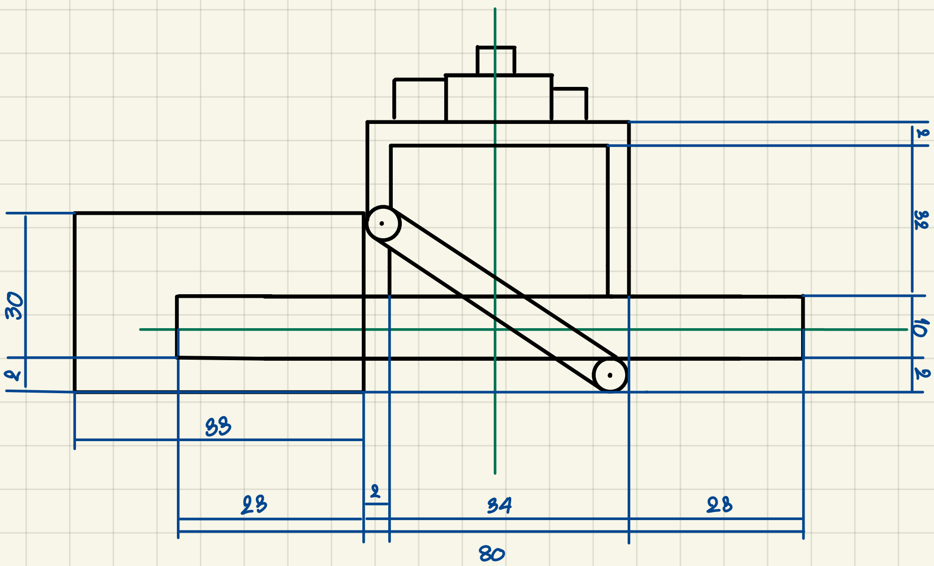
Conclusion 2 : Dimension of Trash box



Conclusion 3 : Ceiling Structure

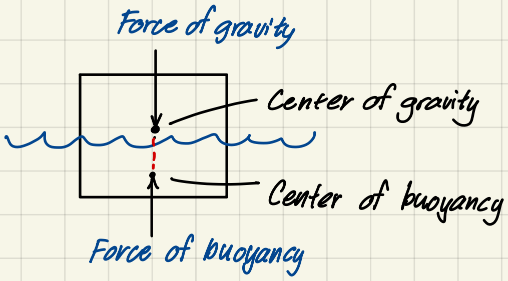


Unit : cm

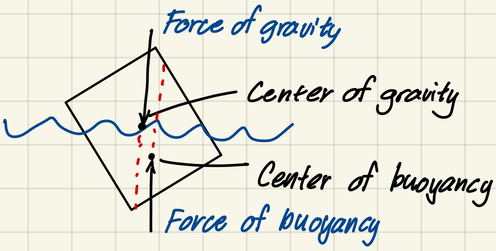


④ Why put everything at center?

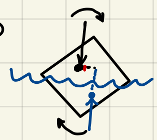
Concepts



Def. "Stable Equilibrium"
↳ Center of g. and buoy. are on the same vertical line



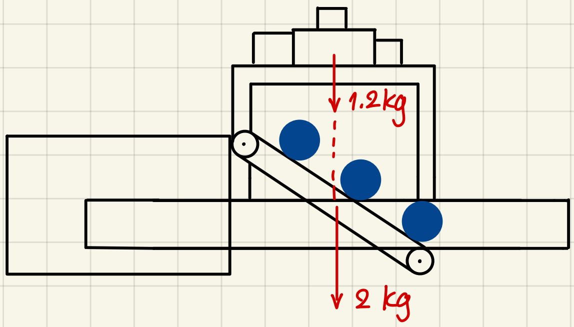
Def. "Roll Over"
↳ Center of g. and buoy. aren't on the same vertical line; Create Momentum (Turning effect)

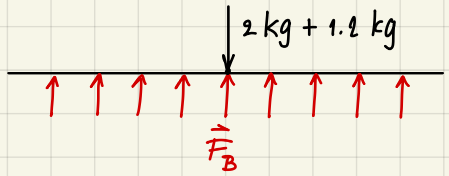


Our senario, heaviest part of our boat is conveyor belt sys. & battery.

Total weight
Battery ~ 1.2 kg
Belt ~ 1.5 kg (Assuming 600 mL water inside bottles)
Component ~ 0.7 kg

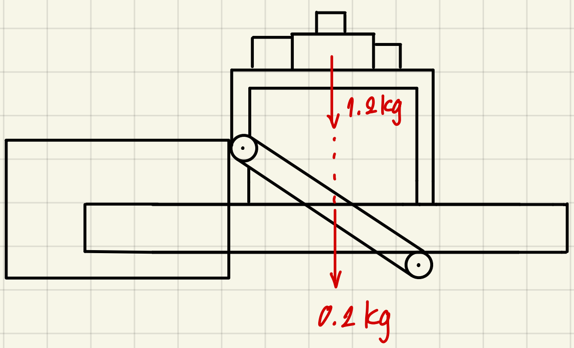
Case 1 : 3 Water bottles on belt

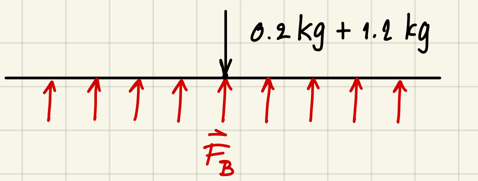




$\tau = (2+1.2)(9.8)(0) = 0 \ N\cdot m$

Case 2 : No bottles



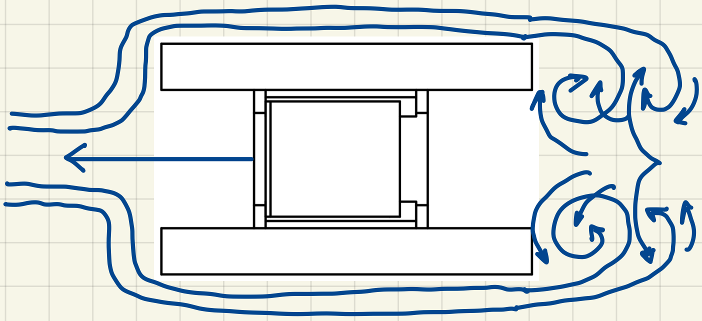


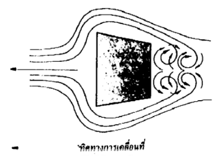
$\tau = (0.2+1.2)(9.8)(0) = 0 \ N\cdot m$

(+) The most stable design we can get
(+) Battery on top

" This placement makes bottles collection on belt has least effect on balance."

⑤ How placement of PVC affects turbulance ?





รูปที่ 2.9 วัตถุปลายบานกว้างวัตถุปลายแคบเล็กเรียว เมื่อเคลื่อนผ่านน้ำจะแยกน้ำ
ออกเล็กน้อย

รูปที่ 2.10 วัตถุปลายแคบเล็กเรียว

จากรูปที่ 2.10 แสดงตัวอย่างของการเกิด Von Karman Vortex ขึ้นของการไหลผ่าน

Notice that, this shape creates less turbulance

รูปที่ 2.8 แสดงการเกิดระลอกน้ำและกระแสน้ำวน Eddies